GROUNDWATER

Groundwater is defined as the water that occurs beneath the water table in soils and geologic formations that are fully saturated. Groundwater studies, however, must also consider subsurface water found above the water table — termed the "unsaturated (or vadose) zone" — as well as water bodies on the land surface. All three are tightly interrelated as part of the hydrologic cycle.

Groundwater is both an important environmental and economic resource in the Piedmont Basin because it provides base flow to streams and wetlands (particularly important during times of low rainfall and drought), and it supplies water for domestic, public, and industrial users. Compared to the remainder of the state of Delaware, where groundwater is essentially the sole source of fresh water, the Piedmont Basin has significant fresh surface-water resources, which support the majority of human needs in the area.

Groundwater Quality Characteristics

Groundwater is found throughout the Piedmont Basin at relatively shallow depths beneath the land surface. However, the quantities of groundwater differ significantly between the two geologic provinces in the basin — the Piedmont and the Atlantic Coastal Plain. With the exception of the Cockeysville Formation, the crystalline rocks of the Piedmont have much less usable quantities of groundwater than the unconsolidated sands and gravels of the Atlantic Coastal Plain. Because of these marked differences between the two provinces and their hydrogeologic character, groundwater quality will be addressed within the watershed assessments with these two provinces in mind.

General groundwater-quality information is provided for each of the six watersheds in the Piedmont Basin. Sources of information include reports from the Delaware Geological Survey; U.S. Geological Survey; public water-supply purveyors; industry reports; Office of Drinking Water records; DNREC; and the Water Resources Agency for New Castle County. This information comes from a patchwork of sources since an overall groundwater-quality monitoring network does not exist for the Piedmont Basin.

Information on existing or potential sources of groundwater contamination has also been assembled; their locations are demarcated on Map 4. These include National Priority List sites, Hazardous Substance Control Act sites, active solid waste sites, hazardous waste treatment/storage/disposal sites, leaking underground storage tank sites, and nonhazardous waste sites. Information on nonpoint sources was obtained from the *1996 Delaware Watershed Assessment Report (305[b])* and includes land used for agriculture and unsewered areas with septic system use.

The special water resource areas referenced in this section are defined as follows:

Class A Wellhead Protection Areas — Areas within a 300-foot radius around community public water-supply wells.

Class B Wellhead Protection Areas — Glendale and Eastern States Wellfield, delineated using EPA code.

Class C Wellhead Protection Areas — Wellhead areas delineated by use of geologic and hydrologic maps and reports.

Recharge Protection Areas — Areas having the best potential for groundwater recharge.

Cockeysville Formation — Areas that are directly underlain by the Cockeysville Formation.

Hoopes Reservoir Watershed — The sub-watershed that drains into Hoopes Reservoir.

Public Water-Supply Intakes — Surface-water intakes used for supplying drinking water to community water systems. Note that only community public water-supply wells are presently included under the Water Resource Protection Area (WRPA) ordinance and the associated WRPA maps. DNREC and New Castle County have, however, identified the locations of all non-transient, non-community wells.

The following material will be presented by watershed; however, some of the studies referenced did not consider watershed boundaries. While many surface-water and shallow groundwater-flow patterns allow for a watershed-by-watershed approach, deeper unconfined or confined aquifer systems do not follow watershed boundaries. Rather, regional flow patterns, large pumping well centers, and other geologic and hydrogeologic factors control flow rather than the topographic boundaries between watersheds and basins. With this in mind, this assessment includes information available for the Potomac Aquifer, including deeper portions where wells draw water from these regional flow regimes. This approach was taken because major groundwater sources occur within these confined or semi-confined aquifers.

Naamans Creek Watershed Characterization

The Naamans Creek watershed extends from northeastern Delaware into extreme southeastern Pennsylvania. The area is underlain exclusively by rocks of the Wilmington Complex. Water-yielding potential is low, and only one shallow public water-supply well (Crestfield Water Company) is found in the upper part of the basin. No other Water Resource Protection Areas are found in the watershed. The watershed is primarily urban/residential (76%).

Water-quality results for the Crestfield Water Company well revealed nitrates at 5.1 and 4.3 mg/l for 1990 and 1995, respectively. These levels are below the drinking water standard of 10 mg/l, but are above an assumed ambient level of 1–2 mg/l. Thus, groundwater in this area is being impacted

by human activities such as septic system use, lawn fertilizer, or present/past agricultural activities. Information on organic chemical analyses for this well was not available from the Office of Drinking Water data base.

Shellpot Creek Watershed Characterization

Almost all of the Shellpot Creek basin is found within the Piedmont geologic province, composed of igneous rocks of the Wilmington Complex that generally have low water-bearing capacity. However, the northwestern portion of the basin parallel to Concord Pike (Route 202) contains sediments of the Piedmont province in excess of 10 feet but less than 50 feet. Considered the Bryn Mawr Formation, these unconsolidated sediments do not yield significant quantities of groundwater due to their thinness and limited areal extent. The extreme southern part of the basin is located in the Atlantic Coastal Plain, composed of the Cretaceous-aged Potomac Formation and Quaternary-aged sediments.

No public water-supply wells or Water Resource Protection Areas are found within this watershed.

Brandywine Creek Watershed Characterization

Almost all of the Brandywine Creek watershed is found within the Piedmont geologic province — with the northern half underlain by rocks of the Wissahickon Formation and the southern and eastern area underlain by the Wilmington Complex. A small area in the northeastern corner, adjacent to Concord Pike (Route 202), contains unconsolidated sediments of the Bryn Mawr Formation.

Water-well production is variable but averages 10 gpm in the gneisses and schists of the Wissahickon while the Wilmington Complex rocks have somewhat lower yields. Water is obtained from weathered rock atop the bedrock and from fractures within the bedrock.

Four public water-supply wells are found in the northern part of the Brandywine Creek watershed within the Wissahickon Formation and are owned by Winterthur. All four are in very close proximity to one another and are found to the northeast of Hoopes Reservoir. Although no other community public water wells are found within this watershed, the City of Wilmington's two water-supply intakes (and its only direct source of water) are found on Brandywine Creek located near the Interstate 95 overpass.

Analytical data available for the Winterthur community public water-supply wells are very limited from the Office of Drinking Water data base. Additional information may be available within hard-copy files.

Red Clay Creek Watershed Characterization

Almost all of the Red Clay Creek watershed is found within the Piedmont geologic province, composed of rocks of the Wissahickon Formation in the northern half and the Wilmington Complex in the south. The extreme southern portion, near Stanton, lies within the Atlantic Coastal Plain. The eastern arm of the Cockeysville Formation is located in the northwestern part of the basin; however, most of the Cockeysville Aquifer extends southwest of this arm into the White Clay Creek basin. The Cockeysville Formation is an important aquifer, with major public water-supply wells owned by the Artesian Water Company. These will be described in the White Clay Creek watershed assessment, since 90% of this formation is found there and all the public water-supply wells are located there.

According to the U.S. Geological Survey, groundwater discharges into Brandywine Creek along most reaches. However, there appears to be some conflict between the U.S. Geological Survey study (1993) and the Delaware Geological Survey – U.S Geological Survey Cockeysville Aquifer study (1995). The former indicated that the Red Clay Creek may be "losing" water into the Cockeysville Aquifer as it crosses the area underlain by the aquifer just west of Yorklyn. This may be the result of either nearby pumping wells or pumping centers in the main body of the aquifer located in the White Clay Creek watershed. Regardless, the aquifer appears very sensitive and vulnerable to surficial contamination.

There are two community public water-supply systems. The Lower Snuff Mill well is located near the Cockeysville Formation in the northwestern corner of the basin. A second system, composed of three wells owned by the Methodist Country Home, is located within the Hoopes Reservoir subwatershed located along the northeastern boundary of the Red Clay Creek watershed. In addition to these public water-supply wells, Hoopes Reservoir and its drainage area are located in the northern half of the basin. This reservoir is used by the City of Wilmington to store water which is pumped from Brandywine Creek to Hoopes Reservoir for storage. In addition, the United Water Company maintains two water-supply intakes at the confluence of Red Clay Creek and White Clay Creek at the southern extreme of these watersheds. While Artesian Water Company relies on groundwater from wells, United Water relies on these surface-water intakes to supply its customers.

Inorganic analytical data for October 1995 from the Methodist Country Home had background nitrate levels (less than 1 mg/l) and iron levels that exceeded the secondary maximum contaminant level of 0.3 mg/l. Organic analytical data were not available from the data base. No

information is available for the Lower Snuff Mill well, and the Office of Drinking Water no longer classifies it as a community public water supply.

The U.S. Geological Survey completed the first of two reports (Vogel et al., 1993) on groundwater quality in the Red Clay Creek watershed. Groundwater base flow discharging to the stream ranged from 62% –71% of stream flow over the study periods. Along most of the stream reach, water flows from groundwater into the stream except where the stream flows over the Cockeysville Formation and possibly along a reach near Hoopes Reservoir. Groundwater-quality sampling was not done as part of the most recent report, but groundwater data from the Pennsylvania portion of the watershed were summarized. A second U.S. Geological Survey report on water quality in the watershed is expected and, when available, should be included in the Piedmont Basin assessment.

White Clay Creek Watershed Characterization

The northern and western portions of the White Clay Creek watershed are found within the Piedmont geologic province, consisting of rocks of the Wissahickon Formation, the Wilmington Complex, and two surface exposures of the Cockeysville Formation. Some thin sections of unconsolidated Quaternary-aged sediments are found atop the Wilmington Complex bedrock from Newark east-northeast toward Stanton. The remainder of the southern and eastern portion of the basin is in the Atlantic Coastal Plain, which contains the Potomac Formation overlain by Quarternary-aged sediments that range from 50 feet thick in the Newark area to 0 feet near the Fall Line.

According to Martin et al. (1984), the lower Potomac Aquifer subcrops within all the Coastal Plain portions of the White Clay Creek watershed and the northern portion of the Christina River watershed located south of the White Clay Creek watershed. Many of the City of Newark's southern wells are screened within this aquifer.

A number of important groundwater supplies are found within the watershed, including supply wells in the Hockessin Valley within the Cockeysville Aquifer, the Laird Track wells within the Wissahickon Formation, and the northern half of Newark's southern wellfield. Eleven Class-A Wellhead Protection Areas (the 300-foot radius surrounding community public water-supply wells) are found within these three well fields. Approximately 90% of the Cockeysville Aquifer is found in the northeastern corner of the watershed, and a second small exposure of Cockeysville marble is located north of Newark along Pike Creek. Two Class-B Wellhead Protection Areas consisting of the Laird Tract wells and the northern part of the Newark southern wellfield are found in the Newark area. Important public water-supply intakes are also found within the watershed including the City of Newark's intake located north of Newark on White Clay Creek and the United Water intakes at the confluence of Red and White Clay creeks. Portions of two small recharge protection areas are also found in the eastern portion of the watershed — one within Newport and the second just to the east of Churchmans Marsh.

The Delaware Geological Survey (1977) investigated groundwater availability within the Piedmont province of White Clay Creek. This study identified the Pike Creek (Cockeysville) Marble Southern Exposure and the Laird Tract as having water-supply potential due to the presence of fractures. Water-quality information from this study indicated that iron and manganese were significant and would require treatment. The City of Newark is not currently using the Laird Tract wells due to the iron problem. However, according to Mr. Stewart Lovell (pers. comm.), Artesian Water Company may begin using existing wells in the southern exposure of the Cockeysville Formation along Pike Creek.

Information on water quality from the Office of Drinking Water is not structured to allow individual wells to be identified with analytical data. However, DNREC is exploring the possibility of obtaining well-specific analytical data directly from Artesian Water Company. The information was not available at the time of this assessment.

Upper Christina River Watershed Characterization

The upper Christina River watershed extends from a line at Ogletown south, with the upper Christina watershed to the west and the lower Christina watershed to the east. Most of the watershed is composed of Potomac Formation sediments overlain by Pleistocene-aged sediments of the Columbia Formation that range from 0 – 80 feet thick. The Iron Hill and Chestnut Hill intrusive rocks rise as an island to the southwest of the University of Delaware stadium and are mapped as gabbro and chert. The Christina River runs along the northeastern face of these rocks. The extreme northwestern corner of the basin south of McClellandville consists of rocks of the Piedmont province, with the Wissahickon in the north and Wilmington Complex rocks south of these. The Fall Line runs essentially along the Baltimore and Ohio Railroad to the west of the City of Newark.

Most of Newark's southern wellfield is located in the northern corner of the upper Christina River watershed. Iron problems, however, have prevented Newark from using these wells to their potential. Another wellfield is located on the south side of Iron Hill, and a portion of the Eastern Estates wellfield is found along the Maryland state line in the southwestern corner of the basin.

Thirteen Class-A Wellhead Protection Areas are found in the watershed, most within the Class-B Wellhead Protection Areas of Newark and of Eastern Estates. Very small recharge protection areas are also found in the southern half of the watershed.

The City of Newark has conducted an investigation of the iron problems within its southern wellfield. Analytical data from the Division of Public Health do not identify specific wells but do give an overall assessment of the types of contaminants found throughout the wellfields. Data from 1993 to 1995 reveal nitrate levels ranging from non-detectable to 8.4 mg/l. No levels above 10 mg/l were found. Iron levels were well above the 0.3 mg/l secondary maximum contaminant level in some of the wells with high values of 8.2 mg/l found in a few samples. Approximately half the samples exceeded 0.3 mg/l of iron.

Organic contaminants also continue to be detected within Newark's public water-supply wells although certain wells appear to be responsible for many of the organic chemicals that were found. However, a much more thorough analysis of the Division of Public Health records is needed to pinpoint those wells that have specific problems. The organic chemicals found include dichlorodifluoromethane, 1,1-dichloroethane, trichlorofluoromethane, chloroform, benzene, tetrachloroethene, trichloroethene, 1,2-dichloropropane, dichloromethane, chloroethane, chloromethane, 1,2-dichloroethane, bromodichloromethane, and trihalo-methanes (disinfection by-products). Some wells, such as Well Number 8, have been taken out of service due to organic chemical contamination.

Lower Christina River Watershed Characterization

The entire southern and western part of the lower Christina River watershed is found within that portion of the Atlantic Coastal Plain composed of the Potomac Formation overlain by Quaternary-aged sediments. The northeastern portion of the basin is composed mostly of rocks of the Wilmington Complex located north of the Fall Line. This area is largely urban with Elsmere and southwestern Wilmington located here.

Quarternary-aged sediments greater than 40 feet have been identified in the eastern end of the basin — in the vicinity of Cherry Island and along the southern shore of the Christina River at its mouth into the Delaware River. Another similar unit is found near Wilmington Airport. Both a recharge protection area and Class-A Wellhead Protection Area exist here also. Thick Quaternary-aged sediments just north of Bear contain an important Wellhead Protection Area and a Recharge Protection Area associated with public water-supply wells (the Glendale wellfield) of Artesian Water Company.

Two surface-water supply intakes used for drinking water are found in the lower Christina watershed on Smalley's Pond, which is located southwest of Christiana, on the Christina River.

Numerous studies associated with the Potomac Aquifer have been conducted within the Christina River watershed. Various references describe two or three recognized aquifer units within the Potomac Formation — the lower, middle, and upper. However, the fluvial processes that deposited these sediments are such that sand bodies are discontinuous both areally and vertically. The lower aquifer unit subcrops within much of the Christina watershed — mainly on the north side of the river, north of Interstate 95. The middle aquifer unit subcrops within the Christina watershed near the Christina River — south of the river in the western area, along it in the central area, and south of it in the eastern part of the watershed. The upper Potomac Aquifer subcrops farther south and outside of the Piedmont Basin within the Delaware River, Red Lion Creek, Dragon Run Creek, and Chesapeake and Delaware Canal watersheds.

Two important wellfields, the Glendale wellfield and the Airport public water-supply wells, are sampled by Artesian Water Company. As with the Cockeysville Aquifer wells, DNREC is exploring the possibility of obtaining well-specific analytical data directly from Artesian Water Company. That information was not available at the time of this assessment.

Trends

Information on groundwater quality is limited to what is available from existing regulatory programs. This discussion will focus on (1) overall quality based on Delaware Geological Survey information, and (2) public water-supply monitoring data from the Division of Public Health's Office of Drinking Water.

Groundwater-quality information is also available on specific sites with potential groundwater-quality impacts such as leaking underground storage tanks, hazardous waste, Superfund, and non-hazardous waste sites. This type of information generally contains groundwater-quality information specific to the facility being regulated. For instance, although there are many monitoring wells associated with leaking underground storage tank sites, analytical data is very specific to gasoline-indicative compounds (benzene, toluene, ethylbenzene, and xylenes). While these data are important for regulatory purposes, they will be of limited value in evaluating overall trends in groundwater quality. See "Sources of Impacts" in this section for a description of the types of groundwater monitoring requirements at these regulated facilities.

Public Water-Supply Well Data

This evaluation focuses on specific public water-supply well systems found within the Piedmont Basin. Data are

derived from the Office of Drinking Water for all systems other than those of the Artesian Water Company. The latter data come from the Artesian laboratory.

Cockeysville Formation. The U.S. Geological Survey and the Delaware Geological Survey (Woodruff and Plank; Werkheiser, 1995) collected water-quality samples from wells and streams in the Cockeysville Aquifer area from 1990 to 1991. Twenty-nine well-water samples were analyzed for major ions, nutrients, trace metals, and radon. Six wells were resampled and analyzed for organonitrogen and organophosphorous pesticides and were scanned for volatile organic compounds. The following were some key findings:

- The chemistry between the streams draining into the Hockessin Valley and the Cockeysville Aquifer supported hydrologic studies that indicate that streams lose water into the aquifer in the Hockessin Valley and thus, are a source of recharge into the Cockeysville Aquifer. None of the chemical constituent concentrations exceeded EPA maximum contaminant levels although three exceeded secondary maximum contaminant levels.
- None of the samples exceeded the nitrate maximum contaminant level of 10 mg/l; however, most were above 2 mg/l, which indicates the influence of human activity.
- No measurable concentrations of pesticides or volatile organic compounds were detected although only six wells were sampled.
- Chloride concentrations were indicative of human activity such as road salting and waste disposal.

Newark South Wellfield. Considerable study has been devoted to evaluating iron and manganese problems from wells in Newark's south wellfield (Duffield and Hill, 1994). This study was an outgrowth of a recommendation by the *Newark Water Supply Advisory Committee Report* (1991), which addressed numerous issues concerning the city's water system.

The Delaware Division of Public Health noted historic problems with organic contaminants: tetrachloroethylene (Well Number 8, 1984), benzene (Well Number 13, 1986), tetrachloroethylene (Well Number 15, 1989), and iron (Well Numbers 15 and 16, 1990). (Well Number 8 was taken out of service due to tetrachloroethylene contamination.)

Treatment of these water supplies reduced concentrations of organic contaminants to below levels of concern. Consequently, the sources of these contaminants have not been thoroughly investigated. There are, however, various potential sources in the area.

The south wellfield was investigated as to the cause of iron and manganese contaminations, which began to rise dramatically in 1989. All these wells are found in the Atlantic Coastal Plain and draw water from both the Potomac and Columbia sands. The key finding of this study was that the source of dissolved iron was from the dissolution of iron-containing minerals — siderite and pyrite. The report argues that marked increases in dissolved iron were due to recharge declines or water withdrawal increases, causing water to be produced from less permeable sections of the aquifer. Since siderite and pyrite minerals were prevalent in these less permeable sections of the aquifer, iron concentrations dramatically increased.

However, there is technical disagreement about these findings. The behavior of production Well Number 15 seemingly favors the consultant's interpretation, with fluctuating iron concentrations declining in 1993 – 1994. An anthropogenic source would be less likely to follow this pattern.

Wellfields Requiring Further Evaluation. The following wellfields may be evaluated further once DNREC has completed work with both the Delaware Office of Drinking Water and the Artesian Water Company aimed at allowing access to analytical data for specific wells: Glendale Wellfield (AWC), Wilmington Airport wells (AWC), Crestfield Water Company, Winterthur, Methodist Country Home, and Newark Laird Tract Wellfield.

Sources of Impact

Groundwater quality may be impaired by both natural and anthropogenic sources. The most common natural quality problems are dissolved iron, chloride, dissolved solids, sulfur compounds, and pH. In many instances, these naturally occurring problems may be the secondary result of groundwater pumpage such as with saltwater intrusion and suspected iron problems at the Newark south wellfield.

Anthropogenic sources are from both point-source discharges and nonpoint source practices. Common contaminants associated with these sources include nitrates, iron, chlorides, pesticides, volatile organic compounds, semi-volatile organic compounds, and dissolved metals. The locations of known regulated point sources have been plotted on Map 4. Estimates for typical nonpoint sources were taken from the *1996 Delaware Watershed Assessment Report (305[b])*. Table 5 summarizes the number and type of contaminant sources by watershed.

Table 6 summarizes the number and type of potential sources of contamination that are within, or less than 150 meters from, Water Resource Protection Areas; and Maps 5 and 6 show their locations. (This type of analysis was not possible prior to the Piedmont Basin Assessment and is the result of improvements in DNREC's GIS capabilities and support from other agencies.)

Groundwater-Quality Data at Regulated Facilities

Hydrogeologic and groundwater-quality information is routinely collected at many facilities that have the potential

to affect groundwater quality. The Delaware Comprehensive State Groundwater Protection Profile summarized state programs that collect groundwater-quality and quantity information. Table 7 summarizes these programs and the type of groundwater-quality information collected. Most programs are found within DNREC, although important programs are also found in the Delaware Department of Agriculture and the Delaware Division of Public Health.

The Delaware Geological Survey also collects basic information but does not regulate facilities causing groundwater-quality problems. Groundwater-quality information from both the Delaware Geological Survey and the U.S. Geological Survey has been described under each watershed assessment.

Naamans Creek Watershed Contaminant Sources

Most potential point sources of contamination in the Naamans Creek watershed are found in the lower portion of the watershed to the east of Interstate 95 and adjacent to the Delaware River. These include 2 Treatment, Storage, and Disposal (TSD) sites (Sun Company and General Chemical) and 19 Leaking Underground Storage Sites (LUSTs). Four of the LUST sites have likely affected groundwater quality. Other sites include 6 federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or state Hazardous Substance Control Act (HSCA) sites, and 33 hazardous waste generators.

The Sun Company refinery straddles the Pennsylvania-Delaware state line, with a small portion extending into the northeastern tip of Delaware. The Pennsylvania Department of Environmental Protection has assumed environmental oversight, with coordination by the Delaware Hazardous Waste Management Branch. The Sun Company has identified 10 contaminated areas at their site, one of which occurs in Delaware and is identified as Area 5. Groundwater monitoring wells have been installed, and sampling has been done since 1990, which identified and delineated both light and dense non-aqueous phase liquid plumes in the unconfined aquifer. Seeps of these contaminants have reportedly occurred along both the northern and southern banks of Middle Creek, which flows into the nearby Delaware River.

The General Chemical Corporation has two major areas being evaluated as part of a Resource Conservation and Recovery Act (RCRA) closure: the Spent Acid Lagoon area and East and West Lagoons area. For the Spent Acid Lagoon, quarterly sampling for pH, specific conductance, Appendix IX metals, and RCRA detection monitoring parameters are required. Monitoring of full Appendix IX parameters are required for the East and West Lagoons area. For the Spent Acid Lagoon, monitoring is required for very low pH and numerous metals with high concentrations, including tin, antimony, arsenic, cadmium,

Table 5

SUMMARY OF POTENTIAL CONTAMINANT SOURCES AND SPECIAL WATER RESOURCE PROTECTION AREAS BY WATERSHEDS FOUND IN THE PIEDMONT BASIN

Sources of Contamination	CERCLA & HSCA Sites	Hazardous Waste Generators	#TSD Sites	# Solid Waste Sites	Resource Province	#LUST w/GW ImpactS	#LUST w/o GW Impacts	Total LUST	#W/W Disposal Sites	Domestic Septics Percent of Basin	Agricultural Percent of Basin	Water Resources	Class-A Wells Community PWS	Wellhead Area Class B & C	Recharge Areas	Cockeysville Aquifer	Surface-Water Intakes
Christina River	62	354	3	14	2	59	96	155	0	10.2%	22%	–	20	4	11	0	1
White Clay Creek	20	104	0	2	0	19	31	50	0	8.70%	26%	–	11	11		90%	2
Red Clay Creek	6	40	1	1	0	6	21	27	1	8%	27%	–	2	2	0	10%	2
Brandywine Creek	10	77	1	0	0	11	43	54	1	15.8%	26%	–	4	4	0	0	1
Shellpot Creek	8	57	2	13	1	11	22	33	0	10.4%	2%	–	0	0	0	0	0
Naamans Creek	6	33	2	0	0	4	15	19	0	<1%	4%	–	1	1	0	0	0
Total in Basin	**112**	**665**	**9**	**30**	**3**	**110**	**228**	**338**	**2**				**38**	**4**	**n/a**	**n/a**	**6**

Table 6

SUMMARY OF POTENTIAL CONTAMINANT SOURCES THAT ARE WITHIN OR LESS THAN 150 METERS FROM WATER RESOURCE PROTECTION AREAS

Water Resource Protection Areas	Sources of Contamination	CERCLA & HSCA Sites	Hazardous Waste Generators	#TSD Sites	# Solid Waste Sites	Resource Recovery Facility	#LUST w/GW IMPACTS	# LUST w/o GW Impacts	TOTAL LUST	#W/W DISPOSAL SITES
	Class-A Wells Community PWS*	0	6	0	0	0	1	5	6	0
	Class-B & C Wells Community PWS*	9	48	0	1	0	4	6	10	0
	Recharge Protection Areas*	5	34	0	0	0	11	13	24	0
	Cockeysville Aquifer*	5	4	0	0	0	3	8	11	0
	Hoopes Reservoir	0	1	0	0	0	0	0	0	0
	Numbered Sites Within All WRPAs	17	71	0	1	0	16	11	27	0

chromium, cobalt, nickel, zinc, cyanide, and mercury. The East and West Lagoon samples are monitored for numerous volatile (especially chlorobenzene and benzene) and semi-volatile compounds (especially the dichloro-benzene family), as well as pesticides.

Nonpoint sources from agriculture and on-site domestic septic systems are negligible although urban runoff and related sources may affect groundwater quality. However, nitrates in a public water-supply well indicate nonpoint source impacts, likely from septic systems or fertilizer application.

Shellpot Creek Watershed Contaminant Sources

The Shellpot basin contains 2 HSCA sites, 2 TSD sites (Harper Thiel site and the DuPont Edgemoor site), 3 solid waste sites (the DP & L Edgemoor Ash Landfill, DuPont Edgemoor Landfill, and much of the Cherry Island Landfill), and 33 LUST sites. All solid-waste facilities, HSCA sites, and 1 TSD site are located in the lower portion of the basin adjacent to the Delaware River. LUST sites are scattered throughout the basin and, of these, 11 have significantly affected groundwater quality. A number of these LUST sites are found within the Bryn Mawr Formation and thus were included within this basin although they are located on the boundary between the Shellpot and Brandywine Creek basins. A clear boundary resolution is needed as well as individual site groundwater-flow direction evaluations. Other sites include 33 hazardous waste generators.

The DuPont Cherry Island Landfill collects water elevations and chemical analyses with semiannual data from wells in the 20-foot zone (dredge spoils), 50-foot zone (recent Delaware River floodplain sediments), and 90-foot zone (Columbia Formation). Analytical data include total dissolved solids, total organic carbon, pH, specific conductance, chlorides, ammonia, iron, lead, zinc, manganese, and nickel.

The DP & L Edgemoor Ash Landfill collects water levels and chemical analyses with quarterly data from three shallow wells completed in the Columbia Formation. Analyses include pH, sulfate, total dissolved solids, specific conductance, chloride, and 13 metals.

The Delaware Solid Waste Authority's Cherry Island Landfill collects water levels and chemical analyses with quarterly, semiannual, and/or annual data from wells developed in the dredge spoil, recent floodplain sediments, the Columbia Formation, and the Potomac Formation. A large number of parameters are measured. The Wilmington Sewage Treatment Plant lagoons are also affecting groundwater quality and are located near the Cherry Island Landfill.

The basin contains 646 acres that are not serviced by central sewer. Thus, there is a potential impact from domestic septic systems. Only 2% of the watershed contains agricultural lands. As in most watersheds in the Piedmont, stormwater and related urban sources of contamination may also contribute to groundwater-quality degradation.

Brandywine Creek Watershed Contaminant Sources

The Brandywine Creek watershed contains 10 CERCLA HSCA sites, 1 TSD site (DuPont Experimental Station), 1

Table 7

STATE PROGRAMS COLLECTING GROUNDWATER QUALITY AND QUANTITY INFORMATION

PROGRAM	FREQUENCY OF GROUNDWATER MONITORING	Typical Analyses	Data Repository	Status of Mapping and Geo-referencing	Responsible Agency
Wastewater Spray Irrigation	Quarterly (could be more or less frequent for specific sites)	Metals, nutrients, water levels	Hard copy; more recent data currently being placed into electronic data base	Sites in DNREC - GIS. Many have corrected GPS locations	DNREC Groundwater Discharges Section
Large On-Site Septics	Quarterly (could be more or less frequent for specific sites)	Nutrients, chloride, bacteria, water levels	Hard copy; more recent data currently being placed into electronic data base	Sites in DNREC - GIS. Many have corrected GPS locations	DNREC Groundwater Discharges Section
Sludge Application	Quarterly (if required)	Metals, nutrients, water levels	Hard copy	Individual site files	DNREC Surface Water Discharges Section
Underground Injection Control	Required at sites with a UIC permit as part of corrective action	Specific to type of cleanup	Hard copy	Individual site files	DNREC Groundwater Discharges Section
Solid-Waste Facilities	Semiannual or quarterly; summarized in yearly reports	Priority pollutants or TCL; (may use indicator parameters); water levels	Hard copy in site files	DNREC - GIS on all active facilities	DNREC Solid Waste Branch
Federal CERCLA/State HSCA (Hazardous Waste Sites)	Various sampling events - site investigation, remedial investigation, corrective action, long-term monitoring - site specific frequency	Priority pollutants; TCL; water levels	Hard copy in site files and summary in remedial investigation reports	Site maps on file; GIS - ??	DNREC Site Investigation and Remediation Branch
Hazardous Waste Facilities	Quarterly with annual summaries; annual Appendix IX sampling	Site specific compounds; RCRA Appendix VIII and IX; indicator parameters; water levels	Hard copy in special groundwater section of files	GPS available on most sites	DNREC Hazardous Waste Management Branch
Underground Storage Tank	One-time during investigation; periodic monitoring during corrective action	Benzene, toluene, ethylbenzene, xylenes, total petroleum, hydrocarbons; haz substances (rarely); water levels	Hard copy in facility file	GPS for leaking USTs in New Castle County, on-going in Kent and Sussex counties	DNREC Underground Storage Tank Branch
Groundwater-Quality Studies	Variable for specific studies; long-term monitoring on established frequency	Nutrients, chlorides, pesticides; water levels	Hard copy for specific studies; long-term monitoring on data base	Sites not mapped; long-term monitoring in site file; GPS on wells	DNREC Water Supply Section
Emergency Response	One-time specific to incident	Specific to incident	Hard copy in site file	Sites not mapped	DNREC Emergency Response Branch
Nonpoint Source	Variable for limited-term special studies	Nutrients; water levels	Site files	Sites not mapped	DNREC Nonpoint Source Program
Water Allocation	Daily water withdrawal rates; weekly water levels reported monthly in annual reports	Water-use reports; well water levels	Hard copy in water-use files; Delaware Water Use Data System data base	Latitude/longitude available in DWUDS (mostly LORAN, some GPS corrected)	DNREC Water Supply Section
Public Water-Supply Program	Varying frequency for different systems and for different chemicals	All chemicals with maximum contaminant levels	Hard copy files; recent data in electronic data base	Almost all community PWS wells have GPS-corrected locational data	Delaware Division of Public Health
Pesticide	System began in 1996 - 111 wells statewide	Six pesticides with SMP requirements	N/A	Confidential data base	Delaware Department of Agriculture

wastewater spray irrigation site, and 54 LUST sites. Of these LUST sites, 11 have significant groundwater impacts. Most of these sites are located in the extreme southern portion of the basin within the City of Wilmington proper. Other sites include 77 hazardous waste generators.

The DuPont Experimental Station has groundwater samples analyzed initially on a quarterly and presently on a semi-annual basis for volatile organic compounds and field parameters. Eleven sampling events are scheduled to be performed over a five-year period. Various chlorinated solvents have been detected at significant levels, and benzene, toluene, ethyl benzene, and total xylene compounds at less significant levels.

The basin contains 2,313 acres that are not serviced by central sewer. The 1995 Delaware Comprehensive Statewide Wastewater Facilities Study identified the community as needing central sewer. This area is located in the extreme northwestern portion of the basin and extends into the Red Clay Creek basin along the Pennsylvania border. Approximately 26% of the watershed, located largely in the north, is used for agriculture, predominantly pastureland. The nonpoint source impacts from domestic septic systems and agriculture are ranked high and low, respectively, by the 1996 Delaware 305(b) report.

Red Clay Creek Watershed Contaminant Sources

The Red Clay Creek watershed contains 6 CERCLA/HSCA sites (Hercules Research Center), 1 TSD site, 27 LUST sites, and 1 wastewater spray irrigation site. Three LUST sites, 1 HSCA site, and 1 wastewater spray irrigation are located within or very near to the Cockeysville Aquifer. Almost all other sites are located in the southern extreme of the watershed near the Fall Line. Of the 27 LUST sites, 6 have documented groundwater impacts. Other sites include 40 hazardous waste generators.

The Hercules Research Center has two Solid Waste Management Units (SWMUs) which analyze for Target Compound List VOCs, semi-volatiles, metals, PCBs, pesticides, and cyanides. Despite significant impacts to soils at the two SWMUs, only low levels of VOCs (chlorinated solvents), pesticides, and a few metals have been detected in groundwater. In addition to groundwater samples collected thus far as part of RCRA Corrective Action, chlorinated solvents have been detected in on-site drinking water wells sampled by the Division of Public Health's Office of Drinking Water.

As with the Brandywine Creek watershed, the Red Clay Creek basin is 27% agriculture, but most is low-density pastureland. Central sewering does not exist for 1,577 acres, and one area in the northeastern corner of the basin has been identified as needing central sewer. The lower portions of the basin are urbanized, and stormwater and related urban sources of contamination may contribute to groundwater contamination.

White Clay Creek Watershed Contaminant Sources

The White Clay Creek watershed contains 20 CERCLA / HSCA sites and 50 LUST sites (of which 19 LUST sites have significant groundwater impacts). Although most of these sites are located in the southern portion of the basin within the City of Newark or the Newport area, five of the LUST sites are located within the Cockeysville Aquifer area in the Hockessin Valley. One of these has documented groundwater contamination. One CERCLA site is located in the Newport area north of Churchmans Marsh. Other sites include 104 hazardous waste generators.

Natural iron problems have been identified within the Laird Track and within wells in the Potomac Aquifer. One northern well of the south Newark wellfield was contaminated by tetrachloroethylene (PCE) and is no longer used, as described more extensively elsewhere.

At the DuPont Glasgow facility, two volatile organic carbon (VOC) plumes, at different locales, have been identified: one in the confined aquifer segment of the Columbia Formation; the other in the water-table aquifer portion. Groundwater is sampled for VOCs and field parameters at both areas. Compounds consistently detected include TCE, 1,1,1-TCA, 1,1-DCE, chloroform, PCE, di- and tri-chlorofluoromethane, total xylenes, ethylbenzene, and toluene.

Approximately 26% of the area within the White Clay Creek watershed is used for agriculture, but as with the Red Clay Creek watershed, these areas are not intensive and are regarded as a lower concern. Approximately 30% of the watershed does not have central sewer and is concentrated in the central part of the watershed in the Pike Creek Valley area. However, no areas have been identified as needing central sewer.

Upper and Lower Christina River Watershed Contaminant Sources

The upper and lower Christina watersheds collectively contain 62 CERCLA/HSCA sites, 3 TSD sites, and 155 LUST sites, of which 59 have groundwater impacts. There are 62 CERCLA/HSCA sites, 354 hazardous waste generators, 14 solid waste landfills, and 2 resource recovery facilities.

In the upper watershed, the LUST sites are scattered, with concentrations in the Newark area and at the intersection of Route 896 and Route 40. In the lower watershed, LUST sites are scattered throughout the basin, both on the northern and southern side of the Christina River watershed, although most are located to the east of Churchmans Marsh. Three

LUST sites and one HSCA site are found within the recharge protection area and close to public water-supply wells near Wilmington Airport. No LUST sites are located near the Glendale wellfield and recharge protection area. The DRPI industrial landfill is found along the south bank of the Christina River near Interstate 295. Two TSD facilities (DuPont – Chestnut Run, and General Motors) are found in the northeastern portion of the basin. DNREC's Superfund Branch and the Water Resources Agency for New Castle County began a study of site locations, historical land use, and environmental impacts from Superfund sites. Detailed maps are available, but no formal report was written.

Currently, quarterly water level and annual analytical data are being collected from the Columbia/Shallow Potomac Aquifer and the deeper Potomac Aquifer, and water level and chemical analyses are being performed at the DRPI Chesapeake and Delaware Landfill. Standard indicator parameters are also being collected.

As mentioned previously, iron problems have risen dramatically in recent years in wells located in the south Newark wellfield. One possible cause may be the oxidation of iron-containing compounds, (e.g., pyrite) which were exposed to oxygen during drought periods. Another possibility could be an as yet unidentified anthropogenic source. Regardless of the cause, iron treatment is needed for these wells. However, the City of Newark is now obtaining much of its water from a surface-water intake on White Clay Creek.

Salt-storage piles on the north side of Interstate 495 along the Christina River have caused local contamination by sodium and chlorides. A groundwater monitoring network existed in the early 1980s for the site. Other salt piles are also found on the southeastern side of Interstate 495. Other potential sources of groundwater contamination in this area include dredge spoils.

Natural saltwater intrusion problems may occur in the eastern portion of the basin. However, most large pumping centers are located to the southeast of the watershed. Sundstrom et al. (1967) argued that thick intervening clays prevent recharge to the Potomac aquifers from surface-water sources, and saltwater intrusion is unlikely. However, Phillips (1987) suggested that saltwater intrusion may occur due to erosion of continuing units and deposition of more permeable sands and gravels during the Pleistocene and Holocene periods in the vicinity of the Delaware River. Chloride concentrations above ambient levels (10 – 21 mg/l) have been found (40 – 8,600 mg/l). However, most of these areas are occurring in wellfields located to the southeast of the Christina River watershed. Modeling using various scenarios indicated that saltwater intrusion could occur due to recharge of river water caused by large pumping centers. DNREC currently monitors wells in the Potomac Aquifer adjacent to the Delaware River although most of these wells are located south of and outside of the Piedmont Basin.

Water in the Potomac Aquifer contains relatively low total dissolved solids (80 ppm), but total iron is higher than for other aquifers (Woodruff, 1970), ranging from 0 – 11 mg/l.

While much of the watershed is served by central sewer, relatively large pockets that are not sewered exist throughout much of the watershed, particularly along the western extent adjacent to the Maryland state line. The Christina River basin is 16% agricultural and 4,598 acres unsewered. The agricultural activities are of low concentration and are of minimal concern.

Positive Initiatives

Efforts to protect groundwater from becoming contaminated and, where contaminated, to clean up or minimize environmental or human health risks, are numerous and occur within local (county and municipal), state, and federal programs. Examples of all of these occur in the Piedmont Basin, where a large part of Delaware's population lives.

Water Resource Protection Area Ordinances

Both New Castle County and the City of Newark adopted ordinances that (1) delineate the most sensitive and valuable Water Resource Protection Areas (see Maps 5 and 6), and (2) establish standards for zoning requirements within these critical areas. Included as important Water Resource Protection Areas are groundwater recharge protection areas, wellhead protection areas (i.e., areas surrounding public water-supply wells), and the Cockeysville Formation (aquifer) protection areas. Both the city and county ordinances rely on the Water Resource Protection Area maps dated 1993. These maps are updated periodically and will likely be modified in 1997.

These ordinances address both groundwater-quantity and quality issues. First, they attempt to control practices that may reduce recharge from the surface into the groundwater system by minimizing the amount of impervious surface allowed on land within these areas, thus protecting the quantity of groundwater. Second, the storage of hazardous substances and petroleum products is controlled. This includes hazardous substances (listed in 40 CFR 116) in quantities above a "reportable quantity" (defined in 40 CFR 117), which are prohibited or tightly controlled by requirements for aboveground storage tanks and underground storage tanks. However, ultimate regulatory control of most hazardous substances resides within state or federal programs.

The county seeks the advice of a technical advisory committee composed of representatives from the following: the chemical industry, a local water company, Consulting Engineer's Council, Delaware Geological

Survey, DNREC, New Castle County Chamber of Commerce, New Castle County Department of Planning, New Castle County Department of Public Works, and the Water Resources Agency for New Castle County.

Water Resources Agency for New Castle County

Created under the auspices of New Castle County, the state of Delaware, the City of Newark, and the City of Wilmington, this agency advises the county, cities, and state on many water-quantity and quality issues, including the Water Resource Protection Area ordinance. The Water Resources Agency also maintains an extensive Geographical Information System (GIS) that covers the entire Piedmont Basin as well as the remainder of New Castle County.

Hazardous Substance and Waste Management Programs

The "Contaminant Sources" section of the *Piedmont Basin Preliminary Assessment Report* describes the numerous programs at the state level that address sources of contamination, including many that impact groundwater directly such as leaking underground storage tank sites, underground storage tank facilities, solid-waste landfills, hazardous waste treatment storage disposal facilities, federal and state Superfund sites, and non-hazardous waste sites. The cleanup and control of groundwater contaminants have always been an important priority in these programs. Most monitor for groundwater contamination using monitoring wells or vadose monitoring techniques.

Safe Drinking Water Act

The Safe Drinking Water Act provides for the regulation of public drinking water supply systems. The Delaware Division of Public Health, Office of Drinking Water, oversees the regulation of these — both surface-water and groundwater dependent systems. These regulations require periodic sampling of systems by the Division of Public Health's Office of Drinking Water. The Artesian Water Company samples its own supplies and provides the information to the Office of Drinking Water. This information is an important component in developing a groundwater monitoring system statewide.

DNREC's Water Supply Section is continuing efforts in coordination with the Office of Drinking Water to automate and link the drinking-water data base with the water-well data base. This type of information exchange allows for evaluations using existing sources of information for groundwater-quality data.

Comprehensive State Groundwater Protection Program (CSGWPP)

The coordination and integration of all programs (federal, state, and local) with groundwater protection responsibilities has been fostered under the Comprehensive State Groundwater Protection Program (CSGWPP) approach. DNREC has developed a profile of the status of all groundwater-related programs, which is included in the *Performance Partnership Agreement* between EPA and DNREC. Delaware's CSGWPP has been provided to EPA for their endorsement. Once the program has been endorsed, Delaware will be seeking greater flexibility in EPA-delegated groundwater protection programs.