New Jersey Ambient Ground Water Quality Monitoring Network:
Status of shallow ground-water quality, 1999 - 2004

Background

Water-quality data from the 150-well New Jersey Ambient Ground-Water Quality Monitoring Network (AGWQMN) yields information about the quality of shallow ground water in agricultural, urban and undeveloped land use areas (fig. 1). The major goals of this NJDEP/USGS cooperative network are to evaluate the status of, and trends in, shallow-ground-water quality as a function of land use related non-point source contamination. Network wells are screened just below the water table and are sampled 30 per year on a 5-year cycle. The first cycle was completed and the second started in 2004. The New Jersey Geological Survey (NJGS) manages the network design, well installation (fig. 2), well maintenance, data interpretation, and reporting. The NJDEP Bureau of Fresh Water and Biological Monitoring and the USGS collect the ground-water samples; the USGS laboratory in Denver, Colorado analyzes them. Chemical and physical characteristics determined (or measured) for each well water sample include: field parameters such as pH, specific conductivity, dissolved oxygen, temperature and alkalinity; major ions, trace elements, gross-alpha particle activity, volatile organic compounds (VOC), and pesticides. Total dissolved solids concentrations, as well as the concentration, frequency, and variety of trace elements, nutrients, volatile organic compounds and pesticides are found at significantly higher levels in wells located in agricultural and urban areas than from wells in undeveloped areas. Shallow ground water in agricultural land use areas have the highest percent of pesticide detections, highest median nitrate concentrations (maximum up to 56 mg/l in this network) and highest gross alpha particle activity. These concentrations are likely related to the application of agricultural chemicals. In urban areas, dissolved oxygen concentrations generally are lower and dissolved solids, dissolved iron, chloride, and VOC (such as MTBE) concentrations generally are higher than in other land uses.

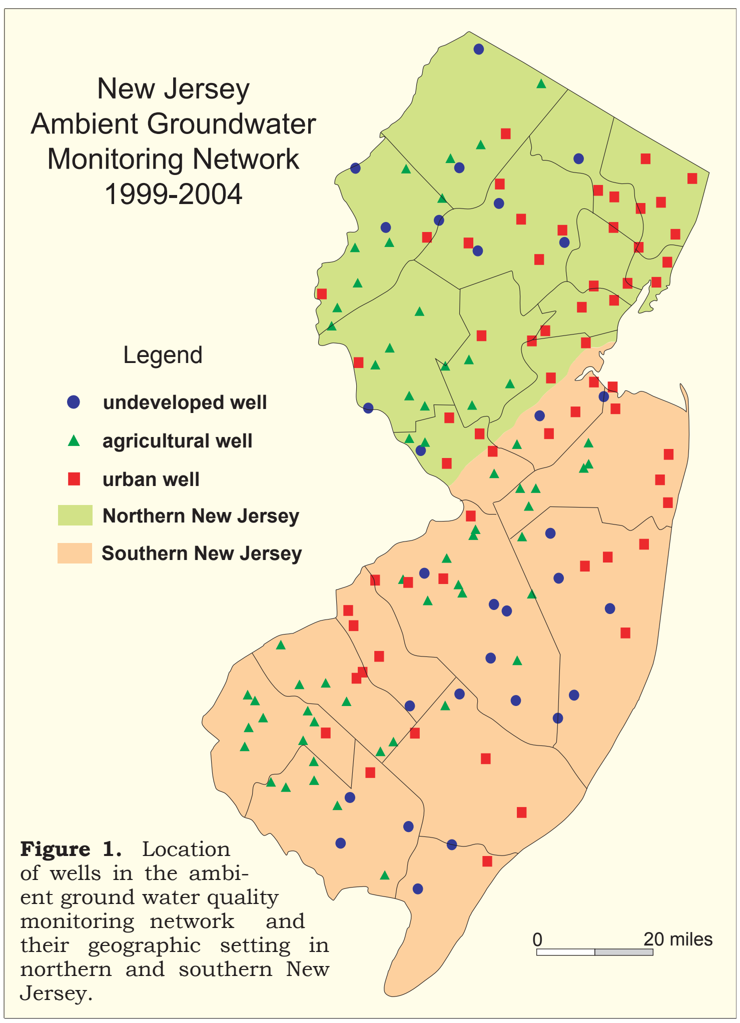

Figure 1. Location of wells in the ambient ground water quality monitoring network and their geographic setting in northern and southern New Jersey.

Figure 2. John Curran and Gregg Steidl of the New Jersey Geological Survey demonstrating the setup and installation of an AGWQMN well.

Introduction

New Jersey is the fifth smallest state in the nation, yet is one of the most hydrogeologically diverse. Approximately 8.7 million people live within New Jersey's 7,836 square miles, making it the most densely populated state. Highly concentrated urban and industrial centers, shrinking agricultural and undeveloped areas, expanding suburban areas, and protected and unprotected forested areas generally characterize the state's land use. Because of its high population and variable land uses, the state's streams, lakes, ponds, bays, ocean and ground water are affected to varying degrees by point and nonpoint sources of contamination. To understand and properly manage the quality of water in the state, effective monitoring programs are needed. One such program is the New Jersey Ambient Ground Water Quality Monitoring Network.

The quality of shallow ground water is important because it is this water that recharges deeper aquifers used for potable supplies and provides base flow to local streams and wetlands. Information presented here was compiled using analytical data associated with wells in the AGWQMN. This 150-well network (fig. 1) is a NJDEP/USGS cooperative project that provides information about land-use-related nonpoint source contaminant affects on shallow-ground-water quality in the state (Serfes, 1998). Wells are sampled, 30 per year, on a 5-year cycle. The first cycle is now complete and the second started in 2004. The water-quality data summarized here are from the first complete sampling cycle of the 150 wells.

The water table is the doorway into the ground-water system and is most vulnerable to contamination. Network wells are screened, or open, just below the water table and the samples collected generally represent relatively young ground water. Goals of the AGWQMN are to: (1) assess ground-water quality status, (2) assess ground-water quality trends, (3) evaluate contaminant sources, and (4) identify emerging water-quality issues. Well sites were located using a stratified-random site selection process as outlined by Scott (1990). The final distribution of wells as a function of land use is 60 in agricultural areas, 60 in urban/suburban areas, and 30 in undeveloped land use areas. Land-use designations were determined using 1986 and 1995 land use coverages, 1995 aerial photographs, site visits, and estimations of ground-water-flow directions based on the local geologic framework and site-specific topographic controls. The 1986 and updated 1995 digital land-use data categories were interpreted from 1986 and 1995 color infrared aerial photography (NJDEP, 2000).

Water Quality Characteristics and Contaminants

Water-quality characteristics such as temperature, dissolved-oxygen concentration (DO), pH and total dissolved solid (TDS) concentrations yield information about the general character of shallow ground water as a function of geology and land use (table 1). Natural ground-water quality in northern and southern New Jersey (fig. 1) is distinctly different in undeveloped land use areas. These differences, such as the lower pH and TDS values in the south, reflect regional differences in geology. Also, it is generally cooler in northern New Jersey,

Northern New Jersey									
Characteristic or Constituent	Agricultural			Urban			Undeveloped		
	Min	Med	Max	Min	Med	Max	Min	Med	Max
Temp (°C)	10.3	13.3	23.0	6.8	12.8	18.3	10.0	12.0	14.0
DO (mg/l)	<0.2	4.3	11.0	<0.2	2.9	4.2	<0.2	4.2	6.7
pH	6.5	7.4	8.1	5.2	6.9	8.4	5.8	7.0	8.1
TDS (mg/l)	167.0	269.0	938.0	208.0	550.0	2200.0	22.0	119.0	387.0
Southern New Jersey									
Characteristic or Constituent	Agricultural			Urban			Undeveloped		
	Min	Med	Max	Min	Med	Max	Min	Med	Max
Temp (°C)	12.0	16.0	22.5	15.0	18.2	29.0	12.0	14.5	18.0
DO (mg/l)	<0.2	6.4	10.5	<0.2	2.1	10.0	<0.2	4.6	9.3
pH	4.0	5.1	7.9	3.8	4.9	7.8	3.7	4.7	6.0
TDS (mg/l)	35.0	194.0	690.0	57.0	161.0	816.0	15.0	27.0	152.0

Table 1. Ground-water characteristics and constituents in Northern and Southern New Jersey. Temp., temperature in degrees Celsius; DO, dissolved oxygen; TDS, total dissolved solids.

which is reflected in the cooler shallow ground-water temperatures relative to the south. Comparing water quality in undeveloped areas with that in agricultural and urban areas yields clues about whether the sources of various constituents are natural or the result of human activity. DO concentrations generally are lower in urban areas in both the north and south than in other land-use areas. This might be a result of the large percentage of heat-adsorbing impervious surface area resulting in a poorer exchange with atmospheric oxygen, higher temperature surface effects on the density of air,

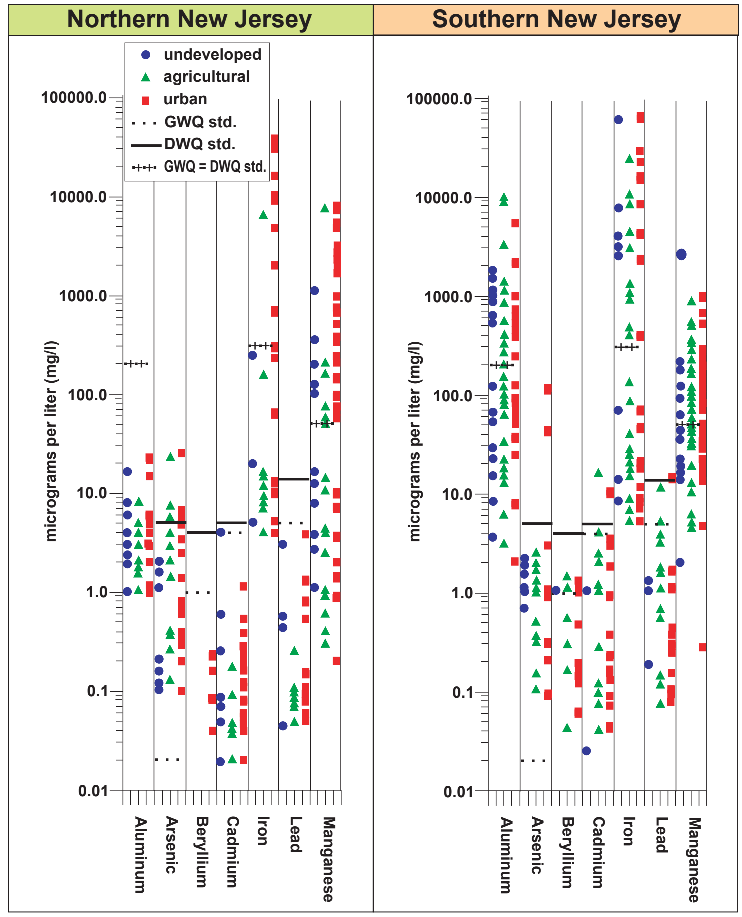

Figure 3. Trace element concentrations in shallow ground water in Northern and Southern New Jersey.

and the reaction of oxygen with organic wastewater contaminants. Higher TDS in urban and agricultural areas are due to road salt, and lawn and agrochemical applications.

Trace Elements

Trace elements shown are those that have at least one concentration that exceeded the New Jersey Ground- and/or Drinking Water Quality Standards (fig. 3). In northern New Jersey, aluminum, cadmium, lead, and arsenic concentrations appear to be mostly natural in origin. Although arsenic is elevated in some agricultural and urban wells, those particular wells are located in areas with naturally elevated arsenic. Beryllium, iron and manganese have an urban and possibly an agricultural association. Beryllium emissions from the burning of coal, fuel oil, and municipal waste can increase concentrations in soil, water and air (ATSDR, 1992 and 2002). Lower dissolved oxygen concentrations in urban ground water indicate more chemically reducing conditions that are conducive to iron and manganese mobility.

In southern New Jersey, aluminum and iron appear to be mostly natural in origin. Some aluminum compounds are more soluble in acidic water and therefore explain the relatively high concentrations found in the south. Two urban wells sampled in 2000 contained 112 ug/l and 42 ug/l arsenic. The elevated arsenic concentrations are likely related to an unusually high degree of iron-oxide dissolution, although the ultimate source of the arsenic is unknown. Beryllium, cadmium, and lead occur more frequently at higher concentrations in agricultural and urban areas. This may be due to the application of fertilizers and other agricultural and lawn-care products either as sources or as mobilizing agents.

Nutrients

Nutrient concentrations are dominated by nitrate, with frequency and concentration greatest in agricultural areas followed by urban areas in both northern and southern New Jersey (fig. 4). The use of nitrogen-based fertilizers in agricultural and urban areas and possibly septic and sewer system leakage in urban areas are considered the major sources.

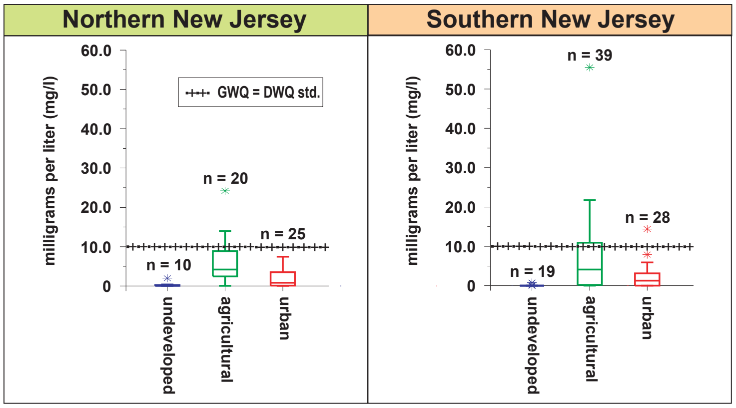

Figure 4. Nitrate plus nitrate concentrations in shallow ground water in Northern and Southern New Jersey.

Radioactivity

Gross alpha-particle activity was measured within 48 hours after sample collection to ensure that the radioactive decay of short-lived radium-224 (half-life of 3.64 days) is measured along with the other alpha emitters. Activity generally is higher in southern New Jersey in all land use settings. Most likely this is because radium-224 is more abundant in southern New Jersey and the pH of the ground water is low, which increases radium's mobility (fig. 5). In both the north and the south, the highest activity is associated with agricultural and urban land use. The use of agricultural and lawn chemical products can compete with naturally occurring radium for adsorption sites, thereby mobilizing more radium into the ground-water system than would occur naturally.

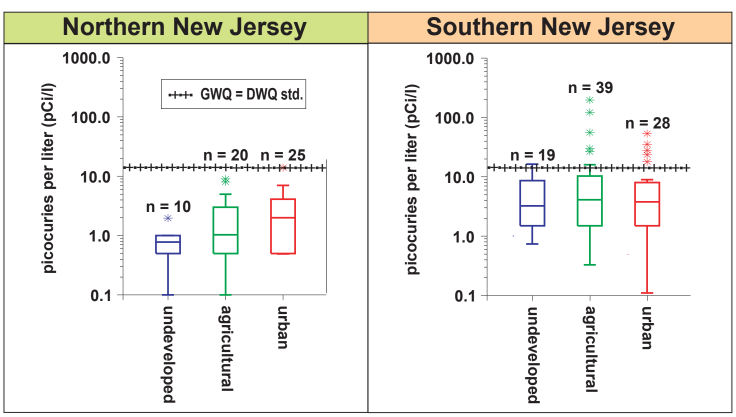

Figure 5. Gross alpha particle activity in shallow ground water in Northern and Southern New Jersey.

Pesticides

The frequency pesticides were detected in individual ground-water samples from network wells is directly related to land use. Agricultural use was highest at 73 percent, followed by urban at 48 percent, and undeveloped use at 6 percent. The concentration of pesticides is considered very low in all of these land-use categories (fig. 6). Atrazine, deethylatrazine, metolachlor, prometon and simazine were the most frequently detected compounds. They are all herbicides used to control grasses and broad leaf plants, except deethylatrazine which is the major metabolite of atrazine. The degradation by-products of these pesticides, except for deethylatrazine, are not measured and may be at much higher concentrations than the parent compounds (Roy Meyer, oral communication, NJDEP Pesticide Control Program, 2006).

Volatile Organic Compounds (VOC)

The frequency VOC's were detected in individual ground-water samples from network wells is also a function of land use. Urban was highest at 65 percent, followed by undeveloped at 43 percent, and agricultural at 25 percent (fig. 7). Most of the VOC's

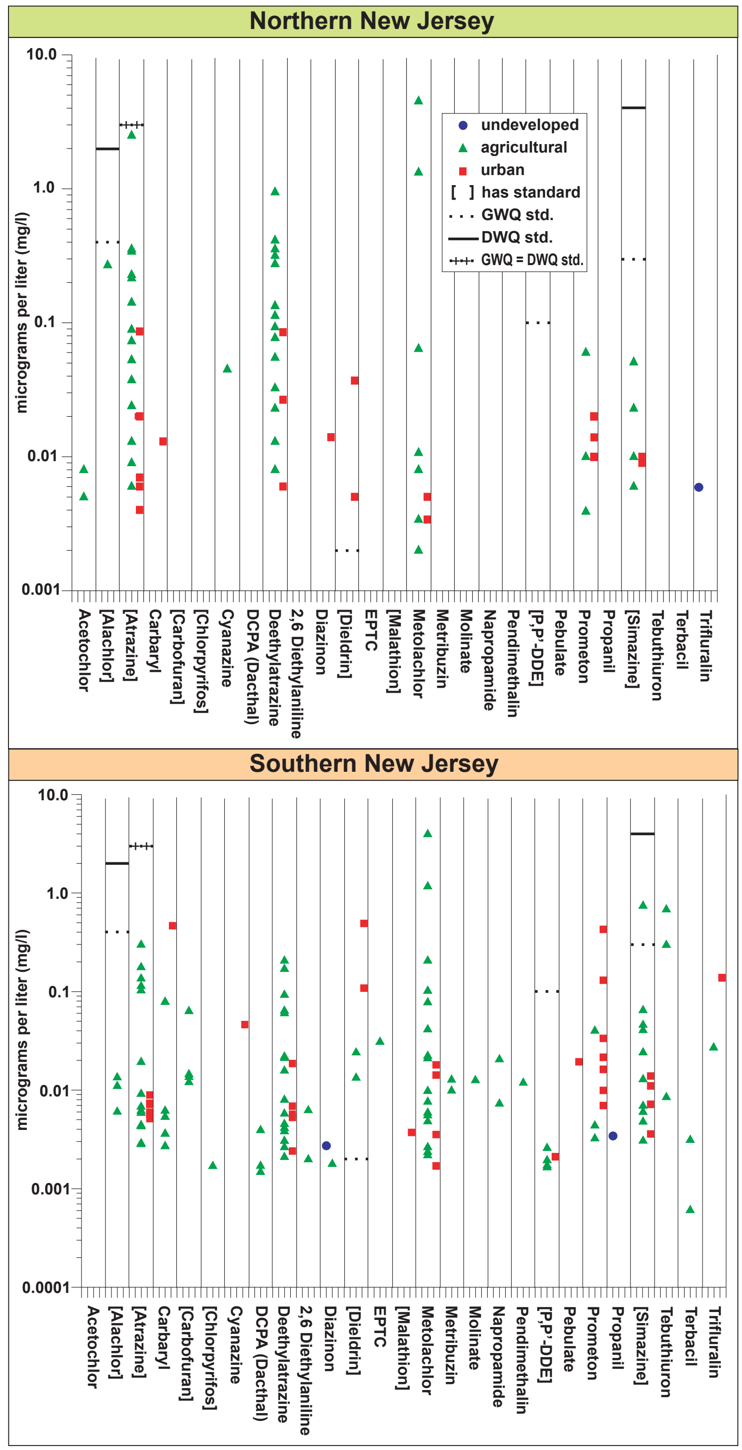

Figure 6. Pesticide compounds and concentrations in shallow ground water in northern and southern New Jersey.

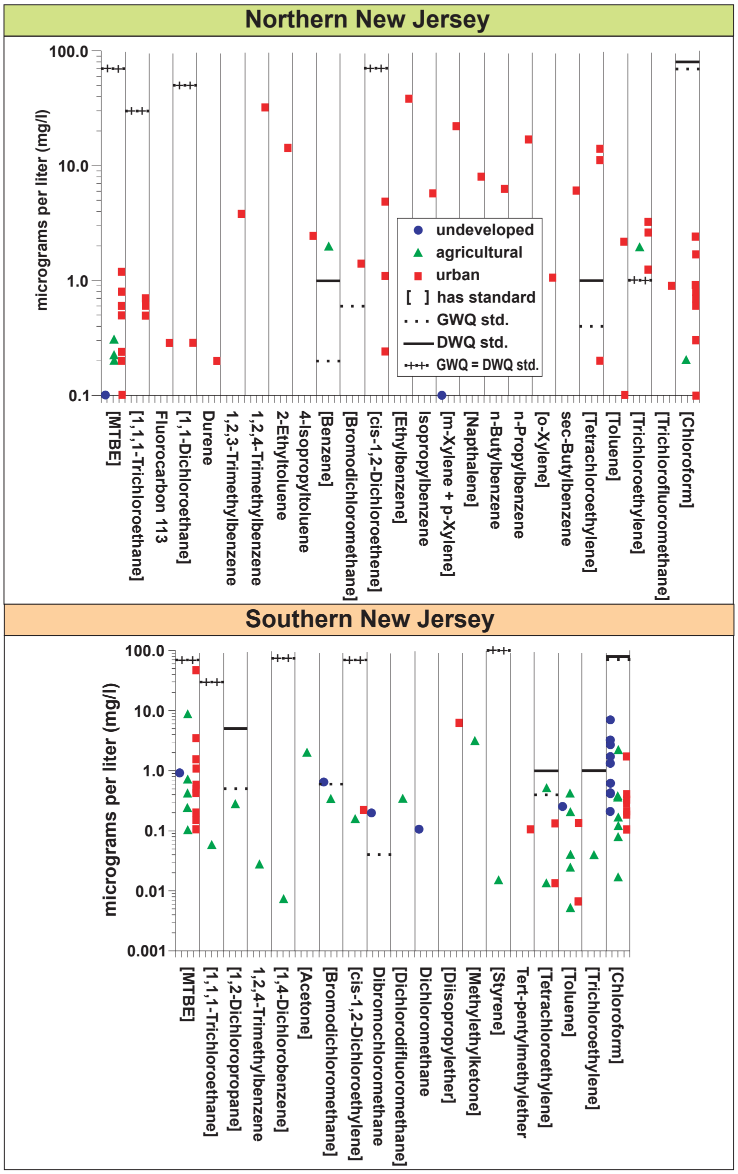

Figure 7. VOC types and concentrations found in shallow ground water in northern and southern New Jersey.

detected were present at very low concentrations. Thirty-eight of 148 network wells had detectable levels of methyl tertiary-butyl ether (MTBE), with a maximum value of 47 ug/l. This well was within 1000 feet of a leaky underground storage tank. Detectable levels of MTBE were found in 47 percent of urban, 13 percent of agricultural, and 6 percent of wells in undeveloped areas. This distribution is not surprising because gasoline, in which MTBE is an additive, is found most frequently in urban areas. Low concentrations of chloroform and MTBE have been measured in the atmosphere and related to concentrations in shallow ground water (Baehr and others, 1999). Chloroform was detected in 34 percent of undeveloped, 32 percent of urban, and 12 percent of agricultural network wells. Nonpoint sources of chloroform include housing developments using individual septic systems, leaking sewers in urban areas, and the use of chlorinated drinking water for watering lawns and gardens and filling swimming pools. VOC's were detected more frequently in southern than in northern New Jersey, but the variety of compounds detected was greater in the north. The lower adsorptive capability of the aquifer materials in the south coupled with the greater number of urban wells in the north may explain these observations. Also, the general west to east weather pattern would carry the most ubiquitous volatile contaminants, such as MTBE and chloroform, from the Philadelphia-Camden urban area over the less developed land use areas near the western border of southern New Jersey. In the north, the urban centers are mostly in the eastern part of the state.

Summary

Total dissolved solids concentrations, as well as the concentration, frequency, and variety of trace elements, nutrients, volatile organic compounds and pesticides are found at significantly higher levels in wells located in agricultural and urban areas than from wells in undeveloped areas. Shallow ground water in agricultural land use areas have the highest frequency of pesticide detections, highest median nitrate concentrations (maximum of 56 mg/l in this network) and gross alpha particle activity. These concentrations are likely related to the application of agricultural chemicals. In urban areas, dissolved oxygen concentrations generally are lower and dissolved solids, dissolved iron, chloride, and VOC (such as MTBE) concentrations generally are higher than in other land uses.

Sources of Information

Agency for Toxic Substances and Disease Registry (ATSDR), 1992, Toxicological profile for antimony. Atlanta, GA: U.S. Dept. of Health and Human Services.

Agency for Toxic Substances and Disease Registry (ATSDR), 2002, Toxicological profile for beryllium. Atlanta, GA: U.S. Dept. of Health and Human Services.

Baehr, A.L., Stackelberg, P.E., and Baker, R.J., 1999, Evaluation of the atmosphere as a source of volatile organic compounds in shallow ground water, Water Resources Research, vol. 35, no. 1, p. 127-136.

NJDEP, 2000, 1995/97 Land use/land cover update by Watershed Management Area.

Scott, J.C., 1990, Computerized stratified random site-selection approaches for design of a ground-water-quality sampling network, U.S. Geological Survey, WRI Report 90-4101.

Serfes, M.S., 1998, History, goals and redesign of New Jersey's ambient ground water quality network, Proceedings of the NWQMC National Monitoring Conference on July 7-9, 1998, Reno NV, p. III-235.

STATE OF NEW JERSEY
Jon S. Corzine, *Governor*
Department of Environmental Protection
Lisa P. Jackson, *Commissioner*
New Jersey Geological Survey
Karl Muessig, *State Geologist*

Prepared by Mike Serfes and Raymond Bousenberry, New Jersey Geological Survey, and Jacob Gibs, USGS
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Comments or requests for information are welcome.
Write: NJGS, P.O. Box 427, Trenton, NJ 08625
Phone: 609-292-2576, Fax: 609-633-1004
Visit the NJGS web site @ www.njgeology.org