Report Prepared for Betz, Converse, Murdoch, Inc.

PINELANDS COMMISSION

NEW JERSEY

HYDROGEOLOGY ASSESSMENT

March 1980

Geraghty & Miller, Inc.
Consulting Ground-Water Geologists and Hydrologists
North Shore Atrium
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PINELANDS GROUND-WATER ASSESSMENT

EXECUTIVE SUMMARY

1. Coastal Plain formations underlying the Pinelands consist of a wedge of unconsolidated sediments that reach a maximum thickness of 6,000 feet beneath the Cape May peninsula lying on crystalline bedrock.

2. Major aquifers or water-bearing units are, from oldest to youngest, the Potomac-Raritan-Magothy sequence, the Englishtown Formation, the Wenonah Formation and Mt. Laurel Sand, the Kirkwood Formation, and the Cohansey Sand.

3. The Potomac-Raritan-Magothy aquifer system is capable of yielding large amounts of water and is heavily pumped along the Delaware River. The top of this aquifer lies at a depth of 500 to 2,000 feet below land surface in the Pinelands.

4. The Englishtown and the Wenonah-Mt. Laurel aquifers are important sources of water in the northern section of the Pinelands. Elsewhere, the formations are not exploited because of great depth or change in lithology.

5. The Kirkwood is an important aquifer tapped by coastal communities including Atlantic City. Yields of wells range from 700 to 1,200 gpm.

6. The Cohansey Sand is a prolific water-table aquifer

that outcrops over a 1,500-square mile area. In some places the Cohansey is hydraulically connected to upper sands of the Kirkwood Formation. Yields of large-diameter Cohansey wells range from 500 to 1,000 gpm.

7. The average thickness of the Cohansey aquifer is 150 feet, but it reaches a total of 300 feet along the coast. The Cohansey is a medium to coarse sand with an overall clay content of less than 20 percent in most areas.

8. Examination of 600 well logs has indicated the presence of two extensive shallow Cohansey clay beds in the southern portion of the Pinelands, which may be important in terms of waste disposal.

9. Recharge to the ground-water reservoir is entirely from precipitation, which averages 45 inches per year. Slightly less than half of this amount infiltrates the ground and replenishes the aquifers. This recharge is equivalent to 0.98 mgd per square mile or 1.6 billion gpd over the entire Pinelands area.

10. Depth to water varies from a few feet in the lowlands area to 40 feet in some upland areas. Water-table gradients range from 5 to 10 feet per mile in the coastal zone to 15 to 25 feet per mile in the uplands.

11. Three distinct ground-water flow patterns exist: a

shallow flow pattern with short flow paths in the water-table aquifer, an intermediate circulation pattern in the Cohansey-Kirkwood aquifer system, and a deep ground-water flow pattern from the water table to the Raritan-Magothy aquifer, which is influenced by pumpage along the Delaware River.

12. Water-level fluctuation in the Cohansey aquifer is minimal. In the upland area, the normal seasonal fluctuation is about 7 feet. In the lowland area, seasonal fluctuation is about 2 feet.

13. Large quantities of water (450 to 1,000 mgd total) can be developed from the Cohansey aquifer. The major constraints on development will be those imposed by man, such as establishment and maintenance of minimum stream-flows and maximum acceptable depth to the water table to protect sensitive vegetation, rather than the aquifer's ability to transmit and yield water. Plans for large-scale ground-water development should be carefully evaluated by means of test drilling and aquifer modeling and simulation.

14. Further development of the Raritan-Magothy aquifer appears possible except in the southern portion of the Pinelands, where the aquifer contains water with chloride concentrations exceeding 250 mg/l.

15. Only limited development of both the Mt. Laurel-Wenonah and Englishtown aquifers should be considered because

of severely depressed water levels in both aquifer systems. Future development should take place by means of properly spaced wells located near the outcrop areas.

16. Long-term pumpage from the Kirkwood aquifer has created a deep cone of depression centered at Atlantic City. However, a substantial quantity of additional water (85 to 115 mgd) can be developed from this aquifer in the coastal region.

17. The quality of the ground water in the Pineland aquifers is generally excellent. Cohansey water is acidic but very low in iron, dissolved solids, and nitrate. Kirkwood water typically contains excessive iron. Dissolved solids concentrations in the Kirkwood increase downdip in a southerly direction. Published and unpublished ground-water quality data are not sufficient to identify possible local and area-wide ground-water quality problems or trends.

18. The entire ground-water reservoir below the Pinelands contains fresh water (except for the lowermost Raritan-Magothy bed in the southern half) and there is no evidence of salt-water encroachment in any of the aquifer systems.

19. The Cohansey aquifer is highly susceptible to contamination from population-density and land-use related activities. Of particular concern in the Pinelands are landfills, deicing salt, spills, leaks, and septic tank effluent.

20. Computation of travel times indicate that under average conditions in the Pinelands, shallow ground water flows at a rate of 4 feet per day. As no point is more than 1.5 miles from a surface-water body, a contaminant in the shallow ground-water system would take about five years to travel from source to discharge point. Travel time along flow paths from intermediate depths in the center of the Pinelands to the Atlantic Ocean would be about 2,000 years.

21. An inventory of potential sources of ground-water pollution shows the following in order of potential significance:

a) Practically no information on type and volume of waste is available for the 46 industrial and municipal landfills in the area. Potential leachate generation based on precipitation and average landfill life is estimated at 860 million gallons per year. These landfills constitute a significant threat to ground- and surface-water quality.

b) The effect of concentrated housing development and septic tank effluent on ground-water quality in the Pinelands is as yet unknown. However, a comparison of the Pinelands with similar hydrogeologic environments, such as Delaware and Long Island, indicate that such quality problems would arise in the Pinelands. The greatest threat to ground-water quality from this source would be excessive concentrations of nitrate, organic chemicals, and metals.

c) Spills occurring as both accidental and deliberate discharges of chemicals and petroleum products are a hazard to ground-water quality. In the 1976-79 period, 41 such spills were reported in the Pinelands.

d) Seven industrial waste-water impoundment sites have been identified. Total leakage of unidentified waste liquids is estimated at 140 million gallons per year.

22. Ground-water quality management zones have been designated based on the concept of allowing maximum retention of waste fluids in the unsaturated zone to protect the deeper ground-water flow system. This zoning takes into account depth to the water table (to locate areas with deep water tables) and presence or absence of shallow clay beds in the Cohansey aquifer (to limit downward movement of contaminants).

23. In order to protect ground-water quality as well as surface-water quality, existing landfills and waste disposal operations should be investigated and prioritized according to their potential threat to the environment as the first step in limiting that threat.

24. Ground-water testing and sampling operations should be carried out at suspected hazardous waste storage and disposal sites in order to devise possible confinement and control measures.

25. Land-use controls should be a primary tool to maintain ground-water quality in the Pinelands. Existing potential sources of pollution should be strictly regulated and monitored on a site-by-site basis.

26. A moderately intensive regional water level and water quality monitoring program should be established to develop baseline data.

1.0 GEOLOGY

1.1 Introduction

The New Jersey portion of the Atlantic Coastal Plain physiographic province covers an area of nearly 5,000 square miles and all or part of five major drainage basins: the Raritan, Delaware Bay, Atlantic Coastal, and Rahway. Population density ranges from heavy in northern Middlesex County and along the Delaware River between Trenton and Philadelphia, to moderate (seasonal) along parts of the Atlantic coast, and to extremely light in much of the interior portion of the plain known as the Pinelands region. As population density is directly related to water use, the greatest demands on the water resources of the region at present are along the Delaware River between Trenton and Philadelphia, in northern Middlesex County, and along parts of the coast, with the resources being virtually unused in the Pinelands region. Ground water is the major source of water for public supply, industry, irrigation, and domestic use in the area. There are a few purveyors who divert surface water for potable use in the Coastal Plain, and some industries who use Delaware River water for cooling and process water, but by far, most of the region is dependent on ground-water supplies. The major reason for this dependence on ground water is the relative abundance of high quality ground water at a relatively low cost, and the lack of suitable sites for the construction of surface-water impoundments. In 1976, estimated ground-water usage in the Coastal Plain amounted to 440 mgd (million gallons per day) for public supply, industrial, irrigational, and other uses.

Located entirely within the Coastal Plain and occupying 1,660 square miles is the Pinelands National Reserve. The geology of the Coastal Plain formations that underlie the Pinelands is discussed below.

The Coastal Plain is underlain by a generally southeasterly dipping and thickening sequence of unconsolidated sediments which lie unconformably upon a floor of crystalline rock. This bedrock floor dips to the southeast at a rate of 80 to 100 feet per mile and is nearly 6,000 feet below sea level in the extreme southern portion of the Pinelands beneath the Cape May peninsula.

The formations crop out in a series of belts roughly parallel to the trend of the Delaware River south of Trenton, which flows more or less along the Fall Line, an imaginary line which divides the Piedmont and Coastal Plain provinces. The oldest sediments, those of the Potomac Group and Raritan-Magothy Formations, crop out immediately adjacent to the Delaware River. The outcrop belt of each successively younger formation occurs progressively further downdip with each formation in turn being overlain by younger and younger sediments and lying at an increasingly greater depth below land surface. Because the formations thicken seaward, the dip of the formations decreases going up the stratigraphic column and the dip of the Cohansey Sand is about 10 feet per mile. Table 1-1 is a generalized stratigraphic column of the Coastal Plain formations. Only the major aquifers and confining units are discussed in this report.

1.2 Potomac Group and Raritan-Magothy Formations

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

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

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	Pliocene(?) and Miocene(?)	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 grey, 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 grey, 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.

Reference: Nemickas, 1976

The Potomac Group and Raritan Formation in their outcrop consist of medium- to coarse-grained, light colored quartzose sands and fine-grained gravel and light colored clays. The Magothy Formation in outcrop is typically composed of dark gray and black clays alternating with fine-grained micaceous quartz sand.

The Potomac Group and Raritan Formation are believed to be for the most part continental in origin although marine 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.

Although in Middlesex County the Raritan has been divided into five distinct units and the Magothy into four, changes in lithology make it impossible to trace these individual units into the Pinelands. In addition to the change in lithology along the outcrop, great variations in sediments also occur in a downdip direction.

1.3 Englishtown Formation

The Englishtown Formation overlies the Merchantville Clay and Woodbury Formation and is in turn overlain by the Marshalltown Formation, a thin confining unit. The Englishtown ranges in thickness in outcrop from 140 feet near Raritan Bay to 50 feet at Trenton and downdip reaches more than 200 feet in the Toms River area of the Pinelands. The formation dips uniformly to the southeast at about 40 feet per mile, and in southern Burlington County is 1,000 feet below sea level.

In outcrop in the northern part of the Coastal Plain, the Englishtown consists of interbedded thin layers of light gray to white, cross-stratified fine- to medium-grained lignitic quartz sand and dark gray sandy silty clay and clayey silt. A lithologic change along the outcrop occurs with the Englishtown in the southern Coastal Plain being a massive dark colored silty sand. A short distance downdip, the Englishtown has been subdivided into two or three poorly defined thick sandy zones separated by one or two silty zones. Further to the southeast, around Lakewood, three distinct lithologic units are recognizable in the Englishtown, consisting of upper and lower units of light colored silty fine-grained lignitic quartz sand with thin layers of dark sandy silt separated by a thick layer of dark gray sandy and clayey lignitic silt. Both marine and non-marine depositional environments have been suggested for the Englishtown.

In Monmouth County, the northern half of Ocean County, and the northeast corner of Burlington County, this aquifer is 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 and the unit is comprised of clay and silt. Sufficient data are not available to contour the sand lithofacies in the remaining portions of the Pinelands National

Reserve, and it appears that the Englishtown aquifer is absent.

1.4 Wenonah Formation and Mt. Laurel Sand

The Wenonah Formation and Mt. Laurel Sand are separated from the underlying Englishtown Formation by the Marshalltown Formation (confining unit) and overlain by the Navesink Formation (generally a confining unit). The Wenonah-Mt. Laurel sequence functions hydraulically as one aquifer.

The Wenonah Formation is usually a micaceous, poorly sorted, silty to fine quartz sand. A brown silty clay has been noted near its contact with the Marshalltown. The Mt. Laurel Sand is a coarse, clastic quartz and glauconitic sand unit that often has a "salt and pepper" appearance due to its light gray and dark green sands. The Mt. Laurel predominates over the Wenonah Formation.

The unit outcrops from Raritan Bay southwestward to Delaware Bay and reaches a thickness of over 200 feet in the subsurface. The upper surface of the Mt. Laurel Sand dips about 40 feet per mile to the southeast and ranges in elevation from over 100 feet above sea level in its outcrop in the northern end of the Coastal Plain to over 1,200 feet below sea level beneath the barrier beaches along the southeast coast of Ocean County. The Wenonah Formation and Mt. Laurel Sand are believed to underlie the entire Pinelands area.

1.5 Kirkwood Formation

The Kirkwood Formation overlies or overlaps the Manasquan Formation, Hornerstown Formation, or Navesink Formation (all generally confining units) depending on the location in the Pinelands and is in turn overlain by the Cohansey Sand. In the southeastern part of the Pinelands, the Kirkwood overlies the Piney Point Formation, which does not outcrop in the state and is only known from well logs (Nemickas and Carswell, 1976). The top of the formation ranges in elevation from over 100 feet above sea level in its outcrop area to over 300 feet below sea level along the eastern edge of Cape May Peninsula and is an irregular surface. The formation is between 50 and 100 feet thick in its outcrop and thickens to over 800 feet in the Atlantic City area.

The Kirkwood is of variable lithology both along outcrop and downdip. In its outcrop in Salem County it 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 to very fine-grained quartz sand, and a thicker member of light gray to light yellow-orange fine-grained sand. The formation is least permeable in outcrop in Salem County where it is mostly silt and clay.

Downdip along the coast in Cape May County, five distinct members have been recognized in the Kirkwood. These are from oldest to youngest: (1) a tough brown basal clay; (2) a gray medium-to-coarse sand (Atlantic City "800" foot sand) or lower aquifer; (3) a blue silty diatomaceous clay; (4) a medium-to-coarse sand (Rio Grande zone or upper aquifer); and (5) a blue diatomaceous clay.

The "800" foot sand, so named because of the depth at which it is most frequently found in the Atlantic City area, 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 occurs only in Cape May and Cumberland Counties. Fossil evidence indicates a marine origin for this formation.

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

1.6 Cohansey Sand

The Cohansey Sand outcrops in an area of approximately 1,500 square miles in the Pinelands. The combined thickness of the Cohansey Sand and overlying Pleistocene deposits ranges from less than 20 feet to 300 feet and averages about 150 feet. The Cohansey Sand overlies the Kirkwood Formation and either crops out at the surface or is overlain by a thin veneer of Pleistocene deposits, except in Cape May County where 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. Lenses of white, yellow, red, and light gray clay occur generally in the upper part of the formation and may be as much as 25 feet thick. The sand is dominantly yellow (limonitic staining), but shades of white, red, brown, and gray also occur. Parallel bedding and cross-stratification occur in the sand.

Lack of fossils or glauconite in the Cohansey Sand along with certain distinct lithologies and sedimentary structures indicate a transitional environment of deposition that ranges from stream and fluvial plain to beach and near-shore environments.

2.0 HYDROGEOLOGY

2.1 Introduction

Throughout the Pinelands area and the entire Coastal Plain physiographic province there are numerous regional and local aquifer systems, aquifers, and sub-aquifers. However, there are only five major aquifer systems that can be considered truly regional in nature and that are capable of producing substantial quantities of water. Characteristics of these five systems are discussed below.

2.2 Potomac-Raritan-Magothy Aquifer System

Lithologic changes that occur in the Potomac Group and Raritan-Magothy Formations along their outcrop and downdip make differentiation between the units difficult or impossible. This is compounded by the discontinuous nature of the sand and gravel beds and clayey confining units which makes the tracing of any particular aquifer over any appreciable distance relatively impossible. As it is believed that the aquifers in these units are hydraulically interconnected, the Potomac Group and Raritan-Magothy Formations are discussed as one aquifer system.

The aquifers contained within the Raritan-Magothy system are prolific and based on present development, the most important in all the Coastal Plain with the exception of the Cohansey Sand. The coarse sands and gravels readily yield supplies of 1 to 2 mgd or more 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 between 500 and 1,900 gpm (gallons per minute) with an average yield of 1,000 gpm. The specific capacities of 96 of these wells averages 29.3 gpm/ft (gallons per minute per foot) of drawdown (Farlekas and others, 1976). Similar yields are reported from other counties.

In Camden County, results of aquifer tests at two sites indicate a range in transmissivity (a measure of an aquifer's ability to transmit water) of 17,000 to 50,000 gpd/ft (gallons per day per foot). In Burlington County, pump test data at five different sites show a range in transmissivity from 46,600 to 513,000 gpd/ft, and in Gloucester County a transmissivity range from 30,000 to 68,000 gpd/ft is indicated. Permeabilities are usually on the order of 1,000 to 1,500 gpd/ft^2 (gallons per day per square foot) or more. These pumping tests indicate that downdip from the outcrop, water in these aquifers is under confined conditions. Similar values of transmissivity can be expected in the Pinelands area even though the materials may be somewhat finer grained and of lower permeability. This is so because the thickness of the aquifer is greater and transmissivity is the product of aquifer thickness and permeability.

Commonly, the Potomac-Raritan-Magothy system has two or three distinct water-bearing zones. Along the Delaware River in Gloucester County, an upper and lower artesian zone exists separated by a thick clay unit (Hardt and Hilton, 1969 and Consultant's files). Pumping test data indicate no apparent hydraulic connection between these zones. About four miles from the river there are three distinct artesian zones with the upper two zones separated from the lower by a thick clay unit. Pumping test data indicate a connection between the upper zones but not with the lower. In Camden County, three separate zones have been delineated and in Salem County, three aquifer zones are known to exist a short distance downdip from the outcrop.

In Ocean County near Lakehurst, data from drilling and pumping wells has revealed the presence of three confined water-bearing zones. The upper two appear interconnected and hydraulically separate from the lower. As these wells are a considerable distance from the outcrop, it seems reasonable to assume that these three water-bearing zones may occur regionally throughout the Raritan-Magothy aquifer system in the Pinelands.

2.3 Englishtown Formation

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 with an increase in clay and silt. Large-diameter wells in the Englishtown usually yield 200 to 500 gpm with some wells yielding as much as 1,000 gpm. Specific capacities for 119 wells completed in the Englishtown Formation in the northern Coastal Plain average 2.9 gpm/ft of drawdown; only four wells had specific capacities of 10 gpm/ft or more (Nichols, 1977). Although many of the Englishtown wells are small-diameter domestic wells, transmissivity values confirm these rather low specific capacities. 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, gave an average transmissivity of slightly over 8,000 gpd/ft where the aquifer is the thickest. Except for the outcrop area, the aquifer is under confined (artesian) conditions.

The Englishtown aquifer exhibits only a moderate to low permeability in Monmouth, northern Ocean, northeast Burlington, central Camden, and extreme southeastern Middlesex Counties. In most of the Pinelands region, the Englishtown is considered to be a confining bed.

2.4 Wenonah Formation and Mt. Laurel Sand

The Mt. Laurel Sand is the major component of the aquifer in the undifferentiated Wenonah-Mt. Laurel Formation. The mean transmissivity values from pumping tests carried out at three locations (two in Salem County and one in Monmouth County), range from about 5,000 gpd/ft to nearly 9,000 gpd/ft with the permeabilities ranging from slightly less than 100 gpd/ft^2 to over 140 gpd/ft^2 (Nemickas, 1976). Additionally, from specific capacities of 33 wells tapping this aquifer in the northern part of the Coastal Plain, an average transmissivity value of 5,900 gpd/ft and an average permeability value of 97 gpd/ft^2 were determined. The three pumping tests indicate that the aquifer in the Pinelands is under artesian conditions east of its outcrop area.

The average specific capacity of the above 33 wells was 4.2 gpm/ft and in Gloucester County, the average specific capacity of over 100 wells was 5 gpm/ft. In Camden County, the median specific capacity of ten industrial and public supply wells tapping the Wenonah-Mt. Laurel aquifer was 3.2 gpm/ft. Although many of these wells are probably of small-diameter, the generally low values of transmissivity support the low specific capacities of these wells. The Wenonah-Mt. Laurel aquifer is very similar to that of the Englishtown Formation in its ability to transmit and yield water.

2.5 Kirkwood Formation

The lower aquifer of the Kirkwood Formation is most permeable and most highly developed in an area centered around Atlantic City. The permeability of this unit decreases sharply in all directions away from Atlantic City.

The results of two pumping tests on wells tapping the lower Kirkwood aquifer at the Atlantic City pumping station shows a range in transmissivity from 66,100 to 93,500 gpd/ft and permeabilities between 810 and 1,140 gpd/ft^2. However, a test at Stone Harbor in east central Cape May County gave a transmissivity of about 26,000 gpd/ft and a permeability of less than 300 gpd/ft^2 (Gill, 1962). Additionally, in Ocean County, an aquifer test on a Seaside Park Water Department well gave a permeability value of 200 gpd/ft^2. These tests indicate that water in the Kirkwood is under confined conditions and that the formation is highly productive in places.

Yields of wells tapping the Kirkwood range from as little as 10 to 50 gpm for domestic wells in its outcrop area to 1,200 gpm for public supply and industrial wells located in the most permeable area near Atlantic City. In Atlantic City, the median yield of 27 public supply and industrial Kirkwood wells is 700 gpm, and the median specific capacity is 15 gpm/ft (Clark and others, 1968).

The Rio Grande zone which only occurs in Cape May and Cumberland Counties, is not as productive as the lower aquifer, and elsewhere shallower sand zones in the Kirkwood are probably discontinuous.

2.6 Cohansey Sand

The Cohansey Sand is a very permeable formation that is equaled in its ability to yield water only by the aquifers of the Potomac-Raritan-Magothy system. Throughout much of the Pinelands area, the Cohansey Sand aquifer includes thin deposits of overlying Pleistocene materials which are generally quite permeable and are hydraulically connected with the Cohansey. However, in Cape May County in places, the Pleistocene deposits are quite thick and are hydraulically separated from the Cohansey Sand by confining layers. In some areas, especially in Cumberland County, the uppermost part of the Kirkwood Formation is in direct hydraulic connection with the Cohansey and forms part of the aquifer.

The thickness of the Cohansey aquifer is shown on Plate 1. The map was constructed by examining about 600 well logs on file at the New Jersey Department of Environmental Protection (NJDEP). It should be noted that the values shown on the map represent the thickness of the upper aquifer down to the first confining bed. In some cases, as noted before, this aquifer zone includes the upper sand of the Kirkwood Formation as well as overlying terrace deposits of the Cape May Formation.

As shown, the Cohansey aquifer system increases in thickness from a few feet along its outcrop line to over 300 feet along the coast. Thick aquifer areas are in Bass River Township between Cumberland and Dorothy (greater than 200 feet), and along the coast from Long Beach to Cape May County (greater than 300 feet). The aquifer is relatively thin (less than 125 feet) in Mullica Township between Hammonton and Weekstown, and near Brookville in Ocean Township. Generally speaking, the thicker the aquifer, the more water can be developed from wells tapping the unit.

In addition to aquifer thickness, the lithologic composition of the aquifer material was examined. Plate 2 shows the percentage of sand in the aquifer. This percentage was calculated by examining each well log for clay and sand content and the map was constructed by contouring the percentage values. As shown, the percentage sand in the Cohansey aquifer is high. A linear pattern is visible in the sand-clay relationship, probably reflecting an ancient depositional channel. This channel, filled with 80 to 90 percent sand, crosses the Pinelands from Hammonton and Indian Hills to Quaker Bridge, Jenkins Neck, and Brookville.

Areas where the Cohansey contains significant percentages of clay (30 to 40 percent) are located between Toms River and Dover Forge, in the Winston area, and between Estellville and McKee City.

Aquifer tests conducted on wells tapping the Cohansey aquifer at more than ten sites give values of transmissivity which range from 27,000 to 220,000 gpd/ft and permeability values between 400 and 3,000 gpd/ft^2. More common values of permeability throughout much of the aquifer are between 1,000 and 1,200 gpd/ft^2 (Rhodehamel, 1973). Generally, the permeability of the aquifer is very consistent over a wide area. The lower values of transmissivity occur to the northwest where the formation thins and in southern Cape May County, while the higher values occur in the central part of the Pinelands and downdip to the southeast where the formation thickens, specifically in Cumberland County and the Mullica River Basin.

Specific capacities for large-diameter Cohansey wells in Atlantic (29 wells) and Cumberland Counties averaged 22 and 30 gpm/ft respectively, and in Atlantic County the median yield of these wells was 720 gpm. Seven wells belonging to Seabrook Farms (Cumberland County) tapping this aquifer had an average specific capacity of 32 gpm/ft and an average yield of over 1,000 gpm. One well in White Bog (Burlington County) reportedly has a yield of 2,000 gpm, and a well near Chatsworth (Burlington County) has a specific capacity of 121 gpm/ft.

As indicated by the above data, the Cohansey aquifer is highly permeable and can store and transmit large quantities of water. Well yields of 500 to 1,000 gpm or more should be obtainable in most areas of the Pinelands.

Usually, the Cohansey aquifer is under water-table conditions except where confined by clay beds. Examination of the well logs and stratigraphy has indicated the existence of extensive clay beds in the Cohansey at relative shallow depth below land surface in some areas. The extent of these clays is shown on Plate 3. Two major clay units have been identified. The first, a white, tan, or yellow clay lies 10 to 40 feet below land surface and has a thickness that ranges from 10 to 50 feet. The second clay unit is blue or gray clay which lies 50 to 115 feet below land surface and has a thickness that varies from 10 to 75 feet. The two clay units are found adjacent to each other and overlap only in a few small areas. As shown in Plate 3, the shallow clays are confined to the southern half of the Pinelands.

2.7 Hydraulic Regime

2.7.1 Recharge and Discharge

All naturally occurring fresh ground water in the unconsolidated formations of the Pinelands is ultimately derived from precipitation falling on the region. Part of this precipitation is returned to the atmosphere through the combined processes of evaporation and transpiration (evapotranspiration). Part of the remaining portions runs overland to surface-water bodies (overland runoff), and part infiltrates the soil and percolates to the ground-water reservoir (recharge). Throughout the Pinelands National Reserve area of approximately one million acres or 1,660 square miles, an average of 45 inches of precipitation as water falls per year. This is equivalent to 2.14 million gallons of water per day per square mile or 3,550 mgd over the entire Pinelands region.

Rhodehamel (1970) has made some estimates of evapotranspiration losses, overland runoff, and ground-water recharge for the Cohansey outcrop area which have been up-dated. Forty-eight percent of all precipitation is returned to the atmosphere by evapotranspiration; the remaining portion consists of 6 percent overland runoff and 46 percent ground-water recharge. Eventually the ground-water recharge portion is discharged to streams and other surface-water bodies as base flow and this combined with the overland runoff makes up stream flow out of the region.

Therefore, recharge to the ground-water reservoir in the Pinelands from precipitation averages 20.7 inches per year or 0.98 mgd per square mile. This amounts to 1,630 mgd over the entire Pinelands National Reserve area. Because the Cohansey Sand outcrops throughout the entire Pinelands area or else is covered by a thin veneer of hydraulically connected Pleistocene deposits, the 1,630 mgd is recharged to the Cohansey Sand aquifer. Actually, a small portion of the Pinelands National Reserve area in the north and northwest is underlain by Kirkwood outcrop and not Cohansey; however, as explained previously, the Cohansey Sand aquifer; in places, includes the upper sand beds of the Kirkwood Formation, especially near the Kirkwood-Cohansey outcrop contact. Therefore, precipitation on the Kirkwood outcrop is in effect recharge to the Cohansey Sand aquifer.

Plate 4 is a water-table map of the Cohansey Sand. This map was prepared by taking stream elevations from the New Jersey State Atlas Topographic sheets and contouring these points, keeping in mind the land surface topography. Water levels from wells tapping the Cohansey Sand were used to supplement the stream and topography data. The basic assumptions in preparing a water-table map by this method are that the shallow surficial aquifer is directly connected to the streams that drain its outcrop and that stream elevations are representative of the true water-table elevation. For the Cohansey Sand in the Pinelands, these are very good assumptions.

Rhodehamel (1970) points out that "The landforms of the area are all of low relief, and they affect the hydrologic regime significantly. The low relief...has a direct bearing on the location of areas of dominant ground-water recharge and discharge." Examination of the water-table contour map shows generally flat hydraulic gradients ranging from 15 to 25 feet per mile in the upland areas to 5 to 10 feet per mile in the low-lying coastal areas. These relatively gentle water-table gradients are to be expected with a highly permeable aquifer such as the Cohansey where less of a driving force is needed to move water through then for a low permeability aquifer with a greater resistance to flow. The water-table map is useful to determine the direction of shallow ground-water flow which is at right angles to the contour lines.

Rhodehamel has mentioned the idea of local and regional flow patterns in the Cohansey Sand aquifer; the concept being that some portion of the recharge to the Cohansey moves only a short distance through the aquifer before being discharged to local streams while the remainder of the recharge follows deeper and longer flow paths in the aquifer and discharges to distant streams at lower elevations. The basis in fact behind Rhodehamel's concept is that long-term stream flow records for parts of the Pinelands show variations in the annual runoff rate above and below the average value of 23.5 inches for all the Pinelands. For example, McDonalds Branch, an upland stream, has an annual runoff rate of 14 inches while the Mullica River near Batsto, a lowland area, has a long-term runoff rate of 33 inches.

These variations in runoff cannot be explained by the variation in precipitation between upland and lowland areas, but indicate that some of the recharge in upland areas moves downward into a deeper flow system instead of being discharged to local streams. In some upland areas, such as the area around McDonalds Branch, stream flows are below the regional average because of reduced ground-water discharge or base flow. Eventually, this recharge in the regional system discharges to some distant stream at lower elevation, such as the Mullica River near Batsto, increasing its base flow and causing a stream flow above the regional Pinelands average.

As far as designation of recharge and discharge areas is concerned, it can be surmised that the entire Cohansey outcrop is a recharge area, except for narrow discharge areas along streams and other surface-water bodies. Major recharge areas, especially for the deeper portions of the aquifer, are restricted to the topographically high upland areas of the Pinelands.

Two hydraulic sections have been constructed to illustrate ground-water flow patterns in the Pinelands National Reserve. Plate 5 shows hydraulic conditions in the Cohansey and Kirkwood aquifers, and Plate 6 is a conceptual diagram of ground-water flow in the entire ground-water reservoir from the water table to the crystalline bedrock. The Cohansey-Kirkwood flow section is based on August 1975 water-level measurements made in a series of U.S. Geological Survey (USGS) observation wells located on the Wharton tract. Some of these wells are screened in the Cohansey Sand and some in the deeper Kirkwood aquifer. The equipotential lines and the ground-water flow pattern illustrate the shallow and intermediate circulation pattern. Local flow paths are short, to the Mullica River for example, but the deeper ground-water flow pattern is toward the Batsto River or through the Kirkwood to the Atlantic Ocean. These hydraulic conditions are typical of the Pinelands region.

On the section, the Cohansey and Kirkwood aquifers are presented as one hydrologic unit. In actuality, of course, flow patterns would be more complex due to the presence of confining beds in the subsurface.

The deep ground-water flow pattern below the Pinelands is shown on Plate 6. This cross section traverses the northern half of the Pinelands and the Lebanon State Forest and terminates at Island Beach State Park. Aquifer and confining zones have been delineated based on the stratigraphic information from deep wells. Potentiometric data from deep aquifer zones is extremely limited; however, it suffices to establish a first approximation of hydraulic gradients and ground-water flow. Long-term pumping of the Magothy-Raritan aquifer along the Delaware River has created a regional cone of depression in this aquifer, which extends below the Pinelands National Reserve to the Atlantic Ocean. Heads in the Magothy aquifer along the Delaware are 80 feet below mean sea level, at the Ragovin observation well (center of section), the potentiometric level is -27 feet and at the Island Beach State Park observation well it is -2 feet.

The cone of depression in the Magothy aquifer appears to be the controlling feature of the flow system and this low-pressure zone influences ground-water movement in the entire saturated zone from the water table on downward. As shown, heads in the aquifer system in the central Pinelands region are 140 to 150 feet above mean sea level. The illustration shows equipotential lines of +100 feet, +50 feet, zero, and -25 feet as well as the ground-water flow pattern. Deep ground-water movement below the central Pinelands region is northwestward toward the center of the cone of depression.

Undoubtedly, there is an eastward component of deep ground-water flow from the upland region toward the Atlantic Ocean. Additional potentiometric information from deep wells is required to map such gradients and flow patterns. A regional ground-water divide must exist somewhere between the Magothy discharge zone (pumping centers along the Delaware River) and the natural discharge area along the edge of the continental shelf. At first glance, such a ground-water divide would appear to lie along the New Jersey coastline.

2.7.2 Water-Level Fluctuation

The water table in the Cohansey aquifer fluctuates in response to recharge and discharge. During periods of precipitation, the water table tends to rise and when precipitation is low, for example, during the summer and fall, water levels fall. Typical water-level fluctuations are shown by the hydrographs of three USGS observation wells (Plates 7 and 8). Plate 7 shows lowest daily water levels in Well 18-V, located in the

Lebanon State Forest, and Plate 8 shows monthly low water levels in the Penn State Forest and in the Crammer observation wells. The location of the three observation wells is shown in Figure 2-1. Both the Crammer and Lebanon State Forest wells are located in the upland area close to the topographic divide between the Delaware River and Atlantic Ocean drainage basins. The Penn State Forest well is located in the Oswego River basin at lower elevation.

Examination of the daily water-level record for the Lebanon State Forest well (period 1959-1967) shows a maximum fluctuation of 5 feet. On an annual basis, the fluctuation is normally 2.5 to 3 feet. Water levels are highest in March and April and lowest during September and October. The effect of drought conditions is visible in the low water levels during the fall and winter of 1965-66 when recharge was insufficient to replenish the aquifer.

The Crammer well hydrograph (period of record 1952-1979) shows a similar pattern. Maximum fluctuation is about 10 feet, but normal annual fluctuation is about 7 feet. During the drought in 1965, the water level declined about 2 feet below normal.

The Penn State observation well located closer to shore shows much less seasonal water-level fluctuation. During the period of record (1959-1979), maximum fluctuation was 2.5 feet,

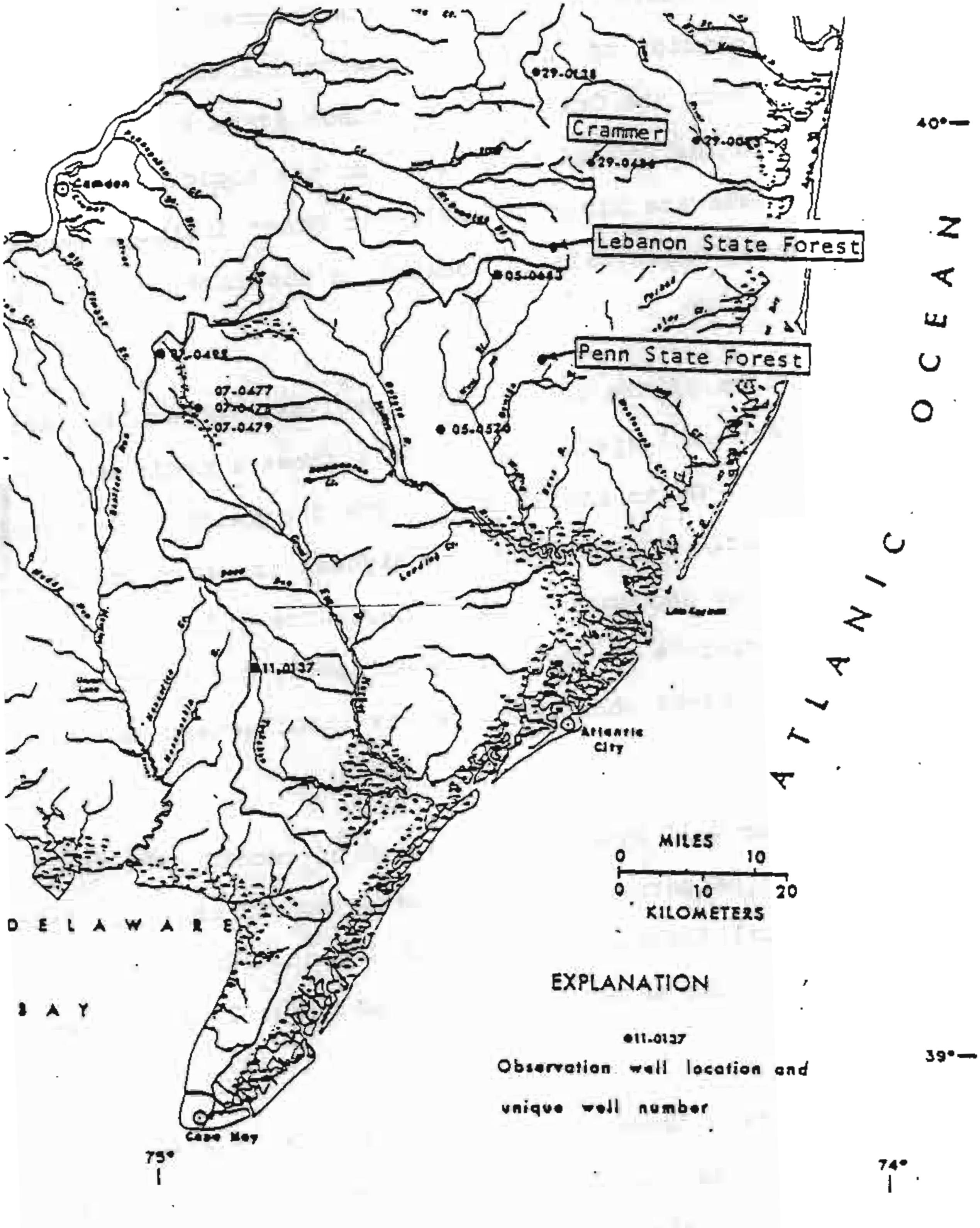


Figure 2-1. Location of Water-Level Observation Wells.

but the normal seasonal variation was only 2 feet. During the 1965 drought, the water level declined about one-foot below normal.

2.7.3 Ground-Water Availability

As discussed previously, all naturally occurring fresh ground water in the unconsolidated formations of the Pinelands is ultimately derived from precipitation. Evapotranspiration losses amount to slightly less than 50 percent of precipitation leaving the remaining portion as recharge and potential recharge to the formations. Most of this recharge is discharged from the region through streams which carry runoff consisting of direct overland runoff and ground-water discharge (base flow). This base flow portion is recharge that has been rejected by the full ground-water reservoir and is theoretically available for development. Water available based on such annual replenishment is often termed "safe yield." In addition to this water, there is a vast amount of ground water in storage within the Pinelands aquifers that can be withdrawn.

It should be realized that although the coastal plain sediments consist of individual aquifers and confining beds, they all act as one huge ground-water reservoir. As illustrated on the hydraulic cross section (Plate 6), the withdrawal of water from one aquifer can cause leakage from adjacent aquifers through confining units and cause changes in recharge, discharge, and movement of ground water in other aquifers.

In the following section, ground-water availability is discussed for the five major hydrogeologic units of the Pinelands taking into account mechanisms of recharge, discharge, present development, and water-level trends.

Cohansey Sand. The Cohansey Sand receives recharge from precipitation that falls directly on its outcrop area. Over the long-term an average of 1.8 bgd (billion gallons per day) of precipitation runs off as stream flow in the Pinelands from the Cohansey Sand outcrop area after water losses from evapotranspiration have been satisfied. Pumping from wells could reduce or even reverse the natural hydraulic gradient toward streams and capture much, if not all, of the surplus recharge which leaves the aquifer. However, as this base flow accounts for most of the stream flow, withdrawal of nearly 1.8 bgd would essentially dry up all streams and surface-water bodies draining the Cohansey outcrop within the Pinelands. This would be undesirable from an ecological as well as aesthetic and recreational point of view.

A more sensible approach to development of the Cohansey Sand has been suggested by Rhodehamel (1970). Initially, a limit of assured minimum stream flow should be established. For example, an average of the minimum mean discharge for 30 consecutive days each year for ten streams (areally weighted) draining 738 square miles of the Cohansey outcrop was computed to be equivalent to 0.46 mgd of runoff per square mile. When this is subtracted from the average mean flow for the above ten streams of 1.07 mgd per square miles, an average of 0.61 mgd per square mile is left to be developed. Over the outcrop area of the Cohansey within the Pinelands, this would amount to 1,000 mgd that could be developed while assuring a minimum flow in the region's streams. Of course, a greater or lesser minimum stream flow could be selected leaving a lesser or greater amount, respectively, of ground water to be developed. However, maintenance of a 30-day minimum flow appears to be a conservative approach.

In order to develop this 1,000 mgd or a significant portion thereof, several factors must be considered. First of all, along the northwest edge of the Pinelands, the sand is too thin to allow development of substantial supplies and along the coast, especially in Cape May County and near Atlantic City, the possibility of salt-water intrusion could place restrictions on development of large supplies. Therefore, large-diameter production wells should be installed in the interior of the Pinelands. Rivers such as the Mullica and Great Egg Harbor, collect and remove from the area the surplus ground water (base flow) and direct runoff, which together average 1.11 mgd per square mile. Pumping from large-diameter production wells along the downstream reaches of these streams (above the head of tide) could induce much of the flow (above the minimum flow established), to re-enter the Cohansey Sand for withdrawal by wells.

A joint study (Granstrom, Nieswand, and Ahmed, 1973 and Durand, Granstrom, and Rudolph, 1974) by biologists and engineers was undertaken to determine the maximum amount of water that could be withdrawn from the Mullica River Basin through conjunctive use of surface and ground water without causing undue impacts on communities in the Mullica estuary. Biological studies of the marine ecosystems in the Great Bay estuary (into which the Mullica flows) over an 11-year period including the drought of the 1960's, were used to establish a salinity regime for the estuary that would result in minimal effect on communities in the estuary. Minimum stream flows necessary to maintain the salinity levels were then established.

A digital model of the ground-water aquifer/stream system in the basin was developed from which it was determined that a maximum monthly withdrawal of 118 mgd of ground and surface waters could be obtained while still maintaining the minimum stream flows established. This withdrawal rate is a uniform one and during some months there would be considerable excess stream flow not used in the model which would average out to 35 mgd over the course of a year. Recharging of this surplus stream flow to the ground water would make it available for use at a more uniform rate over a longer period of time and increase the basin yield to 153 mgd.

Although similar studies may be needed in other basins within the Pinelands National Reserve to determine the applicability of this technique, extrapolation of these results to the whole Pinelands area indicates that 450 mgd could probably be developed conjunctively from the Cohansey Sand with no significant adverse effects on estuarine communities.

Any limits to its development would probably not be related to the aquifer's ability to store, transmit, or yield water but rather to restrictions placed on its development by man relating to assured minimum stream flows, preservation of fish communities, etc. Further information on aquifer characteristics including test well drilling and aquifer modeling would be required to evaluate any proposed large ground-water development scheme in the Pinelands.

Magothy-Raritan-Potomac System. This is the most heavily developed and widely utilized of all the aquifers in the Coastal Plain. Estimated pumpage from this system was over 240 mgd in 1976 and most of it was concentrated in its outcrop area and a short distance downdip of it between Old Bridge (Middlesex County) and the Gloucester-Salem County line. Pumpage from this unit has lowered the potentiometric surface below sea level over a considerable area.

In Burlington, Camden, and Gloucester Counties (tri-county area) in an area extending from the Delaware River to about 20 miles to the southeast, the potentiometric surface has been lowered more than 40 feet below sea level and in smaller areas within this zone it is over 80 feet below sea level. In these three counties, estimated pumpage from the aquifer system totaled 146 mgd in 1976.

Recharge to this aquifer system occurs from precipitation on its outcrop area, induced infiltration from surface water (primarily the Delaware River) leakage through overlying confining beds, and water released from storage in the overlying confining beds.

Discharge from the system occurs as base flow to streams in the outcrop area, vertical leakage through confining beds to subadjacent aquifers where heads are below those in the Magothy-Raritan-Potomac system, submarine underflow that maintains the fresh/salt-water interface where it occurs offshore, and artificial discharge through wells.

Potentially, 320 mgd of recharge from precipitation on the outcrop are available to this aquifer system. This would be more than enough to balance the present estimated pumpage, and therefore, theoretically no significant long-term water level declines should occur in the system.

However, it is now believed that precipitation on the outcrop cannot balance discharge from the confined portions of the aquifer until a steep enough hydraulic gradient is established between the two zones that will allow enough water to be transmitted from the outcrop to balance discharge. Unless this occurs, or some other form of recharge is available, the cone of depression will grow and water levels will continue to decline. To date, this gradient apparently has not become steep enough and other forms of recharge (possibly vertical leakage) are not occurring or are insufficient to balance discharge.

The potential for further development of the Magothy-Raritan-Potomac aquifer system is relatively large. The Delaware River, as discussed above, 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 are only a very small portion of this potential recharge. The 320 mgd of potential recharge from precipitation on the outcrop area is presently only being partially utilized. Additionally, throughout most of the Coastal Plain, the aquifer system is overlain by thick sequences of aquifers and confining units which have large volumes of water in storage and potentially can provide large amounts of recharge through vertical leakage.

In order to maximize future development from this system, wells must be properly located. The present well locations and pattern of pumping are not ideal for maximizing yields as most pumpage is concentrated in a relatively small portion of the

Coastal Plain. The result of this concentration of pumpage has been to concentrate water level declines instead of spreading them out uniformly. It would be more sensible to withdraw water from relatively undeveloped portions of the aquifer system.

In Burlington County, from the fresh/salt-water interface (Figure 2-2) to about the middle of the county, water levels are 20 feet or less below sea level. In these general areas, the potential for further development of the aquifer system is greatest due to the relatively large available drawdowns. The aquifer system in this area is under artesian conditions and will be receiving recharge through vertical leakage. For this leakage to occur, head differences between the aquifer system and overlying units must develop in order to generate leakage down through the Woodbury Clay and Merchantville Formation (which confine the aquifer system) in the Magothy-Raritan-Potomac system. Declining water levels should not be viewed as overpumping the aquifer. Where the aquifer system occurs under water-table conditions, additional supplies can also be developed.

In lower Ocean, Burlington, Camden, Gloucester, and Salem, and all of Atlantic, Cumberland, and Cape May Counties, the Magothy-Raritan-Potomac aquifer system contains water in excess of 250 ppm (parts per million) chloride and so is not suitable for potable use (Figure 2-2). However, some industries needing large volumes of cooling water may be able to tap the aquifer

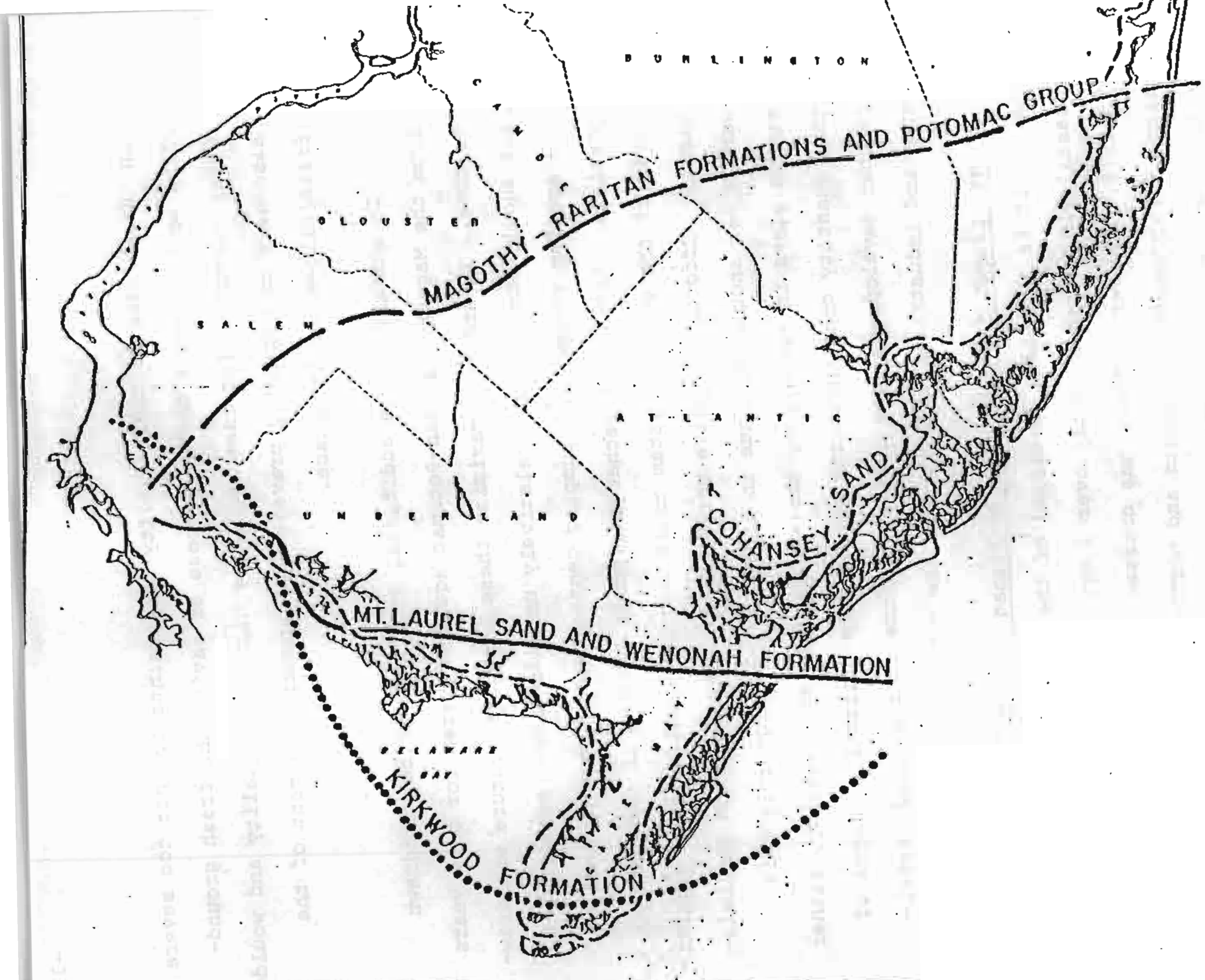


Figure 2-2. Salt ter/fresh water boundaries in coastal plain aq s.

in these areas if their quality constraints are not too severe. This would serve a double purpose of saving the fresh groundwater resources for uses requiring high water quality and would also help to retard or prevent the landward movement of the fresh/salt-water interface.

In summary, large additional supplies can be withdrawn from the Magothy-Raritan-Potomac aquifer system for many years to come. In order to maximize these supplies, future withdrawals should occur in the relatively underdeveloped portions of the aquifer system with pumping centers spread out as much as possible. Artificial recharging ponds located in the outcrop areas of the aquifer system could increase yields there significantly. Efforts to derive more induced recharge from the Delaware River should continue in light of the large role this source plays in recharging the aquifer system. Quality, rather than quantity considerations may be more critical in terms of further development from this system due to the highly developed and industrialized nature of the outcrop.

<u>Mt. Laurel Sand and Wenonah Formation</u>. The aquifer in this unit is the least developed of the major formations in the Coastal Plain with slightly over 3 mgd being withdrawn from it in 1976. However, pumping has created large cones of depression in southeastern Monmouth and northeastern Ocean Counties with water levels as much as 140 feet below mean sea level.

The Mt. Laurel-Wenonah aquifer acts as a source of recharge to the Englishtown Sand and as long as water levels continue to decline in the Englishtown, they will decline in the Mt. Laurel-Wenonah system. No additional withdrawals should be considered from this aquifer in this area. Future development of the Mt. Laurel-Wenonah in the northern part of the Coastal Plain should be in the outcrop area or a short distance downdip of it in order to utilize some of the 130 mgd of recharge potentially available. This would also hold true for the southern part of the Coastal Plain. The aquifer would have to be developed by adequately spaced shallow wells to reduce water-level interference. Domestic and irrigation supplies and industries with small water requirements would be best supplied in this manner. As development in this area will reduce stream flow, the developable amount will depend on the assured minimum stream flow desired. If as for the Cohansey Sand, 43 percent of the potentially developable water is left for stream flow, 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 has occurred in the north. Development in this manner should result in substantial additional supplies with stabilized water levels.

<u>Englishtown Formation</u>. The Englishtown is quite similar in present and potential development to the Mt. Laurel-Wenonah.

The available recharge from precipitation on the outcrop of about 120 mgd is almost identifical to the 130 mgd for the Mt. Laurel-Wenonah. Estimated pumpage from the Englishtown was over 12 mgd in 1976 and nearly all of it was concentrated in an area of severely depressed water levels 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. However, the Englishtown is less extensive that that of the Mt. Laurel-Wenonah and does not occur throughout the entire Coastal Plain.

The generalized potentiometric surface of the Englishtown aquifer is ~~very similar~~ to that of the Mt. Laurel-Wenonah. The area of severely depressed water levels **is** in the same place as that of the Englishtown so that water is able to leak down from the Mt. Laurel-Wenonah through the intervening Marshalltown confining unit.

Water level declines in this aquifer can be expected to continue for the foreseeable future. Utilization of much, if any, of the available recharge in the outcrop area with present well locations is unlikely. 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 it, and primarily for industries with small water requirements, irrigation, and domestic use. This development should take place in Monmouth, Burlington, and Ocean Counties as in the rest of the Coastal Plain the sand facies rapidly thins and pinches out both in outcrop and downdip. Due to its limited extent, only about 50 mgd can probably be developed from the Englishtown. Wells would have to be adequately spaced to reduce drawdown interference effects between wells and thereby obtain the maximum possible yield.

Kirkwood Formation. After the Magothy-Raritan-Potomac system and the Cohansey Sand, the Kirkwood Formation is the next most heavily developed aquifer in the Coastal Plain. Estimated pumpage from this unit was nearly 25 mgd in 1976, and nearly all of it was concentrated along the shore and barrier beaches in Atlantic, Ocean, and Cape May Counties. During the summer, pumpage can be as much as three to four times the winter pumpage as the result of increased demands created by the influx of tourists.

Water-level trends in this formation have been discussed elsewhere in this report, but due to their importance in helping to estimate the potential for future development from this unit, they will be reviewed here briefly. One of the most significant observations is that the profile of the cone of depression in Atlantic and Cape May Counties in 1970 was very similar to what it was in 1934 and water levels apparently have remained unchanged in these two counties since 1970.

In the center of the cone, water levels are over 70 feet below sea level. A hydraulic gradient does exist from the Kirkwood outcrop area to the center of the cone and precipitation falling on the outcrop could be transmitted to the coast. However, as has been discussed previously, 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 other thick clay units are present within the formation itself. Release of water from storage in these clay units is probably providing recharge to the water-bearing zones of the formation and based on data from studies on other confined aquifers in the Coastal Plain, is likely to be more significant than recharge derived from the outcrop area.

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 and since around 1960 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 as the pumpage here has not changed appreciably since 1970, but water levels may be declining in Ocean County in response to increased pumpage there. What is significant is that while public supply pumpage has increased by nearly 300 percent from 1935 to 1970, water levels along the coast between Atlantic City and Wildwood 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 provided that 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 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 available recharge there may be developed.

Although there is approximately 150 to 200 mgd of recharge available to the Kirkwood from precipitation on the outcrop, only about 85 to 115 mgd could be developed, assuming 43 percent of the available recharge is left to maintain stream flow as for the Cohansey Sand. It should be remembered that the water-bearing properties of the formation between outcrop and the coast are relatively unknown and as mentioned before, the permeability at the "800-foot" sand decreases sharply away from the Atlantic City area. Therefore, although pumping centers may be spread out in the future, relatively high yield wells may only be possible along the coast. Recharge from water released from storage in confining units may substantially increase the future yield of this system.

The ultimate yield may be controlled by the movement of the fresh/salt-water interface which except for Cape May County lies an unknown distance offshore. It would be wise to proceed with this development in stages and to install outpost monitoring wells. As pumping is increased, the chloride trend in these wells could be watched and any necessary changes in the pattern or quantity of pumpage could be made based on detected water quality trends.

Computer simulation of the Kirkwood aquifer may be necessary, especially in view of recent development and population growth in the Atlantic City area which will cause an increase in water demand.

3.0 GROUND-WATER QUALITY

3.1 Introduction

In order to assess ground-water quality in the Pinelands, published and unpublished documents were examined. Information on water quality was obtained from USGS and State of New Jersey Water Supply bulletins and from computer printouts of water-quality data from a series of wells installed in the Mullica River Basin. The chemical analyses reported in county bulletins date back to the 1948-1971 period. Ground-water quality data for the Mullica River Basin and selected USGS observation wells reflect the 1973-1978 period.

Data points were plotted on the base map and the aquifer was identified. A series of overlays (Plates 9 through 15) was then prepared for both the Cohansey and Kirkwood aquifers, illustrating the distribution and concentration of pH, total dissolved solids, total iron, and nitrate. Tables of chemical analyses were prepared by county and by aquifer, listing well identification number, approximate screen setting, date of collection, water temperature, and chemical constituents (see Tables 3-1 through 3-7).

It should be noted that the data points are unevenly distributed and that little or no water quality information is available in the northern and southern portions of the Pinelands region. The ground-water quality of each aquifer is discussed below.

3.2 Cohansey Aquifer

Chemical analyses for a total of 65 Cohansey wells were available. A summary table showing the range and median value of the four selected water quality criteria is as follows:

Parameter	Range	Median	New Jersey or USEPA Interim Drinking Water Standards
pH	3.8- 7.9	4.8	6.5-8.5
Total Iron, mg/l	0 - 10	0.05	0.3
Total Dissolved Solids, mg/l	6 -155	25	500
Nitrate-Nitrogen, mg/l	0 - 37	0.3	10.0

Examination of the pH distribution shows values between 4.0 and 5.0 with occasional higher values, confirming the acidic nature of Cohansey water. Iron concentrations in the Cohansey range from very low (less than 0.01 mg/l (milligrams per litre)) to more than 5.0 mg/l. Most of the central Pinelands appears to have low iron ground water, but concentrations rise

Table 3-1. Chemical Analysis of Ground Water in Atlantic County, Pinelands Region.

Location Number on Map	Approximate Screen Setting	Date of Collection	Temperature (^oF)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonat (HCO_3)
COHANSEY FORMATION											
AT 1C	179-195	5-19-64	-	5.4	0.02	0.00	1.5	1.0	4.1	0.0	5
AT 2C	55- 65	5-20-64	-	5.7	0.05	0.10	8.8	7.3	8.5	1.5	0
AT 3C	44- 55	4- 9-64	-	-	1.08	0.0	-	-	-	-	-
AT 4C	91- 98	5-19-64	-	4.3	0.16	0.03	2.8	3.6	7.1	0.0	2
AT 5C	97-107	4- 7-64	-	3.8	0.68	0.00	0.8	0.2	0.9	0.9	6
KIRKWOOD FORMATION											
AT 1K	198-203	11-11-63	59	16	4.6	0.26	7.2	2.4	17	2.2	67
AT 2K	255-315	8-13-63	-	11	0.13	0.03	2.0	0.2	1.5	0.7	1
AT 3K	342-394	10-16-63	-	47	4.0	0.01	2.8	1.5	2.5	2.0	10
AT 4K	363-406	10-16-63	-	51	3.6	0.03	2.4	1.7	2.5	2.0	8
AT 5K	350-430	11-12-64	-	-	2.3	0.05	-	-	-	-	-
AT 6K	718-778	4-21-64	64	28	0.45	0.0	3.2	1.5	21	2.0	40
AT 7K	706-766	4- 2-53	66	-	0.22	-	5.6	2.9	-	-	72
AT 8K	200-230	10-17-63	-	54	2.0	0.03	5.2	2.2	3.5	2.2	20
AT 9K	220-230	5- 1-64	-	-	3.25	0.00	-	-	-	-	-

Source: Clark, G.A. and others, 1968

Table 3-1 (Continued)

Location Number on Map	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids	Hardness as $CaCO_3$ Calcium Magnesium	Hardness as $CaCO_3$ Non-Carbonate	Specific Conductance (micromhos at 25°C)	pH	Color	Use
COHANSEY FORMATION											
AT 1C	0.6	6.0	0.0	7.2	33	8	4	44	5.4	1	Irrigation
AT 2C	0.6	34	0.3	37	155	-	52	221	4.5	3	Irrigation
AT 3C	-	3.0	-	-	66	3	0	-	6.5	-	Domestic
AT 4C	0.6	9.6	0.0	30	68	22	21	116	5.4	1	Domestic
AT 5C	0.6	2.8	0.0	0.0	16	3	0	16	6.0	5	Domestic
KIRKWOOD FORMATION											
AT 1K	12	2.6	0.2	0.5	96	28	-	135	7.4	23	Observation
AT 2K	6.0	1.9	0.0	1.3	51	6	5	36	5.0	2	Public
AT 3K	8.2	3.3	0.0	0.3	73	13	5	47	5.9	6	Public
AT 4K	9.6	3.3	0.0	0.3	77	13	7	59	5.7	5	Public
AT 5K	-	2.0	-	-	98	12	1	-	6.1	-	Public
AT 6K	10	11	0.3	0.2	103	14	0	128	6.9	12	Public
AT 7K	14	4.6	-	0.1	-	26	-	153	7.0	3	Public
AT 8K	9.4	3.4	0.2	0.2	96	22	6	67	6.4	8	Public
AT 9K	-	2	-	-	73	9	0	-	6.0	-	Domestic

Table 3-2. Chemical Analysis of Ground Water in Burlington County, Pinelands Region

Location Number on Map	Screen Setting (Ft)	Date of Collection	Temperature (°F)	Silica (SiO_2)	Total Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$		Specific Conductance (micromhos at 25°C)	pH
																	Calcium magnesium	Noncarbonate		
		ENGLISHTOWN FORMATION																		
BL 1E	- -	5-28-51	55	21	0.64	0.12	37	1.8	2.0	3.3	121	8.4	2.5	0.1	0.2	139	100	1	214	8.0
BL 2E	- -	6-17-59	-	9	0.64	0.03	23	4.6	8.0		104	7.1	0.8	0.0	0.4	150	77	0	176	7.1
		COHANSEY SAND																		
BL 1C	- -	5- 2-51	59	6	0.00	0.00	5.2	0.0	5.0	0.3	10	0.0	3.2	1.9	1.9	44	13	5	46	6.9
BL 2C	- -	8-14-51	56	4.3	0.12	0.00	1.3	1.9	2.4	0.7	3	4.5	8.2	0.0	0.3	26	11	9	79	5.0
BL 3C	53-73	6-21-51	65	6.1	10	0.52	2.4	0.4	3.0	0.9	5	4.2	5.0	0.1	0.2	25	8	4	35	5.5
BL 4C	- -	8-14-51	59	5.2	0.04	0.00	0.2	0.7	2.6	0.8	3	0.0	4.2	0.0	2.1	16	3	1	23	5.5
BL 5C	- -	6-21-51	58	2.7	5.7	0.38	1.2	1.6	3.1	0.6	0	7.5	8.5	0.0	0.3	29	10	10	63	4.4
BL 6C	- -	6-13-61	69	1.5	0.47	0.04	1.6	1.0	1.8	0.5	2	6.7	2.2	0.1	0.2	23	8	7	33	4.8
		KIRKWOOD FORMATION																		
BL 1K	- -	8-14-51	56	32	0.32	0.00	1.0	0.8	2.5	2.0	2	7.0	3.6	0.0	0.2	54	6	4	47	4.7
		MAGOTHY/RARITAN FORMATION																		
BL 1R	916-960	6-19-59	-	9.8	2.4	0.05	16	2.8	9.0		68	12	1.8	0.1	0.2	105	52	0	137	6.5
BL 2R	1030-1051	6-19-59	-	11	2.2	0.04	16	3.3	8.3		68	11	2.8	0.1	0.2	85	54	0	140	6.8
BL 3R	922-1055	3- 1-61	-	7.8	2.0	0.06	15	2.1	8.2	3.8	64	8.2	5.1	0.1	0.4	84	46	0	139	7.1
BL 4R	1036-1089	3- 1-61	-	8.3	2.8	0.09	16	2.6	6.0	3.8	67	8.2	2.5	0.0	0.8	82	51	0	133	6.8
BL 5R	1012-1075	3- 1-61	-	9.8	3.1	0.08	17	2.6	6.0	3.8	69	7.6	2.4	0.0	0.5	84	53	0	135	6.9
BL 6R	407-417	4-27-60	-	9	0.7	0.0	20	4.9	12	-	87	7.0	6.0	-	-	-	70	0	-	8.1

Source: Rush, F. E., 1962

Table 3-2. (Continued)

Location Number on Map	Screen Setting (Ft)	Date of Collection	Temperature (°F)	Silica (SiO_2)	Total Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$		Conductance (micromhos at 25°C)	pH
																	Calcium magnesium	Noncarbonate		
	MOUNT LAUREL SAND AND WENONAH FORMATION																			
BL 1MT	- -	5-22-51	56	14	0.21	0.00	26	2.9	2.8	3.9	92	7.0	2.0	0.1	0.2	100	77	1	167	8.3
BL 2MT	155-185	5-28-51	56	16	0.35	0.00	44	3.0	2.2	4.3	153	5.0	3.4	0.1	0.3	156	122	0	253	7.8
BL 3MT	- -	5- 4-51	59	11	0.30	0.00	21	5.4	3.3	8.4	107	4.5	2.2	0.0	0.9	109	75	0	187	7.7
BL 4MT	294-334	-60	-	-	0.08	0.00	-	-	-	-	113	-	2.0	-	-	112	82	0	-	8.0
BL 5MT	178-198	1-10-61	-	-	0.04	-	-	-	-	-	100	-	3.0	0.0	-	-	80	0	-	7.8
BL 6MT	110-121	6-13-61	70	16	0.50	0.02	36	2.6	1.8	3.2	120	5.0	3.2	0.1	0.2	140	101	2	203	7.8
BL 7MT	247-268	1- 7-61	-	-	0.16	0.00	-	-	-	-	142	-	6.0	0.2	0.2	136	70	0	-	8.1
BL 8MT	353-381	4-23-56	58	9.7	0.24	0.01	27	4.6	2.7	7.4	112	6.4	2.2	0.1	0.9	118	86	0	196	8.0
BL 9MT	- -	6-21-51	57	13	0.28	0.00	22	5.7	5.3	8.5	111	5.0	2.0	0.1	0.0	115	78	0	192	8.1
BL10MT	- -	6-21-51	58	15	0.19	0.00	26	2.4	2.7	3.7	93	6.5	1.8	0.1	0.2	106	75	0	105	8.0
BL11MT	140-150	6-13-61	57	14	0.25	0.10	32	2.1	2.0	3.0	106	4.6	2.8	0.4	0.2	120	89	2	184	7.7

Table 3-3. Chemical Analysis of Ground Water In Cape May County, Pinelands Region

Location Number on Map	Screen Setting (Ft)	Date of Collection	Temperature (°F)	Silica (SiO_2)	Total Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
	KIRKWOOD FORMATION											
CM 1K	250-290	4-15-57	60	35	--	-	26	3.9	---		77	0
	COHANSEY SAND											
CM 1C	125-140	7- 7-55	59	9.0	.10	.10	10	18	22	---	1	0
CM 2C	125-140	2-20-56	59	10	.10	.00	2	5	11	---	--	0
CM 3C	135-160	2-28-57	59	39	1.3	.04	1.6	1.4	4.8	2.1	0	0
CM 4C	134-140	8-27-56	58	9.3	.21	.00	.9	.5	6.2		6	0
CM 5C	137-143	8-27-56	62	9.1	.49	.00	.8	.2	6.3		6	0
CM 6C	110-130	8-27-56	59	25	--	-	4.8	1.9	---		20	-

Source: Gill, H.E., 1962

Table 3-3. (Continued)

Location Number on Map	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (Residue on evaporation at 180°C)	Hardness as $CaCO_3$		Color	Specific conductance (micromhos at 25°C)	pH
						Calcium magnesium	Noncarbonate			
	KIRKWOOD FORMATION									
CM 1K	8.0	4.0	--	---	--	80	--	Up	---	---
	COHANSEY SAND									
CM 1C	45	19	--	---	--	1	27		---	4.4
CM 2C	1.0	10	--	---	--	--	7		---	4.7
CM 3C	2.5	12	.1	5.0	55	0	10		112	4.5
CM 4C	.0	9.0	.0	.2	42	4	0		41	5.7
CM 5C	.0	8.4	.0	.2	40	3	0		41	5.8
CM 6C	4.0	12	--	---	--	20	0		---	7.9

Table 3-4. Chemical Analysis of Ground Water in Camden County, Pinelands Region.

Location Number on Map	Approximate Screen Setting	Date of Collection	Temperature (^{o}F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbona (HCO_3)
KIRKWOOD FORMATION											
AT 1K	344- 372	10- 1-52	-	-	0.10	0.00	15.2	10.5	53	-	134
AT 1K	344- 372	8-22-61	57	12	0.08	0.0	9	3.3	44	6.0	160
AT 2K	306- 331	10- 1-52	-	-	0.4	0.0	15.2	2.6	53	-	138
AT 3K	326- 356	10- 1-52	-	-	23	0.3	77	24	33	-	122
COHANSEY SAND											
AT 1C	141- 167	8- 2-60	59	8.2	0.13	0.05	0.8	0.2	2.8	0.5	3
AT 1C	117- 138	9- 2-53	-	-	0.10	-	-	-	1.8	0.5	10
AT 2C	117- 138	8-22-61	55	7.4	0.04	0.01	0.8	0.5	3.0	0.2	3
AT 3C	72- 103	12-23-70	55	-	0.3	0.05	-	12	-	-	-
AT 4C	64- 90	1- 7-71	-	-	0.2	0.05	-	8	-	-	-
AT 5C	-	3-24-70	-	-	0.42	-	-	-	-	-	-
MAGOTHY/RARITAN FORMATION											
AT 1R	1,485-1,495	8-19-60	74	12	0.52	0.04	11	3.8	254	4.2	176

Source: Donsky, E., 1963

Table 3-4. (Continued)

Location Number on Map	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids	Hardness as $CaCO_3$		Specific Conductance (micromhos at 25° C)	pH	Color	Use
						Calcium Magnesium	Non-Carbonate				
KIRKWOOD FORMATION											
AT 1K	10	2.0	-	-	-	62	0	-	9.3	-	Public
AT 1K	10	2.0	0.4	0.7	175	36	0	265	8.0	3	Public
AT 2K	10	2.0	-	-	-	62	0	-	9.2	-	Public
AT 3K	10	127.0	-	-	-	204	104	-	7.5	12	Observati
COHANSEY SAND											
AT 1C	3.6	2.3	0.1	0.6	15	3	1	19	5.5	1	Public
AT 1C	0.0	2.0	-	0.0	-	8	2	-	6.1	5	Public
AT 2C	3.6	3.1	0.0	0.6	18	4	2	20	5.2	2	Public
AT 3C	7.0	8.0	-	18.2	38	16	-	-	5.0	-	Public
AT 4C	3.0	4.0	-	1.2	22	2	-	-	5.0	-	Public
AT 5C	9.0	5.0	-	4.8	56	12	12	-	4.3	-	
MAGOTHY/RARITAN FORMATION											
AT 1R	6.3	310.0	2.0	0.2	665	43	0	1290	7.2	3	Observatic

able 3-5.Chemical Analysis of Ground Water In Cumberland County Pinelands Region

ocation Number on Map	Screen Setting (feet below land surface)	Date of Collection	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
KIRKWOOD FORMATION											
CU 1K	264-274	1- 9-63	13	71	.00	.00	24	4.1	2.6	2.4	89
CU 2K	262-270	11-29-63	14	47	1.2	.07	22	2.2	10	3.0	94
CU 3K	242-269	1- 8-63	13	58	1.2	.09	22	3.2	9.6	3.2	91
CU 4K	295-315	1- 8-63	14	62	.10	.00	22	4.1	5.5	2.8	85
CAPE MAY FORMATION											
CU 1CM	78	1-29-63	13	8.3	1.5	.25	0.8	1.0	2.4	0.2	5

Source: Rooney, J.G., 1971

Table 3-5(Continued)

Location Number on Map	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids	Hardness as $CaCO_3$	Specific Conductance (micromhos at 25°C)	pH	Color	Carbon Dioxide (CO_2)
KIRKWOOD FORMATION										
CU 1K	8.4	3.8	.1	.5	167	81	177	8.1	2	1
CU 2K	9.0	2.7	.2	.2	153	64	175	7.7	25	--
CU 3K	12	2.4	.2	.3	165	68	165	7.4	5	6
CU 4K	8.1	4.2	.1	.2	156	75	177	7.9	2	2
CAPE MAY FORMATION										
CU 1CM	2.1	5.0	0.0	0.0	22	8	14	5.4	2	30

Table 3-6. Chemical Analysis of Ground Water in Gloucester County, Pinelands Region

Location Number on Map	Screen Setting (Ft)	Date of Collection	Temperature (°F)	Silica (SiO_2)	Total Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$		Specific Conductance (micromhos at 25°C)	pH
																	Calcium magnesium	Noncarbonate		
	CCHANSEY SAND																			
GL 1C	38-58	6- 4-57	13	7.7	0.13	2.1	3.7	3.2	2.8	2	0	4.2	7.0	0.0	19	52	20	18	91	5.2
GL 2C	90-96	5-30-57	14	8.1	1.5	1.3	2.2	8.6	1.2	3	0	0.2	7.0	0.1	22	62	12	10	88	5.3
GL 3C	49-59	5-30-57	14	10	0.93	0.8	0.4	1.0	0.4	5	0	1.7	2.8	0.1	0.3	20	2	0	21	6.2

Source: Hardt, W. F. and G. S. Hilton, 1969

Table 3-7. Chemical Analysis of Ground Water in Ocean County, Pinelands Region

Location Number on Map	Screen Setting (Ft)	Date of Collection	Temperature (°F)	Silica (SiO_2)	Total Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$		Specific Conductance (micromhos at 25°C)	pH
																	Calcium magnesium	Noncarbonate		
		RARITAN AND MAGOTHY FORMATION																		
OC 1R	1320-1350	2-62	-	11	3.2	11	2.8	6.8	2.2	48	0	8.8	4.4	0.0	0.2	72	39	0	111	7.4
Island Beach	2736-2757	9-62	86	16	1.8	31	6.1	485	8.2	188	0	2.5	670	1.0	0.2	1,430*	103	0	2,750	7.3
		KIRKWOOD FORMATION																		
OC 1K	212-236	3-59	-	-	2.6	-	-	-	-	-	-	-	7.0	-	0.08	52	24	-	-	6.1
OC 2K	526-547	7-60	-	-	2.6	-	-	-	-	-	-	-	5.0	0.1	0.27	90	26	0	-	6.3
OC 3K	536-566	5-48	-	30	-	3.0	1.0	-	-	18	-	10	3.0	-	-	-	12	-	-	6.5
OC 4K	-	9-48	-	-	1.5	-	-	-	-	0	-	15	-	-	0.1	-	7.5		74	4.3
OC 5K	-	8-51	56	-	0.07	-	-	-	-	0	-	-	6.0	-	0.5	-	-	-	50.6	4.4
OC 6K	-	8-51	57	-	0.7	-	-	-	-	20	0	-	4.0	-	0.6	-	-	-	67.7	5.5
OC 7K	-	4-52	55	-	2.4	-	-	-	-	-	-	6.0	17	-	0.5	-	-	-	112	-
OC 8K	-	9-62	62	29	1.7	16	1.5	12	4.2	70	0	12	7.0	0.1	0.4	115*	46		179	7.4
OC 9K	-	3-62	54	15	0.81	2.3	1.2	3.4	2.5	6	0	10	4.1	0.0	0.0	40	2.9	-	51	5.9
		UNDIFFERENTIATED WATER-TABLE AQUIFER																		
OC 1U	40-47	12-48	-	3.6	0.20	1.7	1.0	-	-	2	0	2.3	6.1	0.1	3.0	21*	-	-	52.5	5.0
OC 2U	60-80	12-48	-	3.5	0.17	0.8	0.6	-	-	4	0	4.2	3.1	0.1	0.5	14*	-	-	22.5	5.5
OC 3U	48-58	7-58	-	3.0	3.4	0.8	0.2	2.0	0.2	11	0	3.4	3.6	0.0	0.0	26*	12		33	6.2
OC 4U	36-56	7-58	-	4.6	6.8	0.8	0.2	2.0	0.2	4	0	2.8	3.6	0.0	0.1	23*	8		25	5.9
OC 5U	95-110	6-60	-	4.8	-	8.0	6.0	-	-	-	-	14.8	34	-	-	-	14	-	-	-
OC 6U	-	6-61	54	17	22	0.8	1.0	2.8	2.5	0	0	10	4.8	0.1	0.4	45	6	6	60	4.4
OC 7U	-	1-56	-	-	0.3	-	-	-	-	-	-	-	6.0	0.1	-	37	14	-	-	4.7
		8-63	56	18	0.5	1.3	0.2	3.7	0.5	0	0	7.2	5.2	0.1	0.0	35	4	4	55	4.4
		4-46	-	-	-	-	-	-	-	0	-	8	4.6	0.1	-	-	6		-	4.5
OC 8U	-	7-58	-	3	3.4	0.8	0.2	2.0	0.2	11	0	3.4	3.6	0.0	0.0	26	12	3	33	6.2
OC 9U	-	8-61	-	2.8	0.09	0.8	1.0	1.9	0.8	2	0	4.6	3.6	0.0	0.2	19	6	2	26	5.8
OC10U	-	10-64	58	5.8	0.10	0.8	1.0	4.0	0.8	5	0	0.0	7.6	0.1	0.2	23	6	2	35	5.8

* Sum

Source: Anderson, H. R. and C. A. Appel, 1969

Table 3-7. Chemical Analysis of Ground Water in Ocean County, Pinelands Region

Location Number on Map	Screen Setting (Ft)	Date of Collection	Temperature (°F)	Silica (SiO_2)	Total Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$		Specific Conductance (micromhos at 25°C)	pH
																	Calcium magnesium	Noncarbonate		
RARITAN AND MAGOTHY FORMATION																				
OC 1R	1320-1350	2-62	-	11	3.2	11	2.8	6.8	2.2	48	0	8.8	4.4	0.0	0.2	72	39	0	111	7.4
Island Beach	2736-2757	9-62	86	16	1.8	31	6.1	485	8.2	188	0	2.5	670	1.0	0.2	1,430*	103	0	2,750	7.3
KIRKWOOD FORMATION																				
OC 1K	212-236	3-59	-	-	2.6	-	-	-	-	-	-	-	7.0	-	0.08	52	24	-	-	6.1
OC 2K	526-547	7-60	-	-	2.6	-	-	-	-	-	-	-	5.0	0.1	0.27	90	26	0	-	6.3
OC 3K	536-566	5-48	-	30	-	3.0	1.0	-	-	18	-	10	3.0	-	-	-	12	-	-	6.5
OC 4K	-	9-48	-	-	1.5	-	-	-	-	0	-	15	-	-	0.1	-		7.5	74	4.3
OC 5K	-	8-51	56	-	0.07	-	-	-	-	0	-	-	6.0	-	0.5	-	-	-	50.6	4.4
OC 6K	-	8-51	57	-	0.7	-	-	-	-	20	0	-	4.0	-	0.6	-	-	-	67.7	5.5
OC 7K	-	4-52	55	-	2.4	-	-	-	-	-	-	6.0	17	-	0.5	-	-	-	112	-
OC 8K	-	9-62	62	29	1.7	16	1.5	12	4.2	70	0	12	7.0	0.1	0.4	115*	46		179	7.4
OC 9K	-	3-62	54	15	0.81	2.3	1.2	3.4	2.5	6	0	10	4.1	0.0	0.0	40	2.9	-	51	5.9
UNDIFFERENTIATED WATER-TABLE AQUIFER																				
OC 1U	40-47	12-48	-	3.6	0.20	1.7	1.0	-	-	2	0	2.3	6.1	0.1	3.0	21*	-	-	52.5	5.0
OC 2U	60-80	12-48	-	3.5	0.17	0.8	0.6	-	-	4	0	4.2	3.1	0.1	0.5	14*	-	-	22.5	5.5
OC 3U	48-58	7-58	-	3.0	3.4	0.8	0.2	2.0	0.2	11	0	3.4	3.6	0.0	0.0	26*	12		33	6.2
OC 4U	36-56	7-58	-	4.6	6.8	0.8	0.2	2.0	0.2	4	0	2.8	3.6	0.0	0.1	23*	8		25	5.9
OC 5U	95-110	6-60	-	4.8	-	8.0	6.0	-	-	-	-	14.8	34	-	-	-	14	-	-	-
OC 6U	-	6-61	54	17	22	0.8	1.0	2.8	2.5	0	0	10	4.8	0.1	0.4	45	6	6	60	4.4
OC 7U	-	1-56	-	-	0.3	-	-	-	-	-	-	-	6.0	0.1	-	37	14	-	-	4.7
		8-63	56	18	0.5	1.3	0.2	3.7	0.5	0	0	7.2	5.2	0.1	0.0	35	4	4	55	4.4
		4-46	-	-	-	-	-	-	-	0	-	8	4.6	0.1	-	-	6		-	4.5
OC 8U	-	7-58	-	3	3.4	0.8	0.2	2.0	0.2	11	0	3.4	3.6	0.0	0.0	26	12	3	33	6.2
OC 9U	-	8-61	-	2.8	0.09	0.8	1.0	1.9	0.8	2	0	4.6	3.6	0.0	0.2	19	6	2	26	5.8
OC10U	-	10-64	58	5.8	0.10	0.8	1.0	4.0	0.8	5	0	0.0	7.6	0.1	0.2	23	6	2	35	5.8

* Sum

Source: Anderson, H. R. and C. A. Appel, 1969 to above the 0.3 mg/l drinking water limit further south.

Dissolved solids concentrations are very low (20 mg/l) in the central Pinelands but tend to increase to the south and southwest with concentrations reaching 50 and 60 mg/l.

Nitrate concentrations are extremely low in the central area with values of less than 0.1 mg/l. Anomalous values of 10 and 20 mg/l occur in Winslow Township, probably reflecting agricultural practices or waste disposal.

3.3 Kirkwood Aquifer

Kirkwood data points are restricted to the central Pinelands area and the coastal zone. Analyses from 38 wells located mostly in the Mullica River Basin and along the eastern boundary of the Pinelands in Ocean County show the following concentrations:

Parameter	Range	Median	New Jersey or USEPA Interim Drinking Water Standards
pH	4.2- 9.3	6.2	6.5-8.5
Total Iron, mg/l	0 - 23	0.7	0.3
Total Dissolved Solids, mg/l	14 -175	77	500
Nitrate-Nitrogen, mg/l	0 - 13	0.2	10.0

The pH map shows that the Kirkwood water is less acidic than Cohansey water. Most pH values are between 5.0 and 7.0. A anomalous pH value of 9.0 has been recorded in Winslow Township.

Iron concentrations are generally above the 0.3 mg/l drinking water limit and treatment of raw well water would be required to comply with this standard. Concentrations of 2.0 to 4.0 mg/l of total iron are not uncommon.

Total dissolved solids concentrations appear to increase from north to south reaching 120 mg/l in the Atlantic City area. This pattern indicates a gradual and natural increase in mineralization of ground water in a seaward direction.

3.4 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.

Little is known about the horizontal and vertical distribution of saline ground water below the Pinelands because few deep test wells have been drilled. From available well and water-quality data it appears that practically the entire wedge of coastal plain sediments contains fresh water (less than

1,000 mg/l) except for deep Raritan-Magothy beds in the south and along the coastline.

In the Island Beach State Park well, fresh ground water was found to a depth of about 2,500 feet. Below this depth, the salinity of the water appeared to increase steadily to that of sea water according to geophysical well logs. A hypothetical salt-water/fresh-water boundary in the Raritan and Magothy Formations is shown in Figure 2-2. The 250 mg/l (drinking water limit) isochlor signifying this boundary forms a gently curved line that crosses the Pineland National Reserve diagonally from Ocean Beach near Manasquan to Delaware Bay near Salem. The number of wells and chloride records are insufficient to determine the exact position of this saline front, nor can it be determined whether any inland movement of the 250 mg/l line has taken place.

The position of the 250 mg/l isochlor is largely inferred from the results of deep drilling by the USGS at Island Beach State Park in Ocean County (USGS Water Resources Circular 12, Island Beach State Park, 1963); chloride data from the USGS in Brooklyn State Park observation well (USGS Unpublished Records, 1977); and several other wells. Other wells, while apparently remote from the interface itself confirm its existence between. For example, numerous wells tapping the aquifer north of the interface show low chloride values while a single well in Cumberland County on the seaward side of the 250 mg/l isochlor (Ragovin observation well) shows chloride as high as 27,000 mg/l (USGS Water Resources Data, 1974).

There is no record of saline ground water occurring in any of the formations above the Magothy-Raritan group. The Kirkwood and Cohansey aquifers both contain fresh water. The fresh-water/salt-water interface in the Kirkwood has been mapped in southern Cape May County and the fresh-water/salt-water interface in the Mt. Laurel Sand and Wenonah Formation appears to be in southern Cumberland County and northern Cape May County (Figure 2-2). Some shallow wells tapping the Cohansey on the barrier beach near Atlantic City have experienced saline water, however, this is due to the fact that the wells were located too close to the natural fresh-water/salt-water interface.

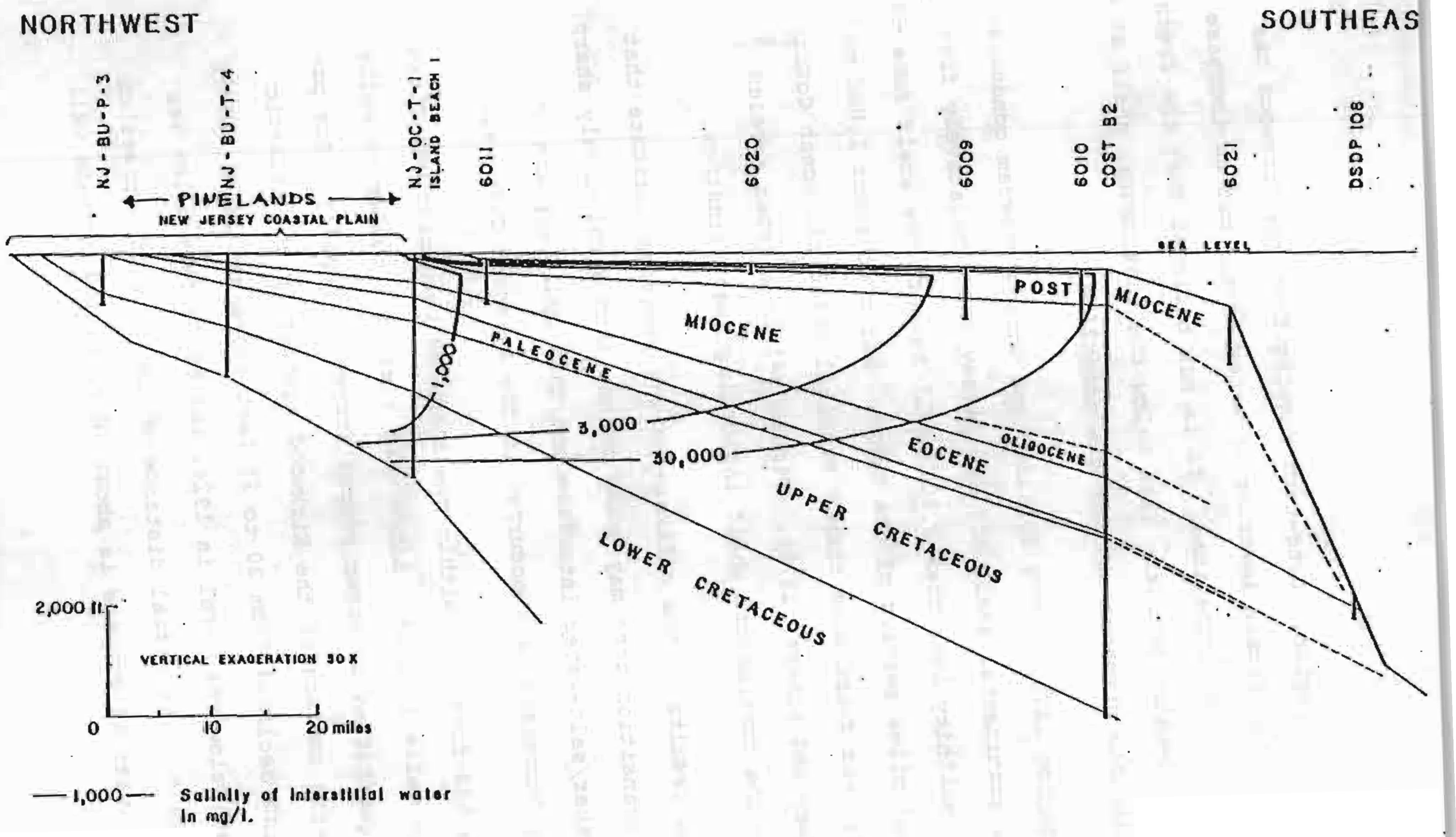
The 100- and 200-foot sands of the Cohansey Formation on the mainland were developed as a source of water by the Atlantic City Water Works early in the 1930's. Early in the 1930's, salt-water intrusion occurred in the well field along Conovers Run, a tributary to Absecon Creek. Wells screened in the 100-foot sand experienced a gradual upward trend in salinity with chloride concentrations reaching 500 mg/l and in some wells, 5,000 mg/l. An extensive test drilling and sampling program was undertaken to investigate the occurrence of this saline water.

The well field is adjacent to a tidal marsh and the 100-

foot sand is separated from the saline water by a clay bed. The Cohansey Sands were found to be irregular in character, ranging from coarse, clean water-bearing sand, to fine clayey sand. The vertical distribution of saline water was also irregular and spotty, probably reflecting changes in permeability of the aquifer. The confining bed was found to consist of a series of irregular lenses of clay instead of a continuous horizon and the intrusion occurred by entrance of saline water through holes in the confining bed. The salt-water body was found to be under the marsh and parallel to the shore line. The origin and occurrence of the saline water was thus local and not indicative of sea-water encroachment (Barksdale and others, 1936).

Saline water in the shallow sand forced the water company to develop 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 miscellaneous private and municipal wells in the Cohansey Sand show no pattern of salt-water contamination, with reported chloride ranging from 5 to 15 mg/l. However, it should be noted that no detailed water quality studies have been undertaken in recent years.

In previous years, concern was expressed regarding potential sea-water encroachment in the Kirkwood Formation in the At-



Modified from Hathaway (1976)

Figure 3-1. Salinity of ground water below the continental shelf.

lantic City region. Long-term pumping from the Kirkwood has produced significant lowering of water levels but no increase in chloride concentrations. It is now believed that the fresh-water/salt-water boundary lies below the continental shelf at a considerable distance east of the coastline.

During 1976, a USGS drilling and coring program conducted 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). Figure 3-1 is a cross section through the continental shelf indicating these findings.

The results of the offshore coring programs indicate that a wide transition zone may exist rather than a relatively sharp fresh-water/salt-water interface and this would explain why no salinity increases have occurred in the Atlantic City wells.

The 800-foot sand within the Kirkwood Formation was first tapped by wells in 1889. Since that time, the number of wells and the quantities of water pumped increased rapidly. The potentiometric surface of the Kirkwood aquifer in the Atlantic City region declined from 20 to 25 feet above sea level (1889) to 55 feet below sea level in 1924, and to 70 feet below sea level in 1970. The radial distance of the cone of depression from the center of pumpage is about 40 miles and extends well into the Pinelands National Reserve. Because of the increased urban and commercial development in the Atlantic City region, increases in pumpage may be expected. Monitoring of water quality in the Kirkwood aquifer should continue to evaluate the possible impact of the pumpage.

In summary, the entire ground-water reservoir below the Pinelands contains fresh water, with the exception of the lowermost Magothy-Raritan Formation in the southern half of the region and along the Atlantic Ocean. There is no evidence of any salt-water encroachment in any of the aquifer systems including the Kirkwood which is heavily pumped in the Atlantic City region. High salinities have been reported in some shallow wells that are located too close to the natural fresh-water/salt-water interface.

4.0 GROUND-WATER CONTAMINATION

4.1 Introduction

Contamination of ground water can occur from a large number of man-made sources. Among those of particular interest to the Pinelands are seepage from sanitary landfills, highway deicing salts, accidental or deliberate spills, leaks in storage tanks or pipelines, septic tanks and sea-water encroachment.

The mechanism of contaminant movement in the subsurface is fairly well understood. In case of a water-table aquifer, such as the Cohansey, contaminants would travel from the land surface through the unsaturated zone and then move with the ground water to a point of discharge, a stream for example. Such a typical flow path is shown in Figure 4-1.

Often fluid disposal in the subsurface creates a mound on the water table (Figure 4-2). The actual shape and size of the contaminant plume in the saturated zone is a function of porosity, hydraulic conductivity of the materials, fluid density,

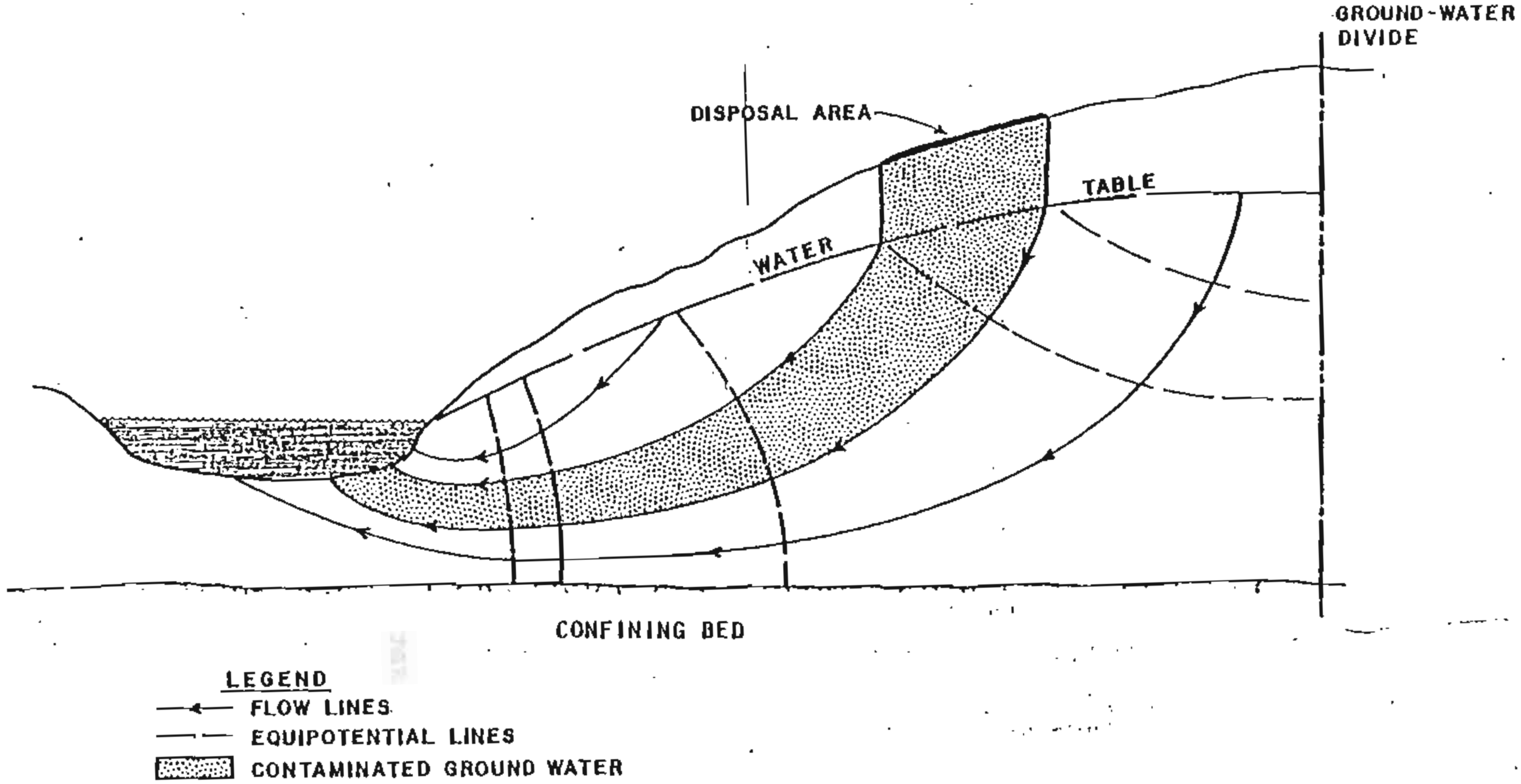


Figure 4-1. Flow in a water-table aquifer

soil attenuation capacity and the volume of the waste fluid. Specific statements cannot be made about the distances that contamination will travel because of the wide variability of aquifer conditions and types of contaminants. Also, each constituent from a source of contamination may follow a different attenuation rate, and the distance to which contamination is present will vary with each quality component. Yet certain generalizations which are widely applicable can be stated. For fine-grained alluvial aquifers, contaminants such as bacteria, viruses, organic materials, pesticides, and most radioactive materials, are usually removed by adsorption within distances of less than 328 feet. But most common ions in solution move unimpeded through these aquifers, subject only to the slow processes of attenuation.

A hypothetical example of a waste disposal site is shown in Figure 4-3. Here ground water flows toward a river. Zones A, B, C, D, and E represent essentially stable limits for different contaminants resulting from the steady release of liquid wastes of unchanging composition. Contaminants form a plume of contaminated water extending downgradient from the contamination source until they attenuate to acceptable quality levels.

The shape and size of a plume depend upon the local geology, the ground-water flow, the type and concentration of contaminants, the continuity of waste disposal, and any modifications of the ground-water system by man, such as well pumping.

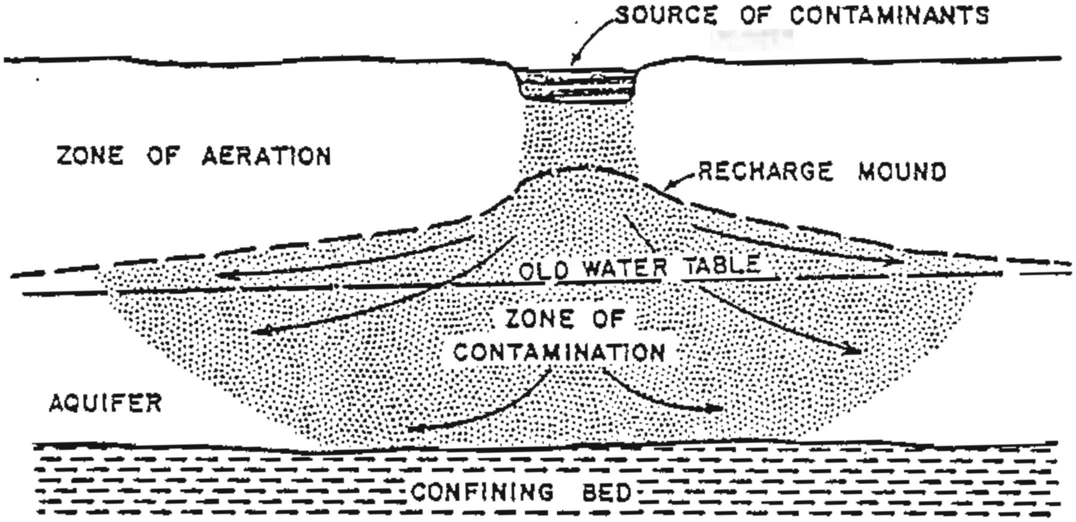


Figure 4-2. Diagram showing percolation of contaminants from a disposal pit to a water-table aquifer.

Where ground water is moving relatively rapidly, a plume from a point source will tend to be long and thin; but where the flow rate is low, the contaminant will tend to spread more laterally to form a somewhat wider plume. Irregular plumes can be created by local influences such as pumping wells and variations in permeability.

Plumes ordinarily tend to become stable in areas where there is a constant input of waste into the ground. This occurs for one of two reasons: (1) the tendency for enlargement as contaminants continue to be added at a point source is counterbalanced by the combined attenuation mechanisms, or (2) the contaminant reaches a location of ground-water discharge, such as a stream, and emerges from the underground. When a waste is first released into ground water, the plume expands until a quasi-equilibrium stage is reached. If sorption is important, a steady inflow of contamination will cause a slow expansion of the plume as the earth materials within it reach a sorption capability limit.

A hydrogeologic investigation of a pollution site normally entails the installation of test wells and water quality sampling. Geophysical exploration methods are sometimes used to map the extent of a contaminated ground-water body.

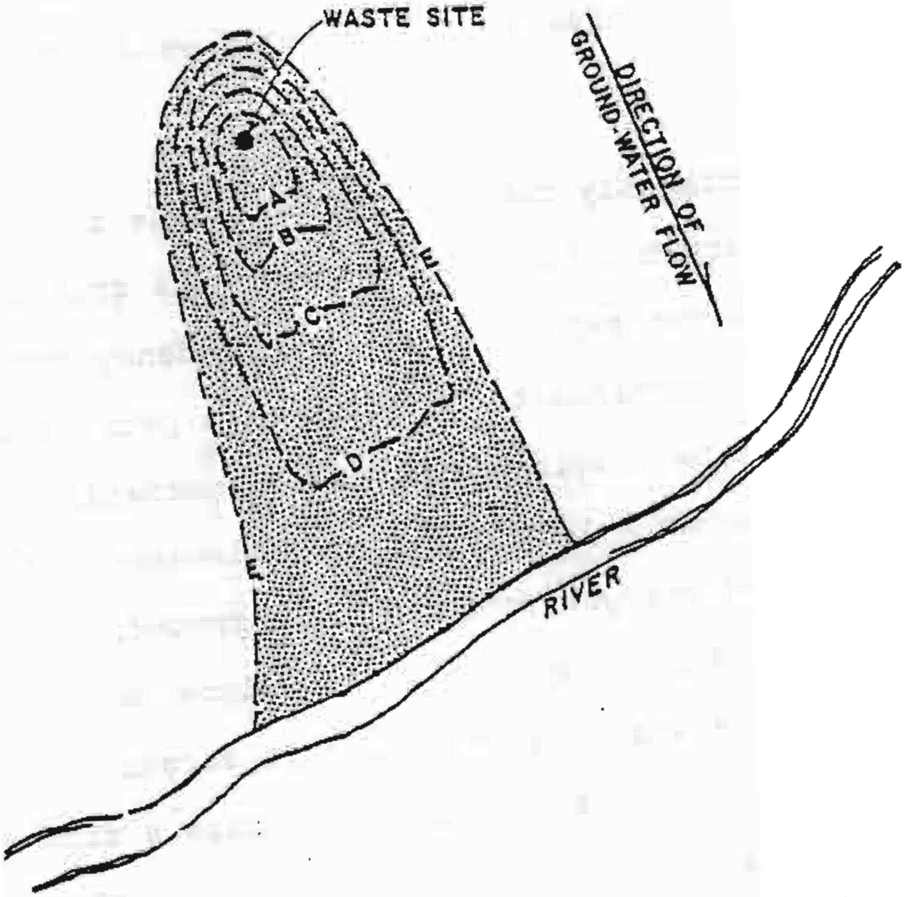


Figure 4-3. Plan view of a water-table aquifer showing hypothetical areal extent to which specific contaminants of mixed wastes at a disposal site disperse and move.

4.2 Travel Time

In order to assess the impact of a pollution problem it is important to understand the ground-water flow pattern and the flow velocity. The probably direction of flow of a contaminant can be deduced from the water-table map as flow is at right angles to the water-level contours. The ground-water flow velocity that applies to the water-table aquifer in the Pinelands has been estimated assuming certain values for aquifer characteristics.

Examination of the topographic map of the Pinelands shows that no point in the region is more than 1.5 miles from a surface-water body. Thus, the maximum travel path is 1.5 miles or 7,920 feet. Assuming a porosity for the saturated material of 30 percent, a conservative horizontal permeability of 2,000 gpd/ft^2 and an overall water-table gradient of 0.0045 ft/ft (23.8 feet per mile), the ground-water flow velocity is 4.01 feet per day. Assuming a 1.5 mile distance from the source to the discharge point, it would take 5.4 years for the contaminated water to travel this path. With a shorter flow path, the travel time would be proportionally shorter.

Similar computations of ground-water velocity in the deeper flow system (Cohansey-Kirkwood) along a line from the middle of the Pinelands region to the Atlantic Ocean, point to a travel time of about 2,000 years. This lengthy time of travel is mainly due to the very low hydraulic gradient.

Information on the deep ground-water circulation system is very limited and data on vertical permeability of the confining beds is missing. Ground-water velocities along the deep path appear to be considerably higher than those of the intermediate path due to the large head differential and steep hydraulic gradient that exists between the water table and the Raritan-Magothy aquifer. First calculations for the deep ground-water circulation indicate a travel time of several hundreds of years.

The relatively short time span for ground-water circulation in the Cohansey aquifer is important in the assessment of ground-water polltuion. Any pollutant entering the shallow ground-water flow system would enter a stream or other surface-water body in a matter of several years. However, pollutants entering the intermediate or deep flow system would travel for hundreds or even thousands of years before arriving at the discharge point.

4.3 Inventory of Sources of Ground-Water Contamination

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.

Most of the case histories cited lie outside the boundaries of the Pinelands National Reserve. Due to the limited development in this area there are less instances of ground-water contamination and less documented occurrences. However, many of the case histories are in hydrogeologic environments similar to those of the Pinelands and, therefore, appropriate to illustrate the type of ground-water contamination that may occur in the Pinelands. Locations and listings of potential sources of contamination including landfills, lagoons, storage tanks, and spills have been mapped and tabulated to indicate the possible magnitude of the problem.

4.3.1 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 decomposing 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, especially 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.

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 4-1 indicates the general chemical make up of leachate generated 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 4-2 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 4-1. 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., 1977a

Table 4-2. Components of Industrial Waste.

	Metals Mining	Primary Metals	Pharmaceuticals	Batteries	Inorganic Chemicals	Organic Chemicals	Pesticides	Explosives	Paints	Petroleum Refining	Electroplating
Ammonium salts		X								X	
Antimony	X				X				X		
Arsenic	X	X	X		X					X	
Asbestos					X				X		
Barium									X		
Beryllium	X									X	
Biological waste			X								
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
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 4-3 through 4-5 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 4-3. 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		USPHS 1) Limits (1962)	USEPA 2) Standards (1976)
		Upstream	Downstream		
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 4-4. 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	 Downstream	USPHS 1) Limits (1962)	USEPA Standa (1976
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 4-5. 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 Standar (1976)
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 yeards 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 overlies the Wenonah-Mount Laurel Formation. This formation is one of the major aquifers in the Pinelands. 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).

A firm in Gloucester County 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. 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 4-6 and 4-7 show chemical analyses from adjacent wells but the actual extent of contamination has not been determined (Geraghty & Miller, Inc., 1976).

EXTENT OF THE PROBLEM IN THE PINELANDS

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.

All landfill sites in the Pinelands were inventoried to assess the potential impact of industrial and municipal landfills on ground-water resources (Table 4-8). The inventory was compiled from data obtained from the New Jersey Solid Waste Administration and the Bureau of Topography and Geology, that describes 208 registered industrial-municipal landfills throughout the state, and the type of industrial or municipal wastes that they accept (Table 4-9). The potential impact of unregis-

Table 4-6. 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 4-7. Summary of Organic Chemical Analyses 1) of Ground-Water Samples From Observation Wells and Other Wells in the Vicinity of JIS Landfill, 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.

Reference: Geraghty & Miller, Inc., 1976a.

Table 4-8. Industrial and Municipal Landfills in the Pinelands

Map No.	Name	Volume of Waste in 1976 Tons	Gallons	Types of Waste
A1	Ocean Co. Sewerage Authority Colliers Mini Site	-	-	-
A2	American Cyanamid	-	-	-
A3	Sunny Pine	-	-	-
A4	Manchester Township Ocean Co. Sewerage Authority	-	-	-
A5	WM Site No. 1 Lakewood	-	-	-
A6	WM Site No. 2 Woodmansie	-	-	-
A7	South Toms River Borough	-	-	-
A8	Berkeley Township	5,609	0	10, 13, 14, 22, 24
A9	Olsens Septic Service	-	-	-
A10	Lacey Township	-	-	-
A11	Southern Ocean	38,835	10,108,225	10,11,13,14,20,22,24, 27, 73, 74
A12	Stafford Township	23,178	1,089,500	10-14,19,20,24,27,70 73,74
A13	Stafford Township Expansion	-	-	-
A14	Tuckerton Borough Eagleswood Township	-	-	-
A15	Little Egg Harbor Township	-	-	-
A16	Maurice River Township No. 1	1,500	0	10
A17	Maurice River Township No. 2	-	-	-
A18	Folsom Borough	-	-	-
A19	Unknown	-	-	-
A20	Joe Esposito	-	-	-
A21	Burough of Buena	-	-	-
A22	Hamilton Township SWDA	-	-	-

Table 4-8. Industrial and Municipal Landfills in the Pinelands (continued).

Map No.	Name	Volume of Waste in 1976		
		Tons	Gallons	Types of Waste
A23	Mullica Township SWDA	138	0	10,27
A24	Hornikle	-	-	-
A25	Galloway Township (3 locations)	-	-	-
A26	Estell Manor City	78	0	10
A27	Port Republic	-	-	-
A28	Dennis Township	-	-	-
A29	Upper Township	4,543	0	10,13,14,24
A30	W. Saduk	-	-	-
A31	Woodbine	105,486	2,253,000	10,12-14,73,74
A32	Dennis Township	-	-	-
A33	Big Hill	227,681	20,000	10,13,14,20,22,24,74
A34	Fort Dix	-	-	-
A35	Pemberton Township	14,449	1,412,000	10,11,13,14,22-24
A36	Winslow Township	12,352	0	10,13,14,22-25,27
A37	McElhone	-	-	-
A38	Bass River	-	-	-
A39	Evesham	-	-	-
A40	Medford Township SWDA	20,923	0	10-15,20-22
A41	Tabernacle Township SWDA	-	-	-
A42	Woodland Township	-	-	-
A43	New Freedom	-	-	-
A44	Ancora Street Hospital	-	-	-
A45	King of Prussia	-	-	-
A46	Jackson Township	-	-	10

tered dumps and illegal disposal sites scattered throughout the state has not been assessed.

The potential volume of leachate was estimated from average landfill size (area), and the average precipitation. Since the area of each landfill in the Pinelands was not known, landfill areas in Gloucester, Camden, Burlington, and Mercer Counties were used as a proxy, and the average size of a landfill in these counties (32 acres) was assumed to represent a general Pinelands average (Bureau of Geology and Topography, 1976). The average precipitation throughout the Pinelands 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. The 46 registered landfills in the Pinelands have the potential collectively of generating 860 million gallons of leachate per year.

It is apparent that substantial volumes of leachate may be recharged to the Cohansey within the Pinelands. Although the Cohansey aquifer is less developed than others in the Coastal Plain, it may be used to provide substantial ground-water supplies in the future. This resource is probably being degraded by landfill operations more than any other aquifer system in the state by virtue of its large outcrop area.

Table 4-9. Classification Code for Industrial and Municipal Wastes.

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 chopped 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

Reference: New Jersey Department of Environmental Protection, Bureau of Solid Waste Management

No extensive ground-water investigations have been carried out near landfills in the Pinelands area and therefore the threat posed by industrial toxic waste fluids known to have been accepted at some landfills, cannot be assessed.

In a recent case, the Jackson Township landfill located along the northern border of the Pinelands Reserve is suspected to have caused ground-water pollution and illness among local residents who drank water from on-site wells. This landfill opened in 1972, apparently accepted industrial toxic and carcinogenic chemical wastes as well as municipal garbage. According to published reports, dumping took place for eight years, with peak deliveries of 300,000 gallons of waste fluids per day (New York Times, Feb. 7, 1980). The NJDEP has filed a suit to permanently close the landfill. Nearby residents are now supplied with drinking water trucked in from a distant deep well and the Township has borrowed $1.2 million from the state for a water treatment plant and a pipeline system.

4.3.2 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 material, 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 4-10 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

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 Pinelands 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).

Table 4-10. Industrial Waste-Water Parameters Having or Indicating Significant Ground-Water Contamination Potential.

PAPER AND ALLIED PRODUCTS (Pulp and Paper Industry)

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

PETROLEUM AND COAL PRODUCTS (Petroleum Refining Industry)

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

PRIMARY METALS (Steel Industries)

- Ammonia
- Chloride
- Chromium
- Cyanide
- Iron
- pH
- Phenols
- Sulfate
- Tin
- Zinc

CHEMICALS AND ALLIED PRODUCTS (Organic Chemicals Industry)

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

Reference: Geraghty & Miller, Inc. 1977a.

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 THE PINELANDS

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 Pinelands 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).

Table 4-11 contains information on the seven industries with waste water impoundment sites identified in the Pinelands. This does not represent the total number of impoundments because many are not permitted, and are essentially unidentified.

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 seven impoundments is 140 mgy.

4.3.3 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.

Table 4-11. Industries Reportedly Having Wastewater Impoundments Within the Pinelands

Map No.	Name	Municipality	County	Type of Waste
B1	King of Prussia	Winslow	Camden	Information not available.
B2	Certain-Tweed	Window	Camden	Information not available.
B3	Unisyl	Maurice River	Cumberland	Information not available.
B4	Owens Illinois	Maurice River	Cumberland	Information not available.
B5	Violet Packing	Monroe	Gloucester	Food processing wastewater.
B6	Johns Mansville	Winslow	Camden	Fiberglass manufacturing wastewater containing phenolic resin binder.
B7	Owens Corning	Berlin	Camden	Pipe insulation manufacturing wastewater.

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 IN THE PINELANDS

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.

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. In areas which are not sewered, housing density is a reasonable proxy for the number and density of individual disposal systems. To date, the actual density of individual disposal systems in the Pinelands has not been mapped. Considering the relatively light development throughout the area, contamination from this source cannot be considered a regional problem at this time.

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 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.

4.3.4 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.

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 IN THE PINELANDS

The age of a sewer system is a major determinant of potential leakage. Sewer systems over 40 years old should be considered leak prone. Although most of the Pinelands is not sewered, there are some areas such as Hammonton, where 90 percent of the sewer lines are 65 years old.

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.

4.3.5 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 4-12). 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).

EXTENT OF THE PROBLEM IN THE PINELANDS

The number of domestic fuel storage tanks in the Pinelands 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.

Major 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. Table 4-13 gives the name and location of facilities operating with Federal permits (U.S. Environmental Protection Agency, 1977) in the Pinelands. 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 Table 4-14 (Office of Hazardous Substances Control, 1977b). These facilities typically store petroleum products.

Approximately 13.9 million gallons are stored in these facilities, and some 147,000 gallons are transferred through them daily. If 0.5 percent of the aggregate stored volume leaks, some 0.7 million gallons will be lost. The potential groundwater quality impact from leakage at these facilities is significant.

Table 4-12. 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.

Table 4-14. Major Storage Tank Facilities Within the Pinelands Area Complying With State SPCC Regulations.

Map No.	Name	Location	Storage Capacity (gallons)	Daily Throughput (gallons)	Product
C1	Atlantic City Electric Co. B.L. England Station	Upper Township	12,600,000	147,000	Petroleum & Chemical
C2	Atlantic City Electric Co. Middle Station	Middle Township	750,000	-	Petroleum
C3	Atlantic City Electric Co. Cedar Station	Stafford Township	550,000	-	Petroleum

Table 4-13. Name and Location of Facilities Complying with Federal SPCC Regulations for Storage Tanks in the Pinelands

Facility Name	Facility Location
Anthony Valerio	Waterford Rd., Hammonton, NJ
Cumberland Farms Gas Station	Route 9, Little Egg Harbor Township, NJ
Fort Dix	Dept. of the Army, Fort Dix, NJ
Holiday City at Berkeley	1433 Hooper Ave., Toms River, NJ
Mar-Tee Contractors, Inc.	Town Bank Rd., RFD #2, Cold Springs, NJ
McGuire Air Force Base	Headquarters 438 Air Base Group, McGuire Air Force Base, NJ
Meenan Oil Co.	30 Fort Ave., New Egypt, NJ
Noble Automotive Chemical & Oil	Cramer Road & Route 206, Vincentown, NJ
Oyster Creek Nuclear Plant	Ocean County, NJ
United Precasting Corp.	Pancoast Mill Rd., Buena, NJ
U.S. Air Force	McGuire AFB, McGuire, NJ

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.

4.3.6 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 increasing 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 concentrations 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 IN THE PINELANDS

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.

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

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

The actual impact on ground-water quality in the Pinelands from this source cannot be determined at present. However, given the road system in the Pinelands, permeable soil and shallow depths to water, the potential for contamination from this source is certainly real.

4.3.7 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 continguous farms ranging in size from a few hundred to several thousand acres. 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.

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 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.

4.3.8 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 4-15).

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 the Pinelands is unknown, and the magnitude of the prob-

Table 4-15. 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.

4.3.9 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 the Pinelands and the number of diffusion wells throughout the entire state is estimated at under 100 (Webster, 1978).

4.3.10 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 4-16 (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 4-16. Facilities Utilizing Land Disposal of Treatment Plant Effluent Operating in the Pinelands

Map No.	Name of Facility	Municipality	County
D1	Crestwood Village #1&#2	Manchester	Ocean
D2	Great Adventure	Jackson	Ocean
D3	Braddock Frosted Foods	Winslow	Camden
D4	Owens-Corning	Berlin	Camden
D5	Stockton State College	Galloway	Atlantic
D6	Scott Paper Company	Buena Vista	Atlantic

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 the outcrop 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 4-17. 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 4-17. Results of Chemical Analyses of Water Samples From Wells at a Spray Irrigation Site of a Frozen Food Processing Plant in Camden County, New Jersey.

	Well 2A	Well 18	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 IN THE PINELANDS

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.

4.3.11 Accidental 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 IN THE PINELANDS

Documented spills as filed by the New Jersey Office of Hazardous Substances Control for the years 1976 through 1979 are given in Tables 4-18 through 4-21. During these years, a total of 41 spills were recorded. Products spilled were crude oil, diesel fuel, gasoline, lube oil, asphalt, acids, paint, ink, herbicides, pesticides, benzene, coal tar, solvents, and unidentified chemicals. Total spill volume in the 4-year period was about 60,000 gallons, however, as indicated, the exact amounts spilled are often unknown.

The locations of the spills are shown on Plate 16. Many spills could not be located precisely due to the insufficient records kept by the state. In many cases, only the municipality is given and it is possible that some of the spills listed actually fall outside the Pinelands protected area.

The inventory provided is not complete because many spills are not reported. Most small petroleum product spills have local water quality impacts only. However, large spills, especially of hazardous chemicals, such as chlorinated hydrocarbons,

Table 4-18. Documented Spills in the Pinelands Region - 1976.

Municipality	Source	Product	Amount	Case No.*	Remarks
Cape May County					
Leesburg	Leesburg State Prison	#6 fuel oil	2,800 gals.	76-11-27-	Overfill of underground tank
Cumberland County					
2215 N. Delsea Drive, Vineland	D&B Auto Body	#2 fuel oil	200 gals.		
Mays Landing Rd. (Broad St.), Vineland	Major Petroleum	#2 fuel oil	100-150 gals.	76-7-9-	truck accident
Ocean County					
New Egypt, Plumstead, Ocean Co.	Meenan Oil Co.	#2 fuel oil	1,500-1,800	76-3-1-	Storage leak (above ground)
Rt. 526, Jackson Township, Ocean Co.	-	oil or chemical wastes	3,850 gals.	76-5-24-	Deliberate dumping
Union, Ocean Co.	Sunoco Service Station	gasoline	50 gals.	76-2-4-	
Little Egg Harbor Township	Cumberland Farms Service Station	gasoline	50-100 gals.	76-12-23	

*As filed by the Office of Hazardous Substances Control

Table 4-19. Documented Spills in the Pinelands Region - 1977.

Municipality	Source	Product	Amount	Case No.*	Remarks
Atlantic County					
Mays Landing	unknown	herbicides, ink, Paint, acids	55 gal. drums	77-2-9-	illegal dumping
Mays Landing	unknown	waste chemicals	55 gal. drums		illegal dumping
Hammonton	A.Berenato Oil	gasoline	5-60 gals.	77-1-30-	
Hammonton	Nugent Bros.	Var chemical	150 gals. +	77-11-8-3&2	illegal dumping
Hammonton	Agway Petroleum	#2 fuel oil	10 gals.	77-1-10-	
Burlington County					
Pemberton	Conn. Fuel Oil	Crude	5,000 gals.	77-11-29-2	
Cumberland County					
Millville	Denton Trucking	Diesel fuel	70 gals.	77-11-17-2	truck accident
Vineland	Vineland Labs.	malathion lindane K-hydroxide	50 12 2,000 lbs.		
Gloucester County					
Newfield	Marshall Services	lube oil	50 gals.	77-12-13-6	
Newfield	Papiawno Peter Hauling	#2 fuel oil	unknown	77-11-28-5	
Newfield	"	oil and gasoline	unknown	77-9-12-4	
Ocean County					
Toms River	Holiday City	#2 fuel oil	7,500 gals.	77-7-29-4	
Waretown	Sunoco Station	gasoline	50-100 gals.	77-6-20-	

Table 4-20. Documented Spills in the Pinelands Region - 1978

Municipality	Source	Product	Amount	Case No.*	Remarks
Atlantic County					
Hamilton	Wingate Apt.	oil	7,000 gals.	78-8-16-2	
Hamilton	AAA Trucking	paint	400 gals.	78-8-18-1	truck accident
Little Egg Harbor	So. Jersey Asphalt	asphalt	1,000 gals.	78-6-15-1	dumping
Brigantine	Arco Gas Sta.	gasoline	4,000 gals.	78-4-10-4	tank leak
Burlington County					
Woodland	Lockhart Sand & Gravel	waste oil	1,000 gals.	78-6-30-5	
Mt. Laurel	Ray's Farm Market	pesticides	300 gals.	78-4-28-1	
Ocean County					
Toms River	Sunoco Gas Sta.	gasoline	7,000 gals.	78-12-18-3	tank leak
Toms River	Finley Oil Co.	#2 fuel oil	60 gals.	78-3-29-3	
Jackson	unknown	ink	33 bbls.	78-8-14-6	illegal dumping
Jackson	unknown	chemicals	25 bbls.	78-5-2-2	illegal dumping

*as filed by the Office of Hazardous Substances Control

Table 4-21. Documented Spills in the Pinelands Region - 1979

Municipality	Source	Product	Amount	Case No.*	Remarks
Atlantic County					
Hamilton	Gropps Lake	organics	35 acres	79-5-25-4	dam failure
Hamilton	Bayer Aspirin	benzine	unknown	79-1-8-3	dumping
Little Egg Harbor	unknown	gasoline	200 gals.	79-1-26-9	
Burlington County					
Wrightstown	U.S. Army Ft. Dix	oil	1,500 gals.	79-10-23-4	
Camden County					
Winslow	unknown	chemicals	unknown	79-3-20-5	unknown landfill
Winslow	Johns Manville	phenol formaldehyde & amonia sulfate	2,500 gals.	79-10-4-3	
Ocean County					
Toms River	Holiday City Apts.	#2 fuel oil	unknown	79-11-6-3	
Toms River	Rob.E.Sons Trucking	coal tar	1,500 gals.	79-10-19-8	Truck accident
Jackson	unknown	mixed chemicals	1,200 gals.	79-6-27-3	drums
Jackson	Mr. Wilkhams	solvent waste	unknown	79-3-5-4	dumping

*as filed by the Office of Hazardous Substances Control

if entering the deeper ground-water flow system could have a serious regional water quality impact.

4.3.12 Sand and Gravel Operations

An inventory of sand and gravel operations (Table 4-22) was made from records obtained from the New Jersey State Bureau of Geology-Topography. This inventory is not complete as records of these mining operations are still in the compilation stage.

Locations of sand and gravel pits were mapped using coordinates found on state records and by inspection of New Jersey Topographic Atlas maps at a scale of 1-inch to the mile. This survey was augmented by examination of USGS Topographic maps on a scale of 1-inch is 2,000 feet.

These topographic maps show the areal extent of sand and gravel operations as they ex isted at the year the map was issued. In most areas, the sand and gravel mining operations were mapped in 1971 or 1972, but maps of portions of the west-central Pinelands reflect conditions of 1950's or 1960's.

Throughout most of the Pinelands region, sand and gravel operations are widely isolated, however, in a few areas such operations are highly concentrated and present a considerable alteration of the land surface. In one such area adjacent to the Manumuskin River between Manantico and Leesburg, more than

Table 4-22. Inventory of Sand and Gravel Pits in the Pinelands.

No.	Name	Location 1)	Acres	Tons/Yr.
ATLANTIC CO.				
A-1	Arawak Paving	Hamilton Twp.	8	10,000
A-2	Arawak Paving	Hammonton	-	-
A-3	Mays Landing Sand & Gravel Co.	Collings Lake	375	200,000
A-4	James Monfredo	Pomona	50	54,000
A-5	Jessie S. Morie	Buena Vista	660	85,000
BURLINGTON CO.				
BU-1	Clayton Sand Co.	32-13-633	10*	-
BU-2	Lockhart Sand & Gravel	32-12-525	-	-
BU-3	Continental Sand & Gravel	32-11-311	35*	-
BU-4	unknown	32-13-633	10*	-
BU-5	unknown	32-11-425	10*	-
CAMDEN CO.				
CA-1	Dun-Rite Sand & Gravel	Turnersville	75	516,800
CA-2	Jesse S. Morie	Winslow	95	150,000
CA-3	Jesse S. Morie	Winslow	-	9,000
CA-4	George Pettinos	Williamstown Junction	-	-
CAPE MAY CO.				
CM-1	Cape Concrete	South Dennis	50	100,000
CM-2	Earthwork Assoc.	Marmora	45	50,000
CM-3	Lentine Sand & Gravel	Seaville	30	25,000
CM-4	Tuckahoe Sand & Gravel	Tuckahoe	1200	350,000
CM-5	Albrecht & Heun Inc.	Dennisville	32	5,000
CM-6	Hollis Caldwell	Petersburg	85	-
CM-7	George Dramis	S. Seaville	20	3,500
CM-8	Earthwork Assoc.	Dennisville	80	50,000

1) Township or New Jersey topographic grid coordinates

\- Unknown

* Estimated from USGS topographic maps

a dozen large sand and gravel operations exist. Dredging and removal of sand has created large lakes, some measuring 1,000 and 2,000 square feet. Some operations cover an area of 0.5 to 1 square mile.

The impact on ground-water resources is primarily that of aquifer mining or removal, resulting in the exposure of the water table to possible contamination. Most sandpit operations are not drained or otherwise connected to a surface-water body. If this were the case, considerable surface-water pollution from suspended solids might take place.

Creation of lakes might be a favorable factor in view of wildlife and bird habitats and recreation. One prime problem with sand and gravel operations is the disturbance of the land surface and the resulting unaesthetic visual impact.

In the Lakehurst area, several very large (up to 1 square mile) sand and gravel operations exist. The impact of these operations on water quality cannot be assessed at this time. It should be noted that abandoned sand and gravel pits have very frequently been converted to waste dumps and landfill operations. This is very poor practice as the wastes are deposited either directly in the water table or a short distance above, so that contaminants can enter directly into the aquifer.

Table 4-22. Inventory of Sand and Gravel Pits in the Pinelands (continued).

No.	Name	Location	Acres	Tons/Yr.
CUMBERLAND CO.				
CU-1	Whitehead Bros.	Port Elizabeth	200	65,000
CU-2	Whitehead Bros.	Maurice River Twp.	1500	130,000
CU-3	Mays Landing Sand & Gravel Co.	Dorchester	200	200,000
CU-4	George Pettinos, Inc.	Manumuskin	-	-
OCEAN CO.				
OC-1	Lentine Materials	32-24-361	-	-
OC-2	Pineland Materials	32-24-391	-	-
OC-3	Johnson Sand & Gravel	32-25-114	35*	-
OC-4	Francis M. Moon	32-24-332	30*	-
OC-5	N.J. Pulverizing Co.	33-02-882	300*	-
OC-6	Fischer Bros.	33-02-881		-
OC-7	Ralph Clayton &Son	33-21-672	35*	-
OC-8	Bay Construction Co.	33-31-485	-	-
OC-9	Bob Kalsch Construction	33-31-244	60*	-
OC-10	Parker Construction	33-12-175	25*	-
OC-11	Parker Construction	33-11-228	-	-
OC-12	Parker Construction	33-11-156	70*	-
OC-13	Harris Bros.	33-11-345	-	-
OC-14	French Contracting Co.	33-11-257	-	-
OC-15	Brick Wall Corp.	33-11-129	-	-
OC-16	Francis Tenner, Jr.	33-21-669	10*	-
OC-17	Gravatt Sand & Gravel	33-11-154	110*	-
OC-18	Peter Arlauckas Gravel	29-33-427	-	-
OC-19	Ralph Clayton and Son	29-31-951	-	-
OC-20	Ralph Clayton and Son	29-41-238	-	-
OC-21	Clayton Sand Co.	29-41-118	300*	-
OC-22	Storola Sand & Gravel	29-41-253	-	-
OC-23	Brick Wall Corp.	29-41-616	120*	-

5.0 COMPARISONS OF HYDROGEOLOGICAL CONDITIONS OF THE PINELANDS WITH THOSE OF LONG ISLAND, NEW YORK

The Pinelands National Reserve ground-water system is essentially undeveloped. In order to assess the impact of future development in the Pinelands on the aquifer system one can study the case histories of development in other regions of the Coastal Plain in a similar hydrogeologic environment.

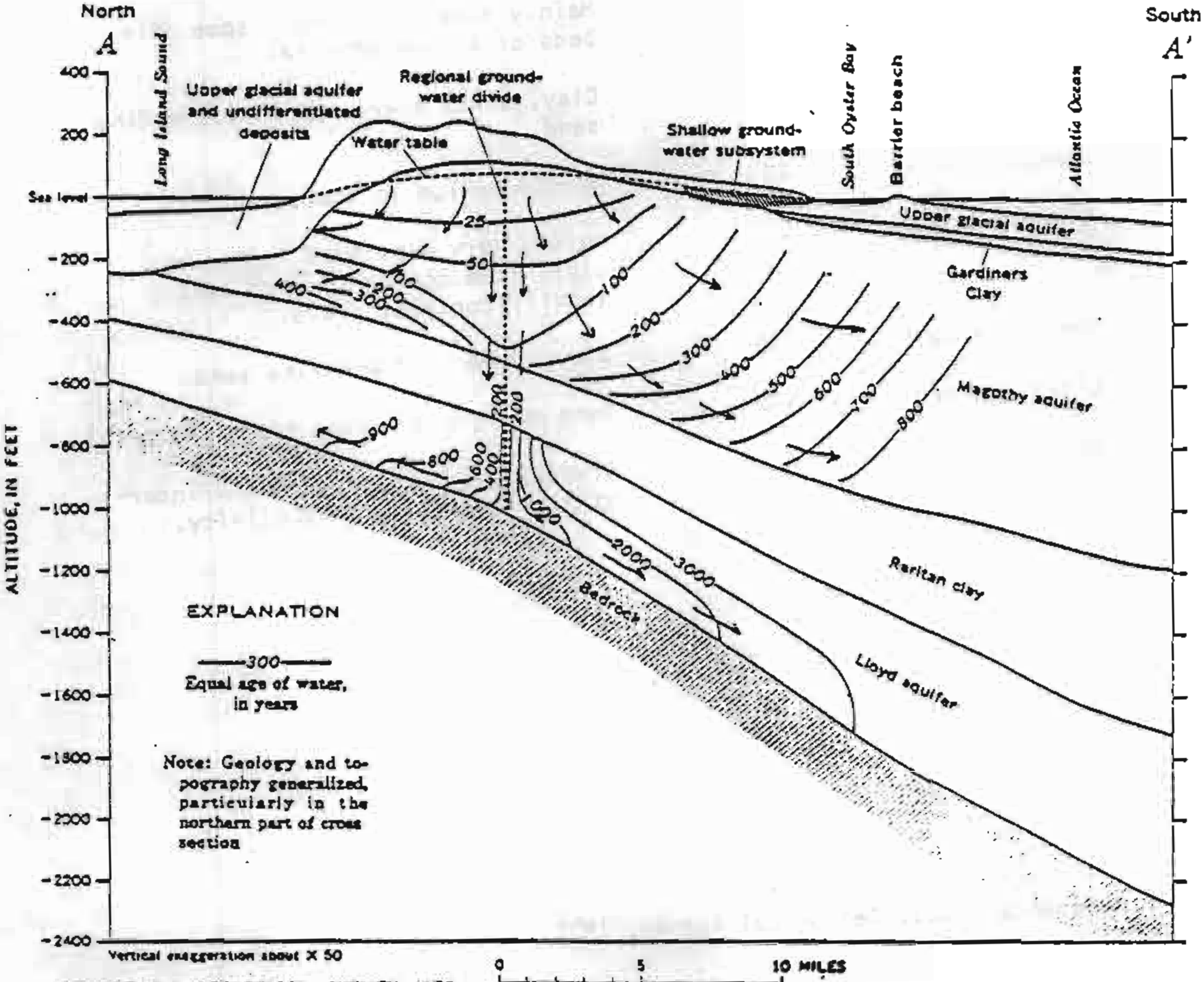
Long Island with a land area of about 1,400 square miles occupies a large detached segment of the Atlantic Coastal Plain. It is one of the most studied ground water areas in the nation and consequently hydrogeologic conditions are known to a high degree. The subsurface geology is quite similar to that of the Pinelands with a wedge-shaped mass of unconsolidated sedimentary deposits that attain a maximum thickness of about 2,000 feet. These deposits are divided into six major stratigraphic units that differ in age, mineral composition, and hydraulic properties, namely, from oldest to youngest, (1) Lloyd Sand, member of the Raritan Formation, (2) Clay member of the Raritan Formation, (3) Magothy Formation, (4) Jameco Gravel, (5) Gardiners

Clay, and (6) Glacial deposits (Figure 5-1). The Lloyd Sand, about 300 feet thick, is the basal aquifer and the overlying clay member acts as a leaky confining bed. Above these units is the Magothy Formation, consisting of interbedded layers of sand, silts, and clay with a maximum thickness of about 1,000 feet.

The Jameco Gravel and Gardiners Clay are localized units present along the north and south shores of the island. Overlying the Magothy, Jameco Gravel, and Gardiners Clay is a highly permeable sand and gravel outwash deposited during the glacial period. Table 5-1 lists the major hydraulic units on Long Island.

A detailed comparison of the hydrologic units beneath Long Island and the Pinelands reveals some strong similarities. The glacial outwash deposits of Long Island range in thickness from less than 50 feet in northwest Kings and central Queens Counties and along the south shore of Nassau and western Suffolk Counties, to as much as 500 feet in buried valleys along the north shore of Nassau County. Generally speaking, the thickness of this unit ranges between 100 and 250 feet (McClymonds and Franke, 1972).

In the Pinelands, the thickness of the Cohansey aquifer, which is the surficial aquifer as are the glacial outwash deposits on Long Island, ranges from a few feet along its outcrop



SOURCE: U.S. GEOLOGICAL SURVEY, 1972

Figure 5-1. Cross section through Long Island ground-water reservoir showing time required for water to move from water-table to points within system.

Table 5-1. Major Hydrogeologic Units on Long Island, New York

Hydrogeologic Unit	Approximate maximum thickness (feet)	Description
Upper glacial aquifer.	400	Mainly sand and gravel; some thin beds of clayey material.
Gardiners Clay.	150	Clay, silty clay, and a little fine sand.
Jameco aquifer.	200	Mainly medium to coarse sand.
Magothy aquifer.	1,000	Mainly very fine sand, silt, and clay; some coarse to fine sand; locally contains gravel.
Raritan clay.	300	Clay; some silt and fine sand.
Lloyd aquifer	300	Sand and gravel; some clayey material.
Bedrock		Crystalline rock of very low interstitial hydraulic conductivity.

Reference: U.S. Geological Survey, 1972

edge in the northwest part of the Pinelands to over 300 feet along the coast. Generally speaking, its thickness ranges from 100 to 200 feet (see Plate 1).

The sand content of the Cohansey aquifer ranges from 60 to 90 percent and averages 80 percent (see Plate 2). Although a sand content map for the glacial outwash deposits on Long Island is not available, based on published information, well logs, and Geraghty & Miller, Inc.'s experience on Long Island, it is believed that the sand content here is very similar to that of the Cohansey, possibly slightly greater.

The permeability of the two units is also quite similar with values for the glacial outwash ranging from slightly less than 1,000 gpd/ft^2 to over 2,000 gpd/ft^2 (McClymonds and Franke, 1972). The permeability values are also fairly consistent over large areas with a general increase observed from the south and north shores of the island to its central part. Permeability values of the Cohansey aquifer range from 400 to 3,000 gpd/ft^2 with values between 1,000 and 1,200 gpd/ft^2 common throughout much of the aquifer (Rhodehamel, 1973). Generally, the permeability of this unit is very consistent over wide areas.

The Cohansey aquifer, as discussed in this report, includes the Cohansey Formation overlying Pleistocene deposits as well as the underlying upper sandy portion of the Kirkwood Formation. Because the Pleistocene deposits and upper sandy

Kirkwood are in direct hydraulic connection with the Cohansey Formation and form one hydraulic unit, these upper Kirkwood sands are considered part of the Cohansey aquifer. Similarly, in many places on Long Island, the upper Magothy is sandy, in direct hydraulic connection with the overlying glacial outwash deposits, and considered to be one aquifer.

As is the case in the Pinelands, recharge to the ground-water system on Long Island is entirely from precipitation. The average annual precipitation on Long Island and in the Pinelands is about 45 inches. Under natural conditions in both areas, about half of the average annual precipitation (or approximately 1 mgd per square mile) percolates down to the water table. Except for about 6 to 10 percent that runs off into streams, the remainder on the land surface returns to the atmosphere by evaporation and transpiration.

The depth of the water table below the land surface on Long Island generally ranges from a few feet near the shore to about 250 feet in the irregular hilly northern region. In most of central Nassau and Suffolk Counties, the water table is at a depth of about 50 feet below land surface. In the Pinelands depth to water ranges from a few feet near the shore to as much as 50 feet and generally is 10 feet or less (Plate 17). Most of the infiltrated water on Long Island moves through the glacial deposits and discharges into streams or bodies of salt water bordering the island similarly to ground-water movement in the Cohansey aquifer. The remaining ground water moves further downward into the Magothy Formation and through the Raritan Clay into the Lloyd Sand. From the deep aquifers the ground water then moves laterally to the Atlantic Ocean and Long Island Sound. The general movement of fresh water is indicated by arrows in Figure 5-1. This illustration also shows the approximate time required for water to move from the water table to various points within the regional flow system. Plate 6 shows a similar flow system for the Pinelands. From the above discussion it is apparent that the Cohansey aquifer beneath the Pinelands is very similar to the glacial outwash deposits and upper Magothy on Long Island, and that development in the Pinelands similar to that of Long Island may result in the same water quality problems. Below the history of development on Long Island is briefly discussed.

Urbanization of Long Island has proceeded at a rapid rate. From a predominantely agricultural economy in the 1930's, western and central Long Island (Nassau and Suffolk Counties) are now predominantely residential, commercial, or industrial. Farms and woodland have given way to housing developments, office buildings, and parking lots.

Ground-water development on Long Island has followed a distinct pattern. During the rural land phase, water was obtained from on-site wells tapping the shallow glacial deposits. The bulk of the water was returned to the aquifer through individually owned cesspools.

After development, at first drinking water was obtained from large capacity public supply wells tapping the glacial deposits, but later, when the quality of water in the shallow aquifer deteriorated, supply wells tapped the deeper Magothy aquifer. This deterioration of the shallow aquifer occurred because of disposal of waste water from hundreds of thousands of cesspools and septic tanks, from agricultural fertilizers, and industrial waste discharges.

Sewer systems either have been or are being installed in Nassau and Suffolk Counties to prevent further waste discharge to the shallow aquifer but it is unlikely that the shallow aquifer will ever be used for drinking water again.

In recent years, several Magothy supply wells have been closed due to the presence of certain organic chemicals in concentrations above USEPA drinking water limits. This indicates that pollutants are traveling downward with the ground water to deeper aquifer zones.

The 208 Study of Nassau and Suffolk Counties, completed in 1977, identified numerous ground-water pollutant sources among which are:

- Cesspools, septic tanks, and leaching fields. About 1.7 million people reside in unsewered areas; an estimated 120 mgd of sewage is returned to the ground.

- Industrial waste water. About 2.1 mgd is discharged to the ground; sources include coin-operated laundries and car washes, metal processing firms, and bottling plants.

- Storm-water basins. About 2,000 unlined recharge basins collect storm water runoff and pollutants from streets and highways.

- Landfills. There are 40 major active and non-active solid waste land disposal sites. Leachate generation is relatively high, and in theory, about 4 million gallons per year for each 10 acres of landfill. Leachate generation in Suffolk County is estimated at 320 million gallons per year.

- Highway deicing. About 80 percent of salt pollution is caused by improper storage practices and the remainder by improper spreading techniques. Salt use in Nassau County averages 32,500 tons per year. This salt is used on 9,000 lane miles of road.

- Fertilizers and pesticides. There is increasing evidence for support of the association between fertilizer use and nitrate in ground water. Lawn fertilizers appear to be as significant a source of nitrogen as discharges from septic tanks.

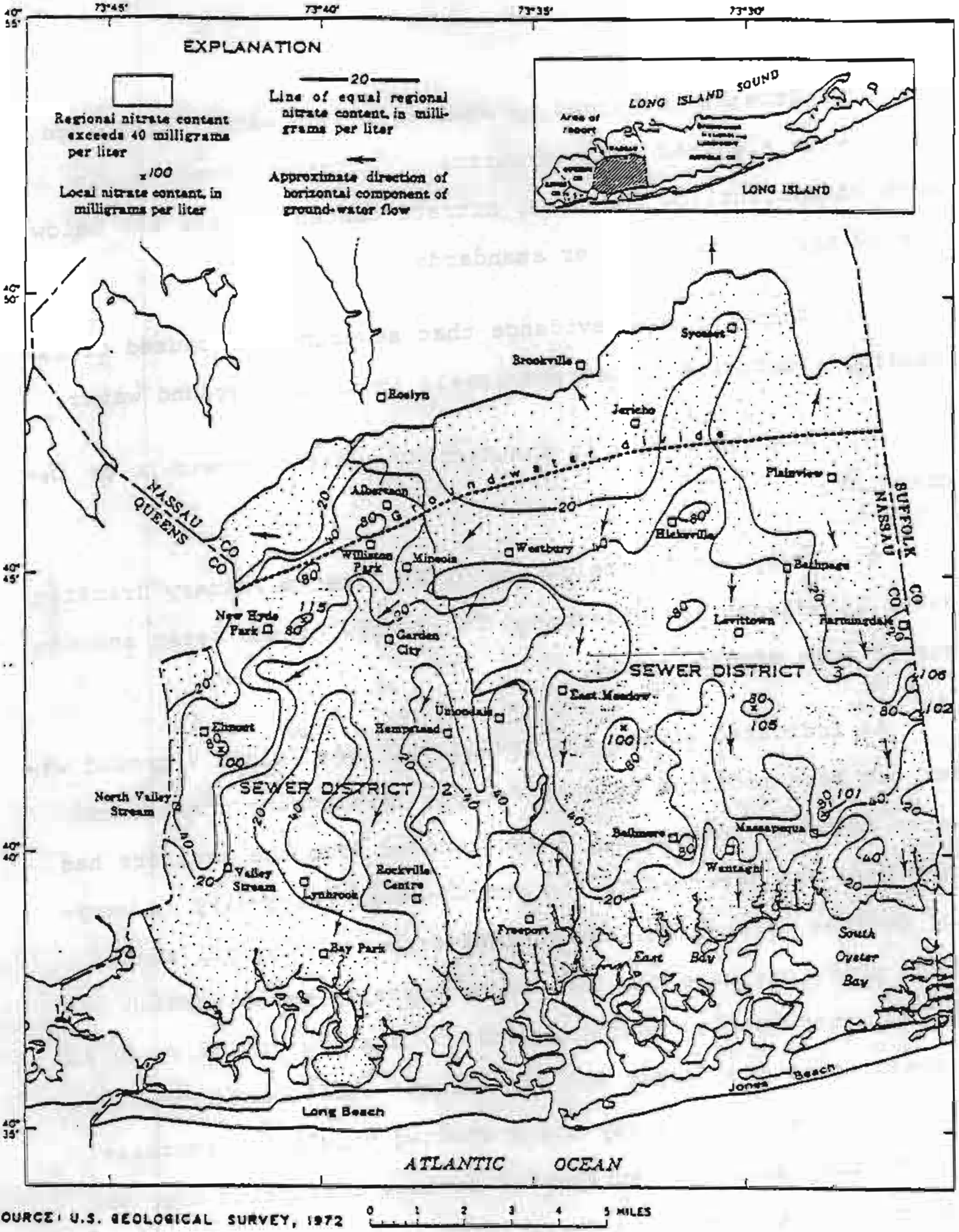
- Gas stations. There are 2,600 service stations and many case histories of ground-water contamination from leaky storage tanks.

- Airborne pollution. The atmosphere and precipitation contain appreciable amounts of ground-water contaminants. Motor vehicle emission amounts to 4,000 tons per day of carbon monoxide, 800 tons of hydrocarbons, and 740 tons of nitrogen oxides. Average sulfate content in rain water is 3.6 mg/l; total nitrogen 1.36 mg/l; sodium 1.89 mg/l; and chloride 3.22 mg/l.

- Diffusion wells. About 20 mgd of cooling water obtained from wells is returned to the aquifer through 500 diffusion wells as a conservative measure. Thermal loading from return of heated water has been observed in some industrial areas.

On Long Island, the quantity and quality of ground water has been studied extensively for over 50 years. Nitrate has been used as an indicator of water quality because of the availability of historical data and because nitrate is associated with almost all waste disposal practices on the island. The results of these water quality studies can be summarized as follows:

1. In the 1972-76 period, median nitrate-nitrogen concentration exceeded 8 mg/l in water from 28 of 212 upper glacial wells. Wells yielding high nitrate water are widely distributed. The distribution of nitrate in Nassau County, 1966-70, is shown on Figure 5-2.



SOURCE: U.S. GEOLOGICAL SURVEY, 1972

Figure 5-2. Nitrate content of water in upper glacial aquifer in Nassau County, Long Island, N.Y., 1966-70.

2. Streams recharged by shallow ground water, discharge water with elevated concentrations of nitrate. However, in most of the shallow aquifers, nitrate concentrations are below the 10 mg/l drinking water standards.

3. There is some evidence that sewering has caused or is causing a decrease in nitrate levels in shallow ground water.

4. Nitrate levels in the Magothy aquifer appear to be increasing.

5. Heavy metals (below the USEPA Interim Primary Drinking Water Standards) are widespread in shallow ground water and occur in some Magothy wells.

As indicated above, the quality of Long Island's ground water has been modified by water supply development changes and waste disposal practices. Water removed from the aquifers has been used and returned to the ground-water reservoirs in varying degrees of chemical alterations from its original state. These practices have resulted in progressive deterioration of ground-water quality starting with the shallow ground water and proceeding to the deeper aquifer zones. Sufficient ground water is available to supply the projected population increase and quantity does not represent a serious constraint over the long term. Water quality degradation appears to be the principal constraint on future water development availability.

The Pinelands Commission is in the enviable position to safeguard the hydrogeologic system on the New Jersey Coastal Plain by controlling water supply and waste disposal activities, thus avoiding the ground-water quality problems that plague Long Island. No regional ground-water deterioration has as yet been documented in the Pinelands, however, local contamination from landfill leachate is known to occur. Uncontrolled growth in the Pinelands region could create similar problems as now exist in Long Island. For example, widespread waste disposal in the Cohansey aquifer could eventually cause regional water quality deterioration which might necessitate tapping the deeper Kirkwood and eventually the Magothy-Raritan water-bearing zones. As pointed out previously, the hydrogeologic systems of the Pinelands region and Long Island are sufficiently identical to make this a distinct possibility.

6.0 GENERAL LAND USE - WATER QUALITY RELATIONSHIPS

The development of the Pinelands area will force resource planners to confront a number of ground-water management issues that are strongly related to population density and the likely activities associated with land uses, economic activities, and the requirements for increased physical infrastructure. These activities will impact ground-water quality and perhaps quantity in the Pinelands. The exact nature and extent of the impacts will not and cannot be known in an a priori fashion, however, it can be forecasted and extrapolated from similar experiences elsewhere.

Resource planners in the Pinelands are confronted with a suite of potential demands on the area's ground-water resources. The planner may have reasonably good information on the individual and aggregate impacts of current demands on the quality and quantity of the area's resources. However, the planner also faces a relatively unknown suite of future demands which he must attempt to accommodate -- he does not know their magnitude, or his planning horizon with any certainty. If the planner knew this horizon, a steady state ground-water regime he could theoretically manage his resources through the horizon. In reality, however, the planning horizon continually recedes, and the planner must therefore manage the resource to assure that the ground-water resource will be adequate for an indeterminate period.

In terms of protecting the ground-water resource, the planner's problems are compounded because there are no generally useful leading indicators which can warn of impending impacts within a sufficient breathing space for remedial action and, once land uses and their support infrastructure are developed in the Pinelands, it will be very difficult to walk away from massive public and private investments.

6.1 Ground-Water Quality Issues Related to Land Use in the Pinelands

The following major issues will become significant as the Pinelands develops from rural to suburban to urban.

- How many people can live and work in an area without causing ground-water quality problems?
- How can the Pinelands forecast "acceptable" damage to its ground-water resources?
- Are there useful leading indicators which will show ground-

water impacts early enough so that remedial action is possible?

- Should portions of the Pinelands area be "written off" from a ground-water quality standpoint?

- If ground-water quality is now impaired in portions of the Pinelands, should specific land uses be assigned to these areas, especially where the activities are desirable for their employment or value added contributions to the area economy?

- What is natural "background" ground-water quality in the Pinelands? (Except for information on the shallow water-table aquifer in certain areas, the natural ground-water quality is not known with sufficient confidence to support major future looking planning decisions which imply land-use impacts on the ground-water system.)

- What are the anticipated ground-water impacts from large lot zoning vs. cluster development? (Large lots may preclude cost-effective sewering and may increase the required infrastructure.)

6.2 Ground-Water Quality Deterioration: Long Island Experience

The ground-water quality impacts experienced on Long Island are strongly related to increased land development and the activities that accompany increased population growth. The Long Island experience hints at the future situation in the Pinelands if their growth paths are similar.

There are many sources of ground-water contamination in developed portions of Nassau and Suffolk Counties including storm water runoff, residential subsurface disposal systems, sewerage treatment plants, industrial pits, ponds, lagoons, landfills, golf courses, and agricultural uses. These land uses may also characterize the Pinelands after a period of unchecked population and economic growth. Major contaminants from these various sources of contamination include nitrate, chloride, metals, and organics. The existing water-quality data demonstrate that ground-water quality impacts are associated with development, particularly where storm water is recharged back into the ground water, and where industrial storage and disposal activities occur in aquifer outcrops and recharge areas.

Once contamination of ground water occurs, abatement is very difficult. Moreover, the impacts generally cannot be known until the problem is extensive and remedial measures may not be possible. Precipitation recharged into Long Island's

Glacial and Magothy aquifers eventually discharges into surface rivers, bays or the ocean, although the storage time in the aquifers may vary from days to hundreds of years. If contaminants enter the ground water where the time of storage for discharge is very long, those contaminants may remain in the ground-water system for long periods of time. Although ground water can be treated at the well head, this is very expensive.

The aquifers of Nassau and Suffolk Counties, in particular the Glacial and Magothy aquifers, are the sole source of drinking water. Because significant degradation of those ground waters has already occurred and will continue to occur from existing sources of pollution, protection of existing high quality ground waters which are not subject to significant degradation from existing point and non-point sources of pollution is essential in terms of long-term ground-water quality management. In addition, because of the range and complexity of sources of contamination, control of land uses in major recharge areas for existing high quality ground water is an appropriate management strategy for Long Island and for the Pinelands area.

6.3 Ground-Water Contamination - Land Use and the Support Infrastructure

There are a number of current and potential sources of ground-water contamination related to land-use patterns in the Pinelands. In general, they relate to activities associated with the use and the physical infrastructure necessary to support the use. These sources can be divided into four categories (see Table 6-1). The first two categories represent discharges of contaminants that are derived from solid and liquid wastes. The third category concerns discharges of contaminants that are not wastes, and the fourth category are not discharges at all.

6.3.1 Domestic On-Site Waste Disposal Systems

Cesspools, septic tanks, and leaching fields are a major source of ground-water contamination. In on-site disposal systems, bacterial action digests the solid materials, and the liquid effluent is discharged to the ground. In theory, filtration by earth materials provides additional treatment so that the liquid is relatively clean when it arrives at the water table. However, many constituents carried by the effluent are introduced to the ground-water system. Those which present the greatest threat to ground-water quality are excessive concentrations of nitrate, organic chemicals, detergents, metals, bacteria, and viruses. Other constituents include halogenated hydrocarbons, chloroform, **carbon tetrachloride,** trichloroethylene and other industrial degreasers, solvents and plasticizers. These compounds regularly occur in discharges from households. Many products common in the home, such as fabric and rug cleaners, workshop cleaners and solvents, and solutions to clean pipes find their way into on-site disposal systems. Septic

Table 6-1.

CLASSIFICATION OF SOURCES AND CAUSES OF GROUND WATER CONTAMINATION USED IN DETERMINING LEVEL AND TYPE OF CONTROL

Category I Systems, facilities or sources designed to discharge waste or waste waters to the land and ground waters.	Category II Systems, facilities, or sources not specifically designed to discharge wastes or waste waters to the land and ground waters.	Category III Systems, facilities, or sources which may discharge or cause a discharge of contaminants that are not wastes to the land and ground waters.	Category IV Causes of ground water contamination which are not discharges.
Domestic on-site waste disposal systems	Sanitary sewers	Highway deicing and salt storage	Airborne pollution
Sewage treatment plant effluent	Landfills	Fertilizers and pesticides	Water well construction and abandonment
Industrial waste discharges	Animal wastes	Product storage tanks and pipelines	Salt water intrusion
Storm water basin recharge	Cemeteries	Spills and incidental discharges	
Incinerator quench water		Sand and gravel mining	
Diffusion wells			
Scavenger waste disposal			

Reference: Nassau-Suffolk Regional Planning Board, 1978

tank cleaners are composed almost entirely of active ingredients which are frequently halogenated hydrocarbons, and one common cesspool cleaner contains more than 99 percent trichloroethylene.

6.3.2 Sanitary Sewers

Should population densities in the Pinelands exceed permeable limits for individual on-site waste disposal systems, it will be necessary to provide community or regional sewage treatment systems. Sanitary sewers frequently leak, and depending on the type of sewer and its altitude relative to the water table, ground water can infiltrate or sewage can exfiltrate. The contamination is from domestic sewage, plus constituents in industrial effluent discharged to sewers.

Permissible maximum infiltration rates are usually written into sewer specifications and commonly vary from 200 to 500 gpd per mile per inch of pipe diameter. Where ground-water pollution is of concern, exfiltration rates may also be specified. Exfiltration may increase over the years as loading cracks pipes and as chemical action deteriorates the joints. Exfiltration may also increase if the ground-water level was originally above the sewer, but has declined to a point below the sewer.

With present materials and construction techniques, a 50-year sewer life is a minimum design estimate. However, a 100-year service life may be a more reasonable estimate. If old systems are infiltrating additional water where the pipes are below the water table, it is reasonable to assume they will also exfiltrate additional sewage where the pipes are above the water table.

6.3.3 Storm Water Runoff and Recharge

As development occurs in the Pinelands, permeable soil areas will be replaced by impermeable roofs and paved areas. Storm water cannot seep into these surfaces, so it accomulates and runs off.

Catch basins are commonly used to control runoff and may account for a significant part of recharge. The basins are also sources of contamination. Inflow into the basins is a combination of precipitation plus constituents that are dissolved and suspended by the water as it runs over the ground. Typical sources of contaminants are fertilizers, pesticides, deicing salts, organic debris, grease and road oil, rubber, asphaltic materials, hydrocarbons, animal feces, and food wastes. Many of the contaminants are not biodegradable and persist in ground water.

As part of a program of storm water runoff and groundwater sampling at two recharge basins along the Long Island Expressway, the Suffolk County Department of Environmental Control detected significant intermitent concentrations of heavy metals (e.g., zinc and lead) and total organic carbon (TOC) in discrete samples of storm water runoff during the storm events. Chloride and zinc were observed in elevated concentrations in the ground water samples obtained from wells located in the two recharge basins receiving storm runoff from the Expressway.

6.3.4 Landfills

As the population of the Pinelands is allowed to grow, the problem of solid waste disposal will assume even greater importance. Landfills receive a wide range of waste materials including paper products, food wastes, septic tank sludge, construction debris, tires, autos, leaves, plastics, glass, chemicals, textiles, cans, oils and hydrocarbons, street and building sweepings, dead animals, and waste water and water treatment sludges. Significant pollutants in landfill leachate are BOD, COD, iron, chloride, ammonia, heavy metals, and organic chemicals (Table 6-2).

Abstracting from experience elsewhere, it is virtually impossible to assure that a landfill will not leach contaminants to the ground-water system over the long term. Moreover, as landfill related ground-water contamination is a hydrogeological problem compounded by technical difficulties, it cannot be assured that regulations will be sufficient to eliminate possible ground-water contamination.

Table 6-2.

LEACHATE CHARACTERISTICS FROM MUNICIPAL SOLID WASTES

(Constituents given in parts per million, 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 – 2.0
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: Nassau-Suffolk Regional Planning Board, 1978

6.3.5 Highway Deicing

The application of deicing chemicals to highway surfaces can cause ground-water contamination. The salt melts snow and ice, and the resulting solution of brine, combined with other pavement contamination, runs off the impermeable road surface and most of it either seeps directly into the ground or is diverted to a storm-water recharge basin.

Contamination can also take place around salt storage piles if they are not adequately protected. Rain falls on the pile, dissolves the salt and runs onto the ground. About 80 percent of all deicing salt pollution is caused by improper storage practices and the remainder by improper spreading techniques (U.S. Salt Institute, 1976).

6.3.6 Product Storage Tanks and Pipelines

A number of potential contaminants are or will be stored in surface and subsurface tanks in the Pinelands and are transmitted in pipelines. Among the most frequently stored fluids are liquid petroleum products; gases (liquefied and gaseous), and industrial chemicals.

A major ground-water contamination threat is posed by liquid petroleum products stored in tanks and transmitted through pipelines. Three types of petroleum products are common. Gasoline service stations store various grades of gasoline in subsurface storage tanks with capacities of 2,000 to 12,000 gallons. Many individual homes and businesses store heating oil below ground or at the surface. Oil depots store one or more grades of fuel oil in surface tanks of various sizes.

6.4 Land Use and Organics Contamination

The Nassau-Suffolk Long Island 208 program included a study designed to determine in a general way whether or not organic chemicals in domestic wastes or runoff would preclude treated sewage recharge. Early in the sampling effort it became clear that every ground-water sample analyzed showed organics contamination.

Over one-third of the 60 shallow glacial wells tested were significantly contaminated by volatiles and by methylene chloride extractables. One-fifth of the wells contained organic contaminants at the 50 ppb level (the level currently in use as the threshold for health risks from potentially carcinogenic organics). The sample size was sufficiently large to indicate that significant levels of organic contaminants occur in Long Island's shallow aquifer. This contamination is probably a direct result of population related activities and land uses.

Tables 6-3 through 6-11 represent the Long Island experience. It is reasonable to believe that this experience will be repeated in the Pinelands area as a direct result of increased population density, economic activities, and the physical infra-

Table 6-3.

SUMMARY STATISTICS—NONVOLATILE ORGANIC COMPOUNDS

Compounds detected at > 10 μg/l for at least one station	Number of Stations > 1 μg/l	Number of Stations > 10 μg/l	Number of Stations > 50 μg/l
methyl naphthalene	45	2	1
dimethyl naphthalene	37	3	0
dibutyl phthalate	34	20	8
octyl phenols	27	4	1
C_4 benzene	20	4	0
di-tert-butyl phthalate	20	6	2
phthalate (composition undetermined)	19	2	1
naphthalene	19	3	0
phthalate derivative (composition undetermined)	14	1	0
dibutoxy-ethoxy-ethyl methane	13	4	1
phthalate compound (composition undetermined)	8	1	0
acenaphthene	6	1	0
C_{16} alkane	6	2	0
C_{28} alkane	6	1	1
tri-t-butyl orthoformate	6	1	0
diethyl benzene	5	2	0
2, 3 dimethyl naphthalene	4	1	0
thymol	3	1	0
cyclohexane	3	2	1
o, m xylenes	2	1	1
isopropyl benzene	2	1	1
C_{20} alkane	2	1	0
trimethyl hexanoic acid	1	1	0

Table 6-4.

SUMMARY STATISTICS—VOLATILE ORGANIC COMPOUNDS

Compound	No. stations measured*	No. stations detected	No. stations occurring @ > 10 μg/l	No. stations occurring @ > 50 μg/l
trichloroethylene	78	62 (79%)	35 (44%)	15 (19%)
chloroform	44	34 (75%)	20 (45%)	4 (9%)
1, 1, 1 trichloroethane	78	57 (73%)	25 (32%)	6 (8%)
carbon tetrachloride	78	28 (36%)	1 (1%)	0
tetrachloroethylene	78	23 (29%)	10 (13%)	5 (6%)
dibromochloromethane	78	15 (19%)	0	0
1, 1 dichloroethane	44	5 (11%)	3 (7%)	0
bromodichloromethane	78	8 (10%)	3 (4%)	1 (1%)
freon-11	44	4 (9%)	0	0
1, 1 dichloroethylene	44	4 (9%)	0	0
1, 2 dichloroethane	44	3 (7%)	0	0
bromoform	78	5 (6%)	1 (1%)	0
1 chloropropane	44	1 (2%)	1 (2%)	0

**Only results from samples JDW 41 to QA 25 have been considered quantitatively reliable for purposes of this summary.*

Reference: Nassau-Suffolk Regional Planning Board, 1978

Table 6-5.

SUMMARY OF VOLATILE ORGANIC SAMPLING OF NASSAU COUNTY MUNICIPAL WATER SUPPLIES

Organic Compounds(1)(2)	number of samples observed at ≥10µg/l(3)	number of samples observed at ≥60µg/l(3)	number of samples observed at ≥100µg/l(3)
1, 1, 2 trichloroethylene	26	7	2
1, 1, 1 trichloroethane	16	7	4
chloroform	11	1	0
tetrachloroethylene	7	5	4
1, 2 dichloroethylene	6	0	0
benzene	3	1	0
toluene	2	0	0
bromodichloromethane	1	0	0
vinyl chloride	0	0	0
trifluorotrichloroethane	0	0	0
carbon tetrachloride	0	0	0
methylene chloride	0	0	0
ethyl ether	0	0	0

[1] *All samples were collected between June 1975 and May 1977.*

[2] *Samples were analyzed by various labs using a variety of analytical methods.*

[3] *The total number of samples is 303; not all compounds were analyzed for in all samples.*

Table 6-6.

SUMMARY OF VOLATILE ORGANIC SAMPLING OF SUFFOLK COUNTY MUNICIPAL WATER SUPPLIES

Organic Compounds(1)(2)	No. of Samples Observed at ≥10µg/l(3)	No. of Samples Observed at ≥60µg/l(3)	No. of Samples Observed at ≥100µg/l(3)	Total No. of Samples Analyzed
1, 1, 2 trichloroethylene	46	29	19	125
1, 1, 1 trichloroethane	41	16	7	121
tetrachloroethylene	18	3	1	122
chlorofrom	8	2	1	123
carbon tetrachloride	4	0	0	105
1, 2 dichloroethylene	2	0	0	30
toluene	1	0	0	48
benzene	1	0	0	49
vinyl chloride	0	0	0	29
trichlorotrifloroethane	0	0	0	45
bromodichloromethane	0	0	0	62
dichloromethane	0	0	0	7
chlorodibromomethane	0	0	0	1

[1] Samples were collected between February 1976 and January 1978.

[2] Analyses were done by the following labs: NYSHD, Stony Brook; NYSHD, Albany; EPA, Ada, Okla.; New York Industrial Testing Lab; EPA, Edison, N. J.

erence: Nassau-Suffolk Regional Planning Board, 1978

Table 6-7.

NASSAU COUNTY DEPARTMENT OF HEALTH
CONSUMER PRODUCTS SURVEY (by Generic Category)

Product Category	Organic Chemical Ingredients Listed
Household Cleansers	Petroleum distillates, glycol ethers, xylenols, isopropanol
Drain Cleaners	1, 1, 1 Trichloroethane
Toilet Cleaners	Chlorinated phenols, xylene sulfonates
Laundry Soil and Stain Removers	Petroleum distillates, tetrachloroethylene
Spot Removers and Cleaning Fluids	Petroleum hydrocarbons, benzene, trichloroethylene, 1, 1, 1 trichloroethane
Hand Cleaners	Petroleum distillates, benzaldehyde
Metal Polishes	Petroleum distillates, petroleum naptha, isopropanol
Cesspool Cleaners	Tetrachloroethylene, methylene chloride, dichlorobenzene
Cleaning Solvents	Pure strength benzene, acetone, trichloroethylene
Paint and Lacquer Thinners	Benzene, toluene, acetone, butyl acetate, methyl ketones
Paint and Varnish Removers, Deglossers	Methylene chloride, toluene, acetone, xylene, ethanol, methanol
Paint Brush Cleaners	Aliphatic hydrocarbons, toluene, acetone, methyl ethyl ketones, methanol, glycol ethers
Degreasers for Engines and Metals	Chlorinated hydrocarbons, dichloroperchloroethylene, toluene, phenols
Degreasers for Driveways, Garages	Petroleum solvents, alcohols, glycol ether
Engine Flushes	Petroleum solvents, ketones, glycol ethers
Radiator Flushes	Petroleum distillates, butanol
Antifreeze	Ethylene glycol, methanol
Auto Transmission, Crankcase Additives	Petroleum distillates, xylene
Car Washes	Alkyl benzene sulfonates
Car Waxes, Polishes	Petroleum distillates, aliphatic hydrocarbons
Bug and Tar Removers	Petroleum distillates, xylene

ference: Nassau-Suffolk Regional Planning Board, 1978

Table 6-8.

NASSAU COUNTY DEPARTMENT OF HEALTH
CONSUMER PRODUCTS SURVEY (by Brand Name)*

Brand Name	Product Usage	Compound
Carbona Spray Spot Remover	Spot Remover	Methylene chloride
Dax (Kocatah)	Scalp Conditioner	Tar oil
3-in-1 Plastic Wood	Wood Filler	Toluene
Flecto Varathane	Spray Paint	Toluene/Xylene
Sal-te Strip	Paint Remover	Methylene chloride
Bix (2 types)	Paint Remover	Toluene, Methylene chloride
Rock Miracle	Paint Remover	Methylene chloride
Formula A	Paint Remover	Methylene chloride
The Remover	Paint Remover	Methylene chloride
Amazon	Sealer	Creosote oil
Cabots	Tree Healer/Paint	Creosote oil
Nankes	Lacquer Thinner	Toluene
Harmel	Spray Enamel Primer	Methylene chloride
Harmel	Spray Enamel Black	Vinyl toluene soya alkdresin carbon black
Miniwax	Polyurethane Sealer	Toluene diisocyanante
Weldwood Woodlife	Wood Preservative	Pentachlorophenols
LS Liquid Sandpaper	Liquid Sanding	Xylene naphtha
Zip Strip	Paint Remover	Methylene chloride
Heddy	Graffiti Remover	Methylene chloride
Weldwood	Spray 'N' Glue	Methylene chloride
Alta	Solvent	Trichloroethylene
Shout	Stain Remover	Tetrachloroethylene
Fabspray Vinyl Colorspray	Paint	Toluene
Lacquer Thinner	Paint Thinner	Toluene
Woodlife	Wood Preservative	Pentachlorophenol
Lysol	Disinfectant	Xylenols
Warner DeGreaser	Auto Degreaser	Methylene chloride
Lan-o Sheen	Engines	1, 1, 2 Trichloroethylene
Ortho	Pruning	Asphalt
Pratt Spray's	Insects	Xylene
Grumbacher	Retouch Varnish	Methylene chloride
Choke	Choke Cleaner	Methylene chloride
Drainz	Cesspool Cleaner	Petroleum distillate
Snap	Choke Cleaner	Xylene
Warner	Choke/PVC Cleaner	Toluene, Methylene chloride
Zing Semi-Paste	Paint Remover	Toluene, Methylene chloride
Red Devil	Brush Cleaner	Benzene
Red Devil	Paint/Varnish Remover	Benzene, Methylene chloride
Five Star	Lacquer-Thinner	Toluene
Bendlite	Epoxy Primer	Halogenated Aromatic Hydrocarbon
Rust-Oleum	Spray Rust Preventative	Toluene, Xylene
Bernzomatic	Flat Tire Fixer	Toluene
Doublesealed	Lacquer Thinner	Toluene
Rich	Liquid Roof Coating	Asbestos fibre
Black Jack	Plastic Asbestos Cement	Asbestos fibre
Empire	Asbestos Cement	Asbestos fibre
Umbrella	Water Proofing	Aromatic Hydrocarbons
NYBCO Silver Touch	Silver Spray Enamel	Toluene
NYBCO Silver Touch	Wet Look Enamel	Toluene
KR2 Spot Lifter	Spot Remover	Chlorinated hydrocarbons
Baldwin	Lacquer Thinner	Toluene
Gumout	Choke Cleaner	Xylenes
STP	Carburetor Cleaner	Xylenes
RP Superfilter Coat	Odor & Dust Removing Air Filter Adhesive for Washable Filters	Hexachlorophene
Imperial Wonder Paste	Paint Remover	Methylene chloride

rence: Nassau-Suffolk Regional Planning Board, 1978

Table 6-8. (continued)

Brand Name	Product Usage	Compound
TM-4	Paint and Finish Remover	Methylene chloride
Weldwood Multipurpose Floor Cement	Cement	Toluene
Weldwood Waterproof Cement	Cement	Toluene
Asphalt Asbestos Fibre Roof Plastic	Roof Coating	Asbestos
Empire Asbestos Cement	Cement	Asbestos
Asphalt Asbestos Roof Fix Roof Coating	Roof Coating	Asbestos
Digest	Sewage Grease and Waste Solvent	Trichlorobenzene
Bilco Creosote Oil Compound	Wood Sealer	Asbestos
3-in-1 Plastic Wood Solvent	Solvent	Toluene
Duro Liquid Solder	Metal Repair Cement	Toluene

These products were identified in a one day survey of supermarkets and hardware stores by the Nassau County Department of Health.

Reference: Nassau-Suffolk Regional Planning Board, 1978

Table 6-9.

CESSPOOL CLEANERS AND DRAIN OPENERS USED IN NASSAU COUNTY: SUMMARY OF KNOWN INGREDIENTS AND SALES INFORMATION

Brand Name	Manufacturer	Ingredients	Source of Information	Gallons Sold Yearly[1]
Action Degreaser	Action Chemicals, Inc. Brooklyn, N. Y.	Petroleum Distillates Orthodichlorobenzene	Product Label	2,210
Cess-Flo	Pequa Industries, Inc. Massapequa Park, N. Y.	Petroleum Distillates	Product Label	660
Drainz	Jan-Cyn Manufacturers 155 Oval Drive Central Islip, N. Y. 11722	Methylene Chloride—35% 1, 1, 1-Trichloroethane—31% Aliphatic/Aromatic Fractions—35%	Laboratory Analysis	27,155
Drainz Super Strength Concentrate	Jan-Cyn Manufacturers 155 Oval Drive Central Islip, N. Y. 11722	Similar to "Drainz"		4,100
Hercules Wham EPA Reg. No. 7687-2	Hercules Chemical Corp. New York, N. Y. 10011	Orthodichlorobenzene—80% Inert—20%	Product Label	2,500 (mfgrs. estimate)
The Unstuffers Liquid Cleaner for Septic Tanks & Cesspools	Coastal Industries, Inc. 190 Jony Drive Carlstadt, N. J. 07072	Solvent Blend	Per manufacturer's representative	2,330
Clog-Buster	Action Chemicals, Inc. Brooklyn, N. Y.	Petroleum Distillates	Product Label	210
Drano Aerosol Plunger	The Drackett Company 5020 Spring Grove Ave. Cincinnati, Ohio	Utilizes pressure to open drain		3,200
Glamorene Drain Power	Glamorene Product Corp. 176 Emin Road Clifton, N. J. 07014	Utilizes pressure to open drain 1, 1, 1,-Trichloroethane Chlorofluorocarbon propellant oil of pepper, perfume	Per manufacturer's representative	3,040
Kitchen Drano	The Drackett Company 5020 Spring Grove Ave. Cincinnati, Ohio 45232	1, 1, 1-Trichlorpethane—75% Paraffinic Oil—25%	Per manufacturer's representative	2,210

[1] Actual response of 60% of surveyed retail establishments.

Reference: Nassau-Suffolk Regional Planning Board, 1978

Table 6-10.

ESTIMATES OF CESSPOOL CLEANER SALES IN NASSAU COUNTY
(by Chemical)

Chemical	Quantity (Gallons/Year)
Methylene Chloride	17,400
1, 1, 1-Trichloroethane	18,600
Orthodichlorobenzene	3,300
Other Aromatic and Halogenated Compounds	17,600
Total Suspected Carcinogenic or Other Harmful Organics	56,900
Petroleum Distillates	10,600
Grand Total	67,500

Reference: Nassau-Suffolk Regional Planning Board, 1978

Table 6-11.

INDUSTRIAL ORGANIC CHEMICAL USAGE IN NASSAU COUNTY: STATUS AS OF NOVEMBER 1977

(Gallons/Year)

Industry	No. Companies	Standard Industrial Classification No.	Priority I Total	Trichloroethylene	Benzene	Tetrachloroethylene	Toluene	Methylene Chloride	Priority II Total	1, 1, 2-Trichloroethane	Xylene	Priority III Total	1, 1, 1-Trichloroethane	Acetone	Freons	MEK	Miscellaneous
Printers	83	(271-279)	1,824		174		660	990	312	312		55,349	120	276		20	64,934
Electrical & Electronic Products	53	(361-365)	70,502	15,167	10	3,800	1,526	50,000	19,416	19,356	60	242,332	2,720	2,440	2,220	7,412	227,540
Mechanical & Engine Repair	50	(353-371-373)	3,482	2,245		625		612	135		135	22,375	102		360	26	21,807
Tool & Machine	88	(345, 346 356, 359)	24,882	14,804	8	5,400	3,430	1,160	7,100	5,000	2,100	70,857	2,600	85		5,530	62,642
Consumer Products	65	(386, 355, 396, 209, 229, 239, 284)	14,536		34	11,000	1,162	2,340	205	55	150	68,751	1,890	59			66,802
Chemical Products	15	(281-289)	409,560	5,400	170	3,080	166,000	234,910	21,600	19,000	2,600	297,770	4,910		4,600		288,360
Misc. Manufacturers	80	(399)	13,982	8,092	65	855	4,190	780	86,230	75,955	10,275	177,070	17,380	3,210	220	4,823	151,437
Aerospace	1	(3721-3761) (3728)	125,070	103,850			21,220		1,230		1,230	60,610	23,375		3,000	19,100	15,135
Dry Cleaners (Extrapolated)	400		350,000			350,000											
Totals	845		1,013,838	149,638	461	374,760	198,187	290,792	136,228	118,678	16,415	995,114	63,177	6,069	10,300	36,911	888,657

Reference: Nassau-Suffolk Regional Planning Board, 1978

structure required to service the population's demands for goods and services.

6.5 Population Density and Nitrate Contamination of Ground Water

The Nassau-Suffolk Regional Planning Board 208 program contained a statistical analysis of nitrate nitrogen concentrations in public supply wells. These wells were grouped according to Nassau-Suffolk Regional Planning Board's land use (density data) maps and time series data were analyzed by regression techniques. It is reasonable to expect that this pattern may be repeated in the Pinelands as a result of increased population density and reliance on individual septic systems.

Population density, ground water nitrate-nitrogen concentrations, and the percentage of violations of the state (New York) drinking water standard can be compared to relate population density to percent violations (Figures 6-1, 6-2, and 6-3). The statistical analysis relating population densities to variation in ground-water concentrations, as specified by percentage violation of the standards may be justified as a planning tool in the absence of statistically valid alternatives.

POPULATION DENSITIES AND THE AVERAGE OF THE MEDIAN NITRATE-NITROGEN CONCENTRATIONS IN WATER FROM WELLS SCREENED IN THE UPPER GLACIAL AQUIFER IN AREAS WITHOUT SEWERS

Grid Cell No.	Persons/Gross Acre	Average Median* (Mg/l)
2	1.5	2.5
55	3.3	6.6
66	0.9	1.9
71	1.5	1.5
81	9.5	19.0
82	4.2	3.1
84	0.7	1.5
104	4.4	2.3
105	10.9	9.6
119	1.6	5.0
120	6.3	9.8
123	11.9	2.3**
133	1.3	1.2
140	12.8	13.0
154	2.1	3.2
157	16.6	8.4
174	8.5	7.5
Overall Average	5.8	5.8

Medians based on observations made during 1972–76 from 27 wells.

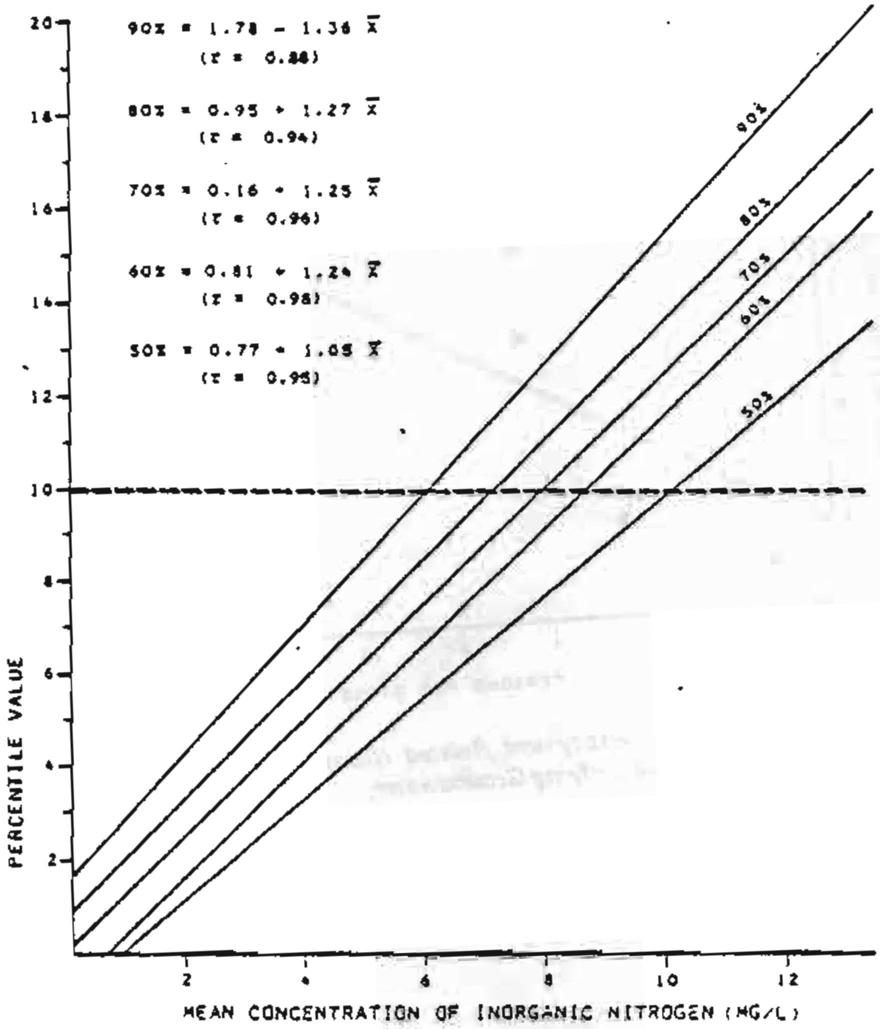


Figure 6-1. *Relationship Between Mean Groundwater Nitrogen Concentrations and Percentile Values.*

NITRATE-NITROGEN CONCENTRATIONS IN WELLS IN GRID CELL 123
(Levittown)

Well No.	Depth (ft.)	No. of Observ.	Mean (Mg/l)	Standard Deviation	Last Year of Observation
2581	55–81	12	15.62	11.74	1965
2403	59–84	12	15.02	3.95	1965
7702	25–28	8	0.99	1.23	1968
2402	164–206	20	7.33	3.23	1968
7703	–	6	3.32	3.49	1970
7698	23–26	13	0.60	0.93	1972
7699	27–30	14	0.89	1.80	1972
7696	28–31	14	5.64	1.67	1972
7701	–	8	1.24	1.02	1972
7700	–	9	2.17	1.28	1972
7687	26–29	14	1.75	.91	1972
		130	5.02	5.25	

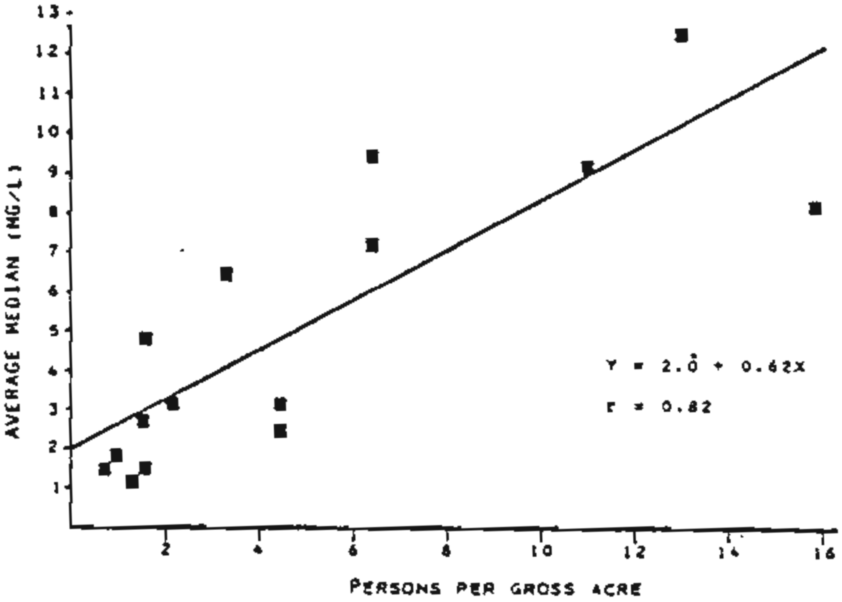


Figure 6-2. *Population Density and Related Nitrate-Nitrogen Concentrations in Underlying Groundwater.*

Reference: Nassau-Suffolk Regional Planning Board, 1978

RELATIONSHIP BETWEEN PERCENT VIOLATIONS OF THE 10 mg/l STANDARD FOR DRINKING WATER, MEAN GROUNDWATER NITRATE CONCENTRATIONS AND POPULATION DENSITIES

Percent violations	mean concentrations mg/l	population densities persons/gross acre
10%	6.0	6.7
20%	7.1	8.6
30%	7.9	9.8
40%	8.7	11.2
50%	10.3	13.7

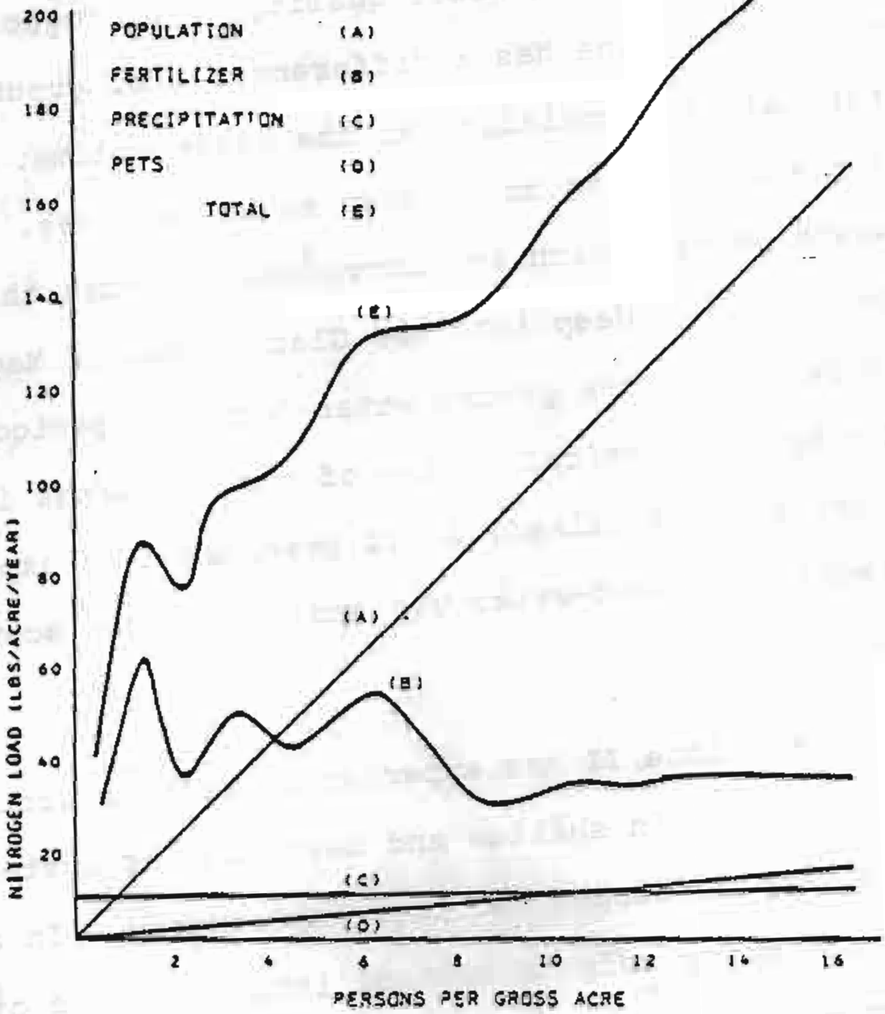


Figure 6-3. *Relationships Between Population Density and Nitrogen Loadings to Groundwater from Major Pollution Sources.*

Reference: Nassau-Suffolk Regional Planning Board, 1978

6.6 The Ground-Water Quality Management Strategy of the Long Island 208 Plan is a Leading Indicator of the Potential Ground-Water Impacts That May Occur in the Pinelands

In recognition of basic principles of ground-water quality management, existing ground-water conditions, surface-water quality objectives, and present and projected water supply needs for the area, the Long Island 208 plan divided Nassau and Suffolk Counties into eight water quality or hydrogeologic management zones. Each zone has a different set of ground- or surface-water quality conditions at the present time. Three of these zones are considered to be deep recharge zones. Precipitation or waste waters which are introduced through these zones generally tend to flow deep into the Glacial and/or Magothy aquifers and remain in the ground water for long periods of time. As the hydrogeological regime of the Pinelands is sufficiently similar to Long Island, it is reasonable to expect that similar patterns of ground-water use and impact can occur with development.

Nassau-Suffolk Zone II has experienced serious ground-water quality problems in shallow and deep aquifer systems. This zone is highly developed and is being sewered. In addition, efforts are being made to control industrial and other sources of organic chemicals. Zone III is an area that still has good quality ground water in both the shallow and deep aquifer systems. Much of Zone III consists of low density land uses. Because much of the ground water in Zone III is of high quality, and a good portion of the zone is relatively undeveloped, the 208 Plan recognized the non-structural controls on land-use development would be the best means of protecting the quality of the ground water over a long period of time.

The Plan recommends that sewering be done where densities exceed one or more dwelling units per acre. In terms of non-structural recommendations, it proposes that land-use control be the primary method for protecting the ground-water resource, at least where more intensive development has not already occurred. Large lot developments, two-acre zoning or greater, are recommended. The general concept is to provide for a density development which is sufficiently low that there will be little or no degradation of ground-water quality. The same non-degradation philosophy is applied to landfills. The 208 Plan recommends that the establishment of new landfills and the expansion of existing ones would be prohibited, and that existing landfills will be upgraded where possible to minimize further ground-water contamination. The Plan recognizes that it may be too late to establish a non-degradation policy for certain areas even though they contribute significant recharge to the ground-water system.

The Plan's "sewering standard" differs for the different water management zones. In some of the zones, such as Zones I, IV, and V, sewering is recommended where development occurs at densities greater than half an acre, i.e., three dwelling units per acre or more. In effect, this means that sewering is recommended where the existing or allowed development would eventually lead to nitrate concentrations of 6 ppm or greater in the ground water. However, since the 208 Plan recommends sewering in Zone III, where densities of one or more dwelling units per acre occur, the effective "sewering standard" is approximately 3 mg/l.

Although residential development based on one-half acre lots may generally result in nitrate concentrations of less than 10 ppm (the USEPA drinking water standard) in the ground water, deterioration of the ground water from very low nitrate concentrations of 6 to 10 ppm is not fully consistent with a non-degradation policy.

Although the USEPA drinking water regulations contain a standard for nitrate of 10 ppm, there are many reasons justifying adoption of a non-degradation standard. If land development in an area becomes more intensive, agencies responsible for protecting ground-water quality gradually lose control of the ability to prevent degradation. As development occurs, many potential sources of contamination begin to appear, and virtually every land use related activity can have an effect on ground-water quality. Furthermore, it is practically impossible to remove contaminants and go from a situation of degraded ground-water quality to high ground-water quality. Thus, if future public health risks are to be avoided, prevention of significant degradation is a reasonable course to pursue even if existing evidence suggests that specific USEPA drinking water regulations will not be violated by land-use activities or population densities which are presently proposed.

6.7 Limiting Population Density to Protect Ground-Water Resources

Although the Pinelands area may contain sufficient ground-water resources to satisfy projected future needs, parts of the reservoir may be effectively eliminated because the ground water will not meet drinking water standards. Ground water in these areas cannot be used as a potable supply because certain constituents, such as nitrate, exceed the maximum concentrations established by public health agencies.

Should this problem occur in the Pinelands it will probably be related to land use and population density. The more people living in a given area, the greater the contaminant loading will be to the ground water. There is an effective limit to the volume of wastes that can be assimilated by the ground-water system before it cannot be used without well head treatment.

In the 1950's, Long Island's water supply managers recognized that there was a relationship between population density and nitrate contamination and embarked upon two plans of action to alleviate the problem. The first was to remove the waste by the use of sewers and sewage-treatment plants. The second was to try and determine exactly what population density had to be exceeded before the ground water became contaminated.

By the time Nassau County officials knew what had to be done to protect their drinking water supplies, a significant portion of the shallow aquifer was contaminated. This aquifer receives wastes percolating downward from the land surface. Most water supply wells were initially installed in this unit because it was the easiest to reach and pump from, and water quality was very good. As this aquifer became polluted, wells were deepened into the underlying Magothy aquifer. This was a short-term solution because water that moves from the surface to the deep aquifer will pass through the contaminated shallow aquifer and carry contamination into the Magothy. This has occurred because the deeper Magothy wells created artificial gradients and actually induced contaminated water to move from the shallow to the deeper deposits.

Nassau County has been the "laboratory" where most of the ground water related information on Long Island has originated. Since it was developed to a very high density before Suffolk County, urbanization related problems became evident, and it provides an example of what may happen in similar urbanizing areas, such as Suffolk County and the New Jersey Pinelands.

Sewering in Nassau County is an attempt to remove a major source of nitrate pollution. Recent studies by the USGS have shown that this will take decades at a minimum for the shallower deposits, and centuries for the deeper zones because ground water moves very slowly, only 1 to 2 feet per day.

The second method that has been tried to avert this problem has been an attempt to limit the number of people living in a certain area. But this has not been successful because recent studies have not been able to determine the maximum population density an area can sustain before the nitrate in the ground water exceeds the standards. Early estimates put the density at one dwelling unit per acre, but recent evidence seems to suggest that two dwelling units per acre (half-acre zoning) will not cause nitrate contamination to occur 90 percent of the time (Porter, 1977).

Organic wastes from residential and industrial activity have now been recognized as a much greater threat to groundwater quality. Organic chemicals reach the ground water as a result of the use, transportation, storage and disposal of chemicals and chemical products. The Nassau County Department of Health completed a survey of household products that can be purchased in supermarkets, auto, hardware, and janitorial supply stores, and identified 230 products that contained organic chemicals that could eventually reach the ground water. These were grouped as follows:

- organic solvent cesspool cleaners
- paint and varnish removers
- household cleansers, disinfectants and oven cleaners
- laundry degreasers
- solvents and cleaning fluids
- engine and metal degreasers
- solid toilet bowl deodorizers
- floor strippers, cleaners, and dressings
- radiator flushes
- car waxes and cleaners

These products can enter the ground water by other means than through a cesspool, negating sewering as a means of alleviating the threat. In addition, as people move into an area, a support intrastructure must be developed and all these related activities may contribute organic loads to the ground water.

6.8 A Strategy to Control Non-Point Sources of Ground-Water Contamination in the New Jersey Pinelands

6.8.1 Storm-Water Runoff

Storm-water runoff is generally controlled through the use of infiltration basins or allowed to flow through drainage systems or overland to surface waters. Storm-water runoff contains plant nutrients, metals, organic compounds, and bacteria. The following control strategies can aid in minimizing problems attributable to this pollution source:

- Require the immediate recharge or on-site detention of storm water, where feasible, in order to reduce the volume of runoff.

- Promote the use of storage areas - either specially constructed detention basins, multi-purpose paved areas, natural ponds or other existing or altered landforms - to reduce sediment transport and contamination from runoff.

- Promote or require the imposition of controls to reduce pollution generated by domestic animals.

- Establish and require compliance with Best Management Practices for land clearance and construction in order to minimize erosion and construction related pollutant discharges.

- Promote or require municipal street cleaning programs to help minimize the pollution effects of storm-water runoff.

6.8.2 Domestic On-Site Disposal Systems

Domestic on-site disposal systems contribute significant amounts of nitrogen and organic contaminants to ground water. The following control strategies can aid in minimizing this pollution source:

- Withold permits for additional individual systems in any area where it has been determined that on-site disposal is causing significant deterioration of ground- or surface-water quality.

- Restrict the use of various classes of products that may contribute to the chemical pollution of the ground water. Such products include various detergents, dry cleaners and septic system cleaners or reconditioners.
- Establish minimum lot sizes in specific area subject to hydrologic constraints or, if such areas are already developed, provide for and require hook-up to a collection and treatment system.
- Promote the establishment of municipal programs for the routine preventive maintenance of on-site systems.
- Provide for a monitoring program in areas where pervasive violations of the nitrogen standard or the presence of heavy metals or organic chemicals is considered likely.
- Convert to alternative disposal techniques in those areas where monitoring indicates unacceptable pollutant concentrations.

6.8.3 Subsurface Leakage From Domestic Collection Systems

Sewer systems develop leaks as a result of improper construction, materials failure or aging. These leaks may permit domestic and industrial commercial waste to be carried to the ground water. The following strategies can aid in minimizing the pollution problems associated with exfiltration and clogging:

- Apply stringent performance standards for construction materials and practices, accompanied by surveillance during construction.
- Require the establishment of regularly scheduled maintenance and cleaning programs.

6.8.4 Product Storage Tanks, Pipelines, Accidental Discharges

Leakage of materials from product storage tanks and accidental discharges will introduce hydrocarbons, organic solvents, and toxic industrial liquids into the ground water. The following control strategies can aid in minimizing the pollution source:

- Require construction standards that will minimize the probability of leakage or, in the event of accident, will minimize the entry of pollutants into ground and surface waters.
- Establish siting and location standards that will prohibit the storage of certain materials in areas where leakage and spills will constitute a significant pollution hazard.
- Establish a monitoring program that will enable a management agency to evaluate the performance of storage facilities in

relation to baseline ground- or surface-water quality.

- Require that owners or operators of storage and transmission facilities develop an emergency shut down, containment and clean-up procedure as a permit condition.

- Require changes in clean-up techniques to minimize the flushing or disposition of hazardous spilled materials to ground or surface waters.

- Establish and maintain an emergency notification system with a trained emergency response team capable of responding to spill emergencies.

- Provide for criminal and/or civil liability in cases of ground- or surface-water pollution caused by violation of permit or operating conditions.

- Require that accurate product records be maintained and made available to regulatory agencies.

- Require that buried tanks be constructed or protected in such a way as to positively prevent the escape of contents due to tank corrosion, both internal and external. Techniques to be considered include, but are not limited to, the use of non-corrosive materials, cathodic protection, coatings and double-walled tanks.

- Prohibit the establishment of waste piles and stock piles containing potential hazardous pollutants within the floodplains of the 100-year flood.

- Prohibit above and below ground storage of potential pollutants in primary recharge or watershed areas except where reasonable safeguards are provided in order to prevent the escape or movement of such pollutants into the ground water.

6.8.5 Discharge and Storage of Industrial Wastes

Industrial wastes discharged to municipal treatment facilities and ground and surface waters may contain a variety of toxic organic and inorganic compounds that constitute a public health hazard. The following control strategies can aid in minimizing this pollution source:

- Require adequate pretreatment levels.
- Prohibit disposal of waste materials on the land surface, or to ground water, unless permitted or exempted.
- Prohibit the discharge of specific classes of industrial waste to ground water in any prime recharge or watershed area.
- Expand permit conditions relating to an enumeration of chemical constituents and allowable limits to ensure maximum protection of the ground-water resource.
- If necessary, require that specified classes of industrial

wastes be subject to a materials recovery process prior to discharge.

6.8.6 Landfills

The use of the land for the ultimate disposal of solid wastes, sludges and toxic chemicals constitutes a significant threat to ground-water quality and the public health. The following control strategies can aid in minimizing this pollution source:

- Prohibit all landfill operations that rely on natural attenuation as a means of leachate control.
- Prohibit the location of new landfill operations in primary recharge of watershed management areas.
- Require that landfill operators adhere to a cover schedule and maintain a minimally exposed face. Where appropriate, require a cover of relatively impervious material.
- Classify all landfill sites according to the materials that may be placed in them, with toxic wastes assigned to specific disposal sites that are strictly controlled and monitored.
- Promote the use of volume reduction techniques, and resource recovery and reuse, wherever economically feasible.
- Require permits for all landfill operations, regardless of size.

- Require the provision of an underdrain system and in impermeable barrier where the landfill is located in a permeable soil and where it can reasonably be expected that the quantity and quality of the leachate will have a significant adverse effect on ground or surface waters. Provide for treatment and disposal of collected leachate.

- Establish, maintain or supplement ground-water monitoring and surveillance at each landfill site, both open and closed.

- Require surface liners, proper grading and revegetation of completed landfills to minimize infiltration and ensure compatability with the surrounding area.

6.8.7 Recharge of Sewage Treatment Effluent

Sewage treatment plant effluent discharged to the ground generally does not constitute a major threat to ground water; however, there may be significant local impacts when discharges are concentrated at a few sites. The following control strategies can aid in minimizing this pollution source:

- Establish and enforce strict control of treatment plant operating procedures.

- Provide for public take-over in instances where private owners and operators consistently fail to meet permit conditions.

- Require the use of advanced waste-water treatment techniques in primary recharge areas, or prohibit sewage treatment plant discharges to ground in prime recharge or watershed management areas.

- Establish monitoring programs to determine baseline water quality and to ensure early detection of any degradation caused by discharges from sewage treatment plants.

6.8.8 Water Well Construction and Abandonment

Improper construction and practices may permit surface pollutants to enter the ground-water aquifer system and may contribute to the movement of contaminated water between aquifers. The following control strategies can minimize pollution from this source.

- Require the registration of all persons and/or firms engaged in well drilling activities.

- Establish a program of well inspection. Inspection priority should be accorded to the classes of wells considered most likely to contribute to ground-water contamination.

- Require a permit for the abandonment, sealing or demolition of any public or private well having a capacity greater than 45 gpm and of any observation well or other well installed for the purposes of scientific investigation.

6.8.9 Highway Deicing Materials

The storage and application of highway deicing materials contribute to chloride and sodium contamination. The following control strategies can minimize pollution from this source:

- Require that salt piles be stored in permanent buildings.
- Require the substitution of inert abrasives, such as sand or cinders, for chemical salts wherever possible.
- Modify application procedures and equipment to allow preferential spreading on high hazard road segments.

6.8.10 Disposal of Heated Cooling Water to Ground Water (Diffusion Wells)

Diffusion wells may cause contamination of ground water through the introduction of heated water and chemical additives used in the cooling process or for the maintenance of cooling equipment. The following control strategies can aid in minimizing pollution from this source:

- Restrict the use of chemical additives in cooling processes or in the maintenance of cooling equipment.
- Require that no cooling waters discharged to the ground differ significantly from ambient water except in respect to temperature.
- Provide adequate surveillance to ensure compliance with diffusion well permit conditions.

6.8.11 Agricultural Chemicals

Pesticides and fertilizers are applied to lawns, golf courses and nursery stock as well as to agricultural land. Contamination hazards from pesticides are generally controlled by natural physical-chemical biological processes in the soil. Recent developments in pesticide chemistry may yield classes of chemicals that are more persistent and/or toxic. Intensive application of fertilizer in domestic, recreational, agricultural, and commercial use results in the leaching of a large part of the nitrogen content to ground water. The following strategies can aid in minimizing pollution from these sources:

Pesticides

- Limit or prohibit the distribution and/or use of specific chemicals that are suspected carcinogens.
- Promote the substitution of less pertinent or less toxic chemicals for those currently in use.
- Control the disposal of used pesticide containers.
- Require licensing of commercial operators.

Fertilizers

- Conduct information and education programs designed to promote the cost-effective use of fertilizers and erosion/runoff control.

- Limit or prohibit the distribution or sale of chemical fertilizer formulations that have effective organic substitutes.

- Promote the use of low-maintenance lawns and natural plant materials in order to reduce the need for extensive watering and fertilizing.

6.9 A Ground-Water Zoning Plan for the Pinelands

Ground-water zoning is a management technique which is often used to identify problem areas or aquifers in need of protection. For example, an area where the aquifer is polluted by industrial waste could be "written off" for certain uses, and a pristine aquifer could be protected by prohibiting selected types of development in the outcrop and recharge areas.

Establishing a zoning system for the Pinelands is difficult, as no specific "problem" areas have been identified. The Cohansey aquifer is very permeable and pollutants entering the aquifer in most cases would travel to a discharge point without contaminating deeper aquifer systems. This so called "flushing" action in the Cohansey is both a blessing and a problem. The flushing would tend to remove the pollutant and transport it to surface water and eventually downstream to the ocean. This action would thus provide for relatively fast rehabilitation of most polluted aquifers and improved water quality.

In contrast, the flushing action and short residence time of water in the aquifer provides for little or no in situ treatment of waste fluids, such as septic tank effluent. As was mentioned previously, the Cohansey formation contains a very high percentage of sand (80 to 90 percent), and thus any natural treatment within the aquifer is very limited. On the other hand, where there is vertical movement of ground water, the presence of shallow clays in the Cohansey could be an important controlling mechanism to divert or retard this movement of pollutants and provide protection to deeper aquifer zones.

For this reason a zoning system has been devised based on the presence or absence of shallow clays and also the depth to the water table. The greater the depth to water, the better the chances are of obtaining some waste treatment in the unsaturated zone.

By combining the shallow clay and depth to water maps, a ground-water vulnerability map of the Pinelands has been constructed (Plate 18). Categories and vulnerability ratings shown on this map are listed below:

Ground-Water Vulnerability Rating	Category
Highest	Water table less than 10 feet below land surface; shallow clays absent
High	Water table greater than 10 feet below land surface; shallow clays absent
Moderate	Water table less than 10 feet below land surface; shallow clays present
Lowest	Water table greater than 10 feet below land surface; shallow clays present

As shown on the map, the areas with the lowest ground-water vulnerability rating are located in the eastern and south-eastern portions of the Pinelands.

6.10 Recommended Priorities for Ground-Water Quality Protection

As discussed previously, the overall ground-water quality in the Pinelands is excellent and the actual and potential sources of ground-water pollution are relatively few in number. The relative importance of each of the significant sources of potential contamination in the Pinelands is given in Table 6-12.

Of key concern are septic tanks because of the volume of waste water discharged, and landfills because of the threat posed by disposal of municipal and industrial wastes. Spills of hazardous chemical substances are also of prime concern. Of moderate concern are surface impoundments (relatively few in number) and highway deicing practices. All other categories, including pipelines, storage tanks, sand and gravel mining operations, salt-water intrusion, water wells, agricultural practices and spray irrigation are considered to be of low significance.

Recommended priorities for ground-water quality protection are divided into (1) solving existing ground-water contamination problems and (2) preventing future ground-water contamination problems.

Table 6-12. Principal Sources of Ground-Water Contamination in the Pinelands and Their Relative Importance.

	High	Moderate	Low
Septic Tanks	▬		
Landfills	▬		
Surface Impoundments		▬	
Spills	▬		
Buried Pipelines and Storage Tanks			▬
Mining Activities			▬
Salt-Water Intrusion			▬
Water Wells			▬
Agricultural Activities			▬
Highway Deicing Salts		▬	
Spray Irrigation by Waste Water			▬

Recommended control measures to solve existing problems are:

a) Further inventory sources of contamination.
b) Define and monitor contaminated ground-water bodies that are considered hazardous.
c) Control use of ground water already affected or threatened by contamination and provide alternate sources of water supply where needed.
d) Contain or clean up pollution where economically and technically feasible.

Recommended control measures for preventing future problems are:

a) Devise a ground-water zoning and management plan.
b) Prepare realistic guidelines and enforce regulations that are truly protective.

A major effort should be directed, within the financial resources available to the Pinelands Commission, toward defining the areal extent and severity of existing or suspected ground-water contamination problems. Such studies can be used to warn against use of certain aquifers or portions of aquifers for specific purposes. Within the legal framework, development or withdrawal of ground water could be limited in affected aquifer zones. It would be the task of the Commission to determine "critical zones" around each known significant case of ground-water contamination. In each "critical zone," ground-water diversion would be restricted from the standpoint of either the quantity that can be pumped or the purpose for which it can be used. Wells and other monitoring techniques would aid in determining when and how to modify the areal extent of a "critical zone" over a period of time.

Among the various options available to the Commission for protecting ground-water quality are such alternatives for control as the enforcement of land-use restrictions in critical areas, imposition of restraints on each individual type of activity that can lead to ground-water contamination, and regulation of patterns of ground-water use. Obviously, the choice of any control method in the Pinelands must be influenced by geologic and hydrologic conditions in the area of interest and must take into consideration the type of activity involved.

Respectfully submitted,
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March 26, 1980

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