
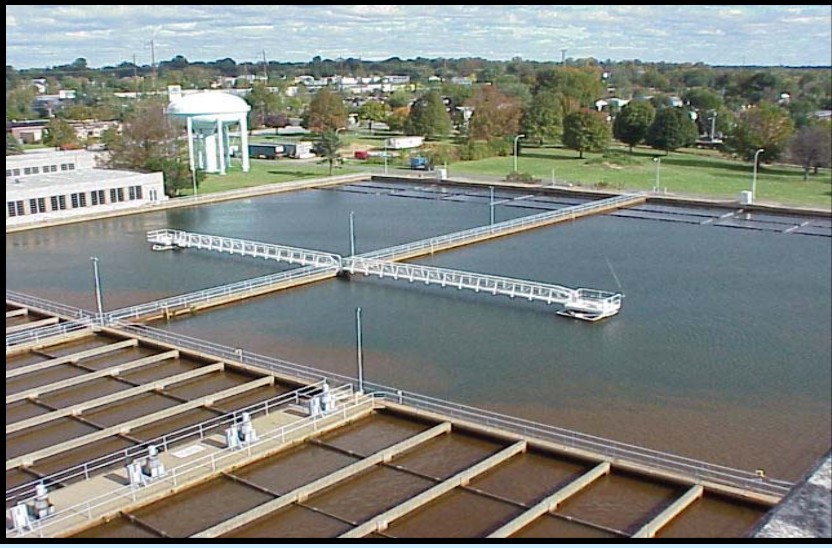

PHILADELPHIA WATER DEPARTMENT
BAXTER WATER TREATMENT PLANT (PWSID# 1510001)
SOURCE WATER ASSESSMENT REPORT
SECTION 1: GENERAL DELAWARE RIVER WATERSHED


This report was produced for the Pennsylvania Department of Environmental Protection in accordance with the Source Water Assessment and Protection Plan.

Philadelphia Water Department

Prepared by The Philadelphia Water Department
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Delaware River SWA
Protect Our Health from Source to Tap

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Executive Summary – Delaware River Watershed Assessment

The 1996 Safe Drinking Water Act Amendments required the assessment of all source water supplies across the country to identify potential sources of contamination, the vulnerability and susceptibility of water supplies to that contamination, and public availability of the information. In response to this charge, the Delaware River Source Water Assessment Partnership, comprised of the Pennsylvania Department of Environmental Protection, the Philadelphia Water Department, the Philadelphia Suburban Water Company, the Pennsylvania American Water Company, and the Bucks County Water and Sewer Authority conducted an assessment with stakeholders to identify water supply protection priorities in the Delaware River Watershed. The following summary includes two main sections. One section discusses the various characteristics and observations made through collection of watershed wide information. The remaining section provides a brief listing of the main recommendations based on the observations and analysis of watershed data.

Observations & Characterization

- Although the Delaware River has been utilized for thousands of years, the quality of the water source began decreasing rapidly from the time of initial European settlement in the early seventeenth century until corrective, preventive, and protective measures were taken beginning in the 1970's and 80's.

- Direct dumping of waste into the river, poor farming practices, the erosion and runoff that resulted from excessive land clearing, and developments in industrialization, transportation, and coal mining all contributed to the watershed's pollution problems.

- The Delaware River clean-up effort that began in the 1960s now serves as a model of successful interstate water resource management.

- The Delaware River Watershed encompasses 40 counties within Pennsylvania, New Jersey, New York, and Delaware. The SWAP study area includes 30 of these counties.

- The Delaware River provides drinking water to 17million people or 10% of the U.S. population.

- According to DRBC, 7,337 MGD total amount of water used each day in the watershed. Approximately 67% is used to generate power in New Jersey. Most of the remaining water is returned to the basin's streams and aquifers with the exception of about 311MGD in consumptive uses within the basin and 900MGD that is diverted out of the basin to New York City and northeastern New Jersey.

- PSE&G in Salem, NJ is the largest of all surface water users within the watershed, taking roughly 1,983 MGD.

- The Philadelphia Water Department, which takes about 361MGD from both the Delaware River and the Schuylkill River, is the largest municipal user. Approximately 311MGD can be used.

- In the Delaware River Basin, 88% of the total amount of water withdrawals is taken from the surface water supplies, whereas 12% comes from groundwater sources. Surface sources supply 60% of the water that is used consumptively, with the remaining 40% coming from groundwater stores.

- The Delaware River Watershed is composed of a number of smaller sub-watersheds, the most notable of which include: the Lehigh River, Crosswicks Creek, Musconetcong River, Rancocas Creek, Neshaminy Creek, and Tohickon Creek watersheds.

- The majority of developed land is located within the southern portion of the SWAP study area, between Lehigh County and Philadelphia County. The majority of the land within the study area remains forested, although a pattern of suburban sprawl has emerged.

- Philadelphia has the highest population density of any county within the watershed.

- The most immense population gains are forecasted to occur within the suburban and rural communities located on the fringe of urbanized areas.

- The development of agricultural and rural lands is a cause for concern because it may lead to a loss of habitat for wildlife and an increase in erosion and pollution, which may adversely affect drinking water supply.

- Over 5,000 potential point sources were identified within the Delaware River Watershed. Most of these potential sources do not and will never discharge into the Delaware River, but may store, generate, or transport hazardous chemicals.

- Sewer systems, dry cleaners, and machine/metal working shops were among the most frequently identified potential point sources.

- The highest concentrations of potential point sources were located in the most highly developed sub-watersheds.

- The Tidal PA Philadelphia, NJ Tidal Lower and Tidal PA Bucks had the greatest number of dischargers per acre of drainage area.

- Delaware River water quality has significantly improved over the past twenty years. As the impacts of point sources have been reduced over the years, the importance of non-point sources such as stormwater runoff from developed areas within the watershed has become evident.

- Of the 14,299 miles of streams and creeks within the Delaware River Watershed, 35% (5,056 miles) have been assessed to determine their compliance with applicable water quality standards. Nearly 65% of the assessed stream miles have attained applicable water quality standards.

- Although water quality data suggests that pathogens are a concern throughout the entire watershed, very few segments are listed as having pathogens as the primary cause of impairment.

- Flow alterations, phosphorus (nutrient), and toxic chemicals fish tissue and sediment were identified as the most significant causes of impairment within watershed.

- Stormwater runoff from urban and suburban areas was identified as the cause of almost half of the impaired stream lengths within the watershed.

- Federal, state, and private grants have provided almost $20 million for environmental projects within the Delaware River SWAP study area over the past several years. Almost 60% of the grants awarded were used for protection/restoration projects.

- Grants were awarded to 54 recipients, with county and municipal groups receiving the majority of funds.

<u>Watershed Recommendations</u>

- Current grant funding appears to be focused appropriately on restoration with most of the grant money going to state organizations. It is recommended that the states make this money available to local municipalities to implement local protection efforts if these monies are not already available.

- Overall, both sewer system capacity and integrity as well as treatment plant capacity during wet weather periods represent the greatest and most difficult sewage related issue in the watershed. Infrastructure improvements for adequate wastewater collection and treatment systems are needed to address infiltration and inflow or system capacity issues. These improvements will eliminate events such as overflowing manholes of raw sewage into downstream water supplies.

- Raw sewage discharges upstream of water supply intakes by communities through CSOs or SSOs need to be monitored, evaluated, and improved. These discharges can significantly impact pathogen concentrations in downstream water supply.

- Compliance requirements for industries and municipalities discharging wastewater into the protection priority corridor between Camden and Easton should be enforced.

- Encouragement of rigorous and regular revision and implementation of ACT 537 Sewage Facilities Management Plans in Montgomery, Bucks, Mercer, and Lehigh Counties. In addition the sewage facility related issues from SWAs should be incorporated into the ACT 537 plan with emphasis on monitoring and measuring progress towards addressing identified problems.

- Wastewater dischargers should be encouraged and given incentives to switch to ultraviolet light disinfection and/or filtration of effluents to reduce *Cryptosporidium* pathogen levels and viability from discharges. Permits for discharge from new wastewater facilities or plant expansions should include ultraviolet light disinfection requirements.

- It is recommended that the DRBC and three PADEP regions covering the Delaware River Watershed develop a watershed wide approach to addressing permit requirements. One suggestion would be a uniform fecal coliform discharge limit for any wastewater discharge upstream of a drinking water intake in the watershed.

- The Phase II stormwater regulations should be fully implemented and enforced throughout the watershed, with first priority for compliance monitoring and inspection recommendation for communities discharging into protection priority areas for drinking water supplies.

- The Delaware River Basin in coordination with the Delaware Riverkeeper, PADEP, and NJDEP should set a goal for achieving a certain number of specific BMPs within the next 10 years. For Example, 1,000 acres of riparian buffers, 1,000 stream miles protected, etc.

- Interaction and communication with petroleum pipeline owners and operators, railroads, and road or bridge construction crews needs to be developed and improved. It is important for these stakeholders to understand water supply issues and impacts from catastrophic accidents and right of way spraying of herbicides. Therefore a series of emergency response workshops needs to be held to raise awareness of the issue.

- Given the catastrophic impacts from spills and accidents, an early warning system similar to that on the Ohio River should be installed along the mainstem Delaware River to provide water suppliers warning and accurate real time data when spills and accidents occur. It is recommended that the USGS should be involved in the implementation of the early warning system.

- New permits should be banned for new storage tanks and facilities that uses or store toxic chemicals including petroleum products within the 100-year floodplain of the river and its tributaries. PADEP should also develop and implement a long-term plan relocate, reduce, or eliminate tanks and sources with toxic chemicals that are currently located within the floodplain.

- An accurate time of travel study needs to be conducted on the Delaware River to determine the time various spills will take to arrive at various water supply intakes and the amount of dilution under various flow scenarios. This should be incorporated into a computer model for emergency planning simulations using various chemicals and scenarios. This is also an important component necessary to make information from the early warning system more useful. The USGS should be involved in the implementation of this effort.

- Signage should be developed in sensitive water supply areas along roadways and bridges that include phone numbers to contact water suppliers during emergencies and spills. The signs should include a unique identification number corresponding to a known location for the water supplier.

- A special workshop with street departments and PennDot should be held to develop a strategy to reduce salt impacts from road salt application. This may include strategies to acquire special funding for salt misting trucks to reduce salt application in sensitive areas.

- Agricultural land that is preserved should have specific riparian buffer and streambank fencing requirements included in its preservation status.

- Additional incentives and efforts should be allocated to develop, monitor, and implement nutrient management and conservation plans for farms in sensitive water supply areas.

- Active agricultural lands adjacent to streams in sensitive water supply areas should be required to have riparian buffers or streambank fencing to reduce impacts from livestock activity, pasture runoff, and crop runoff.

- The targeting of USDA funding for water quality protection under EQIP and enrollment of CRP lands should give consideration to sensitive water supply areas, and the programs should be more accessible to farmers. To maximize water supply protection, water suppliers should be consulted in connection with the allocation of EQIP and CRP funds. A goal should be set by the USDA, DRBC, PADEP, and NJDEP to have approximately 25-50% of all agricultural lands in sensitive water supply areas to have streambank fencing or riparian buffers by 2010.

- Areas of intense or concentrated agricultural activity should also be prioritized for protection and mitigation efforts.

- Special erosion controls and ordinances to reduce stormwater impacts from future development and erosion are needed in protection priority areas for water supplies.

- Conservation Districts need more assistance in addressing erosion control and stormwater runoff issues from development.

- The operation and discharge of contaminants and algae from the many reservoirs in the watershed are suspected of having impacts on water supplies. These areas need to be monitored and investigated or communication about these discharges and the timing of their impacts needs to be better understood.

- The U.S. Fish and Wildlife, PA Game Commission, park managers, golf course managers, and water suppliers should develop and implement a regional management plan to address the exploding population of non-migratory Canada Geese

- Township officials along the protection priority corridor should be educated about stormwater impacts on water supplies through meetings, workshops, or mailings.

- The results of the local source water assessments need to be presented directly to local township officials. The common issues from multiple water supplies should also be provided to show how everybody lives downstream and feels the impact from pollution.

- A combined and coordinated efforts to establish data protocols for proper data comparison (GIS or otherwise) between the various states in the Delaware River Basin needs to be established. Currently most data cannot be compared between states.

- Accurate watershed-wide land use GIS coverage is necessary for TMDLS and runoff impact estimates.

- GIS coverage of farms, types of agriculture, farming density, and EQUP/CRP lands, or lands with conservation easements, should be developed for the entire watershed. GIS coverage of sanitary and stormwater collection systems and outfalls in water communities should also be developed.

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Section 1 – General Delaware River Watershed

1.1 Introduction

Key Points

- **The Delaware River Source Water Assessment Partnership, comprised of the Pennsylvania Department of Environmental Protection and the Philadelphia Water Department, is collecting and evaluating the data necessary to identify water supply protection priorities in the Delaware River Watershed.**

The ability to obtain safe and potable drinking water has always been a key component in the location and development of communities. The quantity and quality of the drinking water supply has often defined a community's ability to grow and succeed. Therefore, protecting, maintaining, and improving the quality of a community's water supply is vital in ensuring its future.

The importance of water supply integrity has been recognized throughout the United States by municipalities and water suppliers who have implemented efforts to protect the drinking water supplies of their communities. From rural wells to the rivers supplying potable water to big cities, everyone is getting involved in protecting the source of their drinking water.

In addition to local efforts, Federal regulations, resources, and initiatives have been implemented to protect drinking water sources. These include the Clean Water Act (CWA), Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Safe Drinking Water Act (SDWA).

Most recently, the Safe Drinking Water Act Reauthorization in 1996 included a specific component for source water protection called the Source Water Assessments (SWAs). The SWAs may be best defined as a process involving water suppliers, watershed organizations and other stakeholders, who together identify the protection priorities of the water supply. Water suppliers will be required to make this information available to the public in their Consumer Confidence Reports in order to help the public understand the source of their drinking water and the challenges that must be met to protect it. It is important to note that these assessments are of the raw water sources prior to drinking water treatment, not assessments of the performance or compliance of public water systems.

As part of its Federal requirement to conduct the SWAs, the Pennsylvania Department of Environmental Protection (PADEP) sought to involve water suppliers and the community in the SWA process. It is believed that the partnership approach increases the potential for public, community, and water supplier involvement to address source water issues after the assessments have been completed.

Using this partnership approach, the Delaware River Source Water Assessment Partnership was formed. The partnership includes water suppliers working with the state to conduct the assessments. The State contractor, the Philadelphia Water Department, has volunteered to lead the Delaware River Source Water Assessment Partnership, and conduct source water assessments for 8 surface water supplies within the Lower Delaware River Watershed.

1.1.1 New Requirements Under SDWA

Key Points

- **The 1996 amendments to the Safe Drinking Water Act require States to implement Source Water Assessment Programs.**

The Environmental Protection Agency (EPA) has supported the efforts of States and communities to protect their water sources from contamination since 1986 with the establishment of the Wellhead Protection (WHP) Program and other Federal initiatives. Encouraged by the WHP Program's success, the EPA has set new goals for source water protection. By 2005, the EPA's goal is to have either Source Water Protection, Wellhead Protection, or Watershed Protection Programs in place for 60% of the country's population served by community water (EPA State Source Water Assessment and Protection Programs Guidance, August 1997, EPA 816-R-97-009, Office of Water 4606).

The amendments to the 1996 Safe Drinking Water Act include requirements for each state to establish and implement Source Water Assessment Programs (SWAPs) that accomplish the following:

1. Set forth the state's strategic approach to conducting the assessments

2. Delineate the boundaries of the areas providing source waters for public water supply (PWS)

3. Identify, to the extent practical, the origins of regulated and certain unregulated contaminants in the delineated area in order to determine the susceptibility of PWSs to such contaminants

4. Complete the assessments within two years after EPA approval, with an opportunity to extend this period up to 18 months

5. Make the results of the source water assessments available to the public.

The intent of Congress in requiring the SWAs was to show water suppliers, municipalities, and the public the potential challenges facing their sources of drinking water and to develop local voluntary support for source water protection programs.

The PADEP has already been working diligently to meet these requirements by developing an approved SWA Program and Plan and by hiring contractors to help assess a portion of its 14,000 water sources. In addition, the PADEP has set aside resources and monies in the form of grants for communities that apply to develop local source water protection plans after assessments are finished. These plans were designed to be linked to the Growing Greener Grant application process. Additional preference would be given to grant applications that can show that the proposed activities are linked to an approved Source Water Protection Plan or River Conservation Plan for that community. Therefore, local organizations seeking funds to conduct protection efforts will eventually be better equipped to make strides in protecting local water supplies.

1.1.2 Designation of a SWAP Study Area

Key Points

- **The Source Water Assessment Partnership has chosen to create a separate study area for the Delaware River Watershed assessment.**
- **The SWAP study area boundaries are primarily used for intake specific information in the report.**

Because of the large size of the watershed, the Source Water Assessment Partnership has chosen to create a separate study area for the Delaware River Watershed assessment. The SWAP study area is the entire watershed coverage modified to exclude part of the Lower Delaware subshed. It includes the entire upstream portion of the Delaware River Watershed, extending into New York State.

The SWAP study area boundaries are primarily used for intake specific information in the report. The southern boundary was chosen based upon the location of the Baxter Water Treatment Plant in Philadelphia County as the southernmost intake within the Delaware Estuary. The area below the Schuylkill and Delaware River confluence will not impact this intake. In addition, the delineation of the SWAP study area also includes the area within a 25-hour time of travel, which is required under the SWA guidelines set forth by the Pennsylvania Department of Environmental Protection. Most of the contaminant source inventories will concentrate on those areas within 25 hours travel time of the intakes, and thus exclude those portions of the intake in New York State when prioritizing the potential contaminant sources. Figure 1.1.2-1 shows the boundaries of the SWAP study area.

Figure 1.1.2-1 Delaware River Watershed and SWAP Study Area Boundaries

1.2 Background and History

1.2.1 Description of the Delaware River Watershed

Key Points

- **The 330-mile long Delaware River is divided into 6 zones for purposes of classification and monitoring.**
- **The river serves a variety of important residential and industrial functions, including fishing, transportation, power, cooling, and recreational purposes, but most importantly, as a source of drinking water.**
- **The Delaware River provides drinking water to 17 million people or 10% of the U.S. population.**

From Point Mountain in the Catskills Range of Hancock (Schoharie County), New York to the mouth of the Delaware Bay in Philadelphia, Pennsylvania, the 330 mile-long Delaware River winds its way through four states on the eastern coast of the United States, encompassing 42 counties and 838 municipalities in the Mid-Atlantic Region of the country. Originating on the western slopes of New York State's Catskill Mountains as two separate branches that meet downstream in Hancock, NY, the river flows southeast for 78 miles through rural regions along the New York-Pennsylvania border to Port Jervis in the Shawangunk (Catskills) Mountains. From there, it heads southwest, along the border between Pennsylvania and New Jersey, through the Appalachian Mountains and 42 miles of the Minisink Valley and the Water Gap in the Kittatinny Mountains (also known as Blue Mountain in PA). Turning southeast again at Easton, PA, where it is met by the Lehigh River (its second largest tributary) at a rate of 2,890 cubic feet per second (cfs), the Delaware then flows approximately 80 miles to the tidal waters of Trenton, New Jersey at a rate of 11,700 cfs, thus completing about 200 miles of its 330-mile journey. About 30 miles downstream of Trenton, the river passes through the fifth largest metropolitan region in the nation—the heavily industrialized Philadelphia/Camden area—and the mouth of the Schuylkill River, its largest tributary, which flows into the Delaware at a rate of about 2,720 cfs. From there, the river flows on past Wilmington, Delaware and through the more rural regions of Cape May, New Jersey on its eastern shore and Cape Henlopen, Delaware on the west, completing its course as it meets the Delaware Bay.

Along its route from the headwaters to the mouth of the bay, the Delaware River drains a total of 13,539 square miles (0.4% of the land mass in the U.S.) in New York, Pennsylvania, New Jersey, and Delaware. Figure 1.2.1-1 presents a map of the entire Delaware River Drainage Basin, its major subwatersheds, and its tributaries.

Figure 1.2.1- 1 Map of Delaware River Drainage Basin

The river, its bay, and 216 tributary streams play a significant role in sustaining life and the economy in these areas. Among other things, these bodies of water are used for fishing, transportation, power, cooling, recreation, and other industrial and residential purposes. Most importantly, though, they provide drinking water for about 17 million people, or almost 10% of the country's population.

There are three reaches of the Delaware River: the 197 non-tidal miles from Hancock, NY to Trenton, NJ comprise the first, the next 85 tidal miles from Trenton to Liston Point, DE, which are referred to as the "Delaware Estuary," are the second reach, and the remaining 48 miles of the Delaware Bay that extend into the Atlantic Ocean between Cape May, NJ and Cape Henlopen, DE make up the third reach. For classification and monitoring purposes, the river has been divided into six separate zones. Each zone represents a particular leg of the Delaware River's journey from its headwaters to the Atlantic Ocean (DRBC, 1994).

Zone 1 encompasses the non-tidal portion of the river, from its headwaters in Hancock, NY to Trenton, NJ, according to the Delaware River Basin Commission's Geographic Zoning of the Delaware River Watershed. One hundred seven miles of this 198-mile zone were included in the National Wild and Scenic River System (NWSRS) in 1978. Established in 1968, the NWSRS is a class of rivers that have been selected to be protected because Congress decided that they "with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations to protect the water quality of such rivers and to fulfill other vital national conservation purposes" (National Park Service, Wild and Scenic Rivers, http://www.nps.gov/rivers).

The whitewater section of this zone, between Narrowsburg, NY and Port Jervis, NY, consists of 36.5 miles of 30 Class I and 6 Class II rapids, which flow through an area of the watershed that at one time saw a great deal of colonial logging and coal mining, but has since recovered. There is minimal development in this sparsely populated stretch of the Delaware, which is used mainly for recreational activities such as fishing, boating, etc. It consists mostly of forested mountains and riverbanks inhabited by a diversity of wildlife. The high quality water that flows through the upper half of this zone is sustained by cold water releases from three New York City-owned reservoirs (Cannonsville, Neversink, and Pepacton). The 77 miles from the Water Gap to the falls at Trenton, NJ is characterized by a mix of both rural and urban areas. Above the confluence with the Lehigh River, the Delaware's second largest tributary, the river follows a relatively tranquil course through forests and mountainous state parks where people enjoy boating, fishing, swimming, camping, and other recreational river activities. Thirty-six and a half miles of this zone are part of the Water Gap, a scenic area that extends from near Stroudsburg, PA to the river's confluence with the Lehigh River at the Forks of the Delaware at Easton, PA. The scenic beauty of the Water Gap draws many tourists and vacationers who make recreational use of the region's mix of gentle waters and rapids that flow between the high cliffs of the Kittatinny Mountains of the

Appalachian Range, some of which reach heights of more than 1,000 feet. While agriculture is still dominant in the top half of this section, it gives way to more populated and developed areas in the lower Lehigh Valley where industrial towns such as Allentown, Bethlehem, and Easton in Pennsylvania, and Phillipsburg and Trenton in New Jersey, serve as major manufacturing centers. Consequently, there are many more surface water withdrawals and wastewater discharges in this lower section of the zone than there are above the Water Gap. However, water quality in Zone 1 is still considered to be good due to the fact that this stretch is above the watershed's largest source of pollution (the Philadelphia/Camden area).

A distinguishing feature of the lower section of Zone 1 is its extensive canal system. The 51 miles from the area near the Forks of the Delaware to the falls at Trenton are characterized by numerous canal linkages connecting various sections of the river. This area contains more canals serving a single river valley than any other region in the U.S. Many small connective streams are also found at this section, which contributed to the colonial economy by providing power for the numerous mills that were built upon their banks shortly after European settlement (Fulcomer and Corbett, 1981).

Zones 2, 3, and 4 divide the freshwater, tidal portion of the river--the 54 miles between Trenton and the upper boundary of Zone 5 at Wilmington, DE. Zone 2 covers 25 miles; Zone 3, 13 miles; and Zone 4, 16 miles. These three zones encompass the majority of the most polluted stretch of the river, where water quality is the lowest: the highly populated and heavily developed and industrialized area between Trenton and Wilmington, DE, which includes the Philadelphia waterfront. This stretch also includes the Delaware's confluence with the Schuylkill River, it's largest tributary, which drains 15% of the river basin.

Along with Zones 5 and 6, Zones 2, 3, and 4 comprise the "Delaware Estuary." The estuary is home to one of the world's most highly concentrated areas of industry where the local economy is driven by chemical, shipbuilding, food processing, steel, and utility plants (Heritage Conservancy). The second-largest oil refining center in the U.S. and the second largest port in the U.S., in terms of tonnage travelling through it are also located within the Delaware Estuary. On account of such a high concentration of people and industry, there are many demands made on the estuary's water. Numerous withdrawals and wastewater discharges affect water quality in these zones, which is classified as intermediate/average at best, with seasonal fluctuations. This current classification, which represents a tremendous improvement from the condition of the river in previous years, is the result of 40 years of pollution clean-up efforts that began in the 1960s. Much remains to be done, however, in order to bring this section of the river up to par with the water quality standards set forth in the Federal Clean Water Act of 1972, which laid the groundwork for national water pollution control methods (Majumdar, Miller, and Sage, 1988 and DRBC, 1994). Current water quality concerns include the presence of toxic compounds and nutrient loadings in the estuary, which also affect dissolved oxygen (DO) levels and prevent these zones from meeting the Delaware River Basin Commission's "fishable" and "swimmable" standards (Sutton, O'Herron II, and Zappalorti, 1996).

Zone 5 covers the 31 miles from Wilmington to the upper boundary of Zone 6 just above the river's confluence with the Delaware Bay. Zone 6 itself consists of the Delaware Bay, a rural area from Liston, DE to the Atlantic Ocean, which is characterized by salt marshes and farmland, and serves as an unloading point for ships with large amounts of cargo. Since the Delaware's channel is maintained at 40 feet for navigation, larger ships transfer their loads to smaller vessels here in order to send them upstream. Due to the good water quality in this zone, the bay serves both commercial and recreational interests. Fishing, boating, and swimming are common in the bay, but there is concern that increases in population and industry in this area are negatively altering the estuarine ecosystem and may adversely affect water quality in the near future (USGS NAWQA, 1999).

As the 33rd largest river in the U.S., in terms of flow, the Delaware may be unimpressive in size, but it is one of the nation's most heavily used rivers as far as the volume of tonnage travelling on it every day. Sixty-seven and a half million tons of cargo moved along it in 1980, most of which consisted of petroleum, ore, and sugar (Toffey, 1982). With no dams on its main stem, it is also one of the few remaining free-flowing rivers in the country. As such, it continues to be an important asset to the regions that comprise its watershed. However, it is a resource that has had to be slowly salvaged from a severely deteriorated state over the last 300 years, and it is still in the process of recovering from those three centuries of abuse. The Delaware's return to a relatively sustainable, healthy condition is one of the world's most successful and ongoing river restoration stories, and it is a project that is studied worldwide today as a model of successful interstate water management.

As discussed in detail in section 1.2.2, when the Europeans arrived, the biota of the Delaware River Watershed was much more diverse than it is today. The immigrants found a plethora of life both in the water and on the land. Sadly, many species that once thrived have since been eliminated or only survive in limited numbers today due to pollution or overfishing/overhunting. Currently, forty-five fish species can be found in the Upper Delaware, where the highest quality river water in the basin is located. These species include American shad, brook trout, brown rainbow trout, chain pickerel, large and small mouth bass, and walleyed pike. Trout, salmon, and walleye are stocked in many of the Delaware's tributaries today, and eels and shad can still be found migrating in its waters, mainly due to the lack of dams on the river that would prevent their passage upstream.

On land, habitat loss, which is primarily due to development, put an end to some animal species that roamed in pre-colonial times. The Canada lynx, mountain lion, and passenger pigeon are a few species that no longer inhabit the watershed. However, there still exists a wide variety of fauna in the basin, such as bear, beaver, bobcat, deer, fox, muskrat, rabbit, raccoon, opossum, skunk, squirrel, and woodchuck, among others, as well as over 200 species of permanent and migratory birds, such as the bald eagle, bluebird, merganser, osprey, pheasant, ruffled geese, turkey, and the woodpecker. The Delaware Estuary, at the lower end of the watershed, is a crucial stop for the second-largest group of migrating birds to North America. As part of the Atlantic Flyway, the estuary provides a respite for food and shelter to these travelers as they journey north.

The Delaware Watershed, and the estuary in particular, was quite a different topographical picture in pre-colonial times. It consisted of a diversity of vegetation that covered a combination of land types. The uplands of the watershed, from the headwaters of the Delaware River in the Catskill Mountains (NY) to the Water Gap (between northern NJ and PA), is the area that has been least affected by colonization, and it retains much of its wild, scenic, natural beauty. Among the 1,100 plant species that thrive in this region are: oak, maple, hemlock, beech, walnut, ash, pine, dogwood, cedar, birch, rhododendron, mountain laurel, wild flowers, mosses, and ferns. Farming continues to play a large economic role in this area.

The middle section of the watershed, from the Water Gap to the falls at Trenton, NJ, used to be a contiguous mature forest that comprised the midpoint between a northern plateau of white pine, Eastern hemlock, beech, and maple trees and southern primeval forests of white oak, American chestnut, hickory, and chestnut oak. Only about half of the middle section remains wooded today. The majority of the original forest, having been cleared by settlers for farms and homes, is still trying to recover.

The estuary section near the lower portion of the watershed has undergone extensive change since colonial times, most notably, its ongoing development from an area of diverse and natural wild land into a rapidly industrialized region of man-made factories and ports, in the upper part of the estuary in particular. Yet, the region remains a vital resource for plant, animal, and human life throughout the watershed, especially the bay area.

A few sections of the river that have managed to retain a healthy level of their pristine pre-colonial condition or recover from former damage have been granted special recognition and protection from future abuse as part of the National Wild and Scenic Rivers System. The Upper River has also been classified as "Special Protection Waters," thus entitling it to increased protective regulation in order to preserve the high quality of its water. The story of the rest of the Delaware's main stem, however, is not so impressive, as the whole of the river has yet to attain such an exemplary condition.

1.2.2 History of the Delaware River Watershed

Key Points

- **The early European settlers in the Delaware River Watershed began a 300-year legacy of pollution in the 1600s that would not be abated until protective measures were deemed a priority in the mid-1900s.**
- **Direct dumping of waste into the river, poor farming practices, the erosion and runoff that resulted from excessive land clearing, and developments in industrialization, transportation, and coal mining all contributed to the watershed's pollution problems.**
- **Significant improvements in water quality have been made in the Delaware River since its darkest days in the 1940s, when pollution threatened the fishing, shipping, and transportation industries, as well as the health and well-being of watershed inhabitants who depended on it.**
- **Except for seasonal violations of a few parameters such as dissolved oxygen and fecal coliform in the estuary area and occasional toxic contaminant and nutrient loading alerts in certain river zones, the Delaware now meets the current water quality standards.**
- **The Delaware River clean-up effort that began in the 1960s now serves as a model of successful interstate water resource management.**

1.2.2.1 Colonial Settlement

The Delaware River Watershed has long been a life-source for inhabitants in these regions. It is believed that the earliest settlers in this area, the hunter-gatherer Paleo Native Americans, used the river and bay and the surrounding lands for food, transportation, and trade roughly 12,000-13,000 years ago, with little resulting damage to the river's ecosystem. Other tribes later moved into the area, one of whom was the woodland Native American Lenape (Le-náh-pay) who made conservative use of the Delaware River system to serve their needs for hundreds of years starting from about 1,400 years ago until the time that a new wave of settlers arrived from overseas (Webster, 1996). The Lenape called the river "Lenape Wihittuck" ("the river of the Lenape"), and they lived, fished, and farmed along its banks, using it wisely, mainly for food and water for their small farms of beans, corn, pumpkins, squash, and tobacco, among other things. However, that situation began to change for the worse in the 1600s when Europeans arrived on eastern American shores, and brought with them not only a greater number of settlers to the watershed, but also rapid industrialization and exploitation of this important resource. The Europeans called the river the "Delaware" and referred to the Lenape who lived along its banks as "the Delawares" (Bryant and Pennock, 1988).

Until colonial times, well-drained high ground, marshland, and extensive woodlands all made for a diverse river basin, and many of the current geographical areas in the watershed still bear their original Native American names, which indicated some aspect of the land's physiography or natural conditions. For example, "Kittatinny," a mountain in the northern part of the watershed, means "mighty mountain;" Cohocksink means "pinelands"; "Wissahickon" means "catfish"; "Passyunk", "a level place below hills"; and "Kingsessing" denotes a place where there is a bog (Toffey, 1982). Unlike their nomenclature, however, the Native Americans themselves disappeared due to westward migration relatively soon after European settlement and subsequent domination of the river, beginning in 1623 with the Dutch, who established a trading post at Fort Nassau near present day Gloucester, New Jersey, and a whaling colony near Lewes, Delaware in 1631, which was destroyed by Native Americans in 1632. They were followed by the Swedes, who settled at what is now Wilmington, Delaware in 1638, and then the Finns.

After Henry Hudson's brief initial stay in 1609 on the Delaware Bay (named in 1610 by English Captain Samuel Argall after Thomas West, Lord De La Warr, the governor of the Virginia colony [Bryant and Pennock, 1988]), the Scandinavian settlers sailed in through the bay area and also established villages in Lewes and New Castle (formerly Fort Casimir) in Delaware; Salem and Greenwich in New Jersey; and Upland (now Chester) in Pennsylvania (Roberts). They controlled the region until about 1663, when the English took control of the Delaware Estuary. Shortly thereafter, development and urbanization in the region began in earnest, particularly in the Philadelphia area following the city's founding by William Penn in 1682.

1.2.2.2 Industrialization

The Delaware Estuary area was a prime choice for colonial settlement since it naturally lent itself to the establishment and success of a new civilization. Opportunities abounded for fishing, transportation, and trade, and soon the new European settlements in the region were connected to the rest of the world through the development of the port city of Philadelphia, an area of high, dry land conveniently bordered by the Schuylkill River on the left and the Delaware on the right. Colonists wasted no time clearing the woodland and filling in much of the wetlands to make way for homes and farms and to procure fuel. Through the use of dikes, dams, and grading of the land, former marshes were soon transformed into fertile farming ground, and throughout the 1700s agriculture was one of the foremost industries in the region, in addition to commerce and trade. Increasing numbers of European immigrants provided plenty of hands to work the land, and Philadelphia thus grew into a major commercial city, which soon became the nation's core of shipbuilding and world's largest freshwater port.

By the 1770s, the Delaware Estuary region, from the bay area up to present-day Trenton, had become the locus of industry in America. An abundance of the necessary resources: coal, iron, water, and wood, drove industrial production (Heritage Conservancy,), and the economy of the area gradually shifted from predominantly agricultural to a more manufacturing-based system. In addition to tanneries, glass works, and brickyards, soon leather, lumber, paper, textile, and coal mills popped up along the river and spewed their waste into its waters. Anthracite coal was abundant in the eastern section of the watershed, especially in Pennsylvania between the Delaware and Susquehanna rivers in Lehigh, Schuylkill, and Wyoming Counties (Rhone, 1902) where the majority of the nation's 7 billion tons of anthracite coal is located. (DEP, http://www.dep.state.pa.us/dep/deputate/enved/go_with_inspector/coalmine/Anth racite_Coal_Mining.htm). Coal was also discovered at the headwaters of the Schuylkill in the late 1700s. Besides being a valuable fuel resource, the mines provided a number of jobs and a new economic backbone for the region. Consequently, many mining towns were established in these coal counties, staffed in large part by the European immigrants that were flooding into America at the time. The massive amounts of anthracite that these regions yielded contributed greatly to the economy of the colonies. In the 11 years between 1860 and 1871, approximately 300,000 acres of coal lands were bought or leased by the leading coal companies (DEP, http://www.dep.state.pa.us/dep/deputate/mines/reclaimpa/interestingfacts/A%20BRIEF%20HISTORY%20OF%20COAL%20MINING.html), and in 1914, employment in this industry peaked with about 181,000 men working the mines in Pennsylvania. Mining reached its hey day in 1917 when more than 100 million tons of coal were mined from the Wilkes-Barre/Scranton region (DEP, http://www.dep.state.pa.us/dep/deputate/enved/go_with_inspector/coalmine/Anthracite_Coal_Mining.htm).

The coal was shipped down canals on the Susquehanna and Schuylkill rivers, over land via wagons, or by rail on the Lehigh Valley Railroad to eastern markets in cities like Philadelphia for use in the rapidly developing iron and steel industries, as well as for the new trains, which required large amounts of fuel. The coal pier at Port Richmond on the Delaware is a current reminder of those days gone by. Pollution from past and present mining operations is another reminder of the significant amount of mining that was and still is carried out in this section of the watershed. Waste from the mines that was dumped or leaked into the rivers caused turbidity and contamination as sulfur from the rocks mixed with oxygen and water, making the water highly acidic. Over 2,400 of the 54,000 miles of streams in Pennsylvania have been polluted by acid mine drainage from mining operations since the 1700s. In fact, acid mine drainage (AMD) is the single largest source of water pollution in Pennsylvania, a problem the state has been combating since 1913, when Act 375 was passed in order to prohibit the discharge of anthracite coal, culm (fine particles of coal and clay), or refuse into streams. Since then, additional legislation has been necessary to protect water resources within the watershed (DEP, http://www.dep.state.pa.us/dep/deputate/enved/go_with_inspector/coalmine/Environmental_Laws.htm), and thirteen AMD treatment plants have been built throughout Pennsylvania (at a cost of $20.7 million) to treat AMD discharges.

However, AMD discharges were not the only pollution problem in the watershed. As the Industrial Revolution began to creep into the colonies at the beginning of the nineteenth century, the waterfront developed into a hotspot for manufacturing and shipping. The quick rate at which this development occurred and the pollution that resulted from such rapid residential and commercial growth stressed the limits of the river's resources. Problems soon developed as a result of the drastic changes the new settlers were making to the land and waterways within the watershed. The clearing of such great expanses of wooded areas left formerly tree-covered land open and vulnerable to erosion. Soil and sediment ran off into the rivers. Sewage from new farms to the mid-1800s, the colonists had buried their sewage in privies in their backyards, but when they realized burial posed a threat to public health, they began discharging it directly into the water by way of drains that carried the untreated waste from the inland areas (Toffey, 1982). These pollutants and the nutrients that washed from farmland changed the chemical balance of the river and adversely affected aquatic life and water quality. In addition, the filling in of wetlands and tidal flatlands for the construction of buildings significantly decreased the shoreline and polluted the wetlands, which also were often the dumping grounds for untreated sewage. Vital areas of shallow waters that had previously sustained diverse aquatic life and provided spawning ground for fish were lost to pollution and development. It is believed that only 500 of an estimated 7,000 acres of shallows that existed at the time of Philadelphia's founding were still viable three hundred years later in 1982 (Toffey, 1982).

The majority of the damage done to the river and shoreline was concentrated mainly within the heavily industrialized estuary region from Wilmington, DE north to the tidal waters at Trenton, NJ, especially near the major cities of Philadelphia and Trenton, which were the largest sources of pollution. The less-populated upper half of the watershed above Trenton, where agriculture was still the predominant economic activity and development proceeded more slowly, was not so severely affected.

As one English visitor to the Philadelphia harbor in 1769 succinctly put it, the Delaware Waterfront near Philadelphia was a "mess," a finding confirmed by the first pollution survey conducted in 1799, which found that pollution from ships, sewers, and contaminated wetlands was threatening the health of the river (Webster, 1996). Soon, the health of colonists themselves, who relied on the Delaware for drinking water, was also in jeopardy. Rivers polluted with human and industrial waste were held responsible for cholera outbreaks from tannery pollution in the 1700s, a vicious yellow fever epidemic that killed 10% of Philadelphia's population in one year alone in the 1790s, and outbreaks of typhoid in the 1890s that plagued urban areas in the watershed.

Pollution levels continued to increase as the Industrial Revolution reached full swing in the mid-1800s. Former fishing towns such as Fishtown, Kensington, and Richmond took on new roles as manufacturing centers, and more piers were built to ship coal, wood, and other goods from these coastal centers (Toffey, 1982). Small industrial mills on the waterfront morphed into large factories with greater discharges of waste. Coal, iron steel, gunpowder, and textile mills, shipbuilding factories, tanneries, and chemical industries, etc., all used and abused the Delaware River.

As a result of decades of continuous contamination, the health of the river rapidly deteriorated. By the end of the 1800s, the fisheries that had flourished in the early days of colonial settlement were hurting for business on account of over-fishing and the excessively polluted water that contained too little oxygen to support much aquatic life (Webster, 1996). In just over a century's time, the riverfront had changed from a predominantly wild, wooded area supported by a clean, healthy river teeming with life in pre-colonial times, to a farming and recreational area whose river supported the needs of new settlements throughout the 1700s, to a dangerously polluted hub of industrial manufacturing beginning in the early 1800s. In the estuary, contaminated water could not even sustain aquatic life and was no longer safe to drink, swim in, or even breathe near the river due to noxious odors from raw sewage that was dumped into it on a daily basis.

By the 1940s, World War II efforts kicked manufacturing into overdrive once again. It appeared that colonial industrialization efforts within the estuary region perhaps had not been justified by the damaging means it had taken to reach them. While the estuary was an industrial giant with a major world port in the metropolis of Philadelphia, the economic success of the estuarine colonies was a Pyrrhic victory for the region as a whole, on account of the heavy environmental cost. The land was stripped and stressed from years of clearing, poor farming practices (colonists did not know about crop rotation to maintain soil fertility), erosion and pollution. The sewage from residential and industrial waste depleted oxygen levels to an extreme that nearly drove fisheries out of business and left the rivers virtually dead. It is estimated that 85% of Philadelphia's untreated residential waste was discharged directly into the estuary in the 1940s (Marrazzo and Panzitta, 1984). As Christopher Roberts (Delaware River Basin Commission) explained it, "the lower Delaware had become an open sewer, spewing septic gases that tarnished ships' metalwork and sickened sailors (Roberts, 1989)." In this way, colonial waste disposal practices made what had once been a pristine, healthy, flowing life source into a stagnant, lifeless, noxious cesspool often referred to as the "black waters" during that time, a period that is recognized as the Delaware's darkest hour (Toffey, 1982).

Riverfront land suffered from industrialization and overuse as well. Factories and transportation thoroughfares had replaced trees and wild land, leaving the waterfront with little remaining open recreational space or aesthetic value. One such area in which these effects were felt particularly strongly was about 2-3 miles below the Fairmount Dam on the Schuylkill River, where even the few remaining large estates and the Gray's Ferry gardens were cleared away during the Industrial Revolution to accommodate more factories and railroads (Toffey, 1982).

1.2.2.3 Transportation

Contributing to the region's economic success and pollution in the early 1800s were the extensive transportation networks constructed during this time. Canals and railroads, which linked regional centers of agriculture and commerce, facilitated the widespread movement of people and products and played a large role in the population and economic growth of the region. Two major canals that contributed to the transformation of the watershed in eastern Pennsylvania were the Lehigh Canal and the Delaware Canal. The former was used to transport anthracite coal through the Lehigh River Valley from Mauch Chunk to Easton, PA; the latter moved coal, lumber, and agricultural products from Easton to Philadelphia and other East Coast markets. Linking the Delaware Valley to eastern New Jersey were the Delaware and Raritan Canal and the Morris Canal (Fulcomer and Corbett, 1981). Canals were especially influential along the Schuylkill River, whose waters were too fast and shallow to allow easy transportation prior to their construction.

The new water linkages were vital to inland travel and especially important in the shipment of coal from the Upper Schuylkill area and other mining regions farther north in the watershed downstream to Philadelphia. On March 15, 1784, the Legislature of Pennsylvania ratified an act that was "for the purpose of improving the navigation of the Schuylkill (river) so as to make it passable at all times, enabling the inhabitants to bring their produce to market, furnishing the county adjoining the same and the City of Philadelphia with coal, masts, boards," etc. (DEP, http://www.dep.state.pa.us/dep/deputate/enved/go_with_inspector/coalmine/anthracite.htm). Unfortunately, canals were also instrumental in carrying pollution from outlying areas, particularly from coal mines, downstream into the rivers. Besides polluting drinking water, the millions of tons of culm that were dumped or leaked from the mines ruined fish habitats, backed up behind dams, and reduced the ability of the rivers to manage stormwater (Toffey, 1982).

The speed of railroads, which were introduced in the early 1800s, made them a more convenient form of transportation, which was responsible for driving much of the urban development in the watershed, and by the 1930s, the canal system was virtually obsolete. Some canals were filled in to make roads, while others simply fell into disuse, later to become landmarks and state park attractions (Heritage Conservancy). Although trains continued to be used for the transportation of agricultural products, by the 1840s the rail lines were also heavily relied upon for industrial purposes: to move raw materials to factories and finished manufactured goods to markets and ports. In fact, many rail terminals were built right up to the Delaware River to hasten exportation. Initially, such easy access to the riverfront brought more residents into contact with the area, where they sought various forms of recreation such as walks along the waterfront. However, much of the waterfront's recreational value was lost as it became more industrialized and polluted, and the rails then provided a means of escape from the busy area's smoke-spewing factories and foul-smelling river. Trains, and later streetcars and improved roads, took people farther inland away from the waterfront "mess," and contributed to the growth of Philadelphia's suburbs.

1.2.2.4 Water Supply

Inhabitants of the Delaware River Basin get their water from surface and ground sources, depending on where they live within the watershed. Urban areas make use of the rivers near which they were founded, while suburban and rural regions rely more on groundwater from regional wells. Eighty percent of the water systems in the U.S. tap a ground water source for their water supply, with 10-20% of people using their own private wells for drinking water. However, the majority of the American population (66%) is served by a surface water system (EPA, http://www.epa.gov/safewater/faq/faq.html#source). In the Delaware River Basin, 88% percent of the total amount of water withdrawals is taken from surface water supplies, whereas 12% comes from groundwater sources (based on 1991 and 1993 data, DRBC, http://www.state.nj.us/drbc/gwsw93.htm). Surface sources supply 60% of the water that is used consumptively, with the remaining 40% coming from groundwater stores (USGS NAWQA, 1999). Consumptive water use, as defined by the DRBC is: "that part of water withdrawn which is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment…not available for other valuable purposes such as public water supply, salinity repulsion in the Delaware estuary, maintenance of streamflows, water quality, fisheries and recreation (http://www.state.nj.us/drbc/consdef.htm) as opposed to water that is used non-consumptively, which is returned to the basin's rivers and streams by means of point sources.

Delaware River Basin Consumptive Use

Table 1.2.2-1 Estimated and Projected In-Basin 122-Day Average (June – September) Million Gallons per Day (MGD)

Category	1991	2000	2010	2020
Municipal	203.4	228	255	284
Rural	27.1	30	32	36
Industrial	46.8	52	56	61
Power	78.1	77	87	99
Agricultural Irrigation	144.7	154	161	169
Golf Irrigation	12.8	13	14	15
Institutions	4.2	5	5	5
Livestock	12.4	12	12	12
Ski Areas	0.0	0	0	0
TOTAL	**529.5**	**571**	**622**	**681**

Table 1.2.2-2 Estimated and Projected In-Basin Average Annual Consumptive Use (MGD)

Category	1991	2000	2010	2020
Municipal	114.0	128	143	159
Rural	15.2	17	18	20
Industrial	41.5	46	50	54
Power	69.8	69	78	88
Agricultural Irrigation	51.9	55	58	60
Golf Irrigation	5.9	6	6	7
Institutions	4.1	4	5	5
Livestock	7.2	7	7	7
Ski Areas	1.2	1	1	1
TOTAL	**310.8**	**333**	**366**	**401**

Table 1.2.2-3 Estimated and Projected Average Annual Exports and Imports of Water (MGD)

Category	1991	2000	2010	2020
Export	796.8	907	910	910
Import	32.1	42	42	42

Table 1.2.2-4 Total of In-Basin Average Annual Depletive Use Plus Net Exports of Water (MGD)

Category	1991	2000	2010	2020
Total Net MGD	1,076	1,199	1,235	1,270

Source: Delaware River Basin Commission, http://www.state.nj.us/drbc/tableii6.txt

The estimated total amount of water used each day in the watershed in 1991 was 7,337 MGD according to the DRBC (USGS NAWQA, 1999). The majority (69%) of that was used to generate power in New Jersey, and most of the remaining water was used by the public (15%) and industry (15%). Most of that water is used non-consumptively, meaning it is returned to the basin's streams and aquifers, with the exception of about 311 MGD in consumptive uses within the basin and 900 MGD that are diverted out of the basin to New York City and northeastern New Jersey (USGS NAWQA, 1999). PSE&G in Salem, NJ is the largest of all surface water users within the watershed, taking roughly 1,983 MGD (DRBC, http://www.state.nj.us/drbc/top10wd.txt). The Philadelphia Water Department (PWD), which takes about 361 MGD from both the Delaware River (~50%) and the Schuylkill River (~50%), is the largest municipal user. (See Table 1.2.2-5).

Table 1.2.2 -5 Top Ten Water Users in the Delaware River Basin

Rank	Name	MGD Withdrawal	MGD Depletive	County
Pennsylvania				
1	PECO-Eddystone	541.957	1.528	DELAWARE
2	Philadelphia Water Department	361.109	36.111	PHILADELPHIA
3	Metropolitan Edison-Portland	257.575	1.097	NORTHAMPTON
4	PECO-Delaware	180.626	0.090	PHILADELPHIA
5	Bethlehem Steel	156.246	2.871	NORTHAMPTON
6	PECO-Cromby	146.257	0.622	CHESTER
7	PP&L-Martins Creek	97.589	2.533	NORTHAMPTON
8	Philadelphia Surburban WCo	84.580	10.941	MONTGOMERY
9	BP Oil Corp	82.542	0.989	DELAWARE
10	USX Corp, Fairless	43.584	2.179	BUCKS
New Jersey				
1	PSEG-Salem	1,982.959	11.621	SALEM
2	PSEG-Mercer	492.778	2.870	MERCER
3	Atlantic City Electric-Deepwater	127.362	0.344	SALEM
4	NJ Water Supply Auth-D&R Canal Export	85.423	51.254	HUNTERDON
5	EI DuPont-Chambers	67.605	0.822	SALEM
6	US Silica Co-Dewatering	52.172	0.072	CUMBERLAND
7	PSEG-Hope Creek	50.935	12.775	SALEM
8	EI DuPont-Repauno	37.715	0.041	GLOUCESTER
9	Trenton Water Works	30.387	3.039	MERCER
10	NJ American Water Co-Haddon	22.900	2.290	CAMDEN
Delaware				
1	Delmarva P&L-Edgemoor	487.931	1.968	NEW CASTLE
2	Star Enterprise	321.410	6.861	NEW CASTLE
3	Wilmington City	28.786	2.879	NEW CASTLE
4	General Chemical	23.155	0.741	NEW CASTLE
5	United Water Delaware	22.955	3.443	NEW CASTLE
6	Artesian Water Co	9.384	0.939	NEW CASTLE
7	EI DuPont-Edgemoor	6.400	0.807	NEW CASTLE
8	SPI Polyols	6.072	0.160	NEW CASTLE
9	Dover City	5.128	0.513	KENT
10	NVF Co, Yorklyn	2.226	0.040	NEW CASTLE
New York				
1	NYC Diversion	700.071	700.071	DELAWARE
2	Port Jervis City	1.665	0.167	ORANGE
3	Monticello Village	1.264	0.126	SULLIVAN
4	South Fallsburg Water District	1.172	0.117	SULLIVAN
5	Kraft Foods	0.883	0.088	DELAWARE
6	Liberty Village	0.751	0.075	SULLIVAN
7	Walton Village	0.633	0.063	DELAWARE
8	Hancock Village	0.573	0.057	DELAWARE
9	Lake Louise Marie	0.422	0.042	SULLIVAN
10	Deposit Village	0.409	0.041	BROOME

Source: Delaware River Basin Commission, http://www.state.nj.us/drbc/top10wd.txt

1.2.2.5 Historical Improvements in Source Water Quality

Although the Delaware River has been utilized for thousands of years, the quality of the water source began decreasing rapidly from the time of initial European settlement in the early 17th century until corrective, preventative, and protective measures were taken beginning in the 20th century. The river's pollution problem developed from abuse and overuse over time, especially in the heavily populated and industrialized estuary region of the Lower Delaware River, into which colonists dumped their domestic, agricultural, and industrial waste. Additionally, contaminants from buried waste leaked into groundwater supplies over the years.

The majority of early colonial Philadelphia's water supply came from wells until the end of the 18th century, when a yellow fever epidemic hit the city in 1793. In 1798, it was discovered that cesspools of buried waste, which were too close to the city's water supplies, were contaminating groundwater. Waste was then dumped into canals, which carried it into the rivers. Lacking wastewater treatment technology and the foresight to predict the problems that would result from their actions, colonists continually dumped millions of tons of raw sewage into the streams and rivers, which increased contaminant and nutrient levels and decreased the pH and dissolved oxygen (DO) in the waters. Thus, their actions adversely affected aquatic life and water quality. Corrective measures to improve the quality of drinking water were undertaken at the beginning of the 19th century. However, preventative measures regarding protecting the quality of the rivers and streams as resources were not initiated until later.

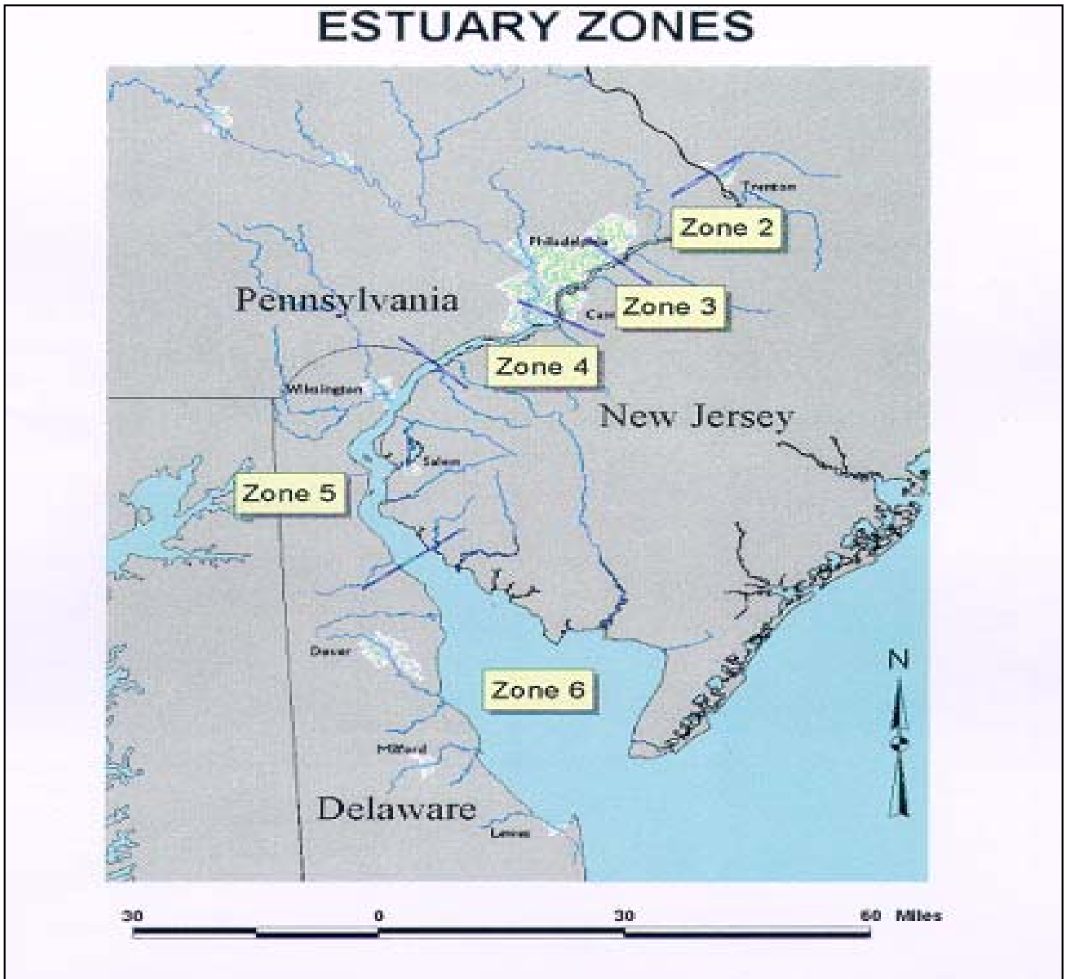
As one of the earliest, most significant, and most polluted areas in the watershed, the City of Philadelphia provides an interesting case study on water quality improvement for drinking purposes. In 1801, Philadelphia began pumping untreated water from the Schuylkill River to supply the city's residents with a reliable source of drinking water. The only primitive form of purification that the water received in the early 1800s was settlement in still reservoirs in order to remove debris. However, as the city became more populated and industrialized, increasing pollution in the rivers led to problems that could not be settled out: odors, tastes and typhoid. Filtration over sand beds was the next step. An 1899 report that resulted from seven studies made between 1858 and 1899 on water sources and treatment led to the construction of 5 "slow sand" filtration treatment plants between 1902 and 1911. Water was first sent through pre-filters of coke or sponge, then it passed over sand beds, and eventually settled in raw water basins. The new filtration system cut the typhoid death rate in the city by one- fourth. Shortly after chlorine treatment was initiated in 1913, typhoid was eradicated.

In order to remove the odors and tastes that were still problematic in Philadelphia's otherwise safe drinking water, chemical treatments with carbon, ozone, and chlorine dioxide were also necessary in the 1940s and early 1950s when Philadelphia's rivers were for all intents and purposes, "open sewers". Despite its pollution crisis, the city developed a successful method for treating river water in order to make it drinkable. Philadelphia continued paving the way in water purification when in 1976 it became the first city in the country to build a plant to research the best ways of removing trace organics, odors, and tastes from drinking water (City of Philadelphia, 1989).

In the 1920s, Philadelphia and Trenton, two of the biggest sources of pollution on the river, both made individual attempts to clean up their wastewater acts by building a wastewater treatment plant in their respective cities in order to cleanse city sewage of most of its harmful components before returning the water to the Delaware River. It was not until after WWII, (during which water quality improvement initiatives were put on hold) that two more regional wastewater treatment plants were built in Philadelphia: the Southwest Plant in 1954, and the Southeast Plant in 1955. However, the first concerted basin-wide efforts to make sustainable improvements in the quality of the watershed's source water resources were not officially implemented until the Interstate Commission on the Delaware River Basin (INCODEL) was founded in 1936. INCODEL, whose members consisted of the four basin states Delaware, New Jersey, New York, and Pennsylvania, was primarily organized as an advisory committee in order to develop solutions to the water pollution problem within the basin and to strategize about how to deal with concerns regarding increasing population and industrial development, which would affect the watershed in the near future. To that end, INCODEL soon expanded its focus to include conservation, water supply, and other issues facing the Delaware River Basin (Delaware Public Archives, http://www.state.de.us/sos/dpa/collections/aghist/0903.htm).

INCODEL's most significant accomplishments include dividing the Delaware River into six water "zones" for monitoring purposes (See Figure 1.2.2-1), establishing water quality standards for those zones, and upgrading sewage treatment plants. According to the Council on Environmental Quality (1975), the number of communities with "adequate" sewage collection and treatment plants increased from 20 to 75% under INCODEL (Marrazzo & Panzitta, 1984). However, this pioneer river management organization had no legal authority to enforce its recommendations, and for this reason, a new organization was necessary in order to enforce water quality initiatives and regulations **(**Roberts). As a result of the signing of the Delaware River Basin Compact in 1961, INCODEL morphed into the present watershed guardian, the Delaware River Basin Commission (DRBC), a revamped group with an expanded vision for protecting the watershed and its resources and with the legal power it needed to enforce its regulations. The chief members of the DRBC are the governors of the four basin states (NY, PA, NJ, and DE), and a federal representative appointed by the President of the United States. Prior to the formation of the DRBC, it took 43 state, 14 interstate, and 19 federal agencies to monitor the basin (DRBC, http://www.state.nj.us/drbc/over.htm). Under this new, unified and more efficient Delaware River Basin Commission authority, the first of its kind in its unique collaboration between State and Federal water management officials, many improvements have been made in the quality of the basin's water resources over the last four decades.

Figure 1.2.2-1 Estuary Zones



Source:: Delaware River Basin Commission

Shortly after taking over the duties of INCODEL, the DRBC took part in a $1.2 million Delaware clean-up program. In 1967, the DRBC began water quality studies and set higher water quality standards based on a computer model that determined the Delaware's waste assimilative capacity. The model led to a DRBC mandate for an 88% reduction in oxygen-demanding waste (BOD) for 90 major dischargers to be accomplished through new wasteload allocations. In addition, water pollution control programs in the 1960s also required the construction of secondary wastewater treatment facilities at more than 90 discharge sites in the estuary (Roberts, and Marrazzo and Panzitta, 1984).

Perhaps the most influential piece of legislation to date is the Clean Water Act of 1972, the nation's first water resource protection legislation. Originally passed as the Federal Water Pollution Control Act in 1948 (Chapter 758; PL 845), the goal was to improve the condition of ground and surface waters by eliminating or reducing pollution in interstate water bodies. Amended in 1972 and referred to as the Clean Water Act (CWA), this law has since been expanded over the years to include many other water quality programs that have contributed to the continuous improvements in the quality of the nation's water. The Clean Water Act is responsible for the implementation of secondary treatment in municipal wastewater treatment plants (City of Philadelphia Water Department, http://170.115.80.16/water/protect.html) and the institution of water quality standards, discharge limitations, and permits (U.S. Department of the Interior, Bureau of Reclamation, http://www.usbr.gov/laws/cleanwat.html).

The act also established the Total Maximum Daily Load (TMDL) program, which affects more than 20,000 river segments, lakes, and estuaries, and attempts to limit excessive discharges of pollution in our water supplies. According to the EPA, a TMDL is "the amount of pollutants that may be present in the water and still meet water quality standards" (EPA, http://gwpc.site.net/news/nws-epa_impaired_waters_rule.htm). A TMDL takes into account such pollutants as fecal coliform, sediment, nutrients, shellfish, organics, metals, pH, and other materials that decrease dissolved oxygen (Water Online, http://www.wateronline.com/content/news/article.asp?docid={14DA2CA3-12C0-11D5-A770-00D0B7694F32}&VNETCOOKIE=NO).

The nation's water systems, and we as users, are daily reaping the benefits of the Clean Water Act and its subsequent amendments. The fruits of these legislative labors have been noted in the Delaware since the beginning of the DRBC's clean-up efforts in the 1960s. To this day there has been a reported 76% decrease in the amount of BOD discharged into the Delaware Estuary (DRBC, 2002) and DO levels have steadily increased in vulnerable zones of the river since 1965, particularly in the heavily industrialized estuary area. (Krejmas, Harkness, and Carswell, Jr., 2000, The Report of the River Master of the Delaware River for the period Dec.1, 1997--Nov.30, 1998, p. 78). As a result, many fish populations that had nearly disappeared before pollution abatement efforts were made have since reappeared in greater numbers (i.e. herring, shad, sturgeon, and other anadromous fish).

Since the CWA, other legislative efforts have been made to improve the quality of water in the Delaware River Basin as we continue to recognize the importance of water quality control. Recent legislation includes protective measures for both our surface and groundwater resources as sources of our drinking water, as well as quality control for treatment plants. In April of 2000, the EPA announced that as part of the new amendments to the Safe Drinking Water Act signed by President Clinton in 1996, a new law will require states to survey the sources of all drinking water systems, including publicly-used groundwater systems, that may be vulnerable to contamination in order to preserve water quality by protecting groundwater supplies from *E. coli* and other disease-causing viruses and bacteria. Currently, only contaminated surface water systems require corrective measures, such as disinfection, to be taken, but the new law will mandate similar actions for contaminated groundwater supplies, as well as alterations to defective supply systems (EPA, http://gwpc.site.net/News/nws-EPAgwsourceprot.htm).

In May of 2001 the EPA issued the Filter Backwash Recycling Rule (FBRR), as required by the Safe Drinking Water Act, in order to reduce microbial contamination by pathogens such as *Cryptosporidium* in drinking water supplies. The FBRR, which is estimated to affect 35 million people, puts an end to the filter "backwashing" that routinely takes place in many drinking water treatment plants that clean filters by pumping water backwards through them to remove particulates, a process that increases the risk of contamination because the backwash water is often recycled back into the plant containing high levels of microbes (EPA, http://gwpc.site.net/news/nws-epa_issues_drinking_water_rule.htm and EPA, http://gwpc.site.net/news/nws-epa_administrator_whitman_further_prot_drinking_water.htm).

In addition, the EPA is still trying to make headway in the fight against acid mine drainage damage to our waterways. Pennsylvania and the Federal government has spent almost $500 million since 1967 to remedy pollution from abandoned surface and deep mines, but more than $15 billion worth of cleanup work still needs to be completed. AMD is still a problem in Pond Creek and Sandy Run Creek in the Lehigh River Basin (central Delaware River Basin). These cleanup efforts are funded by a 35 cent per ton federal fee on coal being mined today, state reclamation funds from fees, and forfeited reclamation bonds (DEP, http://www.dep.state.pa.us/dep/deputate/enved/go_with_inspector/coalmine/Coal_Mining_in_Pennsylvania.htm). In April of 2000, the EPA proposed changes to current discharge guidelines for mines, which would increase the rate at which abandoned mines are reclaimed, thereby using the leftover coal while improving water quality by decreasing the risk of contamination to water sources (Ground Water Protection Council, http://gwpc.site.net/news/nws-july30-01.htm). These new guidelines would be a crucial protective step in the prevention of more AMD damage to watershed waterways, because although there was a sharp decrease in anthracite production after World War II, mining has increased more than 150 percent since 1990 due to new uses of coal in cogeneration, industrial and residential heating, and as a source of fuel for electric power plants.

Presently, anthracite is mined in eight Pennsylvania counties: Schuylkill, Carbon, Luzerne, Northumberland, Lackawanna, Columbia, Dauphin and Sullivan (ranked in order of production), and Pennsylvania is the fourth largest coal-producing state in the United States after Wyoming, West Virginia and Kentucky. More than $1.5 billion in coal sales are responsible for about one percent of the gross state economic product of Pennsylvania. Keeping in mind that mining efforts continue in these areas to this day, it is important that efforts be made to curb pollution from these operations in order to preserve the health of our waterways (DEP, http://www.dep.state.pa.us/dep/deputate/enved/go_with_inspector/coalmine/Anthracite_Coal_Mining.htm).

While it is not anywhere near as pristine as it was in pre-colonial days, water quality in the Delaware River today is the best it has been in over 100 years due to ongoing pollution control, prevention programs and legislation, which were initiated by the DRBC in the 1960s and are carried on today by the DRBC, the EPA, and associated organizations. As a whole, the river exceeds current standards, with the exceptions of seasonal violations of DO and fecal coliform levels in the estuary area, as well as toxic contaminants and nutrient loading alerts, which often result in fish advisories for certain affected sections of the river. However, the tremendous improvement that has been made since the Delaware River's darkest days represents the priority that has been placed on improving and preserving our water resources in the last four decades. The time and effort that will be invested in protecting and bettering the watershed in the future will continue this trend of improvement.

1.2.3 Physiography, Topography, and Soils

Key Points

- **The Delaware River Watershed is composed of a number of smaller subwatersheds, the most notable of which include: the Lehigh River, Crosswicks Creek, Musconetcong River, Rancocas Creek, Neshaminy Creek, and Tohickon Creek watersheds.**
- **The watershed is also divided into five physiographic provinces, each with its own unique geology, groundwater, and soil composition. From north to south, the five provinces are: the Appalachian Plateau, the Valley and Ridge, the New England Upland, the Piedmont, and the Atlantic Coastal Plain.**
- **In 1999, after it was discovered that development was adversely affecting groundwater levels in certain areas, the Delaware River Basin Commission adopted regulations that established groundwater withdrawal limits for 76 watersheds that are within, or partly within, the Groundwater Protected Area of Southeastern Pennsylvania, in order to protect this important resource.**

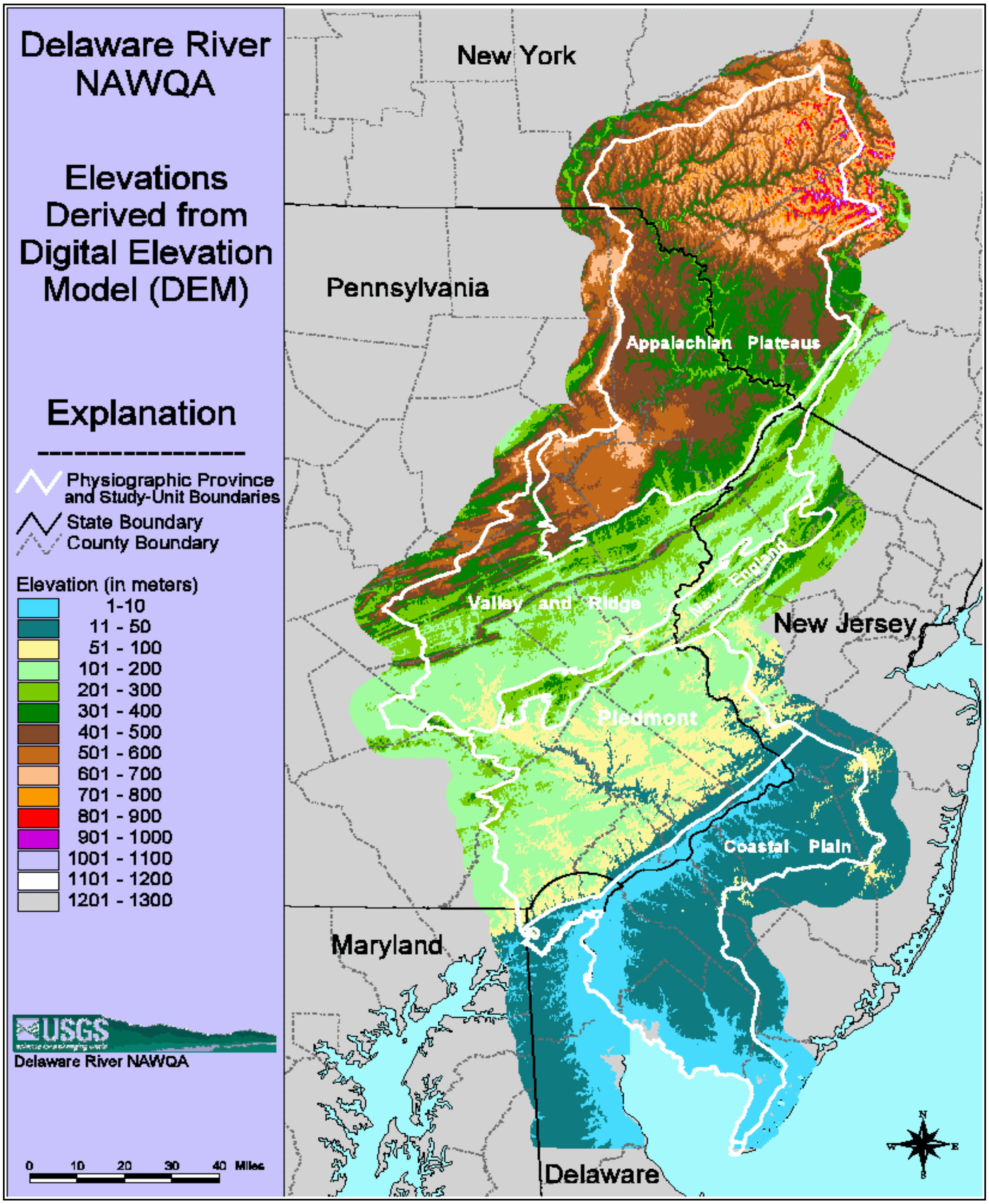
1.2.3.1 Physiography and Topography

The Delaware River Watershed covers a variety of physiographically distinct regional provinces. A physiographic province is an area of land that is composed of a particular type(s) of rock as a result of having undergone certain environmental processes over time which distinguish it from other surrounding areas. Each province is distinguishable by its physical landforms, unique rock formations, and groundwater characteristics.

From north to south, the five physiographical provinces in the Delaware Watershed are: the Appalachian Plateau, the Valley and Ridge, the New England Upland, the Piedmont, and the Atlantic Coastal Plain. (See Figure 1.2.3-1)

Elevations of the Appalachian Plateau generally range from about 300 – 700 meters throughout the area, (roughly 980 – 2,300 feet) with some peaks in New York reaching over 900 meters (3,100 feet) above sea level. The Plateau contains relatively straight valleys with irregular ridges and stretches across the northeastern part of Pennsylvania into New York. The Valley and Ridge Province is comprised of the mountains in the Appalachian Mountain section and rolling farmlands in the Great Valley. Elevations in the Valley and Ridge Province range up to 550 meters (1,800) feet above mean sea level (msl). The New England Upland Province is a very narrow area separating the Valley and Ridge Province and the Piedmont Region in both eastern Pennsylvania and western New Jersey. The New England Province includes the Reading Prong, which is composed of the small mountains east of Reading. The Triassic Lowland of the Piedmont Province is characterized by rich farmland and low rolling hills, whereas the Piedmont Uplands include steep hills with urban development. The rolling hills of the Piedmont Province reach about 150 meters (500 feet) above mean sea level (msl). The Atlantic Coastal Plain Province is mainly lowlands with numerous streams and marshlands at about 30 meters (100 feet) above msl.

Figure 1.2.3-1 Physiographic Provinces and Elevations of the Delaware River Watershed



Source: USGS NAWQA Study

1.2.3.2 Subwatershed Physical Settings

Within the larger Delaware River Watershed, there are a number of smaller subwatersheds that drain the lands surrounding the Delaware's 216 tributaries. Outlined below are some of the major subwatersheds enveloped within the 13,539 square mile Delaware River Watershed, including the Lehigh River, Crosswicks Creek, Musconetcong River, Rancocas Creek, Neshaminy Creek, and Tohickon Creek Watersheds, as well as some of the upper subwatersheds and the tidal areas of the lower subwatershed. These are shown in Figure 1.2.3-2.

Upper Delaware Watershed
The Upper Delaware Watershed is home to the headwaters of the Delaware River at the Cannonsville Reservoir. The West Branch Delaware gets its start in Schoharie County, New York, where it travels down through Delaware County and converges with the East Branch Delaware River along the Pennsylvania - New York border near Hancock, New York. The watershed extends further down the Delaware covering parts of both Wayne County, Pennsylvania and Sullivan County, New York and finally ends with a small piece of northern Pike County, Pennsylvania. The watershed is contained in the Appalachian Plateau Province.

East Branch Delaware Watershed
The East Branch Delaware River Watershed is the only subwatershed located completely in New York. The watershed drains 837 square miles of parts of four different counties. The East Branch Delaware River is home to the Pepacton Reservoir, which is the largest reservoir in the Delaware River Watershed with a surface area of about 10 square miles and a capacity of almost 150 billion gallons of water.

Lackawaxen River Watershed
The Lackawaxen River headwaters are located in northeastern Wayne County, Pennsylvania. The river stretches 27 miles before draining into the Delaware River at Lackawaxen, PA along the Pennsylvania - New York border. Contained solely in Pennsylvania, the watershed covers an area of 596 square miles of Wayne and Pike Counties.

Mongaup Creek Watershed
The Mongaup Creek Watershed covers an area of 1.5 square miles and is located in parts of Pennsylvania, New Jersey, and New York. The watershed encompasses the Bushkill, Brodhead, McMichael, and Basher Kill Creeks, and the Neversink River. As the second largest subwatershed in the Delaware River Basin, its reaches include Sullivan, Ulster, and Orange Counties in New York, Pike, and Monroe Counties in Pennsylvania, and Sussex, and Warren Counties in New Jersey.

Lehigh River Watershed
The Lehigh River Watershed covers 1,360 square miles, and the 107-mile Lehigh River itself serves as a geopolitical boundary between many of the eastern Pennsylvania counties through which it travels. These counties include Berks, Wayne, Lackawanna, Monroe, Luzerne, Carbon, Lehigh, and Northampton. The Lehigh River originates with

a series of glacial bogs and marshes in the area of Pocono Peak Lake, where elevation peaks at 2,100 feet above sea level, near the town of Gouldsboro. During the course of the river's 103-mile journey to its confluence with the Delaware River in Easton, the elevation drops nearly 1,900 feet. Throughout the 17th and 18th centuries, the Lehigh River was referred to as the "West Branch" of the Delaware River. The area of confluence with the Delaware River was called the "Forks of the Delaware." The name "Lehigh" is actually the anglicized version of the Lenni Lenape Indian word "Lechewuekink" which means, "where there are forks."

The Lehigh River played an integral role in the industrialization of the surrounding region. A 72-mile canal system was developed between 1827 and 1829 in order to capitalize on the proximity of the Lehigh River to Eastern Pennsylvania's natural resources, such as coal, and bringing these resources to the marketplaces downstream. After 1934, the canal system, formally known as the Lehigh Navigation Canal System, became part of a larger system of canals including the Morris Canal, which linked the Lehigh River to New York Harbor, and the Delaware Canal, which in turn linked the river to Philadelphia. In 1855, the peak year of its operation, the Lehigh Navigation Canal System carried over 1,000,000 tons of anthracite coal from Carbon County to Easton, Pennsylvania. The vast white pine forest that lined the banks of the upper Lehigh River aided in making Pennsylvania the greatest lumber-producing state in the 1860s. These historic banks of the Lehigh later became the heart of America's iron industry, considering that between 1850 and 1880, approximately one-fourth of America's annual iron production took place there (LEO and the SERVIT Group, <http://www.leo.lehigh.edu/envirosci/watershed/fastfacts.html>, Wildlands Conservancy, <http://www.wildlandspa.org/programs/rivers/lehigh/lehigh_home.html>, and Greenworks Productions,< http://www.greenworks.tv/sojourn/lehigh.htm>).

Middle Delaware Watershed

The Middle Delaware Watershed is primarily located in New Jersey and can be seen as the area between McMichael Creek and Tohickon Creek. The watershed drains an area of 990 square miles and is contained partially within Sussex, Warren, and Hunterdon Counties in New Jersey and Northampton and Bucks Counties in Pennsylvania. The two main tributaries that drain into the Delaware River in this watershed are the Musconetcong and Pohatcong Rivers. The Lehigh River Watershed also drains into the Delaware in the Middle Delaware Watershed, but is not considered to be part of the Middle Delaware Watershed. The largest tributary within this watershed is the Musconetcong River. The Musconetcong River, which joins the Delaware in Rieglesville, is 44 miles in length and flows past state parks, forests, towns, historic villages, vital industries, and one of New Jersey's most scenic agricultural valleys. The Musconetcong River Watershed is a 157.6 square mile area of land that drains to the Musconetcong River. This watershed includes portions of Hunterdon, Morris, Warren, and Sussex Counties as well as all or parts of 25 municipalities. The largest tributary stream to the Musconetcong River is Lubbers Run . http://www.musconetcong.homestead.com/surf~ns4.html).

Tohickon Creek Watershed
The Tohickon Creek Watershed, located in southeastern Pennsylvania, spans 112 square miles and encompasses portions of Bedminster, East Rockhill, Haycock, Hilltown, Milford, Nockamixon, Plumstead, Richland, Springfield, Tinicum, and West Rockhill Townships in Bucks County, Pennsylvania. Included within its borders are the Boroughs of Dublin, Perkasie, Richlandtown, Trumbauersville, and Quakertown. Named by the Lene Lenape Indians to mean "Deer-Bone-Creek," the Tohickon Creek runs from the Nockamixon Dam to its confluence with the Delaware River some eight miles downstream. Historically, the Creek is known for providing shelter to the Doan Gang, who were famous for a string of Bucks County robberies in the 1780s and hid in a small house made of logs along the Tohickon Creek on the Plumstead side while fearing their capture (New Hope, PA, http://www.newhopepa.com/DelawareRiver/tohickon_index.htm, and DEP, http://www.dep.state.pa.us/hosting/efp2/reports/SERO/team14/14%20Draft%202D%20Delaware%20River%20Tohickon%20Creek%20061101.pdf).

Neshaminy Creek Watershed
The Neshaminy Creek Watershed occupies an area of 233 square miles, 86% of which is located in central and lower Bucks County, with the remaining 14% in Montgomery County, both of which are located in Pennsylvania. The northern portion of the watershed lies in the uplands of the Piedmont Province, while the southern portion lies in the lowlands of the Coastal Plain. These two geologic regions are separated by the dramatic Fall Line, which sharply rises to a height of 200 feet. The Neshaminy Creek is 50 creek miles in length and flows approximately 50 miles in a southeasterly direction to its confluence with the Delaware River. The headwaters of the Neshaminy Creek flow from its West Branch (in the Lansdale/Hatfield Area) to its North Branch (Northeast of Doylestown). Topographically, the watershed is predominantly rolling hills and steep-sided stream valleys. Ten impoundments lining the Neshaminy and its tributaries provide public water, recreation, and flood protection for the region.

In terms of land use, some portions of the upper watershed are still rural or semi-rural in nature. Very few, small and scattered, forested areas still exist. The headwaters of the West Branch, the Little Neshaminy, and the southern portion of the watershed are highly developed, which contributes to an increase in the amount of development in the watershed. The municipalities encompassed within the watershed region are Bensalem Township, Bristol Township, Buckingham Township, Chalfont, Doylestown, Doylestown Township, Hatfield, Hulmeville, Ivyland, Langhorne, Langhorne Manor, Lansdale, Lower Southampton Township, Middletown Township, New Britain, New Britain Township, Newtown, Newtown Township, Northampton, Penndel, Plumstead Township, Upper Southampton Township, Warminster Township, Warwick Township, and Wrightstown Township (The Delaware Riverkeeper Network, http://delawareriverkeeper.org/factsheets/neshaminy.html).

Tidal PA Bucks Watershed

The smallest of all the Delaware River Subwatersheds is the Tidal PA Bucks Watershed. Located in the southeast corner of Bucks County, Pennsylvania, it drains 57 square miles of land. The watershed contains only three, second-order tributaries, the longest being Mill Creek.

Tidal PA Philadelphia Watershed

The Tidal PA Philadelphia Watershed drains 152 square miles of land in parts of Philadelphia, Montgomery, and Bucks Counties in Pennsylvania. The area splits the geologic border of the Piedmont Region and the Atlantic Coastal Plain Region. These two distinct regions are separated by a jagged boundary where Coastal Plain sediments have lapped onto the Piedmont crystalline rocks. Located with in this watershed are three second order tributaries that drain directly into the Delaware River, namely, the Poquessing, Pennypack, and Tacony Creeks.

NJ Mercer Direct

The NJ Mercer Direct Watershed is directly across the Delaware River from the PA Bucks Direct Watershed entirely located in New Jersey. Starting in Lower Hunterdon County, New Jersey, the watershed then stretches across Mercer County and into Monmouth County. The total drainage area of this watershed is 155 square miles. The watershed contains 10 short (1.5 – 13.5 miles in length) second-order tributaries that drain directly into the Delaware River.

PA Bucks Direct Watershed

The PA Bucks Direct Watershed is contained entirely within Bucks County and contains the many small tributaries that drain directly into the Delaware River. The 83 square mile drainage area holds 14 Major Tributaries, the four longest being the Paunnacussing, Pidock, Jericho, and Houghs Creeks. The watershed is located in the Gettysburg-Newark Lowland section of the Piedmont Province. This section is characterized by red sedimentary rocks such as sandstone, siltstone, shales, and conglomerates, and average elevations between 450 – 550 feet.

Crosswicks Creek Watershed

The headwaters of the Crosswicks Creek flow from the Fort Dix and McGuire Air Force Military Reserves in New Jersey in a northwesterly direction and then turn sharply south. It is at this point, in the City of Bordentown, New Jersey, that the creek meets the Delaware River. The Crosswicks Creek Watershed encompasses portions of Burlington, Mercer, Monmouth, and Ocean Counties. The length of this watershed measures 25 miles while its total area extends 146 square miles. Some of the creek's significant tributaries include Buck Brook, Buckhole Creek, Culvert Pond Run, Doctors Creek, Edges Brook, Ivanhoe Brook, Jumping Brook, Lahaway Creek, Long Bog Run, Mile Hollow Brook, Negro Run, North Run, South Run, and Thornton Creek. Major municipalities within the Crosswicks Creek Watershed region include Allentown, Bordentown Township, Chesterfield, City of Bordentown, Fort Dix Military Reservation, Hamilton, New Hanover, North Hanover, Upper Freehold, and Springfield.

Land use patterns prevalent in this region are agricultural/undeveloped, forested, urban/suburban residential, commercial, and military (Delaware Riverkeeper Network, http://www.delawareriverkeeper.org/factsheets/crosswicks_creek.html)

Tidal New Jersey Upper Watershed
The Tidal New Jersey Upper Watershed is comprised of seven second-order tributaries that drain directly into the Delaware River. The total drainage area of these tributaries, and thus the entire watershed, is 109 square miles. The area is located within Burlington County, New Jersey.

Rancocas Creek Watershed
The Rancocas Creek Watershed spans an area of 360 square miles, which is the largest in south central New Jersey. Of this area, 167 square miles are drained by the North Branch and 144 square miles are drained by the South Branch. The 31 mile long North Branch is fed by the Greenwood Branch, McDonalds Branch, and Mount Misery Brook. The major tributaries to the South Branch include the Southwest Branch of the Rancocas Creek, Stop the Jade Run, Haynes Creek, and Friendship Creek. The main stem of the South Branch flows approximately eight miles and drains an area of nearly 49 square miles before converging with the Delaware River at Delanco and Riverside. The eastern portion of this watershed drains the Pinelands Protection Area.

Some of the major impoundments located within this region include Medford Lake, Pine Lake, Browns Mills Lake, and Crystal Lake. In terms of land use patterns, approximately one-half of this drainage basin is forested, with the remaining area divided between agricultural use and urban/suburban uses. Significant development is currently taking place in many former agricultural areas (New Jersey Waters.com, http://www.njwaters.com/wma/19.htm).

Tidal NJ Lower Watershed
The Tidal NJ Lower Watershed is the southern most watershed of the Delaware River, draining an area of 185 square miles. It occupies all of northern Camden County, New Jersey and small parts of both Burlington and Gloucester Counties to its north and south respectively.

Figure 1.2.3-2 Major Subwatersheds of the Delaware River Watershed

1.2.3.3 Geology, Groundwater, and Soils

Geology

Figure 1.2.3-3 shows the major rock types within the Delaware River Watershed. The headwaters of the Delaware River are located in the *Appalachian Plateau Province*, the northernmost province in the watershed with an altitude range between 659 and 2,953 feet (210 and 900 m.). This area is characterized by high, flat rock formations comprised of horizontal layers of Carboniferous and Devonian sandstone as well as shale and conglomerates, which serve as aquifers in the Catskill Mountains, a source of high quality water. Glacial lakes and swamps dot the region, interspersed among numerous steep valleys and 80-foot deep sediment plains of sand and gravel laid by melting glaciers during the formation of the plateau. Groundwater in the province is found in bedding planes and fractures in the land. Wells, which average a depth of 35 feet (11 m.), yield about 90 gallons of water per minute (gpm), except in the Catskills, where the average well yield is about 40 gpm. The water table is near the surface in this area, and quality water can also be found in the glacial deposits from approximately 12,000 years ago (Majumdar, Miller, and Sage, 1988).

The 40,000-foot (12,192-meter) thick folded sedimentary mountains of the *Valley and Ridge Province*, located in the center of the watershed just below the Appalachian Province, are the distinguishing features of this region, which is split into two sections: the Ridge and Valley Section (note the difference in word order from its parent province) to the north and the Great Valley Section to the south. These two areas are divided by Kittatinny Mountain, which is also known as "Blue", "North", and "First" Mountain. The province as a whole ranges from 167-1,969 feet (51-600 m.) in elevation. The mountainous Ridge and Valley section was formed as a result of the repeated upward movement of the earth's plates at the closing of the Paleozoic Era and concurrent stream erosion over time, which were responsible for the notable features of this province: parallel ridges and valleys, the great length of the ridges, and the uniform ridge crest lines (Thornbury, 1965 as cited in Majumdar, Miller, and Sage, 1988). Sandstone and shale make up the eastern side of the mountains, while the western side is comprised of shale and limestone, as are the valleys, where numerous marine fossils can be found. The streams of the province follow the lowland and flow into the valleys at right angles. Of the numerous rock formations that yield water in this region, average yields are roughly 23 gpm from 37 to 40-foot (11-12 m.) wells in the Mahantango Formation (PA), 22 gpm from 41-76-foot (12-23 m.) deep wells in the Catskills (NY), and 30 gpm from various other formations (Majumdar, Miller, and Sage, 1988).

Easily eroded Cambrian and Ordovician limestone and shale comprise the rock of the Great Valley Section, a rolling landscape of folded and fractured rock within the Ridge and Valley Province and below the Valley and Ridge section. Only about 60 miles (97 km) of the 1,000 miles (1,609 km) of the Great Valley are located in the Delaware Basin. This area, called the Lehigh Valley, ranges in elevation from 160 to 800 feet (49-244 km). The rest of the Great Valley extends southeast all the way into Alabama. The shale of the Great Valley is mostly concentrated on the north side. The limestone found on the southern side serves as an aquifer for the hard, turbid water of the region, which has necessitated the abandonment of some wells. The wells with the highest capacity are found in the valleys, and those with the least capacity are on hilltops. Those of the Martinsburg Shale Group on the north side yield an average of 250 gpm, and the wells of the Beekmantown Group vary, with an average hovering around 1,000 gpm. Porous 80-150-foot (24-46 m.) thick dolomite clay and sand characterize the Leithsville Formation near the Reading Prong, and serve as storage for groundwater of an amount equivalent to that of the Beekmantown Group. The limestone aquifers of the Allentown Formation have a limited yield, and only 25 gpm are yielded by the carbonate Jacksonburg "cement rock" aquifer, used mainly for residential purposes. Groundwater in the Great Valley Section is located in bedding planes and fractures, with most of it located above the 400-foot (122 m.) level. Although there are only a few slow streams in the thick limestone lowland, many faster flowing streams can be found in the narrow valleys of the slate bench in the northern section of the Lehigh Valley, which rises 50-100 feet (15-30 m.) higher than the limestone.

The oldest igneous and metamorphic rocks in the watershed are found in the *New England Province*, which ranges from 167-1,312 feet (51-400 m.) and includes the Reading Prong geological region. A great deal of metamorphism in this province has yielded gneiss, schist, and quartzite rocks, particularly in the Reading Prong section, located between Reading, Pennsylvania and Sussex and Morris counties in New Jersey. The Reading Prong is a narrow belt of folded and faulted Precambrian crystalline rocks and metamorphosed Paleozoic igneous and sedimentary rock, similar to that which comprises many New England mountains. In New Jersey, long, parallel crystalline rock ridges with limestone valleys make up the Reading Prong; whereas in Pennsylvania, the uplands of the Prong are interspersed with limestone lowland.

The Reading Prong, which ranges from 600 to 1,100 feet (183-335 m.) in elevation, is also known as "Durham Hills" in northern Bucks County, "Reading Hills" in Berks County, and "South Mountain" in Lehigh and Northampton counties. The headwaters of many streams can be found in this region. Groundwater is located in narrow openings along vertical joints and in bedding planes. The granite-gneiss sections, whose wells vary from 8-100 gpm and average 25 gpm, supply water for residential purposes. The Hardyston Formation, which has a high concentration of iron, has an average well yield of 75 gpm, and what little water the Hornblende Gneiss formation yields is harder and contains more nitrates than other rock groups in the province. There is concern today that the groundwater in the northern New Jersey section of this region is contaminated with radon as a result of high uranium concentrations found in certain formations there (some wells measured 150% times the expected Federal standard), particularly hornblende granite. Because uranium tends to accumulate in areas of high temperature, such as faults (which is where the groundwater in this geographic section is located), the wells in this area of the Reading Prong may be at risk. However, no municipalities currently require radon analysis for well water and so there is no monitoring for radon (Hydrotechnology Consultants, Inc., http://www.hydrotechno.com/docs/doc8.html).

The diverse geology of the *Piedmont Province* (below the Reading Prong) includes Precambrian and Paleozoic igneous, metamorphic, and sedimentary rock. The two distinct regions that make up this province, the Triassic Lowland and the Uplands (including the Trenton Prong), range from 36-984 feet (11-300 m.) in elevation and are composed of different rock types. The Triassic Lowland is a gently rising plain of sandstone and shale located between the Reading Prong to the north and the Trenton Prong to the south, at the base of the Uplands section in this province. The rolling hills that are characteristic of the Triassic Lowland have their limits within the Delaware River Basin in Bucks, Montgomery, and Chester counties, although the Lowland actually extends as far west as Adams County, PA. The hills, which rise from 150 to 500 feet (46-152 m.) above sea level, are broken up at various points by diabase dikes and sheets between 400 and 700 feet (122 and 213 m.) above sea level. Igneous rocks make up the higher ridges of the Lowland, whereas below the ridges and valleys, 16,000-20,000 feet (4,877-6,096 m.) of freshwater sediments can be found, especially sandstone (Majumdar, Miller, & Sage, 1988). It is believed that the Lowland basins that traverse the Delaware were cracks created when Africa and North America were separated (River Places, http://www.riverplaces.com/drguide/DRGuideGeology.html).

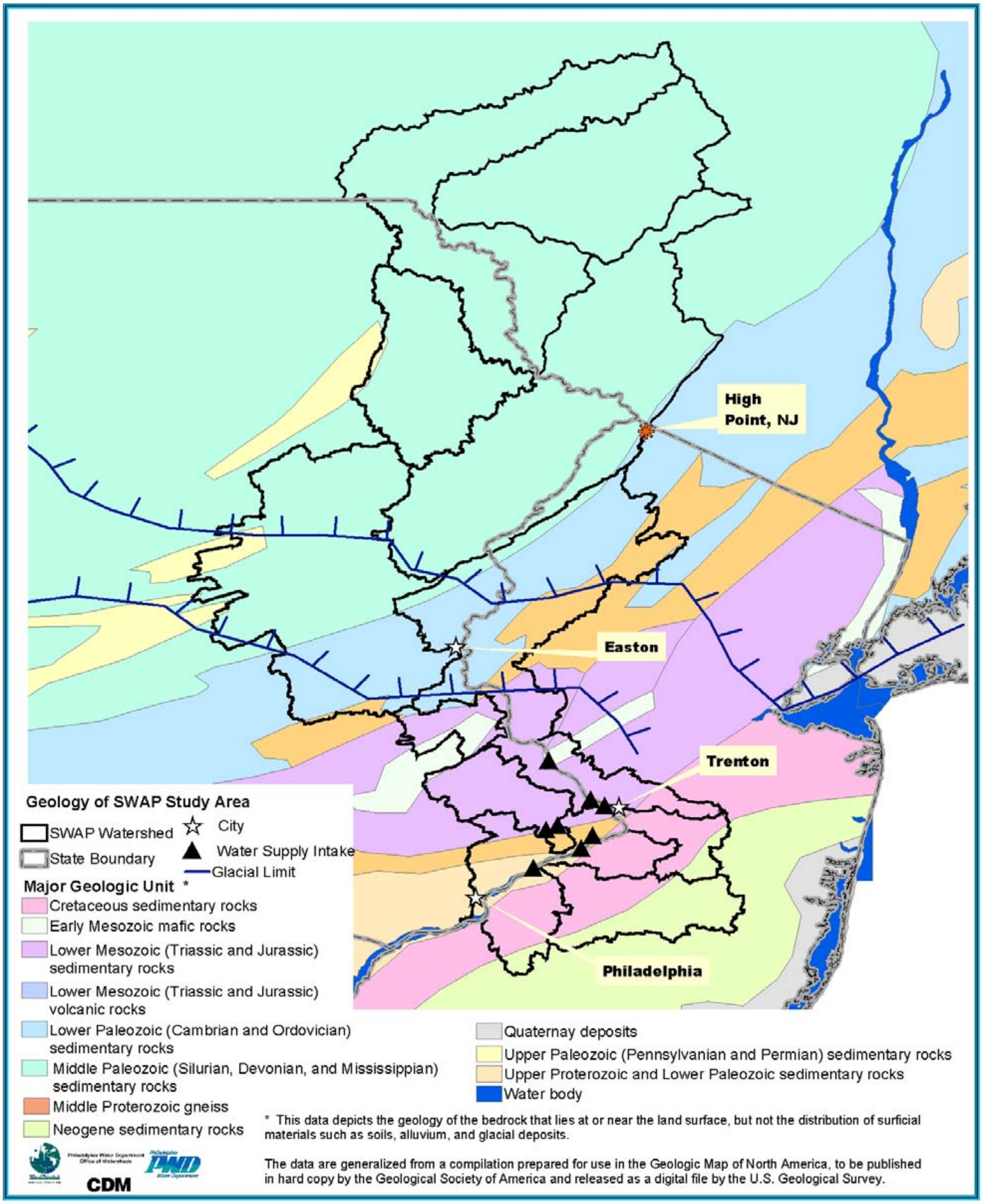
Folds and faults of igneous and metamorphic rock comprise the other section in this province: the Uplands, a low plateau that extends from southern New York to Alabama, and includes large amounts of Paleozoic gneiss and patches of marble. The elevation of the region varies from 300-400 feet (91-122 m.) on the Delaware River to roughly 800 feet (244 m.) at Parksburg. The Trenton Prong is a triangular area in the lower part of this section in southeastern Pennsylvania that encompasses land from Trenton west to northern Chester County. This area is characterized by flat-topped hills and shallow valleys, and consists of a variety of rock types that have been extensively folded and faulted: igneous and metamorphic crystalline rocks, such as granites and gneisses; metamorphosed sedimentary schist, phyllite, and quartzite; and partially metamorphosed limestone and dolomites (Majumdar, Miller, and Sage, 1988). This prong was most likely formed from an eroded mountain range. Most water in the crystalline rocks is located at the surface, with wells yielding only small quantities. Yields in the Piedmont Province vary from 2 to 100 gpm due to the complex geographical layout of this region.

Within the Trenton Prong, about 200-300 feet (61-91 m.) below the harder crystalline uplands, lies the limestone Chester Valley, a structurally-significant area 1-3 miles (1.6-4.8 km.) in width that extends for 55-miles (89 km.) from the Delaware River area to Lancaster County's limestone lowlands. The meeting point of the limestone of the Chester Valley and the igneous-metamorphic rocks of the areas north of the valley is called the Marter Line. Separating the Piedmont Province from the Atlantic Coastal Plain below it is the Fall Line--a physical barrier of falls and rapids that flows over relatively erosion-resistant crystalline rock stretching from New Jersey to Texas, and serves as a natural boundary that marks the extent of navigable waters. Baltimore, New York, Philadelphia, Trenton, and Wilmington are major cities in the Delaware Basin that are located on the Fall Line. Once water power was harnessed, these cities grew into major industrial centers that relied heavily on the Delaware River for their burgeoning success.

The *Coastal Plain Province* ,(just below the Fall Line), was formed when Triassic Era deposits were eroded and redeposited to the southeast by water and glaciers. The plain, which slopes southeast to the Continental Shelf, has a maximum elevation of only about 328 feet (100 m.). The province is divided into two sections: the Outer Coastal Plain, which is comprised of southern New Jersey and eastern Delaware, and the Inner Coastal Plain, which consists of a narrow belt in Pennsylvania, northern Delaware, and an area in New Jersey located roughly 20 miles (32 km.) to the east of the Delaware River. Both sections, which are divided by a line of hills, contain clays, gravels, sands, and silts, but were formed in different geological time periods: the Inner Coastal Plain in the Cretaceous and Pleistocene Eras, and the Outer Coastal Plain in the Tertiary Era.

The Raritan, Magothy, Pennsauken, and Cape May formations are major sources of groundwater in the region between Philadelphia and Wilmington, with wells yielding between 400 and 800 gpm. The sandstone and gravel of the Raritan Formation yield the most water, but the 30-40-foot (6-9-m.) thick sand, gravel, and clay of the Pennsauken and Cape May formations also contribute a significant amount of water. However, much of the water in this province must be treated for quality (Majumdar, Miller, and Sage, 1988.)

Figure 1.2.3–3 Geology of SWAP Study Area



Groundwater

Water from both surface and ground sources is affected by a number of factors, pollution being the foremost concern among them. As such, efforts have been made by the Delaware River Basin Commission, local municipalities, and industrial users to control both point and non-point sources of contamination in watershed rivers and streams. Of particular concern throughout the four basin states are excesses of naturally-occurring substances that result from the geologic makeup of the land, anthropogenic sources resulting from urban and industrial development, acid mine drainage from past and present mining operations, faulty waste storage and disposal, and agricultural runoff of pesticides, fertilizers, and animal waste. Drought and flooding are also important agents that influence water flow and quality by affecting pollution levels in water supplies.

More than 20,000 bodies of water, including more than 300,000 river and shoreline miles and 5 million acres of lakes throughout America, have been identified as polluted (EPA, http://gwpc.site.net/news/nws-epa_impaired_waters_rule.htm). In addition, the EPA estimates that 40 % of our surveyed rivers, lakes, and estuaries do not support basic uses such as fishing or swimming because of non-point source pollution of surface and ground water sources, which means that the majority of Americans—over 218 million out of 275,562,673 (July 2000 est., Yahoo Reference, http://education.yahoo.com/reference/factbook/us/popula.html) —live within ten miles of a polluted body of water (EPA, http://www.epa.gov/owow/tmdl/atlas/intro.html). (EPA, http://www.epa.gov/owow/tmdl/atlas/cover.html).

In the Delaware River Basin, groundwater supplies within the New York portion of the watershed are considered to be excellent. However, there are both natural and anthropogenic causes for concern. Naturally high levels of total dissolved solids, sulfates, iron, chlorides, methane, and radon are present in the bedrock in some areas. More imminent concerns to public water supply users, however, is the contamination closer to the surface: septic tank leaks, spills, and agricultural runoff and subsequent recharge of pesticides and fertilizer (Ground Water Protection Council, http://gwpc.site.net/gwreport/states.htm).

Groundwater in Pennsylvania is classified as good for the most part, but the quality of groundwater is worsening due to anthropogenic causes, such as acid mine drainage from coal mining, leaking underground storage tanks, leachates from landfills and hazardous waste sites, agricultural runoff and recharge, and increasing development. Non point sources of pollution associated with sprawl and development are the suspected causes of recently noted increases in levels of TDS, chloride, calcium, potassium, hardness, and sodium (Ground Water Protection Council, http://gwpc.site.net/gwreport/states.htm)

New Jersey's groundwater is considered to be good overall. Naturally occurring excesses of iron, total dissolved solids, sulfate, hardness, manganese, and pH result from the chemical makeup of rockbeds in certain areas, as do high levels of radionuclides such as radium (in the Piedmont and Coastal Plain provinces of the state), uranium

(Piedmont Province), and arsenic (Piedmont Province). Leaking underground storage tanks, spills, and improper disposal of hazardous materials are problems in highly populated urban areas of the state. Agricultural runoff and contamination by mercury (Coastal Plain) and salt (coastal regions) are also known pollution concerns. (Ground Water Protection Council, http://gwpc.site.net/gwreport/states.htm)

Groundwater in Delaware is classified as good on the whole, with the exception of local problems in some areas, such as excesses of naturally occurring iron, manganese, and chloride, as well as anthropogenic causes resulting from leaking underground storage and septic tanks, hazardous waste sites, urban and industrial activities occurring mainly in the northern part of the state, and agricultural runoff and rechargecausing concerns for nitrate pollution. Petroleum compounds (benzene, toluene, ethylbenze, xylenes), volatile organics (tichloroethylene), nitrates, bacteria, and salinity are the main groundwater contaminants (Ground Water Protection Council, http://gwpc.site.net/gwreport/states.htm).

While sufficient and of good quality for the most part, the Delaware River Basin's source water supplies, both surface and groundwater, are still in need of protection, particularly in known vulnerable sites and highly populated, industrialized urban areas. Various local, state, and federal agencies have been working to improve the quality of the water supplies for the last few decades. Their efforts continue to pay dividends for the health of the rivers and streams, as is evidenced by the noticeable improvements that have been made since the 1940s, when the Delaware River was in the worst condition in its history. At present, the river has shown remarkable recovery, and continues to improve, as new legislation is better able to protect this crucial resource.

Soils

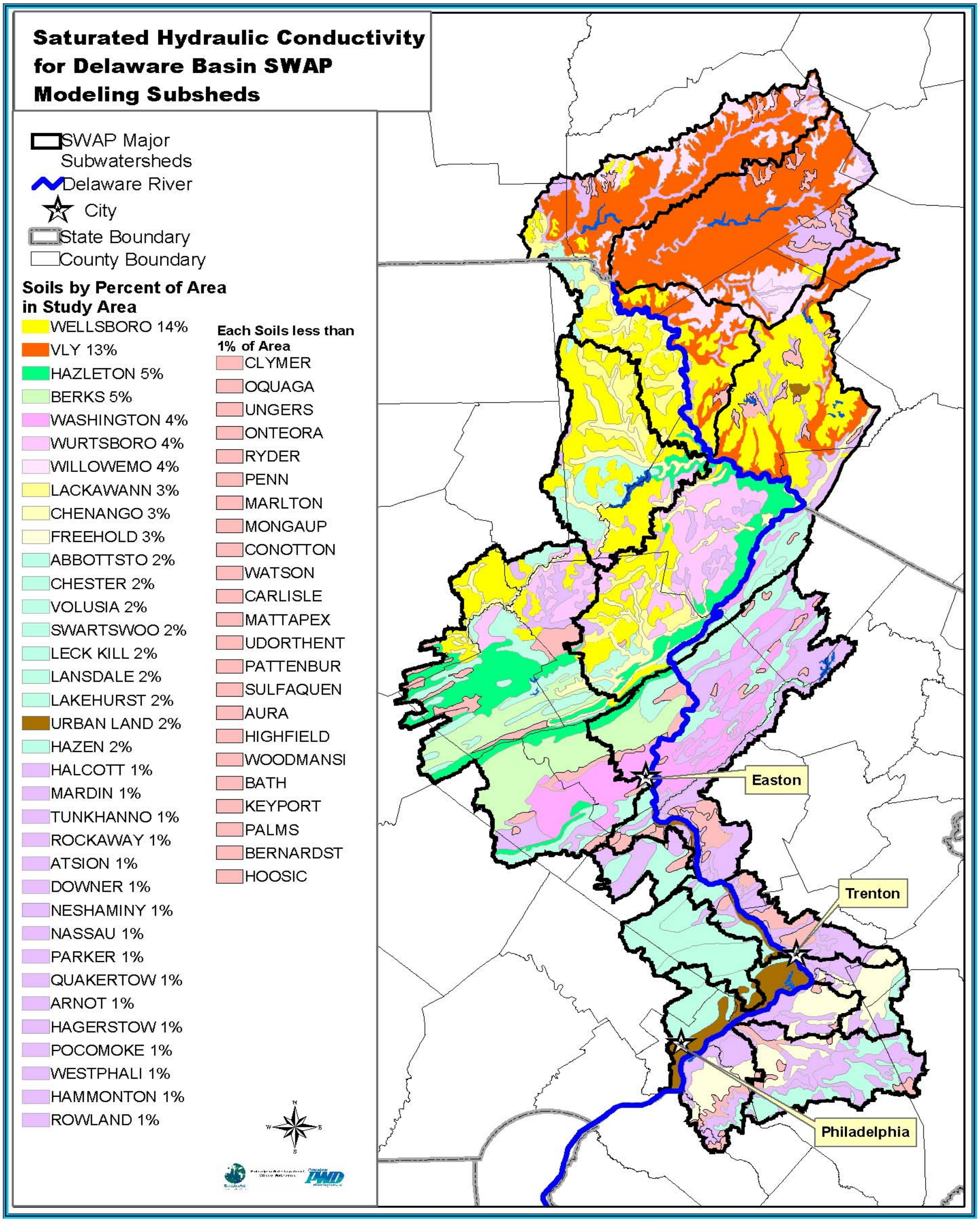
The Delaware River Watershed is comprised of a variety of soils, which determine the landscape of the watershed and the transport properties of the river and its tributaries. Within the major hydrological classifications and groups of soils, there are 58 specific subtypes in the SWAP study area. As shown in Figure 1.2.3-4, these soil subtypes vary with location in the watershed, but in some cases, large portions of the watershed are one soil type. The Wellsboro, Vly, Hagerstown, Hazelton, Berks, Washington, Wurtsboro, and Willowemoc soil classifications define approximately 50 percent of the watershed soils. As shown in Table 1.2.3-1, these soils are generally well drained, experience moderate runoff during rain events, and are typically located on significant slopes. The two poorly-drained soils, the Wellsboro and Wurtsboro soils, are located in the northern and central portions of the study area. The Wellsboro soil is the most predominant soil type within the study area.

Table 1.2.3-1 Prevalence of Various Soil Types in the Study Area

Soil Type	Percentage of Study Area	Slopes %	Permeability	Runoff	Drainage	Found on
Wellsboro	14	0-50	Very slow to slow	Slow to rapid	Moderately well to poorly drained	Level to steep glaciated uplands
Vly	13	0-55	Moderate	Medium to rapid	Well drained to excessively drained	Bedrock controlled glacial till uplands, most soils are forested
Hazleton	5	0-80	Moderately rapid to rapid	Medium	Well drained	Ridges, hilltops, and upper sideslopes
Berks	5	0-80	Moderate to moderately rapid	Slow to rapid	Well drained	Summits, shoulders, and backslopes of dissected uplands
Washington	4	1-15	Moderate	Medium to rapid	Well drained	Level to gently rolling uplands
Wurtsboro	4	0-25	Slow	Slow to rapid	Moderately well to poorly drained	Level to sloping soils of glaciated uplands, almost entirely in woodlands
Willowemoc	4	0-35	Very slow to moderate	Slow to rapid	Moderately well drained	Level to moderately steep uplands, many areas are forested

Source: United States Department of Agriculture. Natural Resources Conservation Service. Pennsylvania Soil Survey. Official Series Descriptions.

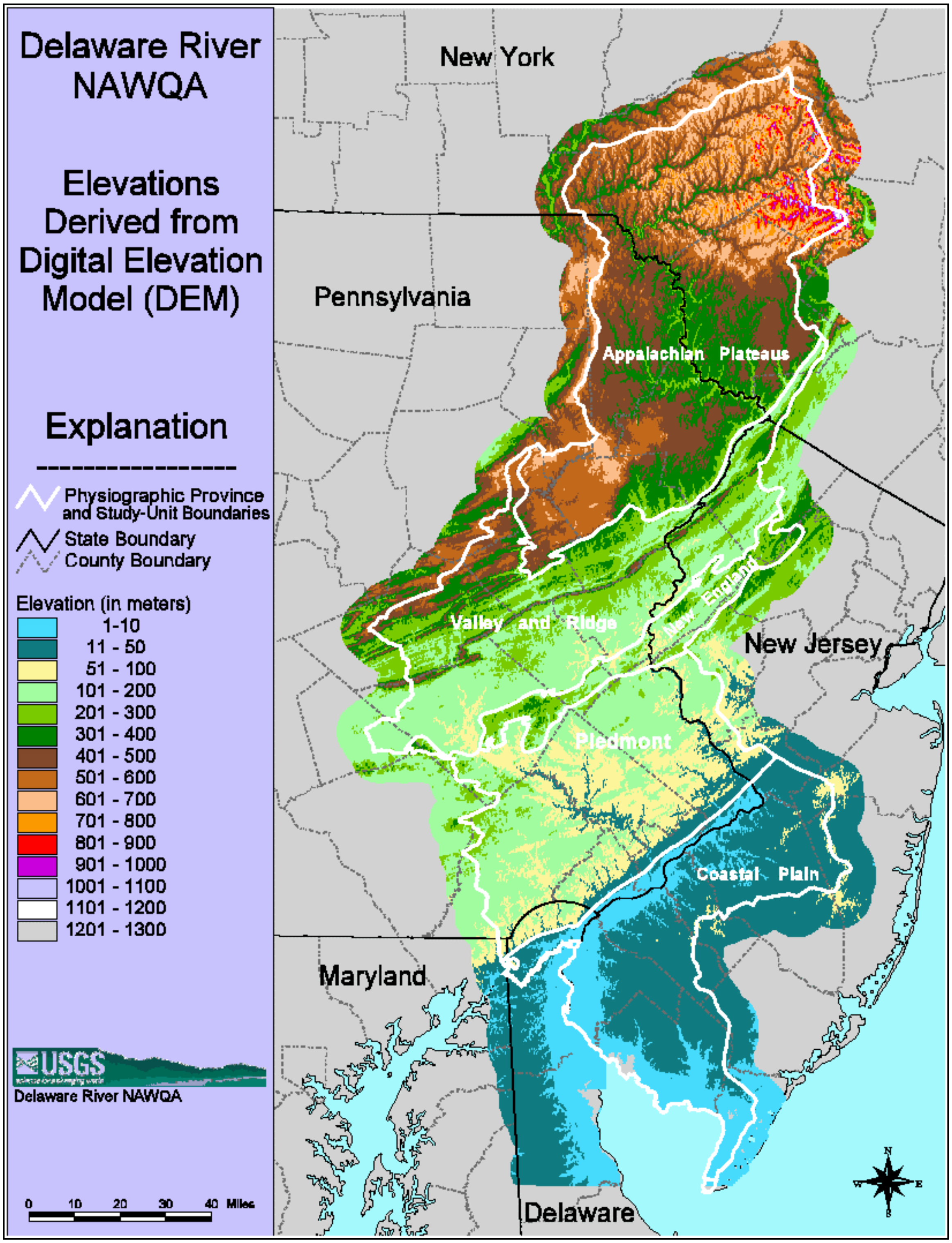
Figure 1.2.3-4 General Distribution of Soils in the SWAP Study Area



The soil characteristics of high runoff and steep slopes make runoff of persistent and conservative contaminants into the rivers and streams very possible if no management practices are in place. These attributes also affect the quantity of the runoff that may erode streambanks.

The general topography of the watershed can indicate where runoff issues may be important. Development on steeply sloping areas can create more of an impact on river water quality than development on gently sloped areas due to the potential to transport polluted runoff farther and faster. As shown in Figure 1.2.3-5 a digital elevation model demonstrates the elevations of the various areas of the study area. The steep valley areas are where the color gradation changes quickly and dramatically. These would be considered sensitive areas where runoff from particular sources or activities could have a potentially significant impact on river or stream water quality. These are also areas that would be ideal for preservation and protection against development pressure to minimize future runoff issues.

Figure 1.2.3-5 Digital Elevation Model of the Lower Schuylkill River Watershed



1.2.4 Hydrology

Key Points

- **The Humid Continental climate pattern that characterizes the Delaware River Basin is responsible for the relatively normal variations in weather that occur within the region.**
- **Cities within the basin are served by surface water from the Delaware, its tributaries, and reservoirs; whereas the less populated areas rely more on groundwater sources.**
- **The Schuylkill and Lehigh Rivers are the largest of the Delaware's tributaries that provide surface water. Flow at the gauge in Trenton averages about 9,149 cubic feet per second.**
- **Due to the persistence of heavy flooding within the Delaware River Basin, two agencies were created, the Pennsylvania State Water Plan and the Delaware River Basin Commission, which have been making great strides in flood prevention.**
- **In 1988, two and a half million people, or 1/3 of the Delaware River Basin, obtained their drinking water from groundwater sources.**
- **The integrity of the basin's groundwater supplies needs to be protected from pollution and development so that watershed residents continue to have a reliable source of drinking water**.

The Delaware River Basin experiences the Humid Continental climate pattern. This pattern encompasses relatively normal variations in weather, which are predominantly the results of a series of high and low-pressure systems. Precipitation and cloudy weather are products of the frontal systems that are associated with low pressure. In contrast, the passage of a high-pressure system results in clear skies. In general, annual average variations of temperature and precipitation are primarily due to differences in elevation and exposure to wind direction within the Delaware River Basin (Majumdar, Millar, and Sage, 1988).

Although the Delaware River Basin experiences a continental climate, temperatures often reach extreme conditions. Maximum temperatures range from approximately 94°F in the northern basin to 105°F in the southern basin, whereas minimum temperatures vary from approximately –34°F in the north to -11°F in the south. Therefore, the maximum temperature range across the basin is 140°F. With respect to seasonal climate, winter temperatures fluctuate between approximately 23°F in the upper basin and 35°F in the lower basin. Conversely, summer temperatures normally average between 65°F in the upper basin and 77°F in the lower basin. Annually, the average temperature varies from about 48°F in the upper basin to about 54°F in the lower basin (Climate and Man, 1941, Climates of the States – Pennsylvania, Annual in Majumdar, Millar, and Sage, 1988).

Annual average precipitation rarely fluctuates within the Delaware River Basin; the area normally receives about 45 inches of precipitation per year. The driest month is normally February, with precipitation totals ranging from 2.7 to 3 inches. In contrast, July and August are the months with the most precipitation, measuring from 4.5 to 4.7

inches of precipitation. The precipitation in the cold months results from the passage of fronts in the low-pressure systems of the westerly wind belt. During the warm months, much of the precipitation occurs as convectional storms, which are supplemented by the occasional passage of a front (Climate and Man, 1941 in Majumdar, Millar, and Sage, 1988).

Long-term historical data in Philadelphia was initially assessed in order to gauge recent decade scale trends against the backdrop of natural regional variation in climate and hydrology. Monthly climate data based on a regional composite index developed by the National Climatic Data Center (NCDC) are available from 1895 through the present day. Historical climate data has been further summarized here by calculating annual totals for precipitation and averages for temperature based on monthly figures.

Annual precipitation in the Philadelphia area has shown a steady increase through the 1900s, with an extended period of drought in the 1960s. Precipitation was high in the 1970s and has most recently varied around the long-term mean for annual precipitation. Annual temperatures in the region have not shown such a strong trend over the entire century, although temperatures appear to have increased over the first half of the century, while decreasing since then, as shown by Figure 1.2.4-1.

Figure 1.2.4-1 Long-Term Average Annual Temperature at Philadelphia

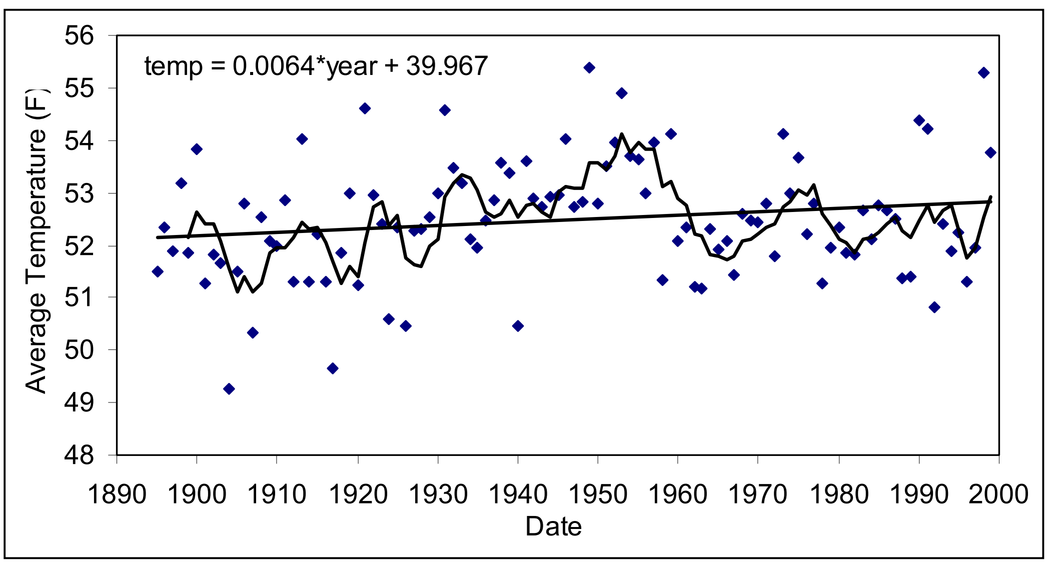
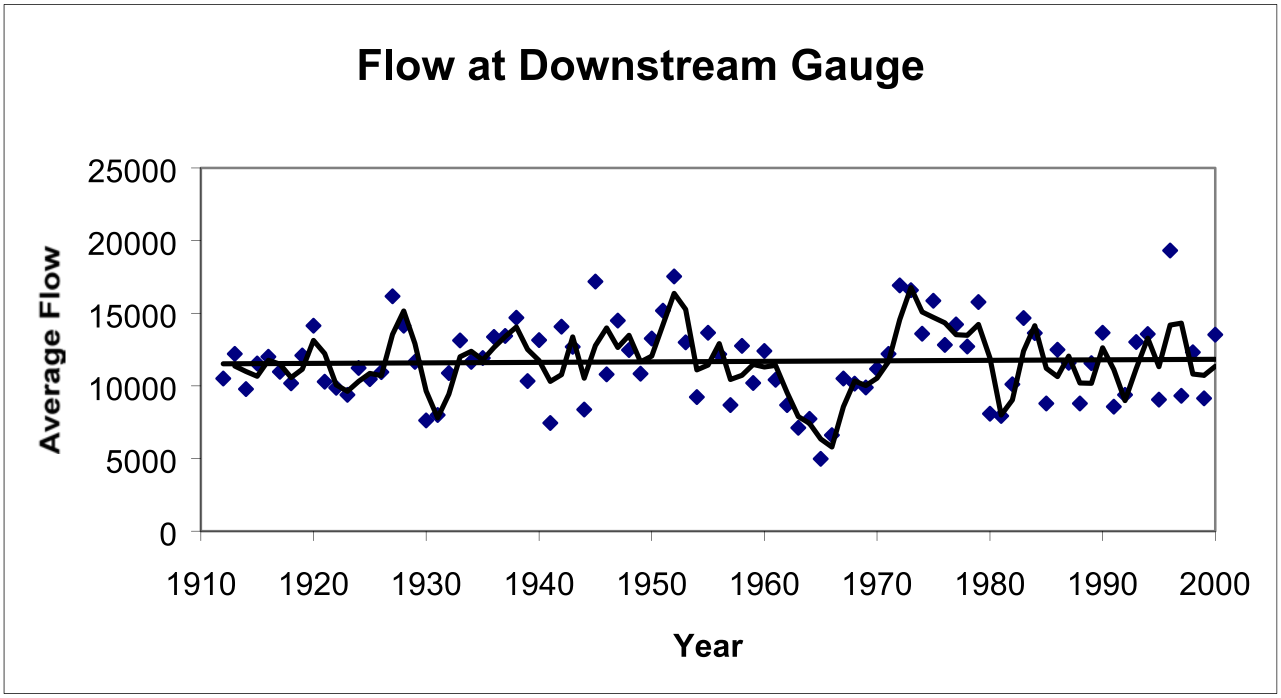


Figure 1.2.4-2 Annual Average Flow at Trenton Gauge of Delaware River

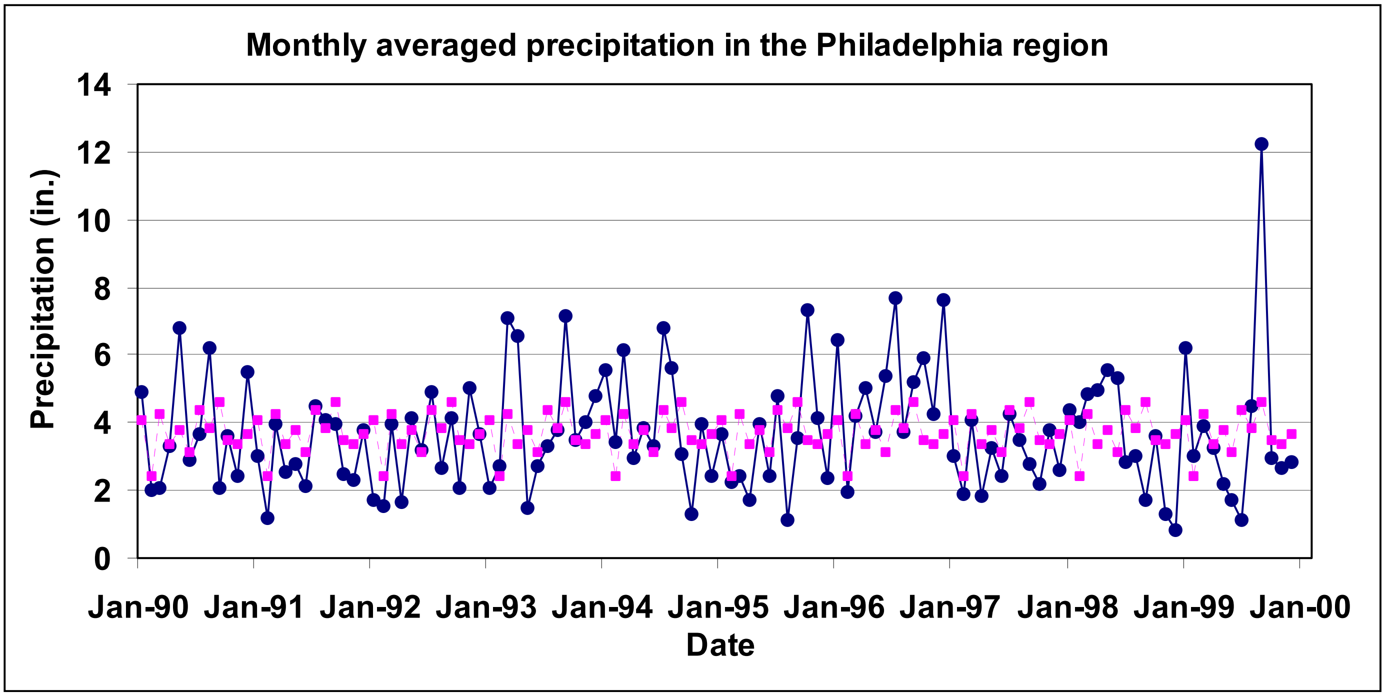


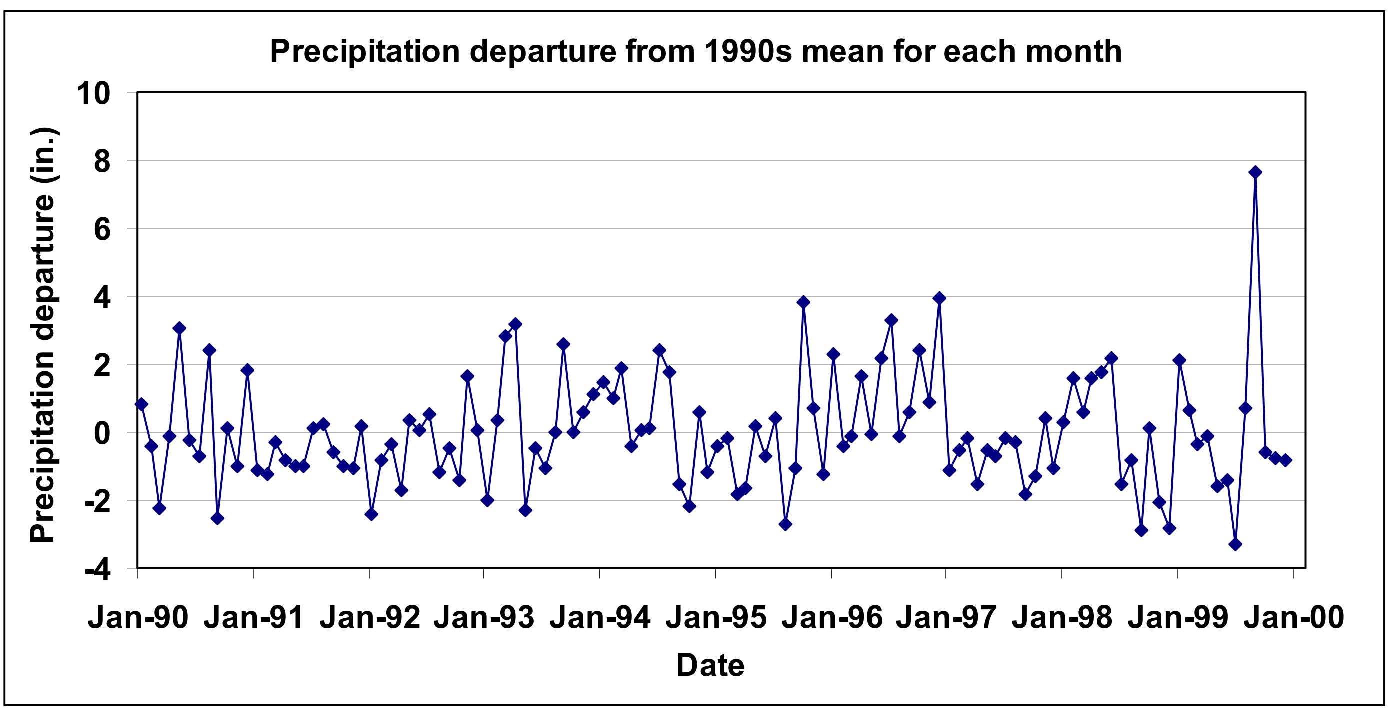
Historical flow in the Delaware River, measured as daily averaged flow at the Trenton gauge from 1910 through the present, is shown in Figure 1.2.4-2. Average annual flow dropped below 5000 cubic feet per second (CFS) only once over the period of record, during the drought of the 1960s.

Recent decade scale patterns in climate and river flow for the region were also assessed to ascertain direct connections between these parameters and Philadelphia Water Department (PWD) intake water quality data. Monthly data for precipitation through the 1990s indicates extended dry periods through 1991 and 1997, along with a severe short-term drought from May through July 1999, as illustrated by Figure 1.2.4-3. February has been particularly dry through the period, while the August average precipitation has been unusually high for summer months. Departures from monthly averages indicate variation from mean precipitation levels and are often a better indicator of climatic condition than are absolute values of precipitation.

Figure 1.2.4-3 Precipitation trends in Southeastern Pennsylvania through the 1990's

Small squares in top panel indicate 1990's monthly flow averages. Deviation from monthly averages indicates interannual trends toward particularly wet or dry weather. Averages are calculated by calendar month, so deviation in January, for instance, is the difference between the 1990's average January precipitation, and that occurring in a given year.





The Delaware River Basin generally averages approximately 18 to 28 inches of runoff each year (Page and Shaw, 1977 in Majumdar, Millar, and Sage, 1988). Runoff from the Upper Delaware Basin is impeded by several ponds, lakes, and swamps that are the legacies of Pleistocene glaciation. Within the central section of the basin, the stream flow of the Lehigh River is partly regulated by the Beltzville Lake and Wild Creek, Penn Forest, and Francis E. Walter reservoirs. The influence of this type of flow is apparent in Table 1.2.4-1, which illustrates the difference in the rate of flow during flood stages at various places along the Lehigh River. Due to the reservoir flood storage on the Lehigh, the mean annual flood runoff at Bethlehem is 21.4 cubic feet per second per square mile; whereas, at Stoddartsville, upstream from the reservoirs, it is 37.5 csm. In addition to reservoir control, other factors that play a role in the amount of runoff within a given area include geology, topography, land use, natural vegetation cover, and basin size.

Stream flow within the Delaware River Basin fluctuates immensely, as evidenced by Table 1.2.4-2. The maximum discharge occurs after the periods of heaviest precipitation with the passage of a tropical storm. The seasonal variation in terms of the amount of runoff recorded is driven by the melting of snow and the thawing of the ground in the late winter and early spring (maximum flows), as well as the time when evaporation of surface waters is highest (low flows), which occurs in late summer and early autumn. (Page, 1977 in Majumdar, Millar, and Sage, 1988).

Table 1.2.4-1 Streamflow Statistics for Selected Gauging Stations

	Years of Record	Drainage Area (sq.mile)	Average Annual Runoff (CSM)*	Mean Annual Flood (CSM)*	Ratio of 100-year to Mean Annual Flood	7-Day 10-Year Low Flow (CSM)*
Upper Delaware Basin						
Delaware River at Belvidere, NJ	1922-72 50	4,530	1.7	16.2**	4.2**	0.20
Lackawaxen River at Hawley, PA	1908-17 1938-72 43	290	1.6	41.7	5.4	0.06
Brodhead Creek at Minisink Hills, PA	1950-72 22	259	2.0	42.6	7.9	0.16
Central Delaware River						
Lehigh River at Stoddartsville	1943-72 29	91.7	2.0	37.5	7.5	0.15
Lehigh River at Bethlehem	1902-04 1909-12 65	1,279	1.8	21.4**	3.7**	0.27
Tohickon Creek near Pipersville	1935-72 37	97.4	1.4	75.6	2.7	0.01
Neshaminy Creek near Langhorne	1934-72 38	210	1.3	60.6	3.4	0.04
Lower Delaware River						
Tuplehocken Creek near Reading	1950-72 22	211	1.4	27.8	3.3	0.21
Schuylkill River at Pottstown	1926-72 46	1,147	1.6	20.7	3.2	0.23
Perkiomen Creek at Graterford	1914-72 58	279	1.3	56.4**	2.9**	0.05
Brandywine Creek at Chadds Ford	1911-53 1962-71 52	287	1.3	27.4	3.0	0.31

** Cubic feet per second per square mile*
*** Flood data for period 1957-72, 15 years*
***Source:** State Water Plan, Upper Delaware Basin, Central Delaware Basin, Lower Delaware Basin, 1983. Department of Environmental Resources, Office of Resources Management, Bureau of Water Resources Management, Harrisburg, PA. SWP2, SWP3, SWP4 in Sutton, O'Herron, and Zappalorti, 1996.*

Table 1.2.4-2 Duration Table of Daily Flow

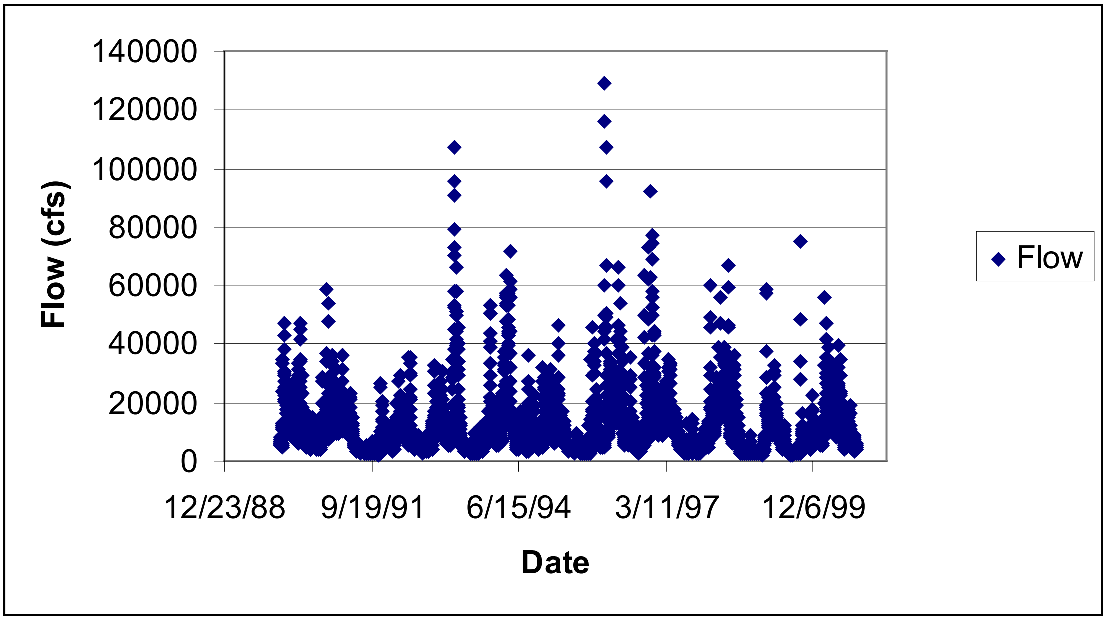
	Delaware River												
Percent	**2**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**95**	**98**
Port Jervis, NY	26,000	18,000	12,000	7,800	5,700	4,300	3,400	2,600	2,000	1,500	1,100	750	530
Montague, NJ	28,500	19,000	13,400	9,300	6,800	5,200	4,000	3,150	2,420	1,880	1,400	1,020	750
Belvidere, NJ	35,000	23,600	17,400	12,000	9,000	7,000	5,500	4,300	3,300	2,420	1,720	1,360	1,120
Riegelsville, NJ	42,500	32,000	23,800	16,400	12,400	9,700	7,600	6,000	4,650	3,500	2,500	1,960	1,600
Trenton, NJ	47,500	33,500	24,800	17,400	13,200	10,400	8,300	6,600	5,100	3,850	2,750	2,180	1,780
	Schuylkill River												
Reading, PA	7,100	4,800	3,300	2,100	1,500	1,200	960	710	550	420	300	230	180
Norristown, PA	11,000	6,800	4,400	2,900	2,200	1,800	1,400	1,100	830	570	380	310	250
Philadelphia, PA	13,000	8,300	6,000	3,900	2,900	2,200	1,600	1,200	880	600	360	240	160

Discharge, in cubic feet per second, that was equaled or exceeded for indicated percentage of time.
Source: Busch, W.F. and L.C. Shaw, 1966. Pennsylvania Streamflow Characteristics, Low-Flow Frequency and Flow Duration. Pennsylvania Department of Forest and Waters. Harrisburg, PA, Water Resources Bulletin No. 1 in Sutton, O'Herron, and Zappalorti, 1996.

Average annual Delaware flow at Trenton is 9,149 CFS for the period 1912 through 1999 (USGS gauge data). Daily average Delaware River flow at Trenton through the 1990s is summarized in Figure 1.2.4-4 and indicates extremely low flow conditions in summer 1999, with less-pronounced low flow occurring in 1991. Lowest flows through the decade were not always associated with extended low levels of summer precipitation, suggesting that evaporation, groundwater storage, and surface water removal are important components in the water budget of the region.

Seasonal variation is driven primarily by precipitation, which is highest in spring, and evaporation, which is highest in summer months.

Figure 1.2.4-4 Daily Average Delaware River Flow at Trenton through the 1990's



1.2.4.1 Surface Water

Philadelphia and numerous other upstream cities and communities make extensive use of the Delaware River Watershed's surface water, which includes the Delaware River, some of its 216 connecting tributaries, and water stored in reservoirs throughout the basin, for water supply. Among the more significant tributaries that supply surface water in the basin are: the Schuylkill River, the Lehigh River, and the Lackawaxen River in Pennsylvania; the Neversink and Mongaup Rivers in New York; and the Paulins Kill, Pequest, Musconetcong, and Maurice Rivers in New Jersey (Majumdar, Miller, and Sage, 1988).

With an average annual flow of 2,620 cfs at Fairmont Dam in Philadelphia (USGS data as of 1999, http://water.usgs.gov/pa/nwis/annual/?site_no=01474500&agency_cd=USGS), the 128-mile Schuylkill River is the Delaware's largest tributary, contributing one third of the Delaware's flow (Schuylkill River Greenway, http://www.montcopa.org/schuylkill/). Originating in the Blue Mountains in Pottsville (Schuylkill County) and emptying into the Delaware River at Philadelphia, the Schuylkill River drains 1,893 square miles in southeast Pennsylvania with the help of 12 smaller creeks within its watershed, namely, Tulpehocken Creek, Alleghany Creek, Hay Creek, French Creek, Pickering Creek, Valley Creek, Little Schuylkill River, Maiden Creek, Monocacy Creek, Manatawny Creek, Perkiomen Creek, and Wissahickon Creek.

The Schuylkill River, whose name derives from the Dutch word meaning "hidden river" (because seven islands concealed its mouth when European colonists first encountered it), has historically been very important to the City of Philadelphia and the surrounding areas through which it flows, particularly as a source of drinking water (Schuylkill River Greenway, http://www.montcopa.org/schuylkill/ and Toffey, 1982). The city began using the Schuylkill for drinking water in 1801 and wisely tried to protect the integrity of this resource at that time by purchasing the land surrounding it in order to prevent contamination of the water supply from pollution due to the rapid spread of industry along the banks of the river. However, the existing industry upstream combined with a lack of knowledge regarding sewage and wastewater disposal, as well as the extensive coal mining being carried out at its headwaters at that time (anthracite coal was discovered in Pottstown in 1770) eventually led to severe pollution problems for the river, which jeopardized Philadelphia's water supply. A series of legislative acts in 1945 called for pollution abatement and the de-silting of the river in order to restore it to health. Unfortunately, pollution is still a problem in the Schuylkill today, particularly due to acid mine drainage (AMD) from old abandoned mines near the headwaters, agricultural runoff, and industrial discharges throughout the watershed. Yet the river continues to play a crucial role in the lives of those within its watershed. As of 1990, there were 902.56 MGD of water withdrawn from within the Schuylkill Watershed. Of that, 683.3 MGD were from surface water intakes and 219.26 MGD from groundwater sources to serve 1.6 million people (USGS, http://water.usgs.gov/cgi-bin/wuhuc?huc=02040203).

The Delaware's second largest tributary, the Lehigh River, which drains 1,359 square miles, has an annual flow of 2,293 cfs **(**1999 USGS data, measured 2 miles southwest of Easton, PA at Glendon). Of the 280.56 MGD that were taken from this watershed daily in 1990, 203.4 MGD were from surface water sources, and 77.16 MGD came from groundwater sources (USGS, http://water.usgs.gov/cgi-bin/wuhuc?huc=02040106) to serve roughly 556,000 people. The majority of water bodies within the Lehigh Watershed are of good quality, with the exception of some smaller creeks that are considered impaired waters, mostly due to AMD from abandoned mines, and agricultural runoff (EPA, http://www.epa.gov/iwi/303d/02040106_303d.html).

The main stem of the Delaware River has an annual mean flow of 9,149 cfs at Trenton (USGS data as of 1999, http://water.usgs.gov/pa/nwis/annual/?site_no=01463500&agency_cd=USGS), which is maintained by releases from three large reservoirs on its tributaries in upstate New York (USGS NAWQA 1994). The Cannonsville, Pepacton, and Neversink Reservoirs are all owned by New York City, the single biggest user of Delaware River surface water. Seventy-five percent of the Delaware River Basin's total surface water storage is contained within these three reservoirs with a total combined capacity of 271 billion gallons (Pepacton Reservoir at 140.1 billion gallons, Neversink at 34.9 BG, and Cannonsville at 95.7 BG) (Roberts and The Catskill Center, NYC Watershed Timeline, http://www.catskillcenter.org/programs/csp/H20/Lesson4/nyctime2.htm**).**

Conditional periodic releases from the Cannonsville, Pepacton, and Neversink Reservoirs in the Upper Delaware have a significant effect on water quality in the rest of the river by helping to maintain both water flow and quality downstream. Releases from the NYC reservoirs help to meet the federal flow standard of 1,750 cfs for

Montague, NJ. During low flow in the summer, more than 70% of the flow in the Upper Delaware River and 40+ % of the flow at Trenton is a result of releases from the three reservoirs, which have the combined ability to divert up to 800 MGD. Consequently, reservoir releases influence many water quality factors, such as flow, temperature, pollution, salinity, and fish migration below the release sites (USGS NAWQA, 1999). As a result, the operation of these reservoirs has created controversy regarding the ownership and use of reservoir water over the years. Most notable was court action in the 1950s, which helped settle water withdrawal/diversion disputes between the four basin states and New York City (which is outside the basin) so that all parties would be assured an adequate water supply in times of drought.

Other significant reservoirs in the watershed are all in Pennsylvania.

Francis E. Walter Reservoir

The Francis E. Walter Reservoir, formerly known as the Bear Creek Reservoir, is situated on the Lehigh River in the Lehigh River Basin approximately 77 miles above the confluence with the Delaware River in Carbon and Luzerne Counties, Pennsylvania. This reservoir is an integral piece of a Lehigh River flood control program and is currently authorized to provide whitewater recreational opportunities. The Francis E. Walter Dam was completed in December of 1960. It measures 3,000 feet in length and is 234 feet high. Its drainage area spans 288 square miles, and its flood control storage measures 107,815 acre-feet (U.S. Army Corps of Engineers, http://www.nap-wc.usace.army.mil/waltr.html)

Beltzville Lake

The Beltzville Lake Reservoir is located in Carbon and Monroe Counties in the Lehigh River Basin in Pennsylvania, more specifically, at approximately 5.2 miles above the confluence with the Lehigh River. This reservoir is an important part of the Lehigh River Flood Control Program, which aids in flood control along the banks of the Pohopco Creek and the Lehigh River as well as operates for water supply, water quality control, and low flow augmentation in the Lehigh River. It also helps provide control of saline water intrusion in the Delaware Estuary. The Beltzville Lake Dam was completed in December of 1971 and is categorized as an earthfill embankment type of structure, also composed of an impervious core with random fill. The dam measures 4,560 feet in length and is 170 feet high. Its drainage area covers 96 square miles, while its flood control storage volume is 27,030 acre-feet (U.S. Army Corps of Engineers, http://www.nap-wc.usace.army.mil/beltz.html)

General Edgar Jadwin Dam

The General Edgar Jadwin Dam, located in the Lackawaxen River Basin on Dyberry Creek, is 30.1 miles above the confluence of the Lackawaxen River with the Delaware River at Lackawaxen, Pennsylvania. This dam is an important part of an integrated reservoir flood control system. In combination with the Prompton Reservoir, the Jadwin Dam provides flood control protection, in varying degrees, to the Boroughs of Prompton, Honesdale, and Hawley, all of which are located within the State of Pennsylvania. In addition, this dam also provides flood control protection to a number of smaller communities lining the Lackawaxen River. The dam was completed in September of 1959 and is an earth and rockfill embankment structure. It has a length of 1,255 feet and a height of 109 feet. The Jadwin Dam's drainage area encompasses 64.5 square miles, and its flood control storage volume measures 24,500 acre-feet (U.S. Army Corps of Engineers, http://www.nap-wc.usace.army.mil/jadrs.html)

Prompton Lake Reservoir
The Prompton Lake Reservoir is located on the West Branch of the Lackawaxen River in the Lackawaxen River Basin, approximately 4.7 miles upstream of Honesdale, Pennsylvania and a half-mile upstream of the village of Prompton, Pennsylvania. This reservoir is an estimated 31 miles above the confluence of the Lackawaxen River with the Delaware River at Lackawaxen, Pennsylvania. The Prompton Lake Reservoir is a part of an integrated reservoir flood control network, in which it, in combination with the General Edgar Jadwin Dam, provides flood control protection, in varying degrees, to the Boroughs of Prompton, Honesdale, and Hawley, all of which are located in Pennsylvania. In addition, the reservoir aids in the flood control protection of smaller communities along the Lackawaxen River. The Prompton Lake Dam was completed in July of 1960 and is categorized as a zoned earthfill embankment type of structure. Measuring 1,200 feet in length and 140 feet in height, the Prompton Lake Dam spans a drainage area of 59.6 miles, with a flood control storage volume of 48,500 acre-feet (U.S. Army Corps of Engineers, http://www.nap-wc.usace.army.mil/prmpr.html)

Neversink Reservoir
Construction on the Neversink Reservoir, located in Sullivan County, New York, began in 1941, but was suspended throughout the World War II period. It resumed in 1946. Although the reservoir was deemed functional and was in operation by 1950, construction was complete three years later in 1953. Fed by the Neversink River, the Neversink Reservoir is considered to be one of the major water sources for New York City as well as the finest of the City's reservoir system, with a storage capacity of 35.5 billion gallons of water, which serves a watershed area of 95 square miles (The Catskill Center,
http://www.catskillcenter.org/programs/csp/H20/Lessons4/nyctime2.htm,
Tri-Valley Central School, http://www.mhric.org/tri-valley/Neversink.html, and the Catskill Watershed Corporation,
http://www.cwconline.org/about/ab_hist.htm).

Cannonsville Reservoir
Located in the village of Cannonsville in southwestern Delaware County, the Cannonsville Reservoir is an estimated 15 miles in length and averages one-half mile in width. In 1967, a dam was constructed across the West Branch of the Delaware River, and the reservoir was created in order to supply water to New York City, where water is diverted via the West Delaware Tunnel. Cold water is also released into the West Branch of the Delaware River via valves, located at the base of the dam. These cold water releases from the bottom of the reservoir have fostered an excellent trout fishery, located in the river below the dam. With a storage capacity of 95.7 billion gallons, the reservoir, when full, comprises 4,800 surface acres and lies approximately 1,150 feet

above sea level (Bear Systems, http://www.bearsystems.com/cannonsville/cannonsville.html, The Catskill Center, http://www.catskillcenter.org/programs/csp/H20/Lessons4/nyctime2.htm).

Pepacton Reservoir

The Pepacton Reservoir, on the East Branch of the Delaware River in Delaware County, New York, was created in 1955 by impounding the East Branch of the Delaware River near the village of Downsville, New York with a 2,400 foot-long dam. With a storage capacity of 140.2 billion gallons, and measuring 18 miles in length, the Pepacton is New York City's largest reservoir. When full, the reservoir comprises 5,700 surface acres and is an estimated 1,280 feet above sea level. Water usage results in seasonal fluctuations of reservoir water levels. Although typically full between the months of March and June, water withdrawals normally result in the gradual drawdown of water during the summer and the fall (Bear Systems, http://www.bearsystems.com/Reservoirs/reservoirs4.htm, the Catskill Watershed Corporation, http://www.cwconline.org/about/ab_hist.htm, and The Catskill Center, http://www.catskillcenter.org/programs/csp/H20/Lessons4/nyctime2.htm)

Lake Wallenpaupack Dam

Lake Wallenpaupack, located in the Pocono Mountains of Northeastern Pennsylvania, partially in both Wayne and Pike Counties, measures 13 miles in length and 2 miles at its widest point. The lake spans a surface area of 5,700 acres and is comprised of 52 miles of shoreline. A dam across the Wallenpaupack Creek was constructed by the Pennsylvania Power and Light Company (PP&L) for the purpose of generating hydroelectric power. Construction began in 1924 and was completed by 1926. Two thousand seven hundred men worked on the dike at Tafton, Pennsylvania, as well as the concrete dam at Wilsonville that measures 1,280 feet in length and 70 feet in height. A power plant, located along the Lackawaxen River, receives water for power generation from the Lake Wallenpaupack Dam via a pipeline that measures 14 feet in diameter and 3.5 miles in length. This power plant, in conjunction with the hydroelectric power generated by the dam, is capable of producing 44,000 kW of electricity. Although the Wallenpaupack Dam was specifically constructed as a power dam, it has also served the purpose of providing flood protection along the Lackawaxen River in past years (Pocono Powerboaters Association of Lake Wallenpaupack, http://www.enter.net/~prodoor/lake.htm).

Flows in the Delaware River Basin are due partially to groundwater discharges (baseflow) and partially due to runoff from rain events. Runoff has a distinct seasonal variation. The most runoff occurs during winter or early spring, and the lowest amount of runoff occurs during the late summer or early fall. Runoff is chiefly dependent on the amount of rainfall that a specific area receives; after the winter months, the accumulated snow melts in the early spring create additional runoff and high water tables. The flow in the rivers are generally higher during this time. During the dry late summer months, there is very little runoff and the water table is lower. As a result, streamflow is generally at its lowest at the end of the summer.

In the Delaware River Basin, Precipitation is normally between 40 and 50 inches per year. As a result of loss of precipitation by evaporation and transpiration, only about half of the precipitation falling within the watershed reaches surface waters.

Pollution has been a serious problem in the lower Delaware River Basin for many years. Mine drainage in the headwaters of some of the tributaries has exacerbated the water quality problems caused by domestic waste discharge, because the resulting toxic environment inhibits stream self-purification. The microorganisms that would normally oxidize the organic wastes are either destroyed or hindered by the acidic environment produced by mine drainage. Thus, the organic waste is preserved until the stream environment becomes favorable for microbiological activity. In recent decades, the water quality in the River has seen substantial improvement, as point source discharges of wastewater have been addressed.

Table 1.2.4-3 summarizes the locations, drainage areas, annual mean flows, and annual runoff at 20 gauging stations along the Delaware River. The first gauging station listed is the northernmost one within the study area located along the Delaware River at Port Jervis, New York. The last gauging station on the chart that is located along the lower portion of the Delaware River is the one near Trenton. Below Trenton, the Delaware River is influenced by the tides, and flows vary within the tidal cycle.

Table 1.2.4-3 Stream Gauging Data in the Delaware River Basin

Station ID	Location	Drainage Area (mi2)	Period of Record *	Annual Mean Flow (cfs)	Annual Runoff (Inches)	10% Exceeds (cfs)	50% Exceeds (cfs)	90% Exceeds (cfs)
1434000	Delaware River at Port Jervis NY	3070	1964-2000	4762	N/A	10300	2850	1500
1438500	Delaware River at Montague NJ	3480	1940-2000	5702	N/A	12100	3440	1600
1440200	Delaware River at Delaware	3850	1909-1996					
1442500	Brodhead Creek at Minisink Hills PA	259	1951-2000	560	2.16	1200	350	93
1443500	Paulins Kill at Blai	126	1921-2000	191.78 **	N/A			
1445500	Pequest River at Pequest	106	1921-2000	157.29 **	N/A			
1446500	Delaware River at Belvidere NJ	4535	1923-2000	7838	N/A	16600	5020	1950
1447800	Lehigh River below Francis E. Walter Res. Near White Haven PA	290	1961-2000	625	N/A	1330	415	108
1449000	Lehigh River at Lehighton PA	591	1983-2000	1302	2.2	2660	899	280
1449800	Pohopoco Creek below Beltzville Dam near Parryville PA	96.4	1968-2000	167	N/A	371	105	36
1451000	Lehigh River at Walnutport PA	889	1947-2000	1862	2.09	3860	1300	410
1451500	Little Lehigh Creek near Allentown PA	80.8	1946-2000	100	1.24	171	79	40
1453000	Lehigh River at Bethlehem PA	1279	1941-2000	2462	1.92	4850	1780	685
1454700	Lehigh River at Glendon PA	1359	1967-2000	2856	N/A	5360	2090	870
1457790	Cooks Creek at Durham Furnace PA	29.4	1990-1993	41.1 **	N/A			
1463500	Delaware River at Trenton NJ	6780	1913-2000	11670	N/A	24600	7940	3000
1464000	Assunpink Creek at Trenton	90.6	1923-2000	133.64 **	N/A			
1465500	Neshaminy Creek near Langhorne PA	210	1935-2000	299	N/A	580	140	32
1465798	Poquessing Creek at Grant Ave. at Philadelphia PA	21.4	1965-2000	32.7	N/A	61	12	4.4
1467048	Pennypack Creek at Lower Rhawn St. Bridge Philadelphia PA	49.8	1965-2000	90.9	1.83	169	49	21

** Information from report for AMF, AR, 10%, 50%, 90% were reported between these dates in water years*
*** Calculated Value from yearly data*
http://pa.water.usgs.gov/ar/wy00/pdfs/v1all-00.pdf

Table 1.2.4-4 and Figure 1.2.1-1 describe the size and location of the various tributaries and drainage areas within the Delaware River Basin. As shown, the Lehigh Creek is the largest tributary discharging to the Delaware River north of Trenton. As noted above, the reservoir releases from the New York City reservoirs provide the most water, and can have significant impacts on water quality of the Delaware River.

Table 1.2.4-4 Characteristics of Tributaries in the Delaware River Watershed (in alphabetical order)

Major Tributary	Drainage Area (mi2)	River Mile Location	Length (mi)
Adams Creek	8.1	240	5.536
Alexauken Creek	15.1	150	6.797
Allegheny Creek	9.1	200	4.642
Alloway Creek	52.8	55	21.513
Aquetong Creek	8.0	149	3.732
Assiscunk Creek	45.9	119	16.310
Beaverdam Creek	10.6	299	10.951
Big Timber Creek	55.2	96	16.004
Buck Creek	7.0	138	3.806
Buckhorn Creek	11.8	193	7.569
Bush Kill (Lower)	123.8	227	34.523
Bush Kill (Upper)	6.6	259	5.480
Bustleton Creek	2.6	121	2.907
Byberry Creek	18.7	112	10.595
Cherry Creek	2.1	213	13.587
Chester Creek	66.4	83	19.271
Conashaugh Creek	2.1	243	2.526
Cooks Creek	29.5	174	13.904
Cooley Creek	3.3	312	3.336
Cooper River	40.2	102	15.807
Copper Creek	3.3	163	3.336
Crafts Creek	13.8	125	11.382
Crawford Branch	1.3	249	2.886
Crosswicks Creek	138.5	129	26.458
Crum Creek	38.3	85	22.110
Cummins Creek	5.3	250	5.231
Darby Creek	77.2	86	24.710
Dark Hollow Run	0.70	148	1.687
Delawanna Creek	4.5	205	5.393
Delaware River, WFK	51.0	331	7.658
Dingmans Creek	16.5	239	9.096
Dry Brook	1.2	241	1.499
Dunnfield Creek	3.6	212	4.069
Dyers Creek	1.2	140	1.832
Equinunk Creek	57.6	323	14.899
Factory Creek	4.3	323	5.512

Major Tributary	Drainage Area (mi2)	River Mile Location	Length (mi)
Fiddlers Creek	2.0	143	2.485
Flat Brook	66.2	225	26.095
Frya Run	6.1	177	3.770
Gallows Run	8.7	172	5.238
Hakihokake Creek	16.7	168	7.904
Harihokake Creek	9.9	166	7.221
Hessian Run	12.0	92	2.941
Hollister Creek	9.5	305	4.986
Hornbecks Creek	9.5	236	1.140
Houghs Creek	0.5	141	5.558
Jacoby Creek	6.4	208	4.178
Jericho Creek	9.6	144	6.384
Kittatinny Creek	1.5	239	2.374
Lackawaxen River	487.6	278	27.074
Lackawaxen River, S	2.0	278	2.178
Lehigh River	1360.4	184	107.467
Little Equinunk Creek	25.2	313	10.813
Little Nishisakawick Creek	3.5	164	3.678
Lockatong Creek	23.2	154	14.797
Lopatcong Creek	14.7	182	10.478
Mantua Creek	49.9	90	18.994
Marcus Hook Creek	5.2	80	7.329
Martins Creek (Lower)	11.5	123	5.057
Martins Creek (Upper)	44.6	191	14.544
Masthope Creek	23.8	284	8.439
McMichael Creek	276.6	213	34.884
Mill Creek	19.8	119	39.958
Mill Run	37.0	105	14.814
Moores Creek	10.2	145	4.686
Mud Run	6.0	189	19.795
Musconetcong River	158.1	175	54.771
Neshaminy River	232.4	116	51.376
Newton Creek	10.6	97	10.580
Nishisakawick Creek	11.0	164	9.137
North Branch Calkins Creek	44.2	296	11.713
Oldmans Creek	45.8	77	20.619
Oughoughton Creek	11.9	194	6.839
Panther Creek	4.2	275	3.722
Paulins Kill	176.9	208	39.469

Major Tributary	Drainage Area (mi2)	River Mile Location	Length (mi)
Paunnacussing Creek	7.9	156	5.270
Peggy Run	2.2	290	1.482
Pennsauken Creek	36.1	106	13.066
Pequest River	157.1	198	32.440
Pidcock Creek	12.7	146	7.064
Plum Brook	26.6	153	19.063
Pohatcong River	55.4	178	28.094
Pompeston Creek	7.7	109	5.375
Pond Eddy Creek	6.9	267	3.974
Pond Run	91.3	134	12.709
Pophandusing Brook	5.5	198	4.819
Rabbit Run	0.4	150	1.116
Rancocas Creek	347.7	111	33.657
Raymondskill Creek	25.2	244	11.655
Repaupo Creek (Lower)	45.5	80	18.800
Repaupo Creek (Upper)	14.4	84	9.716
Ridley Creek	37.9	84	23.237
Rockledge Branch	55.1	110	15.572
Salem River	114.9	59	38.227
Sawkill Creek	23.5	247	7.537
Schoolhouse Creek	2.3	299	3.006
Shoeneck Creek	79.9	184	14.037
Shohola Creek	85.2	274	28.958
Slateford Creek	3.0	210	3.732
Stoney Creek	0.8	81	2.245
Stony Brook	4.1	209	7.598
Swan Creek	3.3	149	1.468
Tinicum Creek	24.0	162	10.927
Tohickon Creek	103.9	157	29.254
Toms Creek	9.4	230	7.228
Twin Lakes Creek	11.5	270	5.425
Vancampens Brook	8.9	220	8.090
Vandermark Creek	5.2	248	4.257
Warford Creek	1.4	161	2.416
Westcolang Creek	4.5	281	1.983
Weston Brook	2.5	320	2.345
White Brook	2.1	246	1.935

Table 1.2.4-5 provides information about the characteristics of the reservoirs in the watershed. As shown, the detention time in these reservoirs is significant, which impacts both water quality and zone delineation boundaries.

Table 1.2.4-5 Reservoir Characteristics in the Delaware River Watershed

RES #	STATE	RESERVOIR NAME	DAM NAME	RIVER NAME	DRAINAGE AREA (mi2)	PERCENT OF BASIN AREA	WATER TOT (DAYS)	DISCHARGE (gal/s)	NORMAL CAPACITY (billions of gallons	SURFACE AREA (mi2)
2011	PA	Francis E. Walter Lake	Francis E. Walter	Lehigh River	674.90	8.9	0.71	10629.07	0.65	0.14
1769	NY	Cannonsville Reservoir	Cannonsville Dam	West Branch Delaware River	496.52	6.6	215.3	5272.27	98.08	7.50
1693	NY	Pepacton Reservoir	Downsville Dam	East Branch Delaware River	364.48	4.8	419.47	4135.97	149.89	10.00
1713	NY	Rio Reservoir	Rio Dam	Mongaup River	258.68	3.4	17.48	2828.38	4.27	0.90
2026	PA	Lake Galena	Peace Valley Dam	Neshaminy Creek	188.80	2.5	8.77	2810.43	2.13	0.59
2035	PA	Beltzville Lake	Beltzville	Pohopoco Creek	179.15	2.4	75.11	2069.85	13.43	1.47
1714	NY	Swinging Bridge Reservoir	Swinging Bridge Dam	Mongaup River	169.49	2.2	59.1	1745.20	8.91	1.56
2056	PA	Lake Wallenpaupack	Wallenpaupack Dam	Wallenpaupack Creek	141.69	1.9	290.39	2787.98	69.95	9.68
2052	PA	Pocono Lake	Pocono Lake Dam	Tobyhanna Creek	124.32	1.6	17.87	1140.03	1.76	1.17
2053	PA	Lake Nockamixon	Nockamixon State Park Dam	Tohickon Creek	97.68	1.3	97.49	1546.97	13.03	2.26
2043	PA	Shohola Marsh Reservoir	Shohola Marsh Dam	Shohola Creek	91.12	1.2	33.81	1406.33	4.10	1.75
2010	PA	Prompton Lake	Prompton	Lackawaxen River	83.01	1.1	11.78	1088.41	1.10	0.43
1718	NY	Neversink Reservoir	Neversink Reservoir Dam	Neversink River	77.22	1	251.89	1677.13	36.49	2.34
1683	NY	Toronto Reservoir	Toronto Lake Reservoir Dam	Black Lake Creek	51.35	0.7	155.45	530.36	7.11	1.25
	PA	Churchville Reservoir	N/A	Ironworks Creek	1.63	N/A	30*	N/A	N/A	0.26
	PA	Silver Lake	N/A	Mill Creek	1.45	N/A	30*	N/A	N/A	0.09
	PA	Core Creek	N/A	Core Creek	3.28	N/A	30*	N/A	N/A	0.27

1.2.4.2 Flooding

The Delaware River Basin has seen a number of major floods during the last century. Often, the flooding does not impact the basin as a whole, but rather, only a portion of it. For instance, within the upper basin, major floods occurred in 1942, 1945, 1955, 1967, 1972, and 1981. In the lower basin, major floods occurred in 1931, 1933, 1942, 1950, 1954, 1955, 1960, 1964, 1967, 1972, and 1975. The most significant amount of flood damage was recorded in the Delaware Basin after the flood of 1955, which was caused by two tropical storms passing over the area within only one week of each other. Tropical Storm Connie saturated the basin's soil and caused minor flooding, only to be followed by Tropical Storm Diane, whose heavy precipitation acted as a catalyst for unusually high surface runoff, which in turn caused severe flooding throughout the basin. More damage was done to the region in 1972, as Tropical Storm Agnes caused major flooding, with particularly heavy damage to the Schuylkill River drainage area. As was the case with previous floods, the area's soil was saturated and subsequent heavy rainfall caused rapid runoff.

Due to the persistence of heavy flooding within the Delaware River Basin, flood control was tackled on two fronts: through the Pennsylvania State Water Plan, and by the Delaware River Basin Commission. Efforts on both fronts have resulted in great strides in flood prevention. A number of flood damage centers and reaches have been identified in the attempt to alleviate the worst flooding. A damage reach may be defined as a place where a single flood causes damage of $25,000 or more, a center is identified as a region where the average annual flood damages per mile of stream length totals $500 or more.[1] With each flood, more centers and reaches have been added. This point is illustrated by the 1972 flood, which resulted in the creation of 58 new damage centers in Pennsylvania within the Lower Delaware Basin alone.

Measures to control flooding can be either structural or nonstructural. Structural measures, including reservoirs, levees, floodwalls, and channel modifications have been used in the past to reduce flood damage. An example of this type of structural measure is a completed earthen levee and a concrete wall developed by the Army Corps of Engineers for the purpose of protecting the City of Chester. In the Lehigh Valley, the Corps of Engineers has also constructed the Francis E. Walter Dam, which aids in reducing flood damage in 29 damage centers. Adding to their list of accomplishments, the Corps has also completed the Blue Marsh Lake Project in an attempt to lessen flood damages in 20 centers, which are located downstream of the reservoir. The Pennsylvania Department of Environmental Resources has completed five projects to reduce damages within Morrisville, Warrington, Weissport, and Allentown. In addition, the Soil Conservation Service is presently carrying out flood damage reduction work.

Since structural measures are not total solutions to the flooding problem, flood protection projects will protect a community against only a particular type or size of flood. If the quantity of water exceeds the design criteria, flood damage will occur. As a consequence, nonstructural measures must also be developed in order to fully mitigate

[1] These dollar amounts are equivalent to 1969 dollars.

flood damage. Of these nonstructural measures, floodplain regulations for land use are among the most effective controls. Because floodplains were major areas of economic development in the past, there must be a relocation of activities in flood-prone areas and land acquisition must assure flood-compatible developments. Other nonstructural measures include flood forecasting, warning systems, and flood insurance. Flooding has been a problem in the Delaware Basin and attempts have been made to diminish the damage, however, permanent solutions to flooding have yet to be found. (Majumdar, Millar, and Sage, 1988).

1.2.4.3 Groundwater

In 1988, two and a half million people, or 1/3 of the Delaware River Basin, obtained their drinking water from groundwater sources (Majumdar, Miller, and Sage, 1988). The reliability of groundwater supplies depends on the geology and soil type. In most areas of the Delaware River Basin, the aquifers are composed of fractured bedrock, and usually yield limited quantities of water suitable mainly for domestic wells.

There are four principal types of aquifers in the Delaware River Basin: unconsolidated deposits, crystalline rocks, carbonate rocks, and clastic rocks. The best areas for large supplies of groundwater are the areas underlain by carbonate rocks in the southern part of the basin (Great Valley). Other high yielding aquifers can be found in Philadelphia and south within the unconsolidated deposits in the Coastal Plain.

Most of the aquifers in the Delaware River Basin are composed of consolidated rocks, with the exception of the Coastal Plain deposits in Philadelphia and the thick, weathered mantle in a few isolated areas. Groundwater can occur under water table or artesian conditions. Water table conditions are generally the rule within the Delaware River Basin. Below the water table, the spaces between the soil particles can store or transmit water. These areas have high permeability if the soil is primarily sand and gravel, and low permeability if the soil has a large fraction of silt or clay. The consolidated rocks have very little primary porosity, except for a few of the coarse sandstone beds, and their ability to store and transmit water is small. In most aquifers throughout the basin, water moves through and is stored in openings developed along joints, fractures, faults, and cleavage and bedding planes in the rock (called secondary porosity). These conditions were formed when rocks were stressed by movements in the earth's crust, and they may be enlarged by solution, earthquakes, and earth tides.

Groundwater flows with very low velocity when compared with surface water. Water that reaches the water table has been in contact with the rocks of the aquifer for a much longer time than it has been in contact with the atmosphere or soil. Therefore, much of the dissolved solids in groundwater are derived from aquifers. As contact time between the water and the rock increases, the mineral content of the water also increases to the saturation point. Groundwater in some areas may be contaminated locally by on-site disposal of domestic waste.

1.2.4.3.1 Stressed Groundwater Areas

In 1999, the Delaware River Basin Commission (DRBC) adopted regulations that establish groundwater withdrawal limits for 76 watersheds that fall either entirely or partly within the Groundwater Protected Area of Southeastern Pennsylvania.

The Protected Area (see Figure 1.2.4-5), where more stringent regulations apply to groundwater withdrawals within the Delaware River Basin, was established by the commission in 1980 at the request of the Commonwealth of Pennsylvania after it became evident that development was negatively impacting groundwater levels. The goal is to prevent depletion of groundwater and to protect the interests and rights of lawful users of the same water source, as well as balance and reconcile alternative and conflicting uses of limited water resources in the region.

Declining water tables in the Protected Area have reduced flows in some streams that are groundwater fed, resulting in some stream beds that are totally dry. This reduction in baseflow affects downstream water uses, negatively impacts aquatic life, and can reduce the capacity of waterways in the region to assimilate pollutants.

The Protected Area uses a two-tiered system of water withdrawal limits. The first tier serves as a warning that a subbasin is "potentially stressed". The second tier establishes a maximum groundwater withdrawal limit. In potentially stressed subbasins, applicants for new or expanded groundwater withdrawals are required to implement one or more programs to mitigate adverse impacts of additional groundwater withdrawals. Acceptable programs include conjunctive use of groundwater and surface water, expanded water conservation programs, programs to control groundwater infiltration, and artificial recharge and spray irrigation.

The Groundwater Protected Area Regulations for Southeastern Pennsylvania also:

- Provide incentives for holders of existing DRBC dockets and Protected Area permits to implement one or more of the above programs to reduce the adverse impacts of their groundwater withdrawals. If docket or permit holders successfully implement one or more programs, the commission will extend the docket or permit duration for up to ten years.

- Specify criteria for the issuance and review of dockets and permits as well as procedures for revising withdrawal limits to correspond with integrated water resource plans adopted by municipalities for subbasins.

- Establish protocol for updating and revising withdrawal limits to provide additional protection for streams designated by the Commonwealth of Pennsylvania as "high quality," or "wild, scenic, or pastoral," as defined by the state's Scenic Rivers Program.

The Groundwater Protected Area includes 1,200 square miles and 127 municipalities. In addition to the Neshaminy Creek Watershed, other large drainage areas include the Brandywine Creek, Perkiomen Creek, and Wissahickon Creek subbasins.

In addition to all of **Montgomery County**, the following areas in surrounding counties fall within the Protected Area:

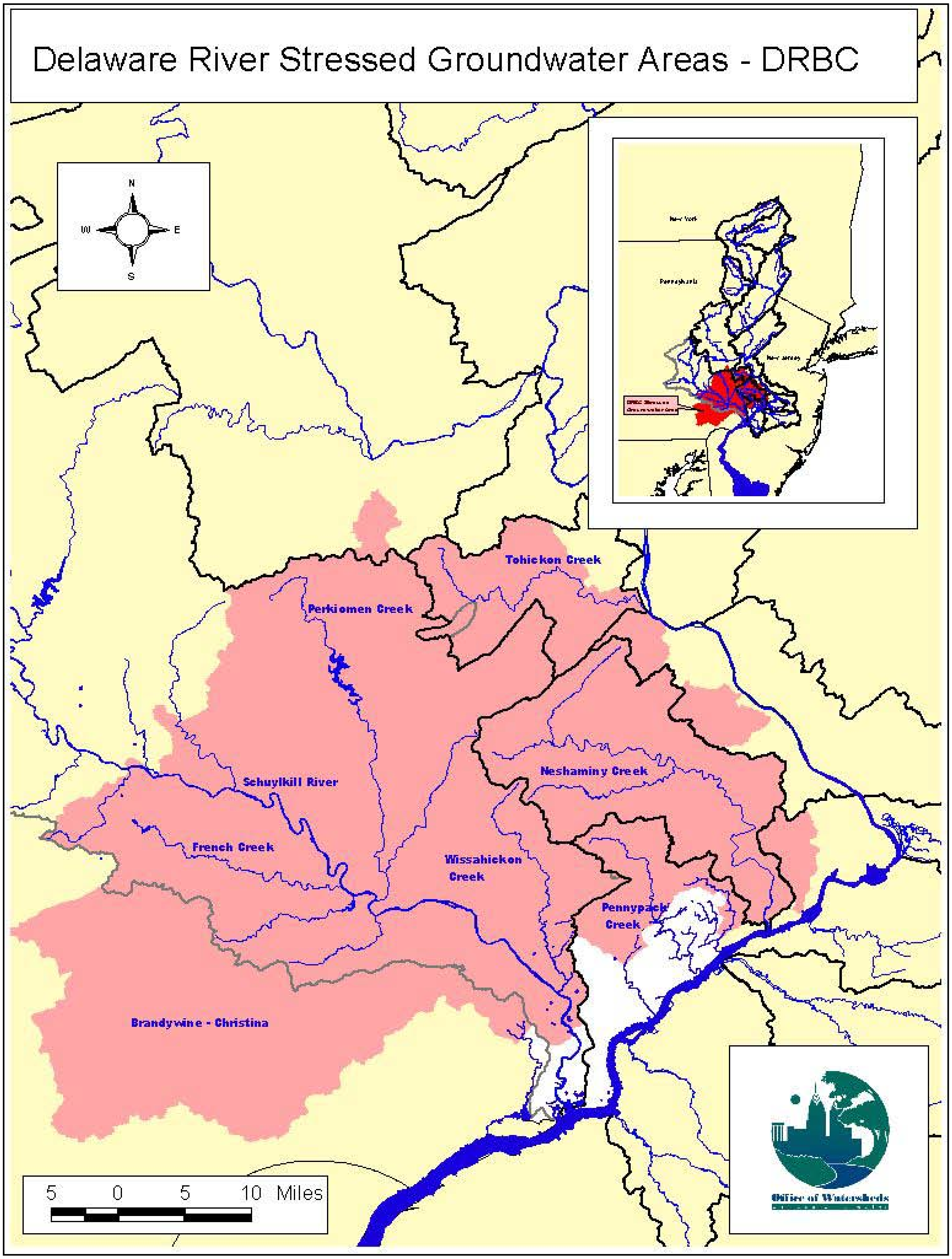
Berks: the Townships of Douglass, Hereford, and Union.

Bucks: the Townships of Bedminster, Buckingham, Doylestown, East Rockhill, Hilltown, Lower Southampton, Middletown, Milford, New Britain, Newtown, Northampton, Plumstead, Richland, Upper Southampton, Warminster, Warrington, Warwick, West Rockhill, and Wrightstown; the Boroughs of Chalfont, Doylestown, Dublin, Hulmeville, Ivyland, Langhorne, Langhorne Manor, New Britain, Newtown, Penndel, Perkasie, Quakertown, Richlandtown, Sellersville, Silverdale, Telford, and Trumbauersville.

Chester: the Townships of Birmingham, Charlestown, East Bradford, East Coventry, East Goshen, East Pikeland, Easttown, East Vincent, East Whiteland, North Coventry, Schuylkill, South Coventry, Thornbury, Tredyffrin, Warwick, West Bradford, West Goshen, Westtown, Willistown, and West Whiteland; the Boroughs of Elverson, Malvern, Phoenixville, Spring City and West Chester.

Lehigh: Lower Milford Township.

Figure 1.2.4-5 Delaware River Stressed Groundwater Areas - DRBC



1.2.5 Land Use in the Delaware River Watershed

Key Points

- **The Delaware River Watershed encompasses 40 counties within Pennsylvania, New Jersey, New York, and Delaware. The SWAP study area includes 30 of these counties.**
- **Philadelphia has the highest population density of any county within the watershed.**
- **The most immense population gains are forecasted to occur within the suburban and rural communities located on the fringe of urbanized areas.**
- **The majority of developed land is located within the southern portion of the SWAP study area, between Lehigh County and Philadelphia County.**
- **The majority of the land within the study area remains forested, although a pattern of suburban sprawl has emerged.**
- **The development of agricultural and rural lands is a cause for concern because it may lead to a loss of habitat for wildlife and an increase in erosion and pollution, which may adversely affect drinking water supplies.**

In order to characterize the Delaware River Watershed and SWAP study area, the National Land Cover Dataset (NLCD) was obtained from the USGS website, http://landcover.usgs.gov/natllandcover.html. The NLCD is a 21-class land cover classification and is based on the USGS' early-mid 1990s 30-meter Landsat Thematic Mapper ™ supplemented with additional data analysis and interpretation of the Landsat data.

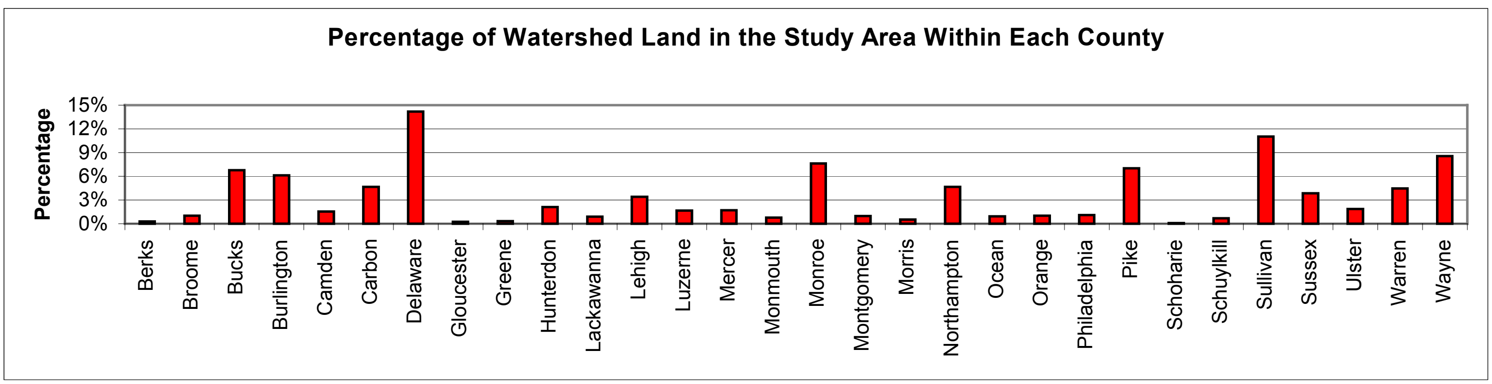
Identifying and characterizing potential contaminant sources within the SWAP study area is just one focus of the Source Water Assessment Program. Reliable characterization of the land use within the study area is important for the source water assessment process, as it is the basis for estimating non-point source loadings. The USGS data set was used as the basis for the land use characterization in the study area because it is believed to the most accurate characterization available.

Table 1.2.5-1 Forty Counties in the Delaware River Watershed by State

Delaware	New Jersey		New York	Pennsylvania	
Kent	Atlantic	*Monmouth*	*Broome*	*Berks*	*Luzerne*
New Castle	*Burlington*	*Morris*	*Delaware*	*Bucks*	*Monroe*
Sussex	*Camden*	*Ocean*	*Greene*	*Carbon*	*Montgomery*
	Cape May	Salem	*Orange*	Chester	*Northampton*
	Cumberland	*Sussex*	*Schoharie*	Delaware	*Pike*
	Gloucester	*Warren*	*Sullivan*	*Lackawanna*	*Philadelphia*
	Hunterdon		*Ulster*	*Lebanon*	*Schuylkill*
	Mercer			*Lehigh*	*Wayne*

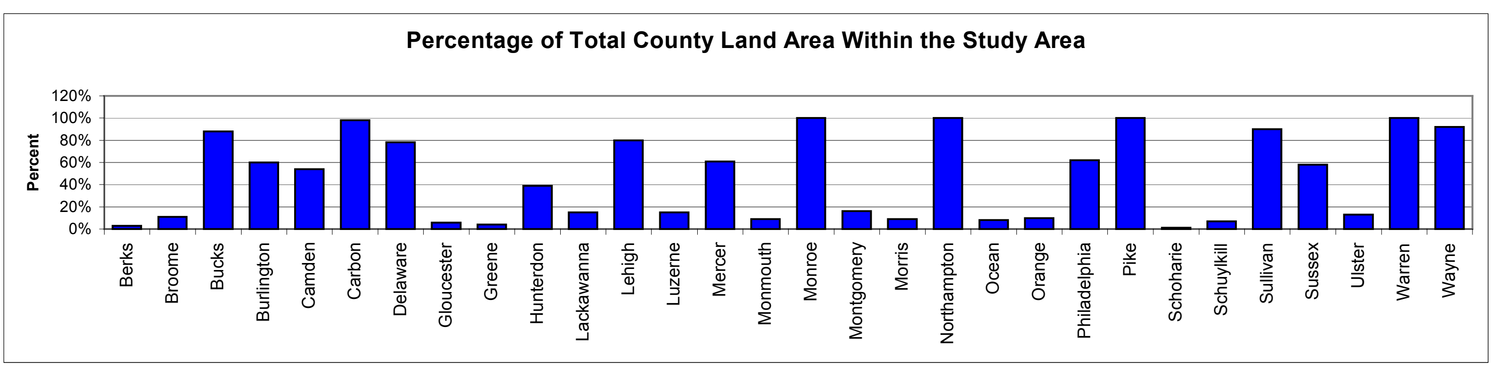
A total of 40 counties have land located within the Delaware River Watershed. Table 1.2.5-1 outlines all 40 of these counties, broken down by state. The counties shown in blue are also located within the SWAP study area. The study area is comprised of 30 counties located within Pennsylvania, New Jersey, and New York. Of these 30 counties, four (Warren County in New Jersey, Monroe, Northampton, and Pike Counties in Pennsylvania) are located entirely within the boundaries of the Delaware River Watershed. (Figure 1.2.5-2) However, since the SWAP study area consists of so many different counties and is 8,106 square miles in size, none of the individual counties make up a majority of the total land area within the study area. Delaware County in New York has the highest percentage of land within the study area at approximately 14%. Warren, Monroe, Northampton, and Pike Counties combined contain about 24%. Philadelphia County, which is the smallest county within the study area but has the largest population, makes up only 1% of the total land within the study area. Sixty percent of Philadelphia County is located within the Delaware River Watershed. The land area totals for each of the counties is shown in Figure 1.2.5-1.

Figure 1.2.5-1 Percentage of Watershed Land in the Study Area Within Each County



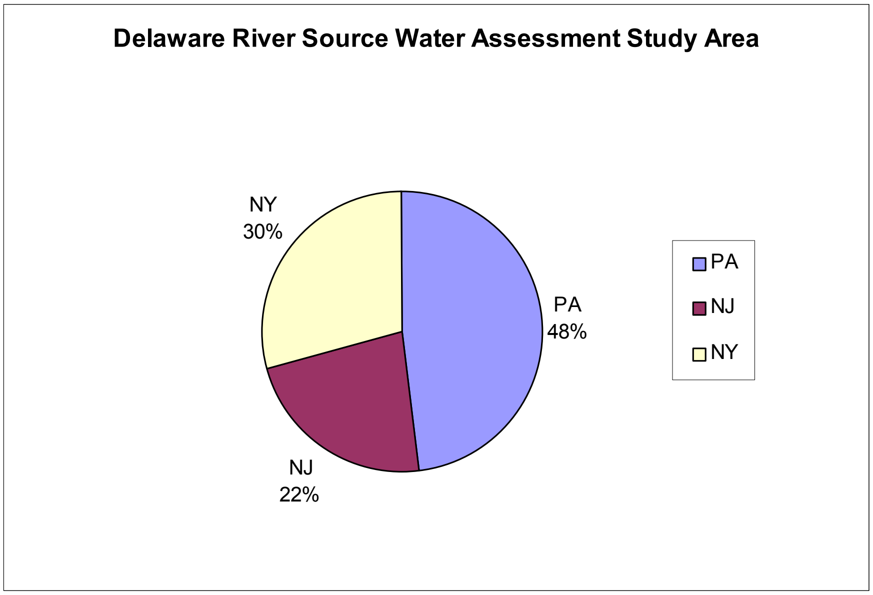
Source: USGS National Land Cover Data 1992

Figure 1.2.5-2 Percentage of Total County Land Area Within the Study Area



Source: USGS National Land Cover Data 1992

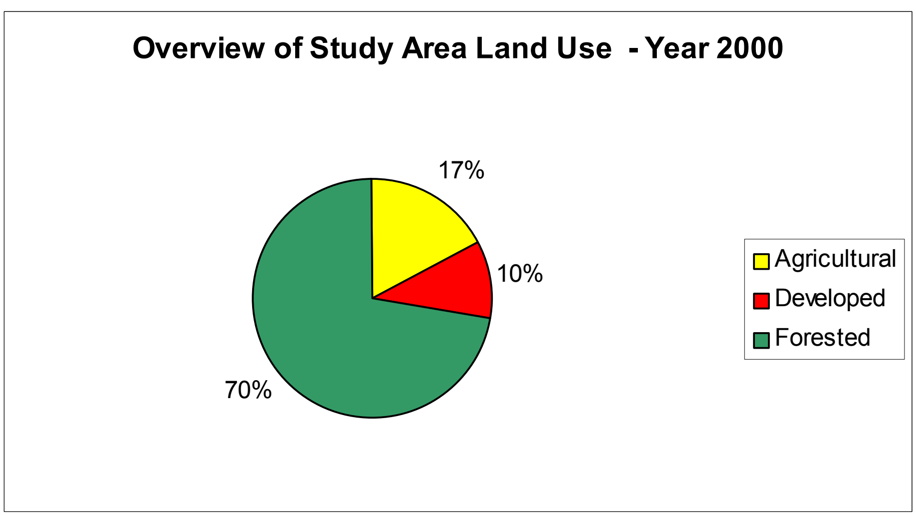
Figure 1.2.5-3 Percentages of Watershed Land by State for the Study Area



Source: USGS National Land Cover Data 1992

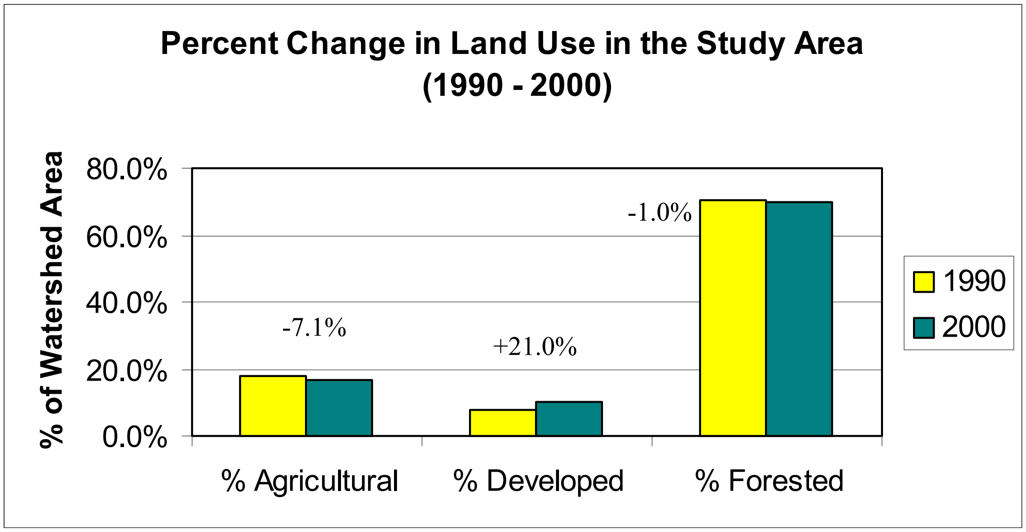
According to the NLCD estimated land use for 2000, 70% of the SWAP study area is comprised of forested lands. Seventeen percent of the area is used for agricultural purposes and 10% is developed. (Figure 1.2.5-4) Decreases in agricultural and forested areas result from increases in development (i.e., residential, commercial, industrial, transportation). Since 1990, there has been a 21% increase in development, and a 7% and 1% decrease in agricultural and forested lands, as shown in Table 1.2.5-2 and Figure 1.2.5-5.

Figure 1.2.5-4 Overview of Study Area Land Use – Year 2000 (Estimated)



Source: USGS National Land Cover Data 1992

Figure 1.2.5-5 Percent Change in Land Use in the Study Area (1990-2000)



Source: USGS National Land Cover Data 1992

Table 1.2.5-2 Land Use Changes in the Study Area: 1990 – 2000

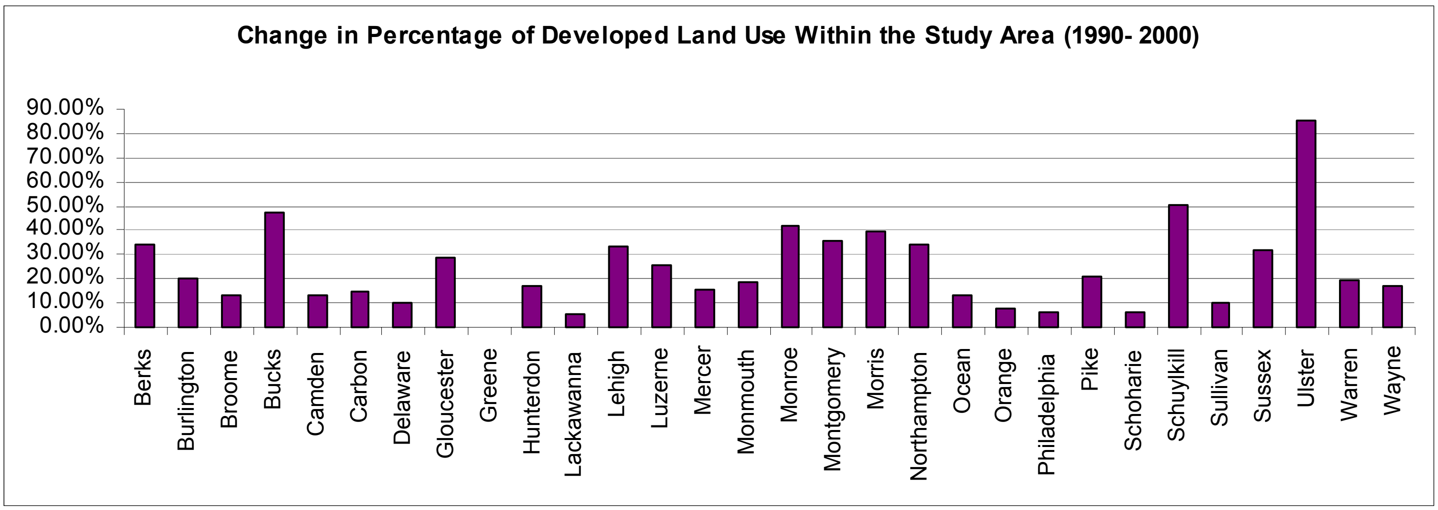
	1990	2000	% Change
% Agricultural	18.2%	17.0%	-7.1%
% Developed	7.9%	10.0%	21.0%
% Forested	70.7%	70.0%	-1.0%

Source: USGS National Land Cover Data 1992
*Note: To calculate % change in agriculture land from 1990 to 2000: [(17.0-18.2)/18.2]*100=-7.1%*

Ulster County in New York had the highest change in percentage of developed land from 1990 to 2000 with an 85.5% increase, although Ulster County still remains one of the least developed counties overall within the study area. Schuylkill County in Pennsylvania experienced a 51% change in developed land during this time, but also remains one of the least developed counties. Philadelphia County is the most developed county within the study area with a developed area rate of about 83%. However, since Philadelphia is already so developed, there was little change from 1990 to 2000. Bucks County in Pennsylvania experienced the greatest actual development increase with 27,645 acres developed. This increase reflects a 32% change in developed land within the Bucks County portion of the study area. This overall percentage is lower when compared to the other counties, but the amount of development is equal to approximately 43 square miles and is all located within a single county. (Figure 1.2.5-6 and Table 1.2.5-3)

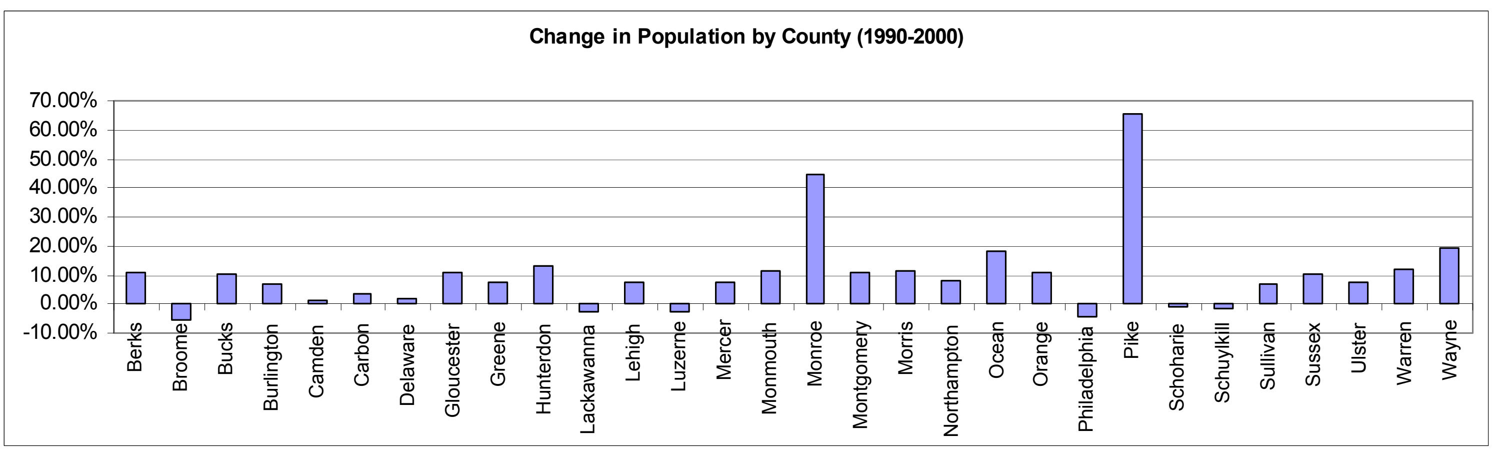
County populations between 1990 and 2000 had the greatest increase in Pike, Monroe, and Warren Counties, all of which are located at the northern end of the study area near the New York and north New Jersey State borders. Pike County alone experienced a 66% change in population from 27,966 to 46,302 persons. Increases in population generally occurred in the suburban Philadelphia counties, which follow a pattern of suburban sprawl within this area. This increase in population is a direct indicator of the increase in development activities that have occurred in these counties as well. Philadelphia, Lackawanna, and Luzerne Counties in Pennsylvania and Broome County in New York, each experienced a loss of population from 1990 to 2000, but still lost acreage to development. (Figure 1.2.5-7)

Figure 1.2.5-6 Change in Percentage of Developed Land Use Within the Study Area by County



Source: USGS National Land Cover Data 1992

Figure 1.2.5-7 Change in Population by County (1990-2000)



Source: 2000 U.S. Census

Table 1.2.5-3 Change in Percentage of Developed Land Use Within the Study Area by County

	1990	2000	Change in Percentage
Berks	3.24%	4.35%	34.27%
Burlington	19.51%	23.38%	19.82%
Broome	0.58%	0.66%	12.88%
Bucks	16.70%	24.59%	47.21%
Camden	65.72%	74.55%	13.35%
Carbon	2.86%	3.28%	14.79%
Delaware	0.58%	0.64%	10.28%
Gloucester	43.96%	56.54%	28.62%
Greene	0.00%	0.00%	0.00%
Hunterdon	2.35%	2.74%	16.78%
Lackawanna	2.32%	2.44%	5.06%
Lehigh	16.39%	21.92%	33.75%
Luzerne	2.57%	3.23%	25.46%
Mercer	33.55%	38.84%	15.78%
Monmouth	2.58%	3.06%	18.85%
Monroe	3.44%	4.88%	41.69%
Montgomery	47.69%	64.75%	35.78%
Morris	10.33%	14.41%	39.52%
Northampton	10.38%	13.95%	34.40%
Ocean	3.70%	4.18%	12.92%
Orange	4.48%	4.82%	7.69%
Philadelphia	77.92%	82.54%	5.92%
Pike	1.39%	1.69%	21.13%
Schoharie	0.43%	0.45%	6.26%
Schuylkill	0.66%	0.99%	50.81%
Sullivan	2.23%	2.46%	10.40%
Sussex	4.53%	5.99%	32.12%
Ulster	0.01%	0.02%	85.50%
Warren	4.53%	5.42%	19.57%
Wayne	0.90%	1.05%	16.81%

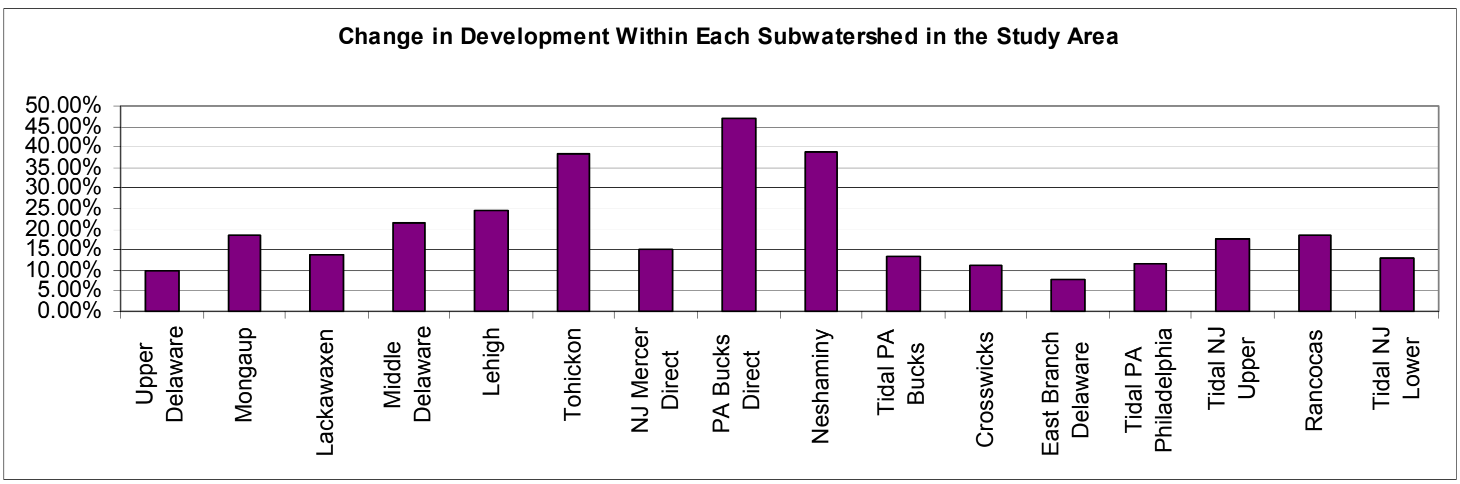
Source: 2000 U.S. Census

Subwatersheds

In general, the subwatersheds within the southern portion of the study area are much more developed than the subwatersheds in the northern portion up through New York. The land surrounding the Delaware River within the Middle Delaware Subwatershed is part of the National Scenic River Corridor and contains the Delaware Water Gap National Recreation Area, which remains protected from development under Federal regulation. The Tidal NJ Lower, Lehigh, and Tidal PA Philadelphia Subwatersheds contain the largest amount of developed land within the study area as illustrated in Figure 1.2.5-8. The Lehigh Subwatershed is also continuing to develop rapidly and experienced a 24% change in development from 1990 to 2000. During this time, 30 square miles of agricultural and forested land was developed within this area. However, developed land still only makes up about 9% of the entire Lehigh Subwatershed. The PA Bucks Direct Subwatershed experienced the largest change in percentage of developed land at approximately 47% from 3,593 to 6,750 acres developed from 1990 to 2000. The Tidal PA Philadelphia Subwatershed remains the most populated and densely developed subwatershed of the entire study area at 79% developed despite the rapid development activities occurring in the other subwatersheds.

The Tidal NJ Lower Subwatershed contains the most total acres of developed area within the study area and experienced a 13% change in development between 1990 and 2000. This change in development is equal to an additional 16.4 square miles. South Jersey currently depends upon groundwater for its water supply. If suburban sprawl continues at this rate, the supply will be quickly depleted and New Jersey may ultimately need to use the Delaware River to obtain drinking water. Table 1.2.5-4 includes the total acres developed for each of the subwatersheds and the change in the percentage of total land developed from 1990 to 2000.

Figure 1.2.5-8 Change in Development Within Subwatersheds of Study Area



Source: USGS National Land Cover Data 1992

Table 1.2.5-4 Change in Development Within Subwatersheds of Study Area

	Acres of Development 1990	Acres of Development 2000	% Change in Developed Land
Upper Delaware	4551.41	5046.65	9.81%
Mongaup	27001.52	33093.84	18.41%
Lackawaxen	4725.27	5483.82	13.83%
Middle Delaware	33860.95	43275.75	21.76%
Lehigh	59690.28	78932.32	24.38%
Tohickon	2487.94	4049.22	38.56%
NJ Mercer Direct	24595.54	28970.82	15.10%
PA Bucks Direct	3593.11	6750.28	46.77%
Neshaminy	35448.08	57821.79	38.69%
Tidal PA Bucks	17050.59	19661.84	13.28%
Crosswicks	12893.44	14491.35	11.03%
East Branch Delaware	2777.72	3016.52	7.92%
Tidal PA Philadelphia	67614.56	76694.49	11.84%
Tidal NJ Upper	9983.61	12095.74	17.46%
Rancocas	33171.31	40632.08	18.36%
Tidal NJ Lower	71663.61	82198.52	12.82%

Source: USGS National Land Cover Data 1992

Actual land use within the SWAP study area is extremely variegated. The forested and rural upper Delaware River Watershed paves the road for suburban development. South of Trenton, the urban complex fosters a suburban/agricultural mix. In the State of Pennsylvania, Bucks, Chester, and Montgomery Counties are furnished with considerable open space and agricultural lands. At the southern portion of the study area, heavy urbanization has run its course within the Philadelphia/Camden area. Table 1.2.5-5 summarizes the land use characterization for the study area. More than 88% of the study area is characterized as agriculture, forests, and wetlands. Developed and urbanized areas account for about 8% of the entire area.

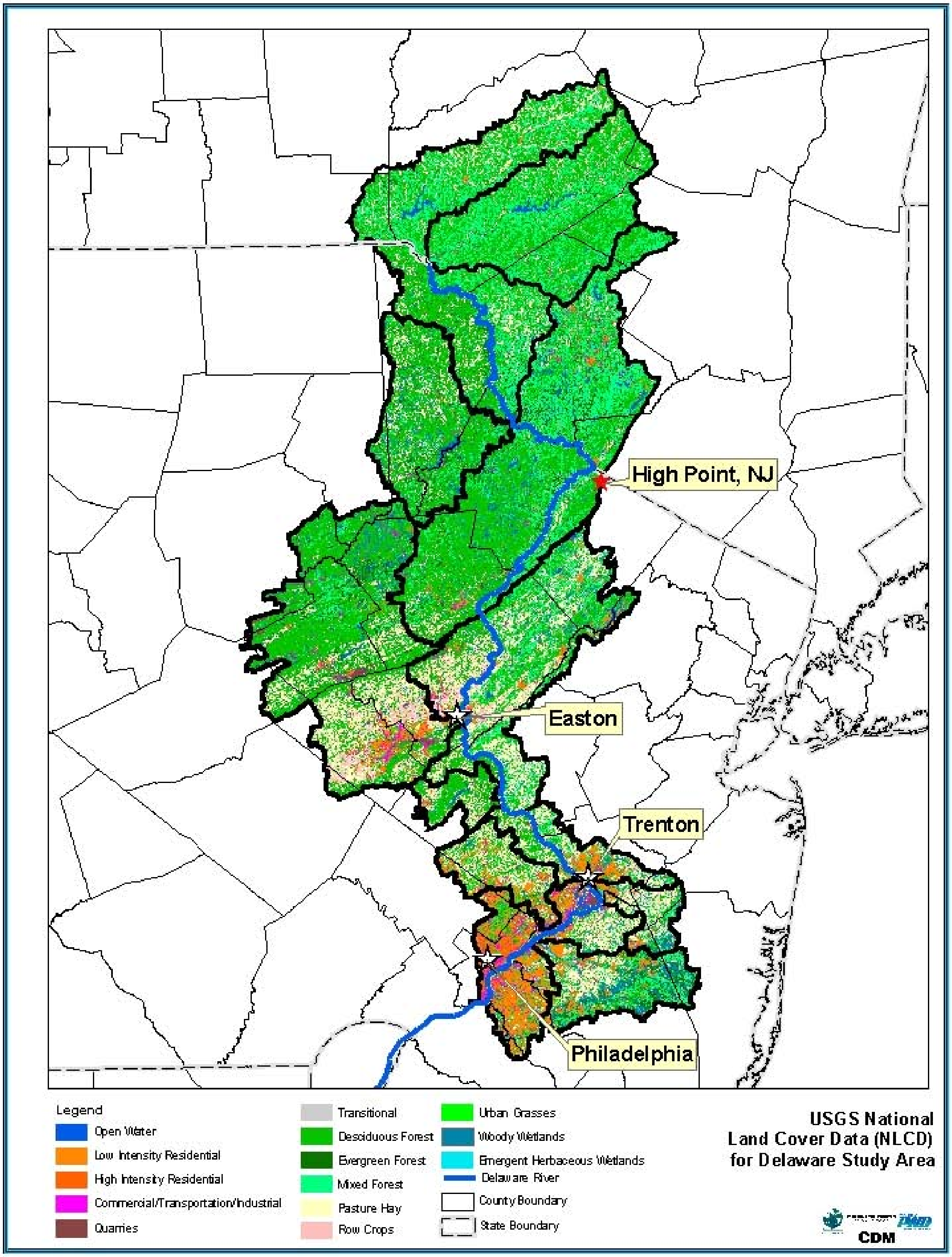
Table 1.2.5-5 Updated Land Use Categories

Land Use Category	Subcategory	Area (acres)	Percentage of Schuylkill Watershed Area
Agricultural	Pasture/Hay	709,269.97	13.65%
	Row Crops	208,963.35	4.02%
Commercial/Industrial/Transportation		87,203.64	1.68%
Forested	Deciduous Forest	2,260,850.70	43.50%
	Evergreen Forest	256,769.73	4.94%
	Mixed Forest	986,204.68	18.97%
Open Water		126,210.27	2.43%
Quarries/Strip Mines/Gravel Pits		20,411.81	0.39%
Residential	High Intensity Residential	61,355.96	1.18%
	Low Intensity Residential	262,549.57	5.05%
Transitional		7,090.90	0.14%
Urban/Recreational Grasses		25,641.07	0.49%
Wetlands	Emergent Herbaceous Wetlands	23,655.40	0.46%
	Woody Wetlands	148,503.83	2.86%

Source: USGS National Land Cover Data 1992

This land use characterization is believed to provide the most accurate and up-to-date coverage of land use for the SWAP study area, and the characterization demonstrates a consistent trend in increased development within the study area and Delaware River Watershed. One final trend that is evident within the study area is the protection of open space along the Delaware River, especially in Pennsylvania. The land surrounding the Delaware River within the Middle Delaware Subwatershed is part of the National Scenic River Corridor and contains the Delaware River National Recreation Area, which remains protected from development under Federal regulation. Further south, along the Neshaminy Subwatershed is the Delaware Canal State Park, which is also protected from development. Figure 1.2.5-9 shows the updated land use for the SWAP study area.

Figure 1.2.5-9 Updated Land Use in the SWAP Study Area



1.3 Summary of Past Reports and Studies

1.3.1 Introduction

Key Points

- **There have been several large studies conducted on the Delaware River by a large number of agencies including DRBC, USGS, USEPA, NJDEP, PADEP, NYDEC, NYDEP, and water suppliers.**

Recently, numerous governmental agencies, watershed organizations, educational institutions, and citizen groups have focused their efforts on improving the ecology of the Delaware River and its tributaries. A listing of reports and studies completed by these groups is given below as a resource reference. Due to the size and complexity of the Delaware River Watershed, it should be noted that this list is not exhaustive.

1.3.2 Delaware River Studies

William E. Toffey's technical paper, **Philadelphia's River Resources,** published in June 1982, is a summary of the conditions of both the Delaware and Schuylkill Rivers' ecosystems. The paper focuses on the challenges that face organizations working towards improving these ecosystems in order to restore them to their former aesthetic and environmental vitality. Industrial development and pollution from sewage treatment plants, specifically in Philadelphia, are mentioned as the main causes of the deterioration of these ecosystems, which is evident in the poor water quality and the lack of an abundant, diverse, and productive fish population. The author makes recommendations for the renewal and maintenance of the rivers with the primary objective of creating a sustainable recreational fishery, a sign of a healthy river system, through the reduction and management of pollution and the cultivation of a fishery.

The Economic Impacts of the Delaware Estuary by William R. Latham, III and John E. Stapleford (1987) discusses how the Delaware Estuary economically affects surrounding areas of the state of Delaware. The report critiques common economic impact models for determining the estuary's total effects and then proposes a seemingly more precise approach to estimating those effects. After describing their alternate methodology, the authors note how they determine the limits of the estuary and define estuary-related activities (versus non estuary-related activities) which are necessary measures before proceeding to tally the estuary's economic contribution to surrounding regions.

Flowing Toward the Future: 21st Century Visions and Directions for the Delaware River and its Watersheds (Governors 21st Century for Environment Commission, *1999)* summarizes the results of ten workshops held in April and May of 1999 to discuss the future of the Delaware River and it watersheds. Five idealistic visions for these areas are outlined: The Ecological Vision, The Water Supply Vision, The Livable, Pleasing Places Vision, The Vibrant Economy Vision, and The Stewardship Vision. The report also lists challenges facing the attainment of those goals and includes six directions for eventually achieving them: The Good Science Direction, The Watershed Education Direction, The Watershed Image and Marketing Direction, The Land Resources Direction, The Water Management Direction, and The Working Better Together Direction. In addition, a list of recommended actions is included for both government and non-government organizations, as well as citizens, in order to bring about the visions for the economic improvement and beautification of the river.

Water Snapshot '96, a report prepared by the Delaware River Basin Commission, contains simple listings of information pertaining to the water quality of the Delaware River and its many streams. The data was compiled over nine-day period of water quality monitoring throughout the Delaware River Basin in a large-scale 1996 Earth Day awareness program focused on clean water. Data collected by government and non-government agencies, environmental, industrial, and concerned citizen groups, and school children includes measurements of air and water temperatures, pH, and levels of dissolved oxygen, nitrate, and phosphate. While the testing area was extensive (samples were taken from a total of 335 locations in 174 waterways in Pennsylvania, New Jersey, New York, and Delaware), it is important to keep in mind that the pooled data was collected by people of widely varying levels of expertise, from elementary-age school children to professionally-trained Water Department employees, and only during a short period of time in the Spring of 1996.

The Delaware Estuary Monitoring Report, August 1998, is the first annual report completed by Delaware River Basin Monitoring Coordinator, Edward D. Santoro, in conjunction with the Monitoring Implementation Team of the Delaware Estuary Program. This report contains a wealth of information regarding the current biological, chemical, and economic status of the Delaware Estuary, and discusses the results of former monitoring efforts, as well as what needs to be done in the immediate future with regard to further improving the vitality of this resource. Also mentioned are issues relevant to the condition of the estuary such as water quality, toxics, living resources, and habitat/land cover/land use. Qualitative and quantitative data on the nutrient/algal relationship, fish populations, and levels of chloride, dissolved oxygen, nitrate, phosphorus, bacteria, pollutants, and metals, etc. are among the many important factors affecting the estuary's health that are discussed.

The Report of the River Master of the Delaware River for the Period of Dec. 1, 1997-Nov. 30, 1998 by Krejmas, Harkness, and Carswell, Jr. is a thorough discussion of the condition of the Delaware River and its monitoring and management by surrounding states during this time period. The report includes both qualitative and a great deal of quantitative data on the year's precipitation, and hydrologic conditions, water quality, flow, controlled releases, discharges, diversions, and storage for the river and its reservoirs, as well as measured levels of chloride, dissolved oxygen, pH, and water temperature.

The Delaware River Basin Commission's **Annual Report 1998,** compiled by Christopher M. Roberts, provides general qualitative data on the river's water supply and water quality and an overview of the DRBC's present and future objectives with regard to the protection, use, and maintenance of this important resource, particularly to increasing monitoring of the river and abating the pollution problem. A "who's who" list of DRBC staff and a financial summary of the commission's operations for the year are also included.

The Delaware River and Bay Water Quality Assessment 1992-1993 305(b) Report, published by the Delaware River Basin Commission in May of 1994, describes the quality and uses of the river between 1992 and 1993. The report contains both quantitative and qualitative data on surface water assessment (including water quality data for the six zones of the river, as well as biological data regarding fish populations, wetlands, and concerns over public health and aquatic life), groundwater assessment, and the DRBC water pollution control program. The appendix contains quantitative data on the following water quality factors for the various river zones: overall use, swimmable, aquatic life support, drinking water safety, fish consumption, aesthetics, and non-degradation.

The Delaware River and Bay Water Quality Assessment 1996-1997 305(b) Report, published by the Delaware River Basin Commission in August 1998, describes the quality and uses of the river between 1996 and 1997. The support of uses such as agricultural, secondary contact, swimming, drinking water, shellfish, aquatic life, and fish consumption are rated as "full", "full but threatened", "partial", or "none" for the various zones of the river and are compared to the ratings of the previous year. Pollution, pH, bacteria levels and fish populations are assessed as well. Also discussed in the report is the DRBC's plan to implement a biological monitoring program for the entire river basin in order to gain a fuller understanding of the relationship between water quality and surrounding flora and fauna.

Delaware Estuary Environmental Indicators, published by the Delaware Estuary Program in January 2001, discusses nine environmental indicators that the program uses to monitor the health of the estuary and the balance between nature and industry that make use of this resource. Agriculture, American shad population, developed land vs. population, water use efficiency (potable water withdrawals), acres of public parkland, dissolved oxygen, contaminated sediments, shellfish resource populations, and suitability of estuary waters for swimming are the nine factors used to analyze the health of the estuary. Brief sections discussing the trends, importance, and the economic, environmental, and social impacts of each indicator demonstrate the program's commitment to preserving and enhancing the estuary ecosystem.

The **Watershed Assessment** for Allentown, Pennsylvania (September 30, 1998), prepared for the Environmental Protection Agency by The Cadmus Group, Inc., provides a wealth of information on the Lehigh River Watershed including geology, lithology, topology, hydrology, land use, population, water quality, pollution, and nutrients, among others. The report also includes the Cadmus Group's recommendations for controlling and combatting watershed problems, such as reducing soil erosion and sedimentation in streams (Allentown's two biggest difficulties). Instituting a source water protection plan for the Allentown Water System based on the establishment of a watershed coalition is another strategy for helping the city share and manage the decision-making, problem solving, and funding involved in water quality control.

The **Lower Delaware River Conservation Plan** prepared by the Heritage Conservancy in September of 1999 proposes a long-term course of action for the management and conservation of the Lower Delaware River Watershed in the face of commercial and residential expansion. With input from the general public and representatives from agencies in the 23 participating municipalities (in New Jersey and Pennsylvania combined), as well as an advisory task group, a list of goals for the maintenance and/or improvement in six areas of the Lower Delaware was formed. Water quality, natural resources, historic resources, recreation, economic development, and open spaces are the foci of the LDRCP's efforts. The conservation plan also includes each municipality's recommendations for meeting these goals.

The **New Jersey Source Water Assessment Program Plan**, submitted to the EPA in October 1999 by the New Jersey Department of Environmental Protection, gives an overview of the Source Water Assessment Program, lists current standards which drinking water must meet, and details New Jersey's strategies for achieving and/or maintaining compliance with those conditions. Ground water, surface water, and pollution issues are addressed in the plan, as well as a variety of oral and written public responses, concerns, and questions regarding the program, which can be found in the appendices.

The **Delaware Estuary Monitoring Report** (July 2000), prepared by Edward D. Santoro in cooperation with the Monitoring Implementation Team of the Delaware Estuary Program, covers continuing estuary monitoring efforts and data from 1998. Qualitative and quantitative data are provided for main issues such as water quality, toxics, and living resources, as well as nutrients, fish populations, and levels of dissolved oxygen, nitrate, phosphorus, bacteria, pollutants, and metals, etc. A variety of charts, graphs, and maps clarify data and facilitate comparisons with previous years.

M.B. McPherson's report for Commissioner S.S. Baxter of the Philadelphia Water Department, **Integration of Instantaneous Dye Release Tests to Simulate Continuous Releases in the Delaware Estuary Model** (April 1963), describes fourteen model tests performed using the Delaware River estuary model at the Waterways Experiment Station in Mississippi in order to recreate the flow of continuous dye releases by incorporating characteristics of instantaneous dye releases. Both qualitative and quantitative data provide experimental details and results of the tests.

Determination of Travel Time in the Delaware River, Hancock, New York, to the Delaware Water Gap by Use of a Conservative Dye Tracer is a U.S. Geological Survey by Kirk E. White and Todd W. Kratzer that was prepared in cooperation with the Delaware River Basin Commission in 1994. This highly quantitative report presents the results of dye experiments carried out on the Delaware River to determine the travel time of a soluble substance over the aforementioned 120-mile span of the river. This information is useful to river authorities for planning a course of action in the event of a possible toxic spill in the study area, as well as for constructing accurate water quality models.

The Delaware Estuary: Discover its Secrets, written by the Delaware Estuary Program in September of 1996, is an environmental management plan for the Delaware Estuary, which takes a global approach to watershed management. This plan addresses the environmental and economic issues that are specific to the Delaware Estuary, while also providing a framework for the effective integration of ongoing management activities. Four focal points are outlined in the plan: land management, water use management, habitat and living resources, and education and involvement. In addition, the plan discusses seventy-six recommended actions that will foster improved environmental quality within the Delaware Estuary.

The Scientific Characterization of the Delaware Estuary (April 1996)**,** a publication of the Delaware Estuary Program, provides a broad description of the state of the Delaware Estuary in 1996. This report primarily focuses on eight characteristics of the estuary: status and trends, physical characteristics, historic use, land use, water quality, toxic substances, living resources and their habitat, and fish and fisheries. Additionally, this report outlines the goals and objectives set forth by the Delaware Estuary Program in its effort to preserve the water and resources of the Delaware Estuary.

Water Quality Monitoring at F. E. Walter Reservoir During 1999, is a report prepared in January of 2000 for the U.S. Army Corps of Engineers by Frederick S. Kelley and Erin Klingebiel of Versar, Inc. This report summarizes the results of water quality monitoring at the F.E. Walter Reservoir from May to September 1999, while also discussing the relevance of water quality measures to the ecology of the Reservoir and making recommendations for future water quality monitoring. Furthermore, this summarization identifies and describes the three types of monitoring performed in the study of the F.E. Walter Reservoir: monthly water quality and bacteria monitoring, drinking water monitoring, and sediment priority pollutant monitoring.

Living Resources of the Delaware Estuary was prepared by the Habitat Task Force of the Delaware Estuary Program (DELEP) in July of 1995. This document provides information regarding the key species and groups of plants and animals residing within the Delaware Estuary. It is designed to familiarize the reader with the living resources of the estuary, with the intent to promote support in caring for these resources. Additionally, this document focuses primarily on four topics relevant to the Estuary: Status and Trends, Habitat Requirements, Special Problems, and Management Considerations and Recommendations. These topics are meant to provide essential information to those interested in undertaking projects within the Delaware Estuary.

William J. Marrazzo and Susan Panzitta's report, Progress on the Delaware River Cleanup Program (August 1984) briefly discusses water quality of the Delaware River over the approximate 40 years since cleanup efforts began. The strategies of the Interstate Commission on the Delaware River (INCODEL) and the Delaware River Basin Commission (DRBC), are the foci of the paper, which highlights some of the most significant periods of pollution and cleanup in the history of the river's use since colonial times. Comparisons are drawn between past and current water quality in the river's six regions.

1.4 Identification of Universal Water Quality Issues

1.4.1 Introduction to Water Quality

Key Points
- **Delaware River water quality has significantly improved over the past 20 years.**
- **As the impacts of point sources discharging to the Delaware River have been reduced over the years, the importance of non-point sources such as stormwater runoff from developed areas within the watershed has become evident.**
- **While conductivity, nitrate, and iron levels have slightly increased over the past few decades, levels of dissolved oxygen, ammonia, phosphorus, and fecal coliforms have significantly improved, due to reductions in agricultural runoff and improved wastewater treatment.**

The Delaware River is a much healthier river now than it was over the past century, when it was branded as "too thin to cultivate, too thick to drink". The periods of the river smelling of raw sewage, covered in sheens of oils, or foaming with detergent bubbles are now gone, resulting in tremendous improvements in fish, wildlife, and water quality over the past 20 years. These improvements can be directly related to the following major events:

- The decline of the coal industry;
- The decline in the presence and size of the manufacturing industry (steel, paper mills, textiles, glass, etc) throughout the watershed;
- The increased cost of oil;
- The construction of sewers and sewage treatment plants;
- The improvements in sewage and industrial waste treatment plants;
- The Clean Water Act;
- Regulations limiting the presence of phosphates in detergents; and
- Regulations phasing out the use of certain toxic chemicals.

While some of these improvements were related to regulatory initiatives, most changes in water quality were caused by the activities that occurred in the watershed. These recent improvements in water quality have allowed us to see that in a growing number of areas, the main challenges to water quality now come from polluted runoff and not point source discharges. Therefore, the focus of activities that impact water quality are now becoming as much land use related as they are specific point source or facility related.

The process of examining changes in water quality over time is very difficult. The data usually are not available to characterize long periods of record for most chemical parameters. If data are available, changes in analytical methods over time can skew results. It is important to note that based on these factors, the following sections attempt to examine general trends in water quality based only on readily available data. Just because a change is noticed at one location does not mean that it is occurring at all locations. In addition, just because data are not available to characterize an area of the watershed does not imply that the water quality is good, bad, or not meeting water quality standards.

General temporal analysis focused on long-term and past decade trends in water quality in the Delaware River at Philadelphia and data trends provided by the Delaware River Basin Commission. This site was chosen because it is at the downstream end of the Delaware River Watershed, had the most significant and extensive monitoring data available, and because it provides evidence of the dominant changes in long term water quality in the watershed as a whole. Ultimately, it is believed that impacts observed at Philadelphia are possibly occurring at a number of locations along the river and throughout its tributaries to some extent. However, this does not mean that every trend observed at Philadelphia may be happening to the same extent, or at all, in other parts of the watershed. It is hoped that as coordination of watershed monitoring is improved to provide appropriate data to describe long-term trends, evaluations at other key locations throughout the watershed can be performed.

The analytical techniques used involved developing mean annual concentrations and also developing linear regressions of the individual data points to predict long term and future trends. The linear regressions may not be appropriate for accurate predictions or fits for most chemicals since as a concentration of chemical increases or decreases it tends to reach a natural or analytical limit resulting in more of an exponential or logarithmic function.

Analysis of the data yielded the following observations:

- Philadelphia Water Department (PWD) intake data indicate significant decreases in dissolved solute concentrations through the 1990s, including elevated levels of alkalinity, dissolved solids, total phosphorous, ammonia, and fecal coliforms. These trends appear to extend back through the early 1970s. Only nitrate, chloride, and conductivity concentrations appear to be increasing over time. If they continue, they have the potential to adversely affect drinking water treatment processes for the City of Philadelphia in the future.

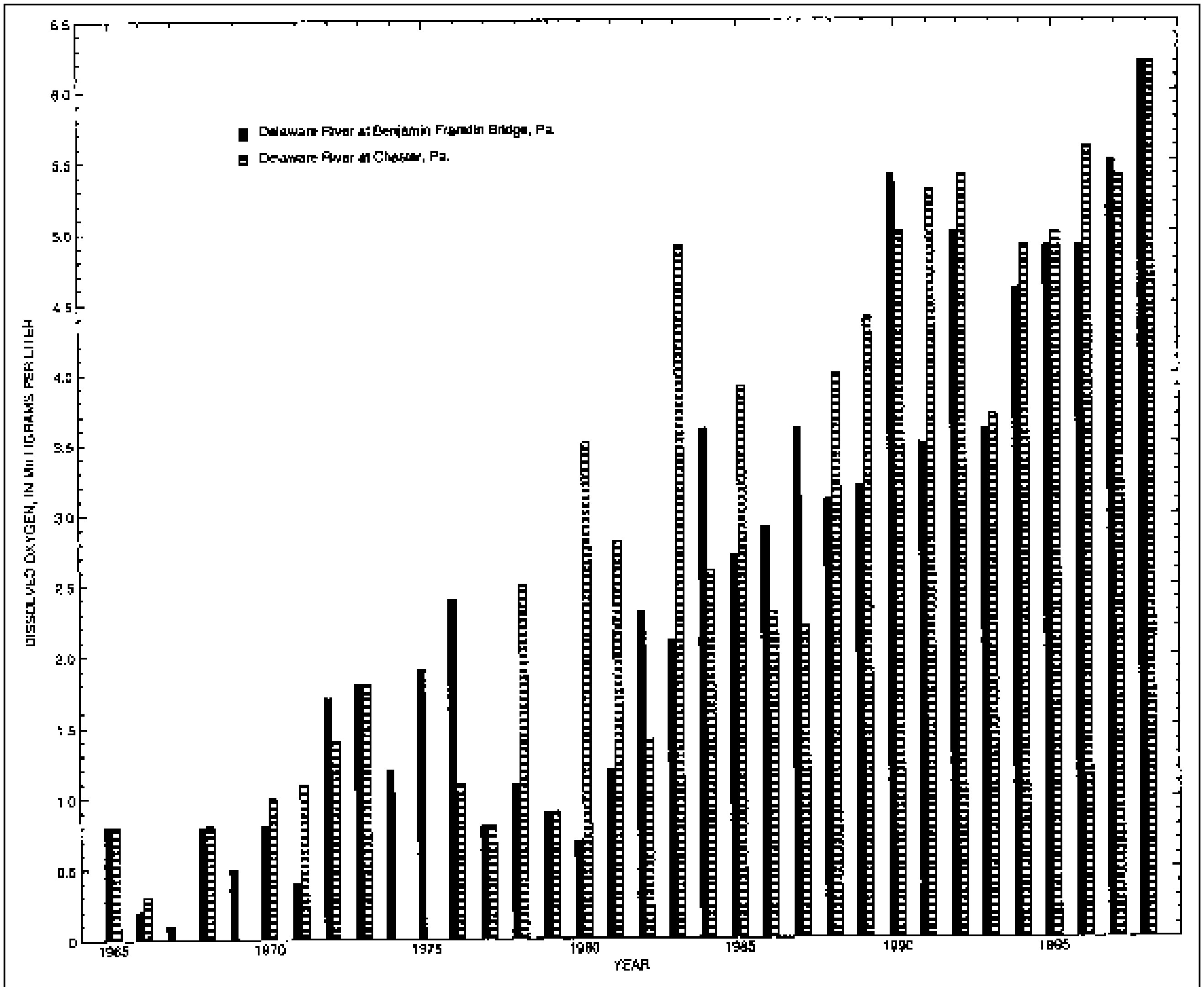
- Spatial analysis of water quality data throughout the watershed indicates that there are no common trends throughout the watershed.

- Increased mass transport levels of sodium and chloride, particularly in winter months through the 1990s, suggest that increased deposition of road salts are significantly impacting water quality at Philadelphia's Delaware River drinking water intakes.

- Though this study focused on adverse changes in river water quality parameters, the Delaware River has seen significant improvements in important water quality parameters such as dissolved oxygen, ammonia, nitrate, total phosphorous, and bacteria since the 1970s. Delaware River nutrient levels (nitrogen and phosphorus) have remained stable or decreased over the past decade due to decreased agricultural runoff within the watershed, along with improved wastewater treatment practices.

- Analysis completed in the 1998 Delaware Estuary Monitoring Report shows dissolved oxygen values have been steadily increasing over the past several decades as seen in Figure 1.4.1-1. The report substantiates improvement in DO from late 1960 through 1990. Since 1990, dissolved oxygen is typically at saturation. Along the main stem of the estuary, from the Pennsylvania/Delaware border, through Philadelphia, and up to Fieldsboro, minimum dissolved oxygen values are 3.5 to 4 mg/L. This meets the DRBC 24 hour criteria for the estuary (Santoro, 1998).

Figure 1.4.1-1 Dissolved Oxygen Levels in July from 1965-1998



Source: *U.S. Department of the Interior and United States Geological Survey, Report of the River Master of the Delaware River for the Period of December1, 1997 - November 30, 1998, p. 78.*

1.4.2 Long-Term Water Quality, Historical Trends, and Comparison to Other Rivers

Key Points
- **Levels of fecal coliforms (bacteria), ammonia, and phosphorous have decreased over the past thirty years. These improvements have led to increased levels of dissolved oxygen which is beneficial to aquatic life.**
- **Levels of nitrates, chlorides and total residue in the Delaware River have increased over the years.**

Previous assessments of century-long water quality trends in the Delaware River and other northeastern watersheds have demonstrated long term increases in salt concentrations through the 1900s. For instance, nitrate, chloride and total residuals all increased steadily in the Delaware River from 1900 through 1970. These indicators of water quality appeared to level off and remain relatively stable from 1970 through 1990, most likely as a result of improved wastewater treatment and slowing rates of development in the northeastern region (Jaworski and Hetling 1996). Increased national prosperity following the recession of the late 1980s spurred a strong increase in development in suburban regions, including parts of Bucks, Lehigh, Montgomery, Chester, Gloucester, and Burlington counties within the Delaware Watershed. This recent development appears to be causing increases in solute concentrations, driven by increasing wastewater discharge and increased solids transport directly related to land use change.

Recent water quality assessments have indicated long-term temporal increases in nutrient fluxes in major waterways (e.g. Bollinger et al. 1999) in the United States, which may have adverse impacts on water supplies for both drinking water and irrigation systems. These recent trends are apparently driven by major increases in diffuse loading of solutes from both agricultural and urban sources (Novotny and Olem 1994, Reimold 1998). While agricultural sources typically result in increases in nutrient and herbicide concentrations, urban sources of solutes, particularly from highway runoff, can result in increased loading rates of a more diverse suite of solutes. This analysis addresses many of the potential solutes derived from both sources. Urbanization in the Delaware River Watershed has resulted in decreases in land used for agricultural purposes, so long-term decreases in nutrient loading along with long-term increases in other dissolved solutes, including metals and other inorganic constituents, might be expected. Effects of increased loading of solutes to the Delaware River can be complicated by changes in specific ion activities which are directly related to ionic strength, organic content and other bulk water chemistry characteristics that are dynamic as well (Buckler and Granato 1999, Bricker 1999).

As seen in Table 1.4.2-1, increasing levels of nitrate in the Delaware River are particularly significant because the Delaware has the third highest level of nitrate compared to the other eleven major northeastern rivers assessed by Jaworski and Hetling (1996). The rate of increase of nitrate from 1906 to 1993 is also the third highest. Chloride and total residue (total solids – TS) levels and rates of increase place the Delaware in the middle of the other rivers. Levels of these constituents are close or better than the average values across all the rivers. Overall, these trends, particularly the levels and change in nitrate and chlorides, are a concern for the Delaware River, a major river water supply. Figures 1.4.2-1 and Figures 1.4.2-2 depict the long-term historical trends in nitrates, chlorides, and total residue in the Delaware River since the turn of the century.

Over the past thirty years, a number of significant regulatory and environmental initiatives have occurred nationwide. A supplementary analysis was conducted of existing data to examine the trends in water quality since 1970 and determine if the river water quality has been improving. Figures 1.4.2-3 through 1.4.2-7 are trends observed by the Delaware River Basin Commission for dissolved oxygen, nitrate, ammonia, total phosphorus, and fecal coliforms. Figure 1.4.2-8 provides a summary of three decades of changes in levels of water quality indicators, such as ammonia, nitrate, dissolved orthophosphate, conductivity, alkalinity, TSS, turbidity, fecal coliform, total coliform, total iron and total manganese. As shown, there have been significant reductions in the concentrations of ammonia, total phosphorus, and fecal coliforms. In addition, these improvements in water quality have caused significant increases in dissolved oxygen. Of all the different parameters examined, only nitrate appeared to have a strong increasing trend, while conductivity and chlorides appeared to increase at slower rates. The increased nitrate concentrations are the direct result of the installation of secondary wastewater treatment, which converts ammonia to nitrate. The nitrate trend from the 1970 to 1990 does show significant increases related to this event. However, when examined after 1990, the rate of increase appears to slow or stop.

Table 1.4.2-1 Summary of Historical and Current Water Quality Concentrations and Rates of Change For Northeastern Watersheds

Watershed	USGS Station No.	Timeframe	NO_3[(1)] (mg/l)	NO_3[(2)] (mg/l)	NO_3 Change (mg/l/yr)	Cl[(1)] (mg/l)	Cl[(2)] (mg/l)	Cl Change (mg/l/yr)	T Res[(1)] (mg/l)	T Res[(2)] (mg/l)	T Res Change (mg/l/yr)
Delaware	1474500	1913-1993	0.27	2.9	0.0329	6	30	0.3	122	229	1.3375
Potomac	1646580	1921-1993	0.6	1.76	0.0161	3.3	13	0.1347	103	203	1.3689
Delaware	1463500	1906-1993	0.25	1.01	0.0087	2.9	13	0.1161	70	104	0.3908
Blackstone	1111230	1890-1993	0.21	0.97	0.0074	5	44	0.3766	60	154	0.9126
WB Susquehanna	1553500	1906-1993	0.16	0.7	0.0062	4	8	0.046	74	137	0.7241
Rappahannock	1668000	1929-1993	0.15	0.55	0.0063	1.1	5	0.0619	43	53	0.1587
Hudson	1385000	1906-1993	0.18	0.52	0.0039	4	17	0.1494	108	119	0.1264
Connecticut	1184000	1888-1993	0.08	0.35	0.0026	1.5	11	0.0905	53	67	0.1333
Merrimack	1100000	1888-1993	0.07	0.32	0.0024	1.8	19	0.1638	43	68	0.2381
James	2035000	1906-1993	0.06	0.3	0.0028	2.3	9	0.077	89	100	0.1264
Androscoggin	1059010	1906-1993	0.02	0.18	0.0019	2.3	12.5	0.1229	42	66	0.2892
St. John	1015000	1921-1993	0.02	0.15	0.0018	0.7	2.9	0.0306	45	65	0.2778
Average			0.17	0.81	0.0078	2.9	15.4	0.1393	71	114	0.5087

Note: (1) = Earliest historical year
(2) = Four year average for the period 1990-1993
Source: Jaworski et al. 1996

Figure 1.4.2-1 Historical Nitrate, Chloride and Total Residue in Delaware River

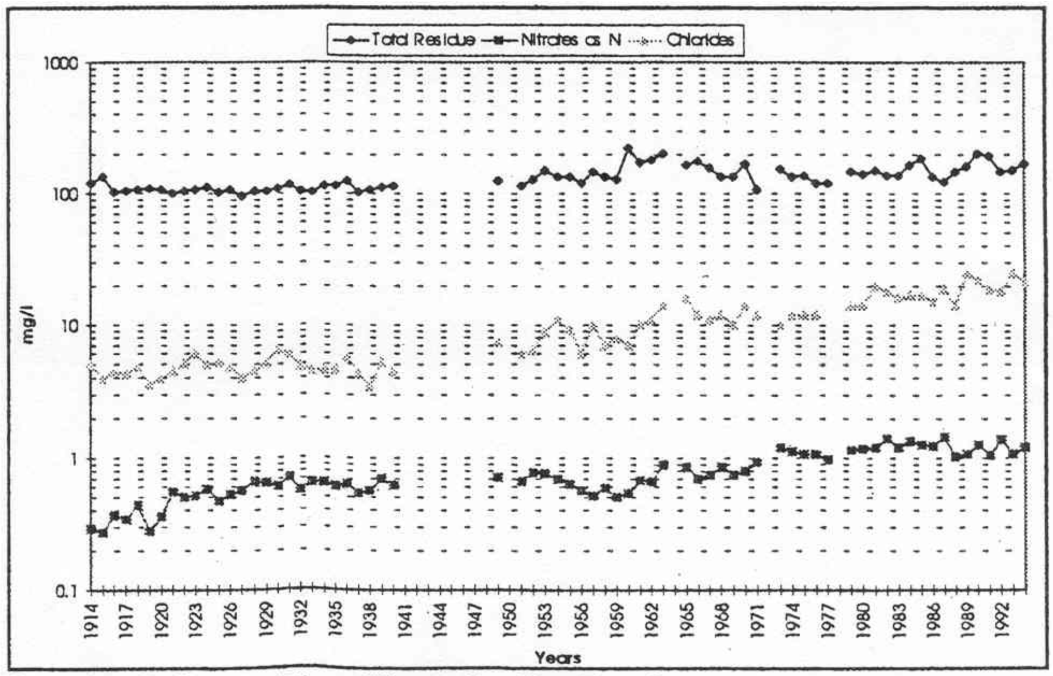
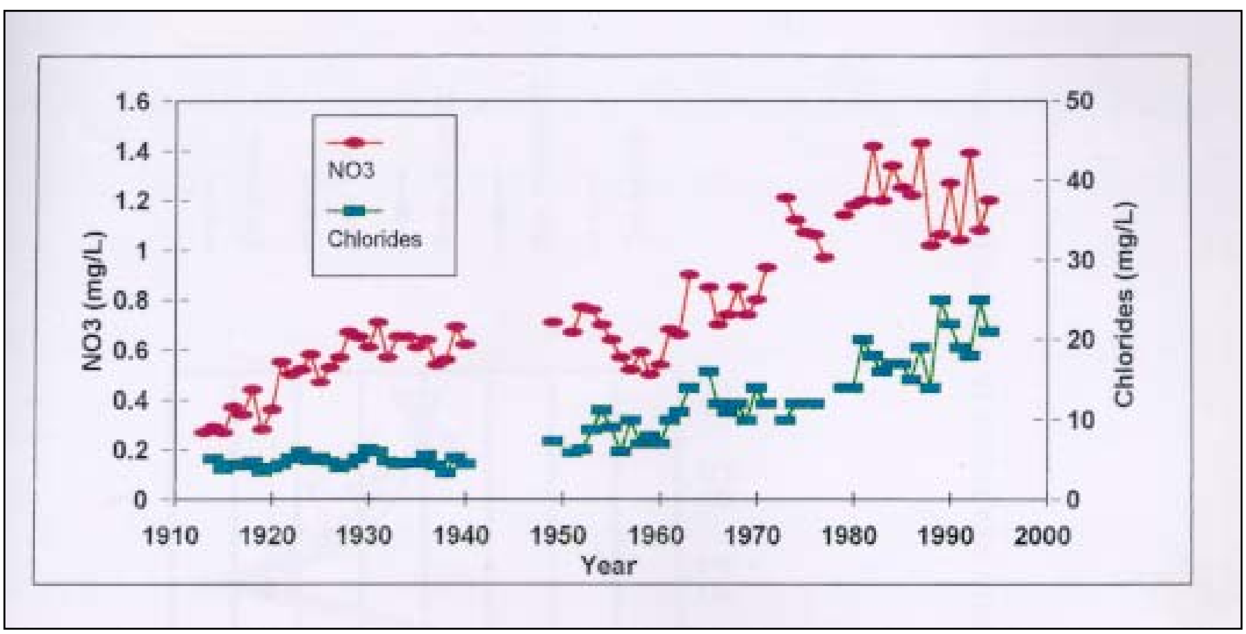


Figure 1. Delaware River Water Quality Trends.

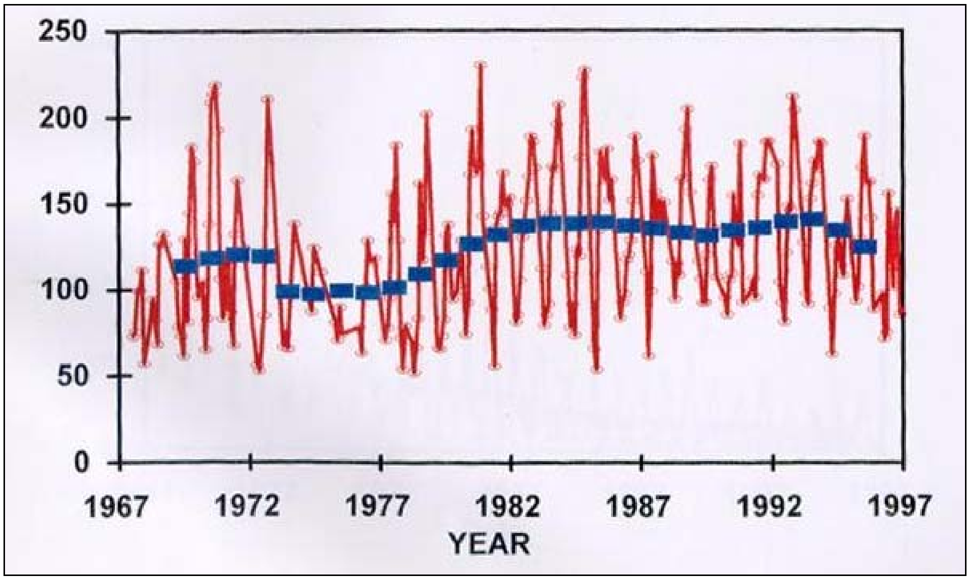
Source: JJaworski et al., Watershed 1996

Figure 1.4.2–2 Long Term Nitrate Trends at Marcus Hook



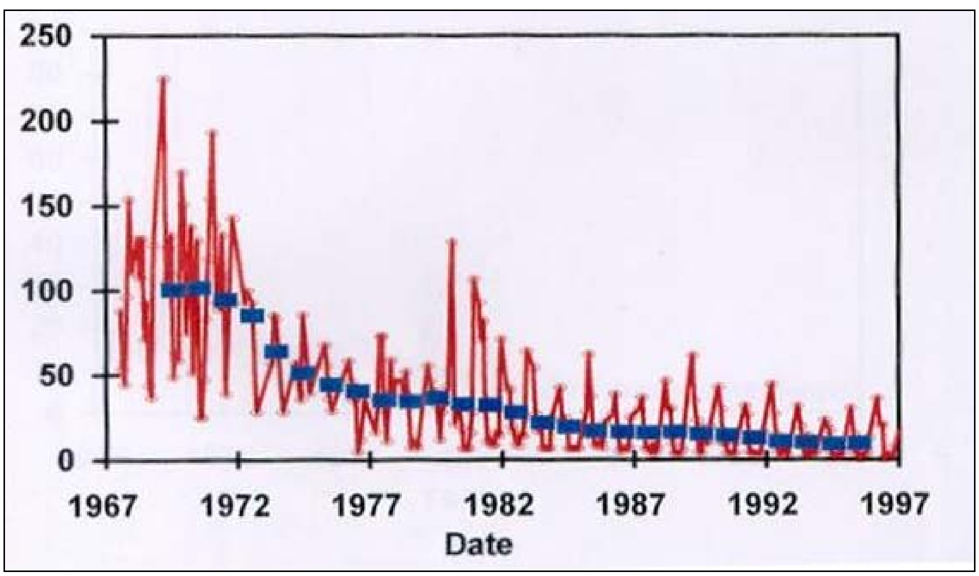
Source: Santoro, 1998

Figure 1.4.2–3 Monthly Average Nitrate-Nitrogen Trend at Marcus Hook, Delaware River: 1967–1997



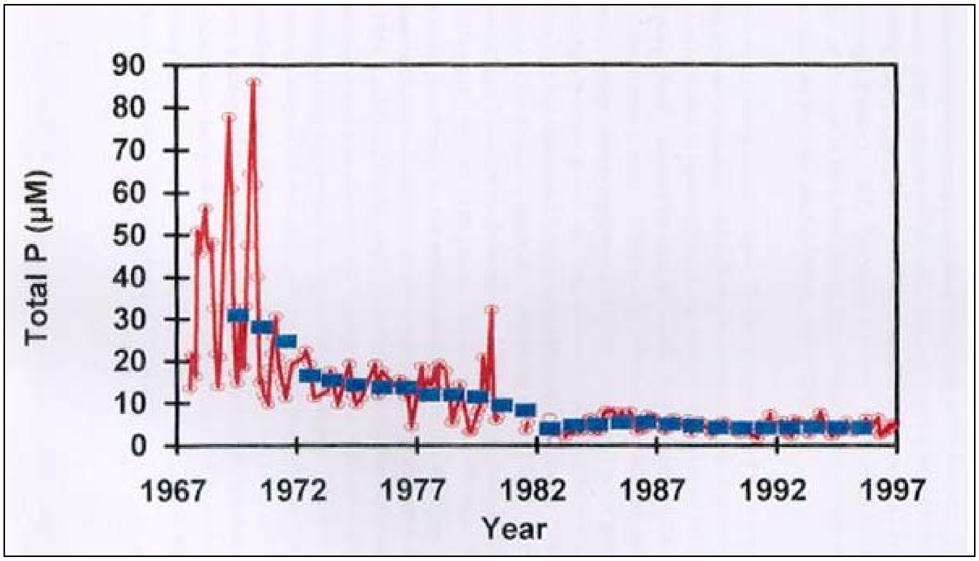
Source: Santoro, 1998

Figure 1.4.2-4 Monthly Average Ammonium Nitrogen Trends at Marcus Hook, Delaware River: 1967 – 1997



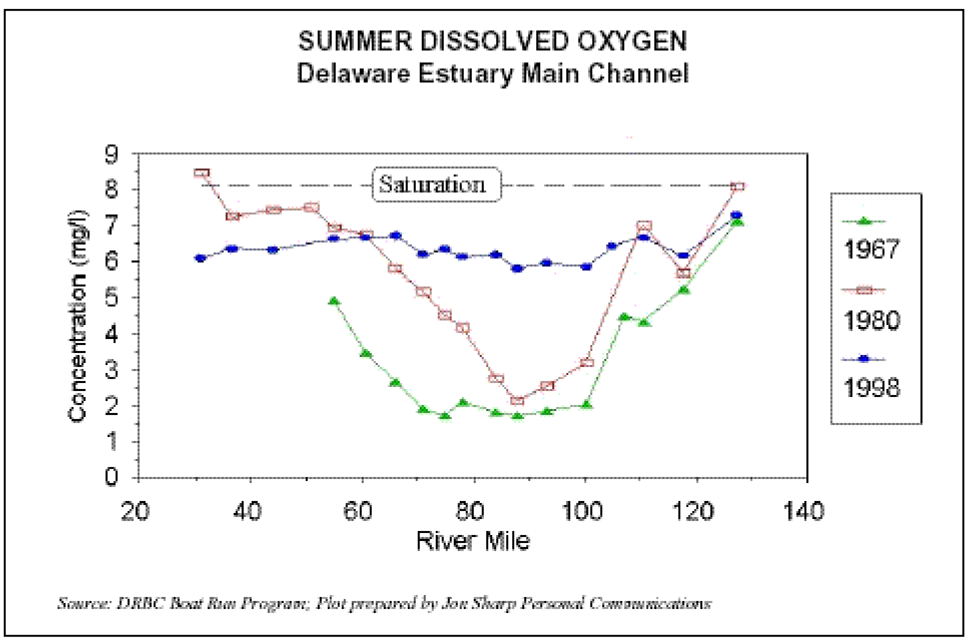
Source: Santoro, 1998

Figure 1.4.2-5 Monthly Average Total Phosphorus Trends at Marcus Hook, Delaware River: 1967 – 1997



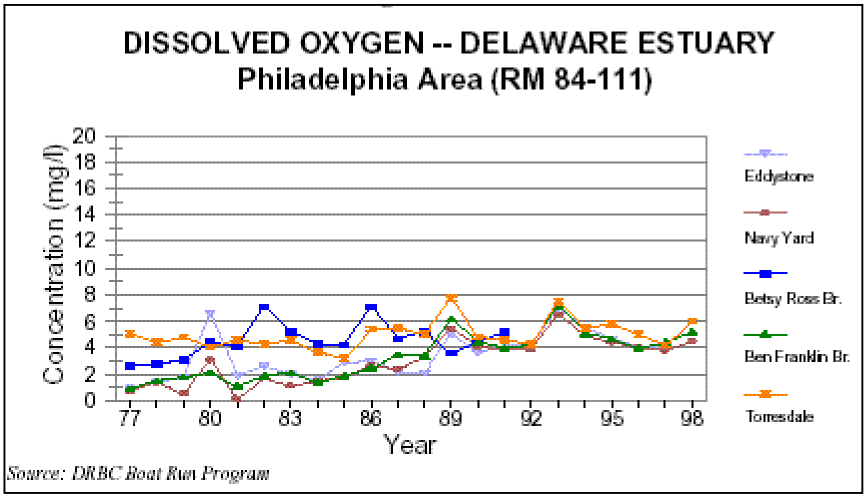
Source: Santoro, 1998

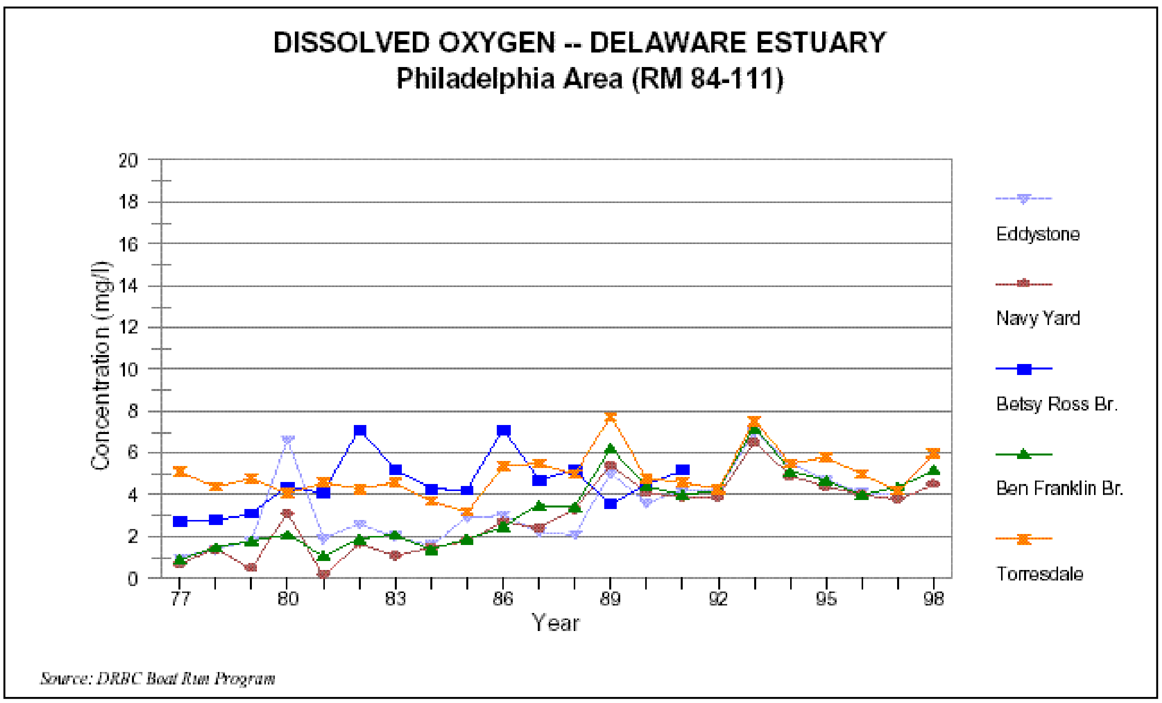
Figure 1.4.2-6 Annual Average Dissolved Oxygen Trends Along The Delaware River During Summer Periods: 1967 – 1998



Source: Santoro, 2000

Figure 1.4.2-7 Annual Average Dissolved Oxygen Trends Along The Delaware River Near Philadelphia: 1977–1998





Source: Santoro, 2000

Figure 1.4.2-8 Changes in Water Quality Indicators in the Delaware River at Philadelphia

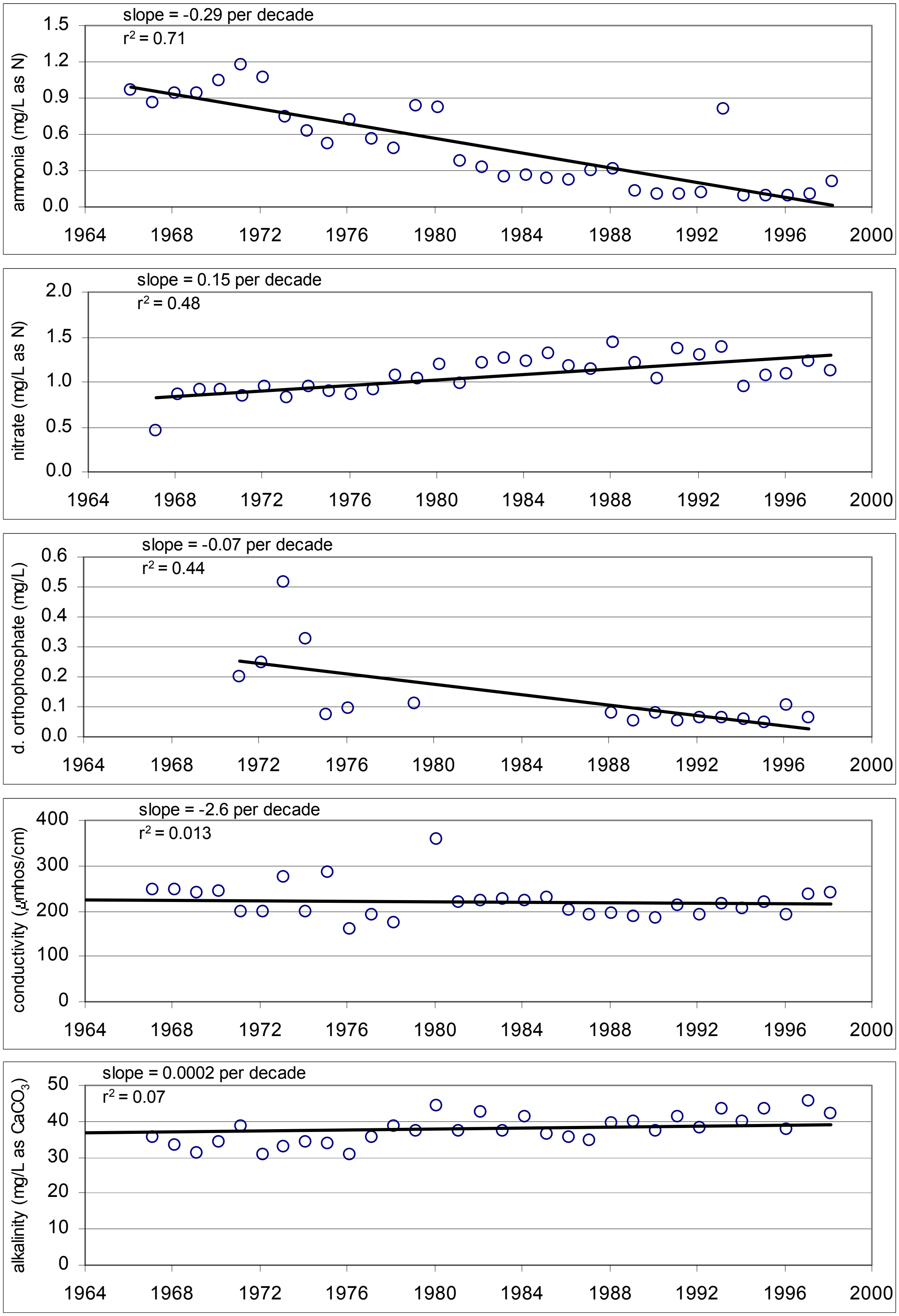
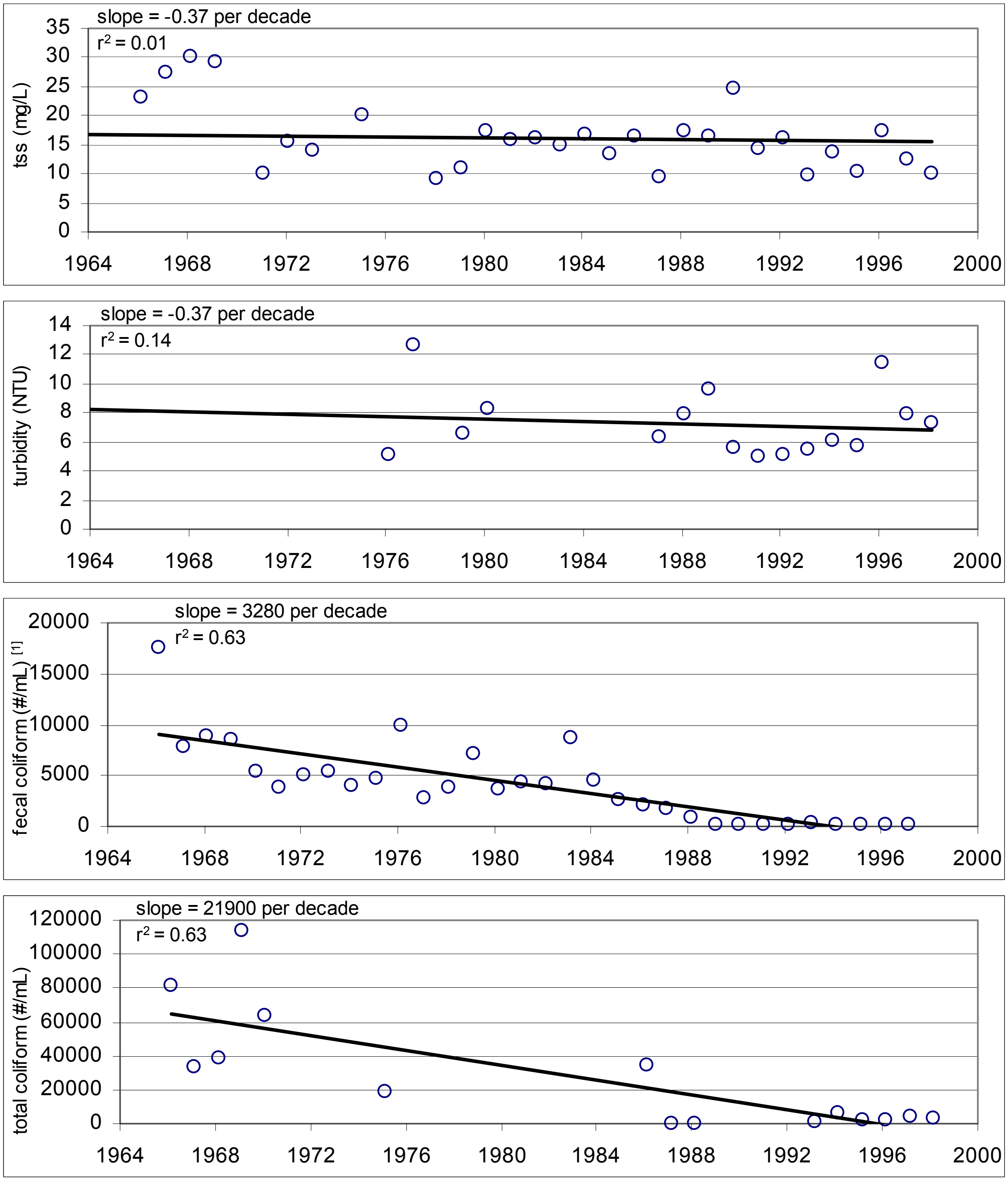
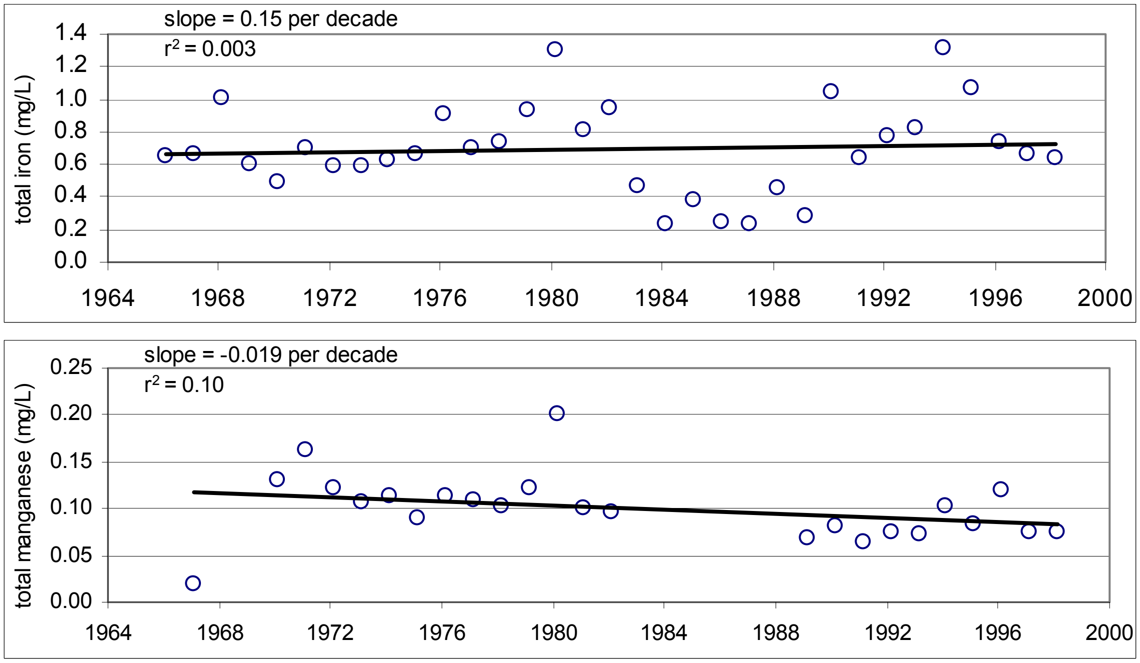


Figure 1.4.2-8 Changes in Water Quality Indicators in the Delaware River at Philadelphia



[1] data prior to 1987 measured under EPAID=31616 and after 1987 by EPAID=31611

Figure 1.4.2-8 Changes in Water Quality Indicators in the Delaware River at Philadelphia



1.4.3 Changes in River Water Quality over the Past Decade

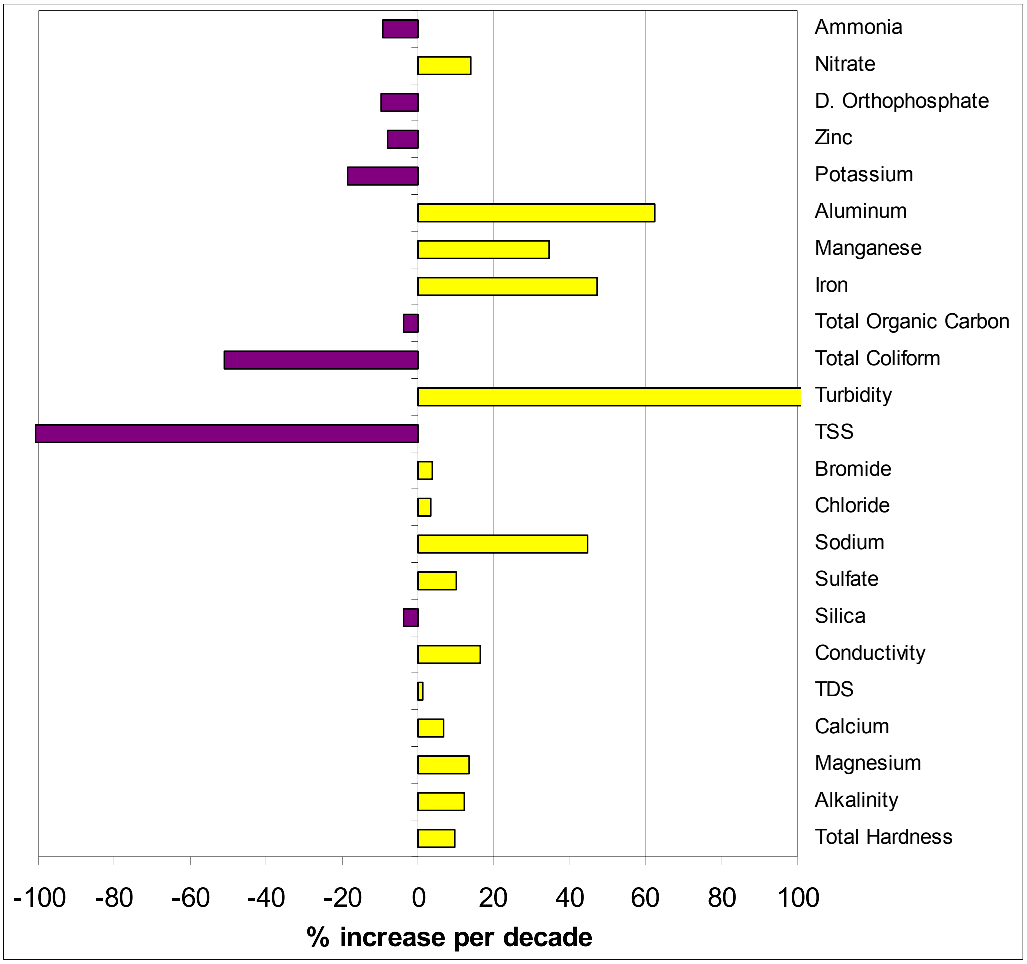
Key Points

- **Over the past decade, levels of alkalinity, conductivity, sodium, chloride, bromide, iron, manganese, nitrate, and turbidity in the Delaware River have increased.**
- **Increases in levels of salts and iron are believed to result from contaminated runoff due to increased development, increased use of de-icing chemicals, and from acid mine drainage.**
- **As point sources throughout the watershed have been abated and wastewater treatment improved, levels of coliforms, total organic carbon, total suspended solids, phosphate, and ammonia have decreased.**

Trends in river water quality over the past decade were examined in order to identify sources of contamination, and to predict future water quality concerns. This process involved the examination of data from 135 different water quality parameters measured at the Philadelphia Water Department river intakes between 1990 and 1999 and data from STORET for the Delaware River Watershed between 1990 and 2000. Of that data set, 22 parameters had sufficient numbers of measurements or detectable results to conduct a proper analysis that included comparisons between parameters and regional climate and development patterns.

Analysis of the data identified the following trends in water quality changes as shown in Figure 1.4.3-1 and Tables 1.4.3-1 and 1.4.3-2. Overall, 14 water quality parameters increased in concentration over the past decade, while levels of eight parameters were observed to decrease, and one parameter changed very little (total dissolved solid). Of the 14 water quality parameters exhibiting increasing trends, most were salts and metals. Future increases in alkalinity, conductivity, sodium, chloride, bromide, iron, manganese, and turbidity in the river water could potentially impact water treatment process operation and finished water quality, and therefore require further investigation.

Figure 1.4.3-1 Percent Change per Decade in Delaware River Quality Parameters at the Baxter Intake, Philadelphia, PA between 1990 and 1999



The observed trends led to efforts to determine the origins and types of sources and activities that would significantly impact river water quality. These observed trends suggested that although significant improvements to protect river water quality have been made for point sources, the sources of the changes in these parameters were most likely due to polluted runoff. If all of the affected parameters were regulated for point source discharges during this period without changes, then it suggests other sources may be impacting these changes. Salts, such as sodium and chloride, that appear to be increasing at significant rates in the river can be the result of increased application of de-icing chemicals in the watershed due to increased road, sidewalk, and parking lot areas in the watershed (see Table 1.4.3-3). Other parameters exhibiting increases, such as aluminum, iron, and turbidity, can be the result of increased erosion of land surfaces and streambanks due to new construction or increased flows in streams from development. The increases in salts and metals also impact conductivity, which has increased throughout portions of the watershed.

Table 1.4.3-1 Parameters That May Have Water Treatment Operation, Distribution System, or Finished Water Quality Impacts over the Past Decade or by 2020 Given Current Trends

Parameter	Decade Mean	Decade Max	Decade Min	Predicted Mean Concentration in 2020
Nitrate	1.2	2.5	0.9	1.6
Aluminum, total	0.7	3.6	0.03	1.4
Iron, total	0.9	8.3	0.05	1.7
Manganese, total	0.08	0.63	0.01	0.15
Turbidity	7.8	65	0.3	21
TOC	2.7	5.4	0.7	2.5
Bromide	0.03	0.136	0.015	0.04
Conductivity, μmhos/cm	204	607	95	279
TDS	125	240	70	179
Calcium	16	30	6	19
Magnesium	6	11	2	7
Alkalinity, mg/L as $CaCO_3$	41	86	18	53
Total Hardness, mg/L as $CaCO_3$	63	121	0.8	78

Units are mg/l unless otherwise specified.
Predicted concentrations are based on linear trends from 1990-2000.

Table 1.4.3-2 Summary of Water Quality Changes in the Delaware River at Philadelphia During the 1990's that May Impact Water Treatment and Possible Sources

Parameter	Group	Change	Possible Sources/Activities
Alkalinity	Physical	Increasing	Acid Mine Drainage and Acid Rain
Conductivity, TDS	Physical	Increasing	Polluted Runoff from Impervious Surfaces
Bromide	Salts	Increasing	Groundwater and Wastewater
Phosphorous	Nutrients	Decreasing	Improved Wastewater Treatment, Less Agricultural Activity in Watershed
Nitrate	Nutrients	Increasing	Wastewater Discharge
Ammonia	Nutrients	Decreasing	Improved Wastewater Treatment, Less Agricultural Activity in Watershed
Total Organic Carbon	Organics	Decreasing	Improved Wastewater Treatment and Reduced Agriculture
Turbidity	Particulates	Increasing	Erosion, Construction, Farming/Tilling
Total Suspended Solids	Particulates	Decreasing	Improved Wastewater Treatment and Reduced Agriculture
Manganese, Aluminum, & Iron	Metals	Increasing	Acid Mine Drainage, Construction, and Erosion from Due To Impervious Surfaces

Table 1.4.3-3 Reference Pollutant Concentrations (mg/l) in Roadway Runoff

Pollutant	Normal Highway Runoff (FHWA)	Highway Snow Wash-Off (FHWA)	Urban Runoff (NURP)
Chloride	13	400 - 5600	
Total Suspended Solids	93	204	100
Nitrate	0.660	0.680	0.680
Total Phosphorus	0.293	0.570	0.330
Copper	39	91	34
Lead	234	549	144
Zinc	217	420	160

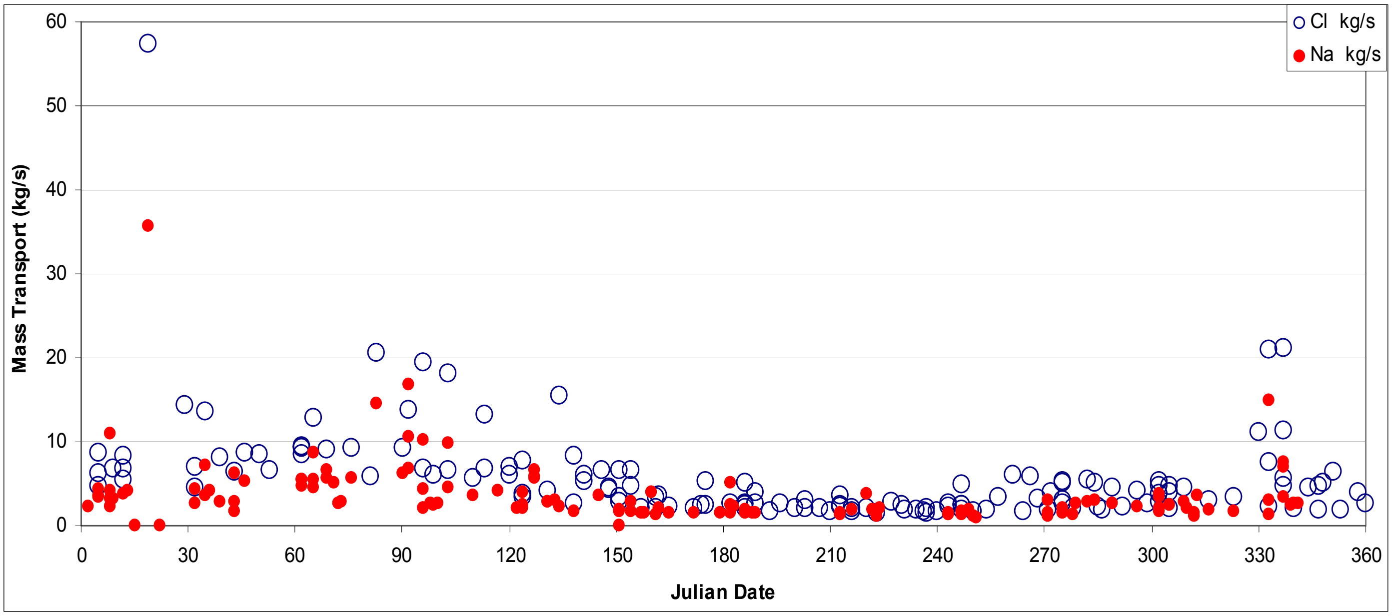
Table data excerpted from Reimhold (1998), FHWA - Federal Highway Administration Study Data (Reimhold, 1998), NURP - National Urban Runoff Pollutants Study (Reimhold, 1998).

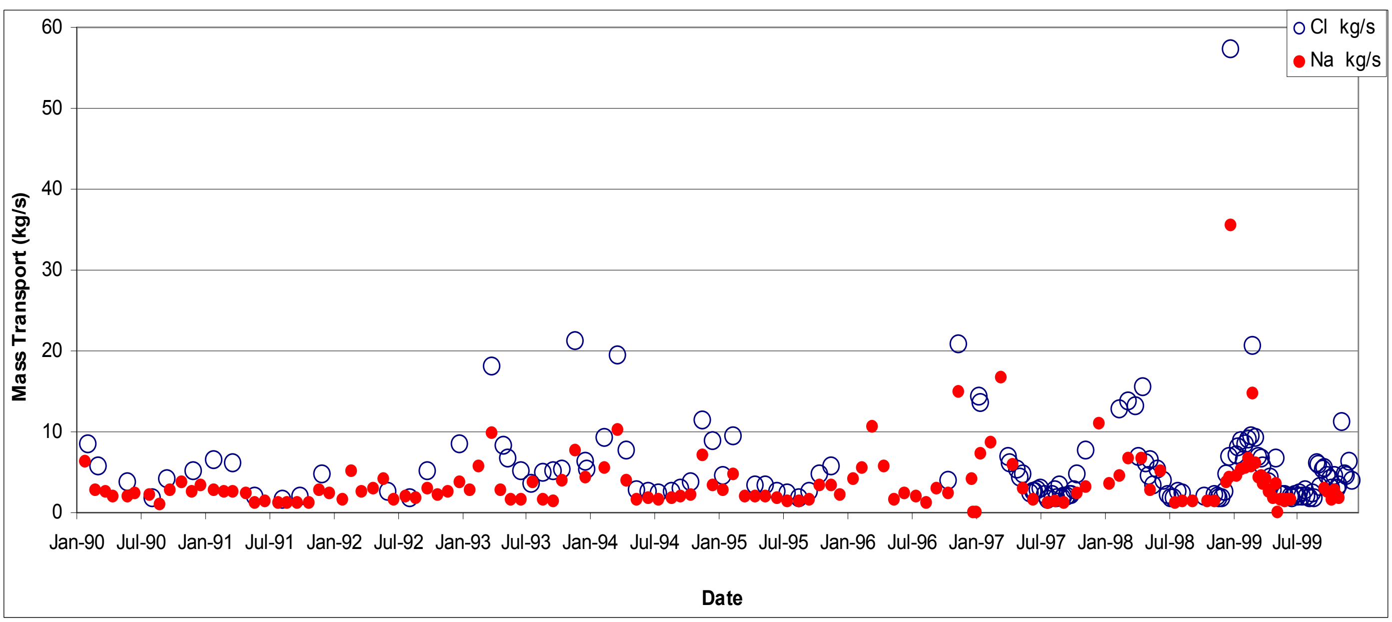
Solute mass transport rates also increased over the course of the 1990s, providing further evidence for adverse impacts of regional development on water quality. Rates of mass transport were calculated for individual samples from PWD Baxter Intake, which were based on the daily averaged flow rate data from the Trenton sampling location for the specific sample dates. Since the Delaware River is tidal downstream of Trenton, the daily average flow data from Trenton was used. Trends in Na and Cl fluxes indicate seasonal variation in mass transport, with highest rates of flux occurring during winter months when salt applications for road deicing can contribute dissolved solids to river water. Increases in flux rates for both ions are evident on a decade scale, with the most striking trends occurring in maximum measured flux rates through the period.

While relatively low discrete flux rates can be measured at any given time, maximum measured discrete fluxes within a given year are dramatically increasing, suggesting that major storm related discharge is driving increased solute transport in the watershed (Figure 1.4.3-2). Increased flux rates (which are calculated by multiplying an individual concentration measure by the average flow for that day) are direct evidence for increased loading rates and transport through the system.

Figure 1.4.3-2 Bulk Mass Transport of Sodium and Chloride in the Delaware River in the 1990's

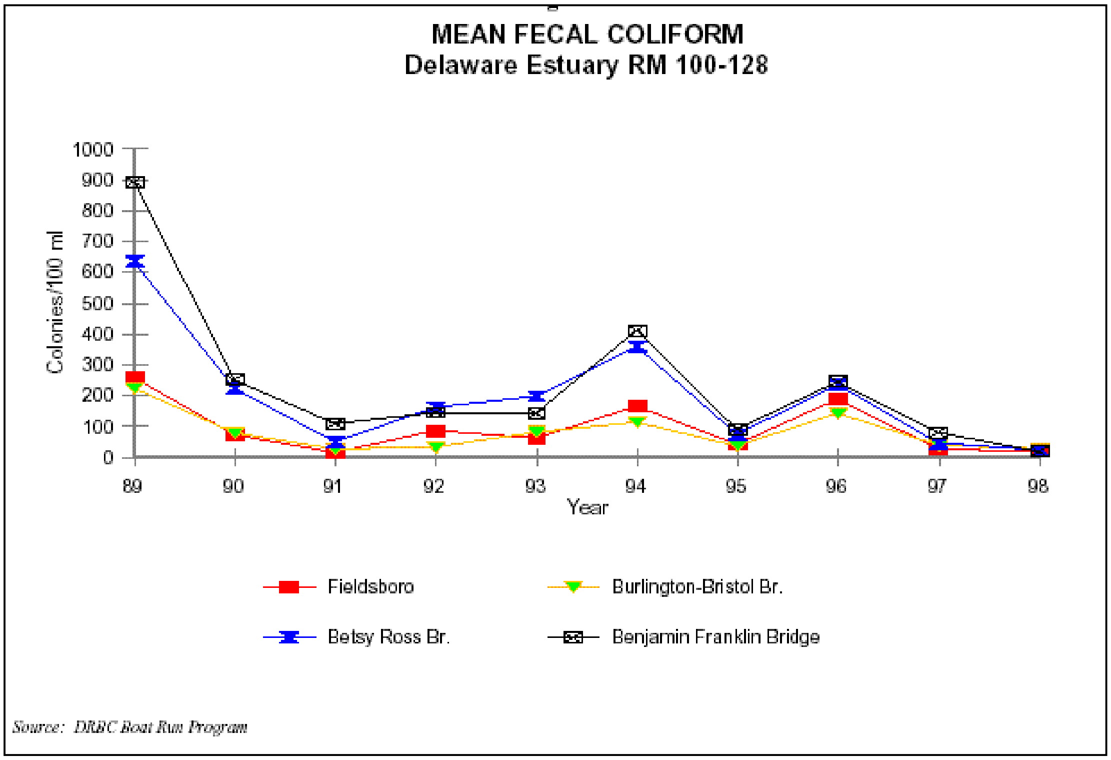
The top panel illustrates elevated concentrations in winter months associated with stormwater discharge and deposition of road salts for de-icing. The bottom panel illustrates increases through the decade possibly driven by the fast rate of development in suburban areas within the watershed.





Though the concentrations of some parameters have increased the past decade, others are improving. As shown in Figure 1.4.3–3, fecal coliform bacteria concentrations have been decreasing significantly over the past decade. Mean annual concentrations are actually lower than the fishable/swimmable standard set by the USEPA. This is largely due to the improvements in wastewater treatment and reductions of discharges from overflowing sanitary sewer systems.

Figure 1.4.3-3 Mean Fecal Coliform Concentrations in the Tidal Delaware River Near Philadelphia : 1990–1998



Source: Santoro, 2000

The plausibility that changes in water quality at Philadelphia were representative of other watershed locations was analyzed by comparing trends at Philadelphia with water quality data throughout the watershed. Figure 1.4.3-4 shows the changes in various water quality parameters in the mainstem of the Delaware River from Port Jervis down to Philadelphia over the past decade. The data indicates that there are few watershed wide trends in water quality. Only fecal coliforms, total dissolved solids, and dissolved oxygen observed similar and improving trends at all three locations along the mainstem Delaware River over the past decade. Other parameters differed in trend by location due to the localized influences that various land uses, industries, and activities have on water quality. Another confounding factor is the number of data points or samples collected at the locations to determine trends. The most upstream location, Port Jervis, usually had less than 12 observations for the decade (See Table 1.4.3-4). The number of samples analyzed at Trenton was greater reaching 63 samples with a minimum of 13 collected for the decade. The Philadelphia location (Baxter) had over 100 samples collected for the decade. The quantity of samples collected suggests that only the trends for dissolved oxygen, alkalinity, turbidity, and fecal coliform can be properly compared at Trenton and Philadelphia. Only the trends in fecal coliform and dissolved oxygen concentrations over the decade appeared to match for Trenton and Philadelphia. Trends in alkalinity and turbidity at the two locations did not match over the past decade suggesting that either more data are needed at the Trenton location or that there are local influences impacting water quality between the two locations.

Figure 1.4.3-4 Watershed-wide Trends in Percent Increase per Decade in Various Water Quality Parameters in the Mainstem of the Delaware River from 1990-1999

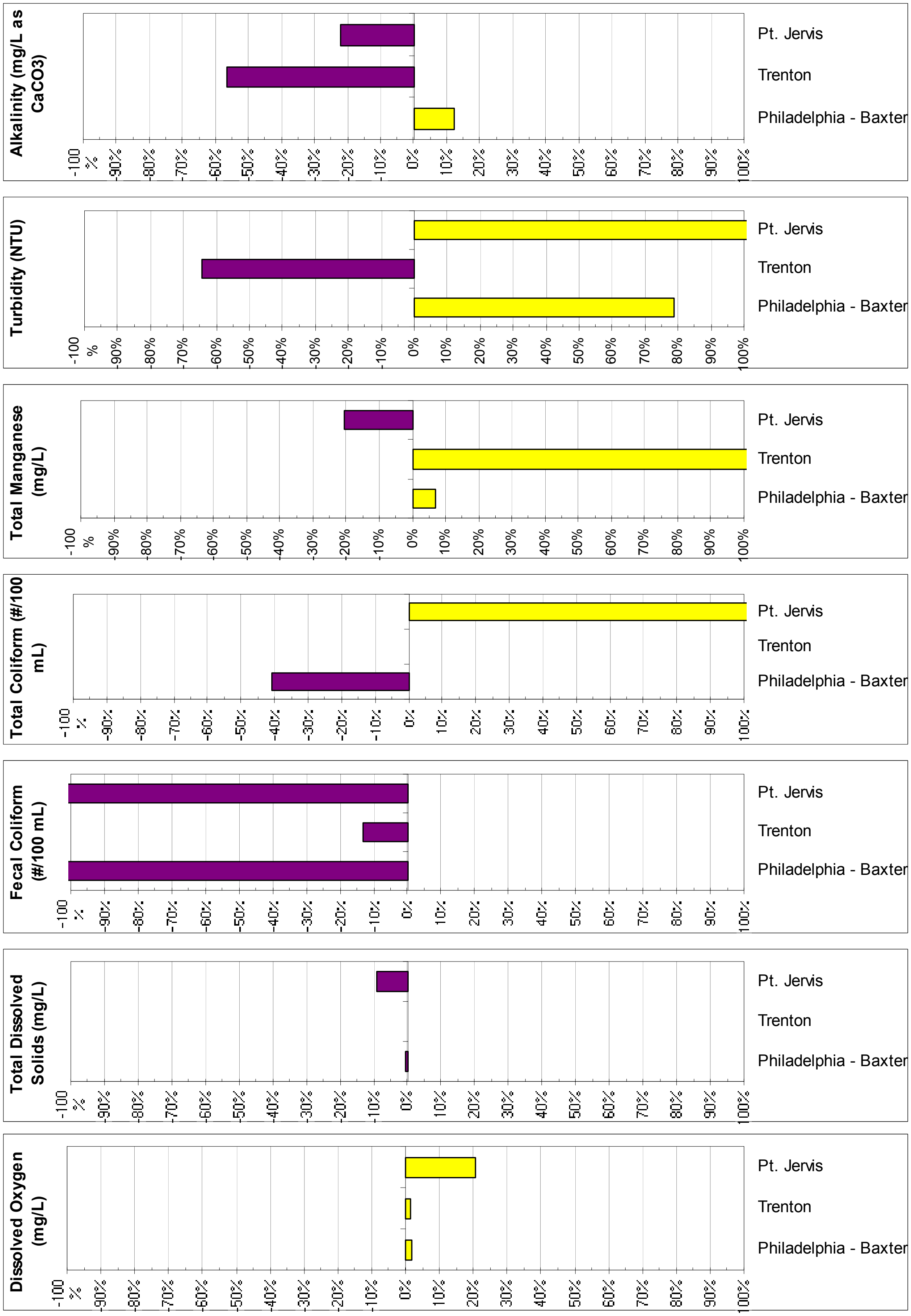


Table 1.4.3-4 Summary of Spatial Changes in Mainstem Delaware from 1990-1999

	Philadelphia - Baxter	Trenton	Pt. Jervis
Alkalinity (mg/L as $CaCO_3$)			
% increase over 1990 - 1999	12%	-56%	-22%
2020 prediction	53	-31	5
Decade Min	17	0.6	6
Decade Max	86	72	19
Decade Median	41	30	13.5
Count	649	63	20
Turbidity (NTU)			
% increase over 1990 - 1999	79%	-64%	268%
2020 prediction	19	0	6
Decade Min	0.28	0.6	0.2
Decade Max	65	62	14
Decade Median	5	2.9	1
Count	692	63	18
Total Mn (mg/L)			
% increase over 1990 - 1999	7%	146%	-21%
2020 prediction	0.45	0.13	0.02
Decade Min	0.01	0.01	0.01
Decade Max	0.63	0.16	0.06
Decade Median	0.07	0.03	0.04
Count	332	16	10
Total Coliform			
% increase over 1990 - 1999	-41%		13757%
2020 prediction	0		9562
Decade Min	0		32
Decade Max	45000		1000
Decade Median	890		245
Count	231		9
Fecal Coliform			
% increase over 1990 - 1999	-368%	-13%	-190%
2020 prediction	0	134	0
Decade Min	0	2	2
Decade Max	2333	2400	110
Decade Median	83	20	44
Count	155	43	8
Total Dissolved Solids			
% increase over 1990 - 1999	-1%		-9%
2020 prediction	122		38
Decade Min	70		31
Decade Max	240		60
Decade Median	121		48
Count	65		19
Dissolved Oxygen			
% increase over 1990 - 1999	2%	1%	21%
2020 prediction	9.82	10.91	14.32
Decade Min	4.80	7.20	7.20
Decade Max	15.50	14.80	13.70
Decade Median	8.98	10.70	10.22
Count	100	109	23

Given the potential for spatial differences in water quality trends, a spatial-temporal comparison was conducted for approximately 12 watershed locations. As shown in Table 1.4.3-5, the Little Lehigh Creek observed some of the highest concentrations of nutrients, conductivity, and total dissolved solids due to influences by heavy agricultural activities in that watershed. The Neshaminy, Poquessing, Rancocas and Pennypack Creeks observed greater concentrations of chlorides and iron due to runoff from impervious surfaces in these highly developed watersheds. The Lehigh River observed the greatest manganese concentrations due to the influence from acid mine drainage.

Table 1.4.3-5 Spatial Comparison of Water Quality Parameters in the Delaware River Watershed

Source Water	Location	Conductivity (umhos/cm)	Total Dissolved Solids (mg/L)	Total Phosphorus (mg/L as P)	Ammonia (mg/L as N)	Nitrate (mg/L as N)	Chloride (mg/L)	Total Organic Carbon (mg/L)	Fecal Coliform (col/100 mL)	Iron (mg/L)	Manganese (mg/L)
Delaware River	Port Jervis, NY	81	48	0.013	0.010		8.6			0.14	0.040
Little Lehigh Creek	Robin Hood Bridge	359	261	0.060	0.040	3.85		2.35		0.18	0.021
Lehigh River	PA State Road 115 Bridge, Stoddartsville	74	60	0.028	0.020	0.26		2.70		0.18	0.068
Lehigh River	State Road 4022 Bridge, Walnutport	105	78	0.050	0.090	0.57		2.20		0.16	0.101
Delaware River	Trenton, NJ	171		0.070	0.030		15.0		20	0.11	0.034
Neshaminy Creek	Route 13, Bristol, PA	367	236	0.190	0.040	1.87	45.0		190	0.78	
Delaware River	PSWC -Bristol Plant Intake				0.040	1.80	37.5	3.00		0.32	0.064
Poquessing Creek	State Road, Philadelphia		248	0.060	0.035	1.47	57.5			0.47	
Rancocas Creek	Browns Mills, NJ			0.030	0.050		4.9	7.80	11	2.40	0.040
Rancocas Creek	Mount Holly, NJ			0.098	0.270		12.8		490		
Delaware River	PWD - Baxter Intake	201	121		0.080	1.17	21.0	2.65	0	0.61	0.070
Pennypack Creek	State Road, Philadelphia		268	0.455	0.060	3.51	50.0			0.30	
Delaware River	Ben Franklin Bridge	219		0.103	0.090	1.20	21.0			0.18	

Given these varying water quality profiles, watershed wide trends in water quality were examined. Figure 1.4.3-5 compares the changes in various water quality parameters in the tributaries to the Delaware River over the past decade. As shown, several watersheds have observed significant changes in conductivity over the past decade. The median increase per decade for all locations combined was 15%, but ranged from 3 to 70%, depending upon the location. Figures 1.4.3-5 and 1.4.3-6 provide an in-depth view of the conductivity trends in the Little Lehigh Creek (Robin Hood Bridge) and Lehigh River (Stoddartsville, PA) Watersheds.

Figure 1.4.3-5 Watershed-wide Trends in Percent Increase per Decade in Water Quality Parameters in the Tributaries of the Delaware River from 1990-1999

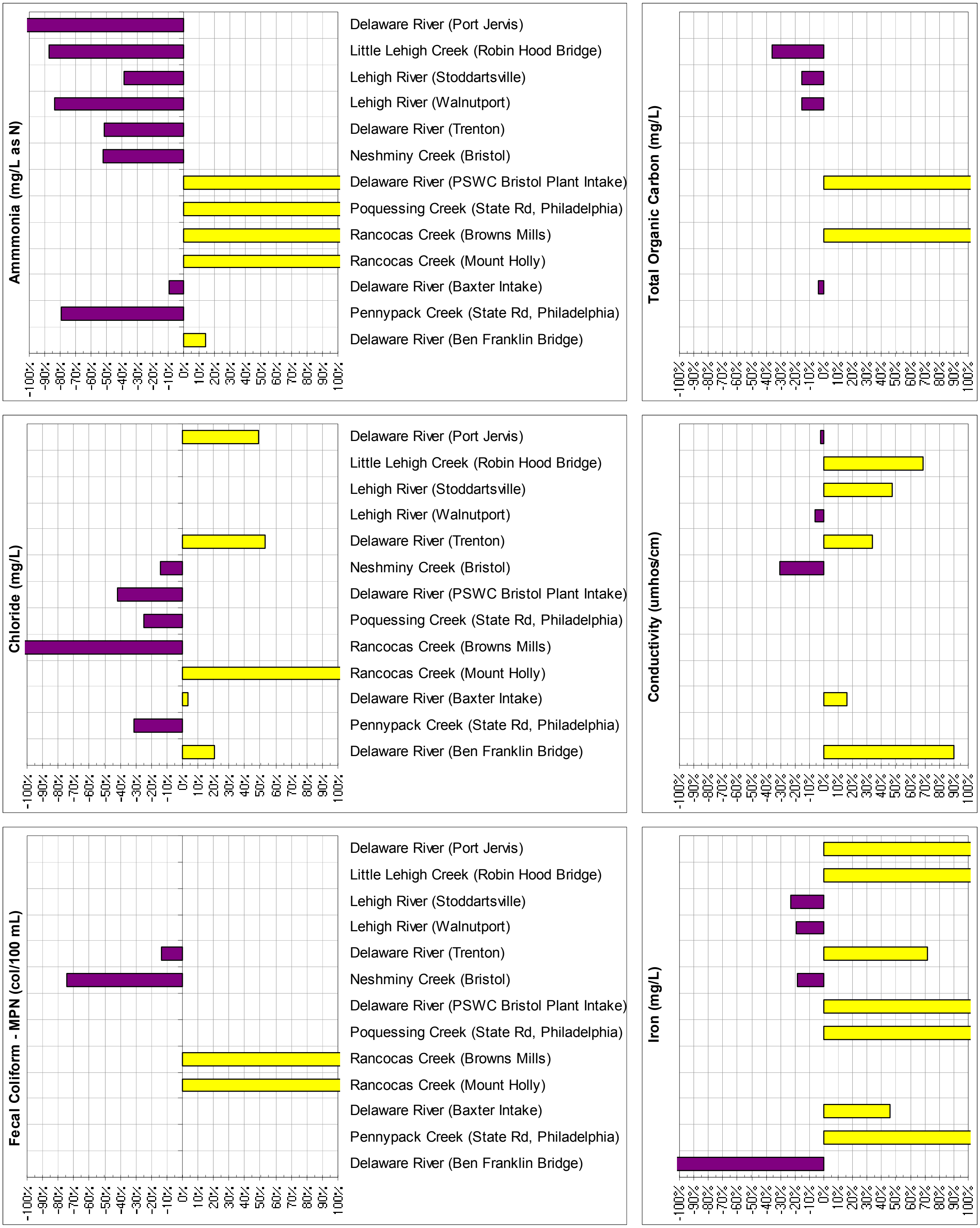
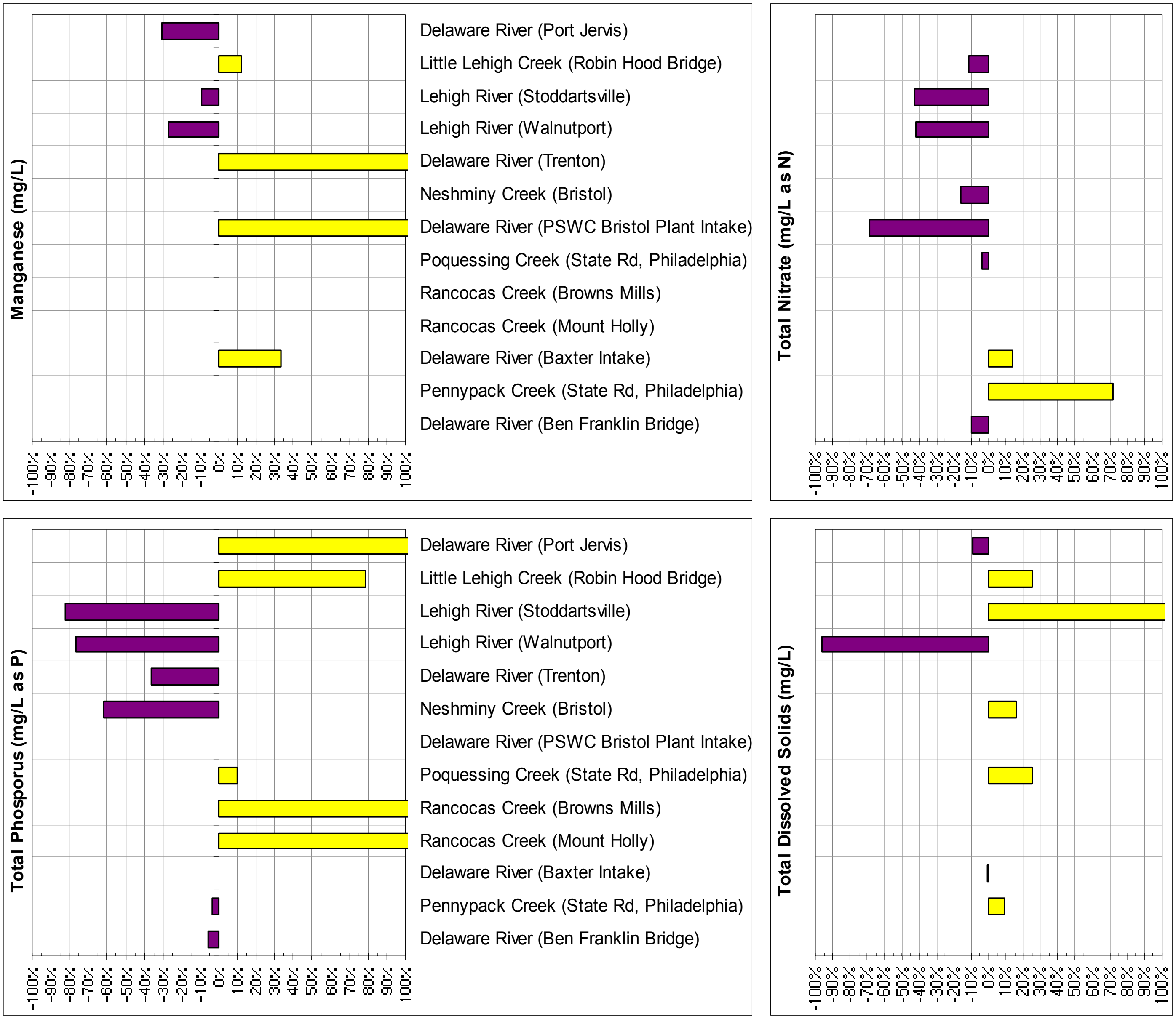


Figure 1.4.3-5 Watershed-wide Trends in Percent Increase per Decade in Water Quality Parameters in the Tributaries of the Delaware River from 1990-1999



A brief summary of the observations for watershed wide trends based on the observations from Figure 1.4.3-5 is provided in Table 1.4.3-6. The upward and downward trends for each location and parameter were compared in Table 1.4.3-6. Only upward or downward trends of greater than 10% were considered great enough for a directional assignment, otherwise they were considered unchanged for the decade.

As shown, there is no obvious parameter that is increasing throughout the entire watershed over the decade. However, there are geographical trends that are discernable. The sites in the mainstem Lehigh River are seeing the most improved overall water quality including reduced metals and nutrients. It is believed that these improvements are due to acid mine drainage mitigation and improvements in wastewater treatment in the Lehigh Valley.

The Neshaminy Creek, which has a number of mixed uses and activities including intense agriculture and development appeared to have improvements in almost all categories except total dissolved solids suggesting some influences by runoff from impervious cover.

The Rancocas Creek, Poquessing Creek, and Little Lehigh Creek appeared to have the most number of increasing parameters observed. The Rancocas and Poquessing Creeks are highly developed with little riparian buffers and are influenced by urban and residential runoff. The Little Lehigh Creek is located in an area near Allentown that has intense agriculture and is seeing increased development as well.

The mainstem Delaware River at all locations appears to have an equal amount of increasing and decreasing parameters at any given location, but they are not identical. This is most likely due to changes in land use and activities in any geographical region of the watershed.

On a parameter basis, ammonia, total organic carbon, and nitrate appeared to be increasing in the area draining into the tidal section of the watershed while it decreased in the non-tidal section of the watershed. Conductivity and total dissolved solids appeared to be the only two factors increasing watershed wide and that correspond to one another. Total phosphorus, iron, and manganese appeared to have no discernable geographical trend.

Figures 1.4.3-6 and 1.4.3-7 provide specific examples from the Lehigh River Watershed of the increasing trends of conductivity occurring throughout most of the watershed. The Lehigh River is facing increased development pressure from the New York City, Philadelphia, and Harrisburg areas. As shown, the smaller streams and creeks tend to show more steep increases in conductivity due to their sensitivity, but even in the mainstem Lehigh River these impacts are noticed.

Table 1.4.3-6 Spatial Comparison of Water Quality Trends in the Delaware River Watershed: 1990-1999

Location	NH3	TOC	Cl	Cond.	Fecal Coliform	Fe	Mn	Nitrate	TP	TDS
Delaware River – Port Jervis	↓	----	↑	NC	↓	↑	↓	----	↑	
Little Lehigh Creek (Robin Hood Br.)	↓	↓	----	↑	----	↑	↑	↓	↑	↑
Lehigh R. (Stoddartsville)	↓	↓	----	↑	----	↓	↓	↓	↓	↑
Lehigh R. (Walnutport)	↓	↓	----	↓	----	↓	↓	↓	↓	↓
Delaware River – Trenton	↓	----	↑	↑	↓	↑	↑	----	↓	----
Neshaminy Cr. (Bristol)	↓	----	↓	↓	↓	↓	----	↓	↓	↑
Delaware River – Bristol	↑	↑	↓	----	----	↑	↑	↓	----	----
Poquessing Cr. (State Rd.)	↑	----	↓	----	----	↑	----	NC	↑	↑
Rancocas Cr. (Browns Mills)	↑	↑	↓	----	↑	---	----	----	↑	----
Rancocas Cr. (Mt. Holly)	↑	----	↑	----	↑	---	----	----	↑	----
Delaware River – Baxter	↓	NC	NC	↑	↓	↑	↑	↑	----	NC
Pennypack Cr. (State Rd.)	↓	----	↓	----	----	↑	----	↑	NC	↑
Delaware River - Ben Fr. Br.	↑	----	↑	↑	----	↓	----	↓	NC	----

Figure 1.4.3-6 Increased Conductivity Trends in the Little Lehigh Creek Watershed at Robin Hood Bridge during 1990-1995

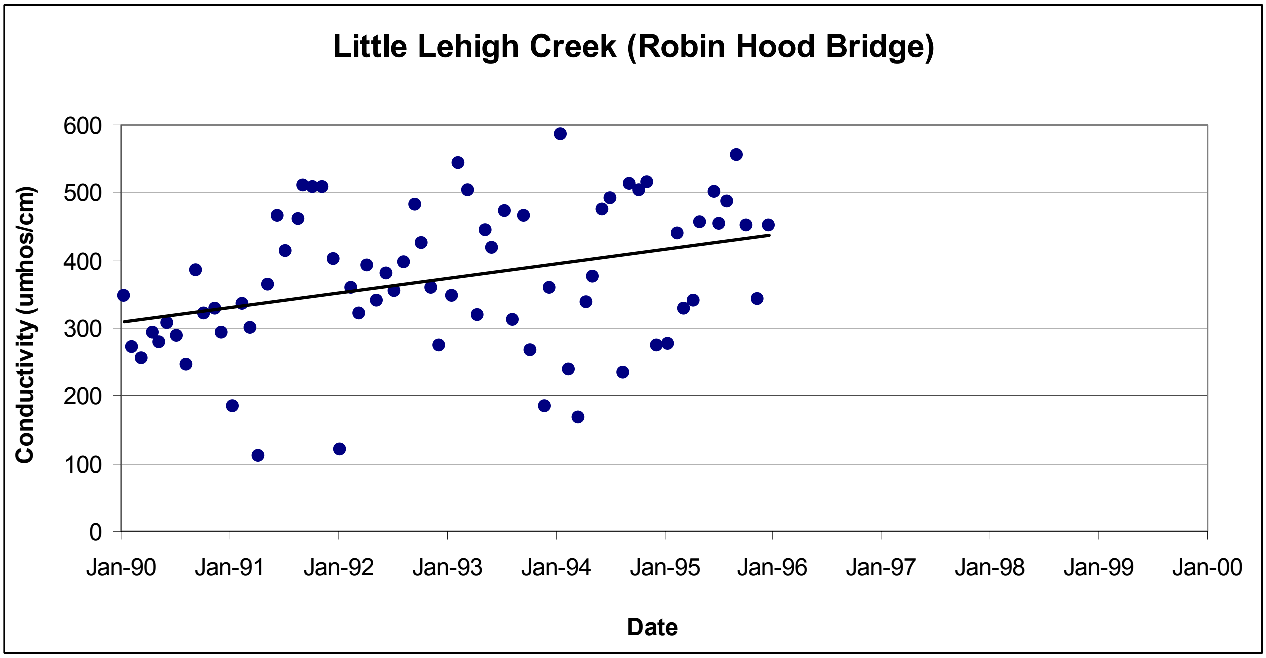
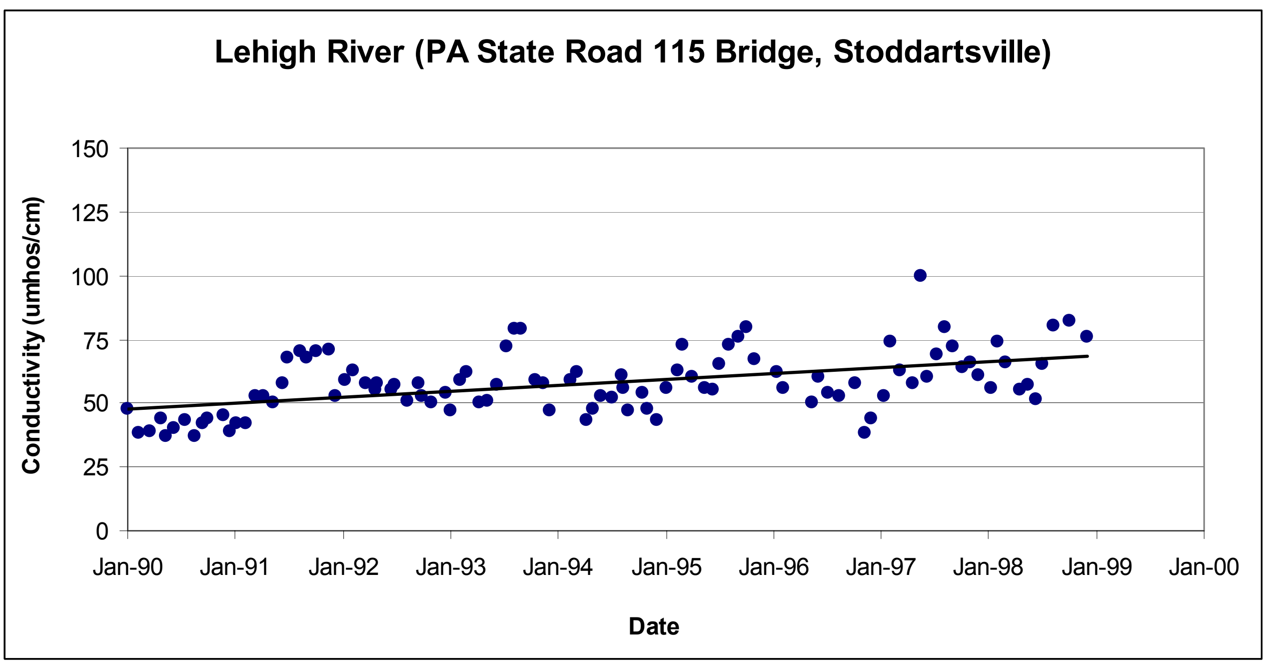


Figure 1.4.3-7 Increased Conductivity Trends in the Lehigh River Watershed at Stoddartsville, PA during 1990-1999



1.4.4 Differences in Water Quality Throughout the Watershed

Key Points
- **Subwatersheds with high levels of conductivity tend to have higher levels of phosphorus, chloride, nitrate, iron, and total dissolved solids.**
- **Conductivity measurements may serve as an indicator of areas within the watershed that are being impacted by non-point sources.**

Spatial analyses were performed to determine if there were relationships between the mean conductivity in a watershed and other water quality parameters (see Table 1.4.3-4). Though water quality data throughout the watershed were limited, correlations between the mean conductivity and total phosphorous, chloride, nitrate, ammonia, total dissolved solids, iron, manganese and total organic carbon were discovered. As shown in the tables below, watersheds with higher conductivity tended to have higher concentrations of other water quality parameters. Mean watershed conductivity also correlated with mean values of total phosphorous, chloride, nitrate, iron, and total dissolved solids (see Table 1.4.4-1). These correlations suggest that the abundant and frequently measured conductivity data may provide a useful screening tool to identify watershed areas with water quality challenges. In addition, these correlations also suggest that trends in conductivity may be useful for indicating changes in certain water quality parameters (most inorganic or ionic water quality parameters) and serve as an indicator parameter for tracking watershed health.

Table 1.4.4-1 Spearman Rank Order Correlations of Mean Conductivity and Mean Water Quality Parameters in the Delaware River Watershed

Mean Conducitivity vs.	Number of Watersheds	R - value	p-value
Total Dissolved Solids	6	0.885714	0.018845
Total Phosphorus	7	0.857143	0.013697
Ammonia	8	0.457865	0.253941
Nitrate	6	0.942857	0.004805
Chloride	5	0.974679	0.004818
Total Organic Carbon	4	-0.4	0.6
Fecal Coliforms	4	0.8	0.2
Iron	8	0.706599	0.050063
Manganese	6	-0.37143	0.468478

Table 1.4.4-2 Universal Water Quality Issues for the Delaware River Watershed

Analysis of water quality data, impaired stream information, and observations from watershed surveys led to the conclusions that were made regarding the universal water quality issues which are presented in Table 1.4.4-2.

Source Type	Activity	Contaminant Source	Tidal Watershed	Middle Watershed	Upper Watershed
Nonpoint Source	Mining/Acid Mining Drainage (AMD)	AMD and Metals		X	
	Agricultural runoff	Nutrients, herbi-cides/pesticides, pathogens		X	X
	Urban/Suburban Runoff	Salts, nutrients, metals	X	X	
	Erosion	Sediment	X	X	
	Construction	Sediment	X	X	
Point Source	Sewage Discharge	Pathogens, Nutrients	X	X	X
	Abandoned Industrial Facilities	Metals, Organics	X	X	
	Industrial Discharges	Organics, Metals	X	X	
Special/Spills	Oil Pipelines	Organics	X	X	
	Truck/Railroads	Organics	X	X	
	Tire Piles/ Junkyards	Special	X	X	X
	Reservoir Releases	algae / metals	X	X	X
	AST / USTS	Organics	X	X	

1.4.5 Analysis of Stream Impairments and Sources in the Delaware River

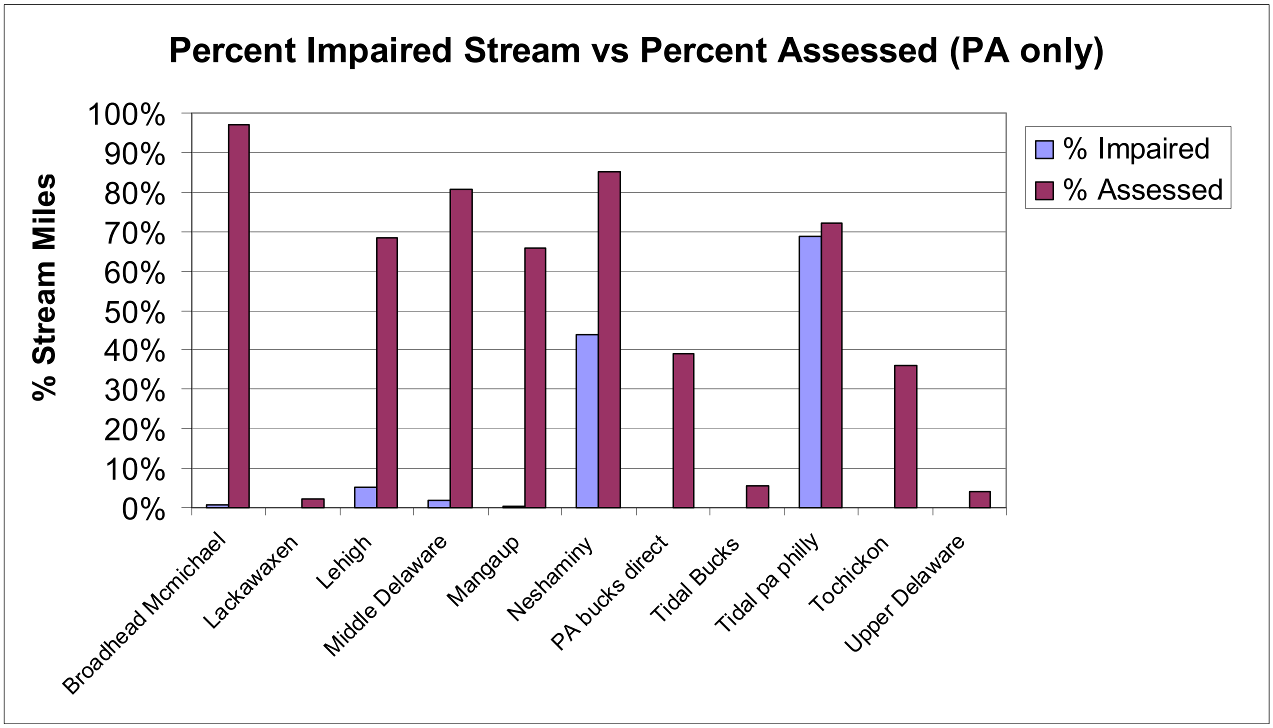
Key Points

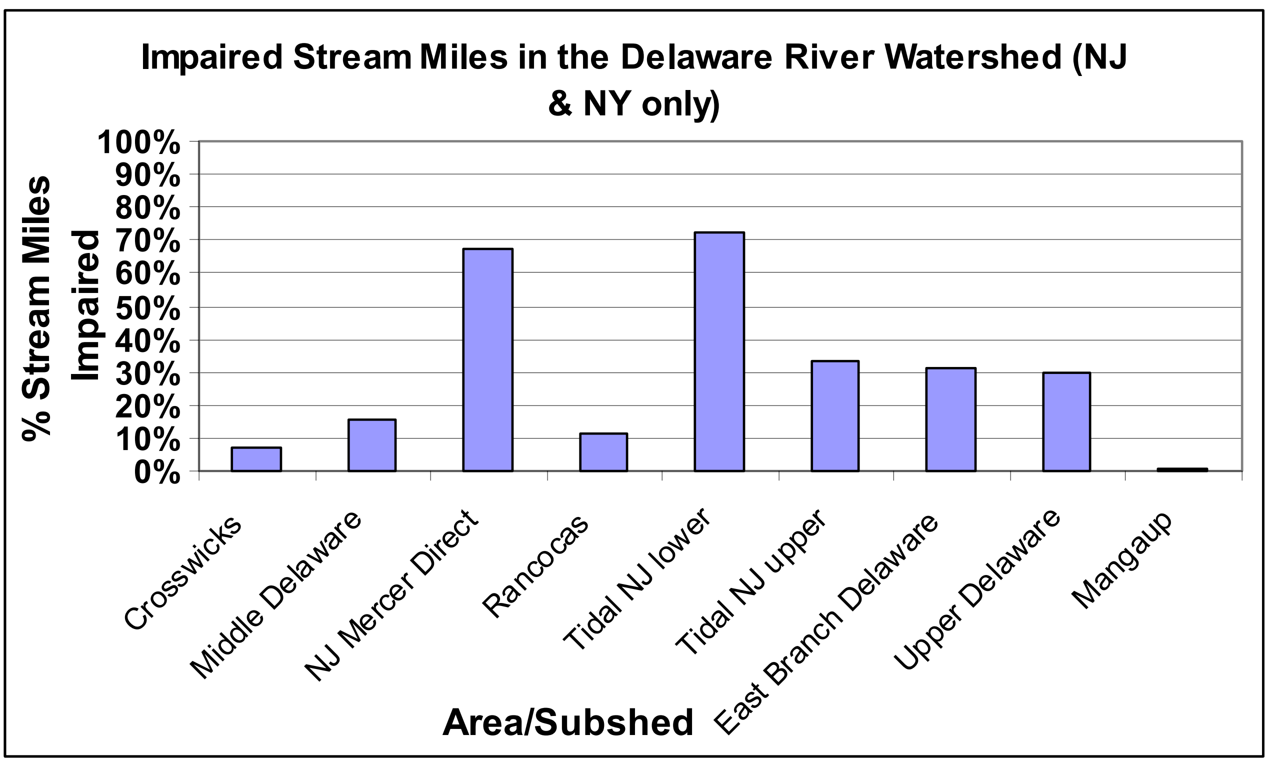
- **Of the 14,299 miles of streams and creeks within the Delaware River Watershed 35% (5,056 miles) have been assessed to determine their compliance with applicable water quality standards.**
- **Nearly 65% of the assessed stream miles have attained applicable water quality standards.**
- **Flow alterations, phosphorus (nutrients), and toxic chemicals in fish tissue and sediment were identified as the most significant causes of impairment within the watershed.**
- **Stormwater runoff from urban and suburban areas was identified as the cause of almost half of the impaired stream lengths within the watershed in Pennsylvania.**
- **Although water quality data suggests that pathogens are a concern throughout the entire watershed, very few segments are listed as having pathogens as the primary cause of impairment.**

In accordance with Section 305 (b) of the Federal Clean Water Act, the Pennsylvania Department of Environmental Protection (PADEP) prepared a 305 (b) Water Quality Assessment Report in 2000. The Report summarizes water quality management programs, water quality standards, and point and non-point source controls. The Delaware River Watershed includes 14,299 miles of streams and creeks. Of these streams, 6,916 miles are located in Pennsylvania. New York contains 4,457 miles of streams within the Delaware River Watershed. The remaining 2,926 miles of streams of the total 14,229 are located in New Jersey. Thirty five percent, or 5,056 miles, within the watershed have been assessed in order to determine compliance with applicable water quality standards. Almost 65% of the stream miles that have been assessed – 3,270 miles - have attained the applicable water quality standards. Streams that are impacted by contaminant sources (point sources, or non-point sources such as stormwater runoff or acid mine drainage) causing water quality standards to not be met, are designated as impaired. Thirty five percent of the stream miles (1,786 miles) that have been assessed do not meet applicable water quality standards and are designated as impaired. To date, 9,243 miles of streams within the watershed have not been assessed. Most of the unassessed stream miles within the watershed, 65% of the total unassessed streams, are located in New Jersey and New York. 47% of Pennsylvania's total stream miles within the Delaware River Watershed have not been assessed.

Figure 1.4.5-1 shows the percentage of assessed miles within each watershed that do not meet water quality standards and have been designated as impaired.

Figure 1.4.5-1 Impaired Miles vs. Miles Assessed in Each Subwatershed of the Delaware River Study Area by State





The areas of the tidal Delaware River in Pennsylvania and New Jersey as well as the Neshaminy Creek and streams in Mercer County have the greatest percentages of impaired stream miles. Impairments were also identified in other subwatershed areas as well, but to a lesser extent.

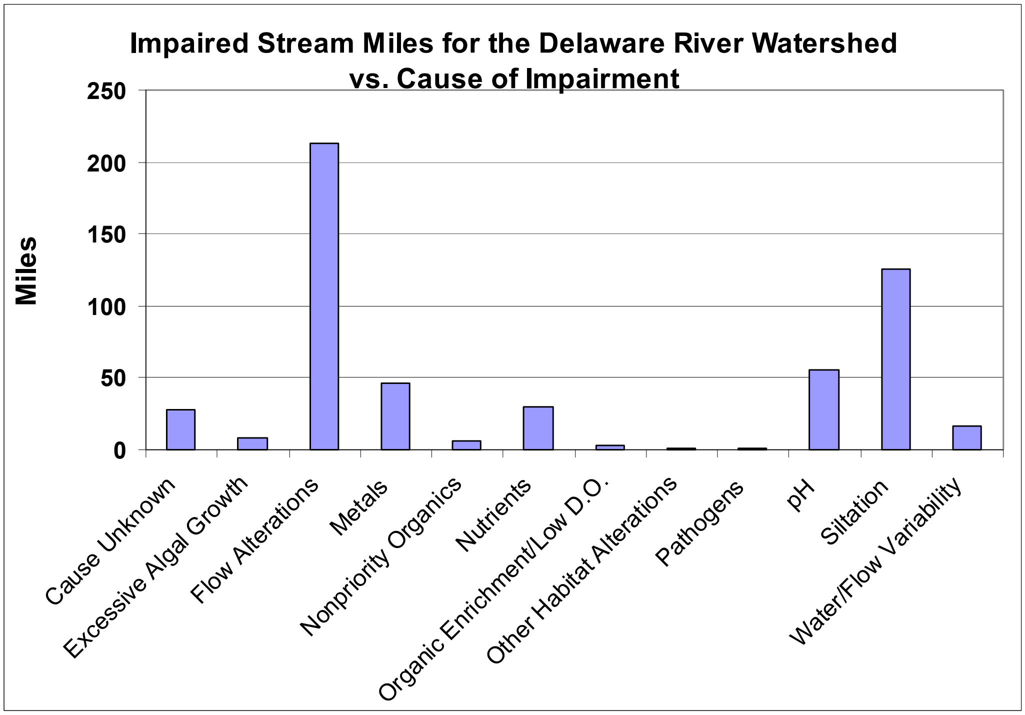
Excessive algal growth, flow alterations, pH, mercury, PCBs, nutrients, siltation, and water/flow have all been identified as causes of impairment within the Delaware River Watershed. Figure 1.4.5-2 summarizes the miles of impairment and their primary causes throughout the Delaware River Watershed.

In Pennsylvania, the leading cause of impairment has been identified as water/flow variability. Siltation is the second leading cause of impairment, while pH, metals, and nutrients make up the largest remaining impairments. In New York and New Jersey, the leading cause of impairment was phosphorus (a nutrient). Toxic chemicals such as mercury, lead, and PCB's in sediments and fish tissues were the second leading cause of impairment. Metals such as chromium, arsenic, and beryllium made up the remaining major impairments. Comparison of the observed causes of impairment between the three states indicates some common issues with nutrients and metals. However, there are very unique and special geographical divisions in the types of impairments and their significance depending upon the region or state. These could be related to development, geology, or industrial factors that cannot be easily discerned at the level of gross comparison conducted in this analysis.

Point and non-point sources, such as agriculture, municipal point sources, urban stormwater runoff, small residential runoff, land development, and acid mine drainage, are the leading sources of impairment in the Pennsylvania portion of the Delaware River Watershed, as shown below by Figure 1.4.5-3. The sources of impairment for New York and New Jersey were not reported. It is assumed that these sources may generally be similar given the common causes of impairment in the three states. However, toxic chemical related impairments in New York and New Jersey may suggest sources of impairment from industrial discharges and manufacturing.

Figure 1.4.5-4 displays the status of stream assessment within the Delaware River Watershed. Green lines represent streams where applicable water quality standards are being met. The red lines represent impaired streams where water quality standards are not being attained. The blue lines represent the streams that have not been assessed yet. Impaired stream reaches are most common in the southern sections of the watershed. The central portion of the watershed has the greatest amount of unassessed streams, compared to the rest of the watershed. More efforts should be made to assess the middle portions of the Delaware River Watershed.

Figure 1.4.5–2 Causes of Impairment Within the Delaware River Watershed



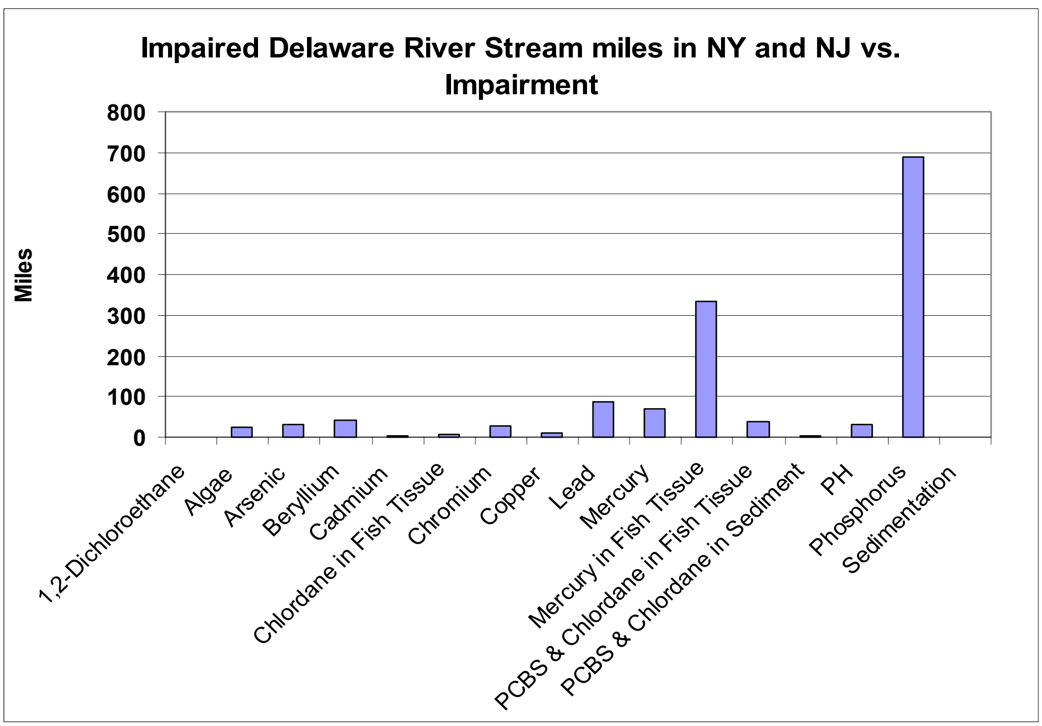


Figure 1.4.5-3 Miles of Impairment within the Delaware River Watershed vs. Their Primary Sources of Impairment

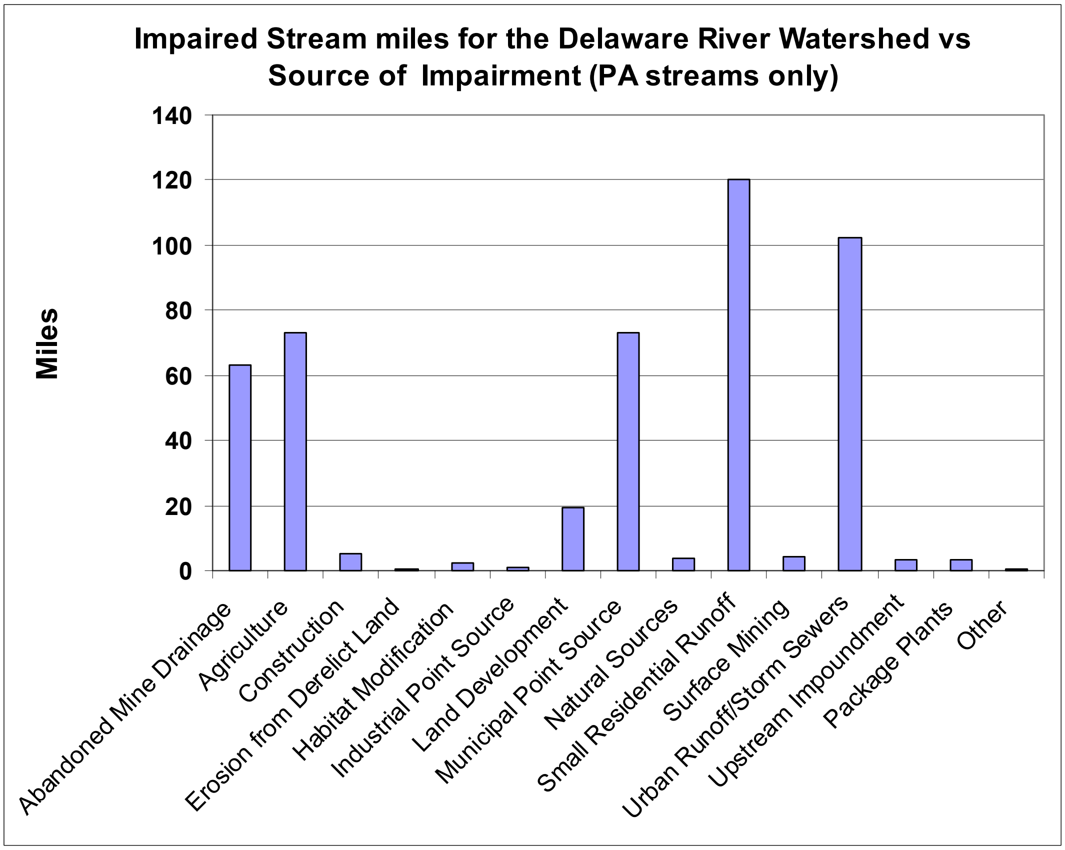
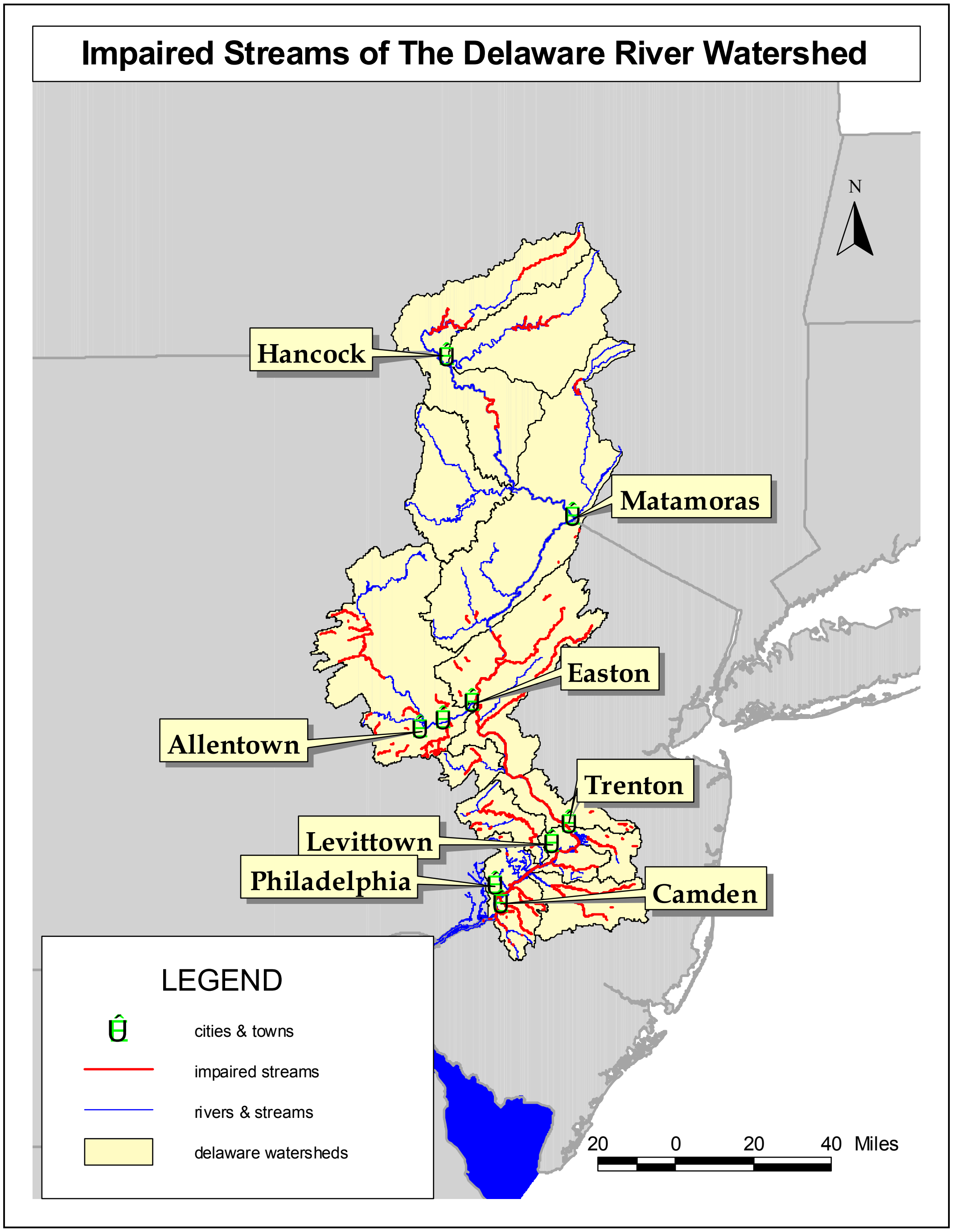


Figure 1.4.5-4 Impaired Streams Within the Delaware River Watershed



1.4.6 Universal Water Quality Issues

Key Points

- **Potential sources of contaminants affecting Delaware River water quality include acid mine drainage, sanitary wastewater, abandoned industrial sites, agricultural and construction runoff, reservoir operation, catastrophic accidents, road runoff, and wildlife.**
- **Untreated or inadequately treated sanitary wastes can contribute significant bacterial loads to the river.**
- **Abandoned industrial sites and dumpsites located within the river's floodplain could significantly impact downstream water users.**
- **Erosion resulting from agricultural activities and pathogens from livestock wastes introduce sediment and microbial pathogens into the river.**
- **Erosion from construction sites without well-maintained sediment controls can significantly increase sediment loads to the river. To date, impacts from catastrophic accidents and spills have been insignificant, due to skillful, well-prepared responses.**
- **Storm runoff containing deicing salts and herbicides from right-of-way application cause increased levels of chlorides, sodium, SOCs, and urea in the river.**
- **Algal blooms resulting from excessive nutrients can significantly affect water treatment requirements.**
- **Increasing populations of Canada geese in the watershed have resulted in impacts on various localized stretches of the river.**

Based on the analysis of the water quality data, stream impairment data, stakeholder input, and several watershed inspections, a number of specific issues were identified that have impacts throughout the watershed. These issues are:

- Acid mine drainage
- Discharges from septic systems, sewerage systems, and wastewater treatment plants
- Dumping, tire piles, salvage yards, and abandoned industry in or near the floodplain
- Agricultural runoff of herbicides, pesticides, fertilizer, sediment, and phosphorus
- Erosion and construction runoff
- Dam removal and sediment releases
- Catastrophic accidents and spills, particularly oil delivery spills, from roads, trains, and fires
- Road runoff
- Wildlife management

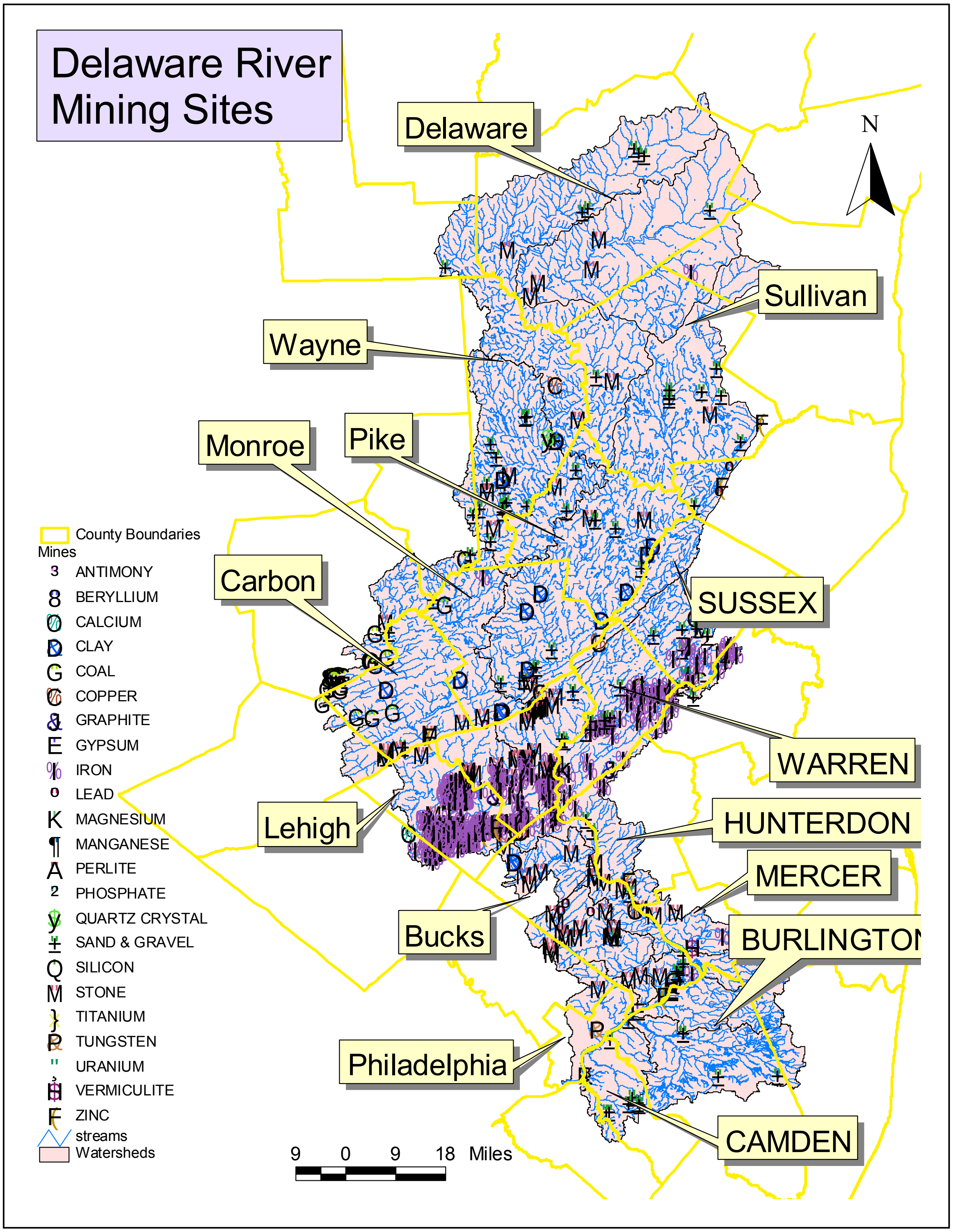
These topics will be discussed in detail throughout this section.

1.4.6.1 Acid Mine Drainage

There are 659 known surface and underground mining facilities in the Delaware River Watershed. Mining of sand and gravel, iron, and stone make up 86 % of those operations. Although coal mining has historically been the most predominant, iron mining is now just as common. Approximately 4% (25) of the mines currently operating in the watershed are coal mines located in the Upper Lehigh River Watershed within Carbon and Monroe Counties (See Figure 1.4.6-1).

Acid Mine Drainage (AMD) is generated when the iron sulfide-bearing materials created by the interaction of the sulfate in coal beds and sulfate-reducing bacteria are exposed to oxygen in air or water during mining. The iron sulfides react with the oxygen to produce hydrogen sulfide, which makes the water more acidic. As the water becomes more acidic, its ability to leach metals from the existing rock layers increases. Therefore, the water from mines is not only acidic, but often contains increased concentrations of aluminum, iron, manganese, calcium, magnesium, and sulfate. Acid mine discharges can come from shafts, tunnels, boreholes, drifts, and seeps. AMD can also come from culm piles or spoil piles that run off into nearby streams.

Figure 1.4.6-1 Mining Locations in the Delaware River Watershed



1.4.6.2 Discharges from Septic Systems, Sewerage Systems, and Wastewater Treatment Plants

Improper wastewater collection and treatment causes pathogens and nutrients to impact the quality of source water supplies, recreational water quality, and aquatic life. Improper wastewater collection and treatment may result in the following:

- Wet weather overflows of raw sewage by the sewer system (manholes and pump stations) due to treatment plant capacity limitations
- Wet weather overflows of raw sewage by the sewer system (manholes and pump stations) due to lack of collection system capacity and infiltration/inflow sanitary sewer overflows (SSOs)
- Wet weather overflows of raw sewage by the sewer system due to combined sewer overflow systems (CSOs)
- Wet weather overflows of raw or partially treated wastewater by the treatment plant due to treatment plant capacity limitations or lack of treatment upgrades.
- Dry weather overflows caused by blockages (tree roots, grease, etc.) sometimes due to poor collection system maintenance.
- Dry weather discharges of raw sewage due to defective sewer lateral connections and improperly operated CSOs
- Routine discharges of raw sewage due to lack of adequate septic systems, sewerage systems, and enforcement
- Routine discharges of raw sewage due to failing septic systems
- Periodic discharges of partially treated sewage due to treatment plant performance limitations

Most of these issues can be observed throughout the Delaware River Watershed. Though not as prevalent as in the original watershed inspections conducted in the 1880’s, 120 years of progress still have not resulted in the use of adequate and proper sewerage systems within the entire watershed, and discharges of raw sewage still occur to this day. These discharges come from “wildcat” sewers (illegal sewers discharging directly to the river), and the numerous cabins and cottages throughout the watershed that are suspected of making illicit discharges into the river and local streams and lakes. Some are discharging raw sewage, while others are operating with septic systems that have failed, or septic systems that are not located on properly draining soils or which drain to areas of fractured rock and limestone. In addition, there are several communities with CSO discharges upstream of drinking water intakes. These include Bethlehem, Allentown, Easton, Gloucester, and Camden.

The impacts of wet weather issues extend beyond wastewater treatment plant performance. Sometimes the lack of treatment capacity by the wastewater treatment plant causes a "back up" in the sewer system entering the wastewater plant and results in overflows at manholes and pump stations (Figure 1.4.6-2). Other times, the infiltration and inflow of rainwater and groundwater into the sewer pipes themselves, either due to age or disrepair of the sewer system, will also cause manholes and pump stations to overflow. The communities most affected by these issues are older communities with decaying infrastructure and new communities without enough sewer and treatment capacity to handle the increased residential populations as people move further out from urban areas. Overall, sewer system capacity and integrity as well as treatment plant capacity during wet weather periods represent the greatest and most difficult sewage related issues in the watershed.

Figure 1.4.6-2 Overflowing Manhole Near a Stream

Though some communities are facing consent orders and enforcement action against them due to stormwater runoff problems, other communities are working hard to address stormwater issues. For example, Bucks County has been working hard to address inflow and infiltration issues and has become a model for other communities to emulate. The City of Philadelphia has also made strides to identify and mitigate defective laterals as well as piloting innovative stormwater reduction techniques.

1.4.6.3 Dumping, Tire Piles, Salvage Yards, and Abandoned Industry Near the Floodplain

The Delaware River Watershed was one of the first areas in the United States to feel the effects of industrialization. However, as metal manufacturing and other manufacturing industries have declined, the sites of these industrial activities were abandoned, leaving valuable riparian area damaged and unrestored. Some of these abandoned sites have old spoil piles, or lagoons that still leach remnants of contaminated materials. These sites are also neglected, and therefore, no one organization is responsible for the monitoring or mitigation of the old lagoons and spoil piles. These abandoned and somewhat isolated areas also encourage dumping and general neglect by the nearby communities since they are considered to be hazardous eyesores.

In addition to abandoned industrial sites, there are numerous salvage yards and several trash transfer stations located along the river and stream banks. These sites appear to be in or near areas prone to flooding, and seem to have limited environmental practices in place to prevent contaminated runoff or debris from entering the river. Old oil tanks and chemical containers in or near areas prone to flooding have been observed at some of these facilities and warrant special concern. Other areas include tire piles, as shown by Figure 1.4.6-3, which if ignited by vandalism or accident, will result in significant damage to the entire Delaware River below them.

Figure 1.4.6-3 Dumping and Abandoned Industry Along The Delaware River

1.4.6.4 Agricultural Runoff

Agricultural activities without proper controls can release pathogens, nutrients, herbicides, pesticides, and sediment into streams, which impacts source water quality, recreational water quality, and aquatic life. More than 17% of the Delaware River Watershed is agricultural land.

Over the past several decades, the amount of agricultural land has been decreasing in the Delaware River Watershed, but this does not mean that the level of agricultural activity is decreasing proportionally. It is suspected that residential development of agricultural land is concentrating agricultural activity into smaller areas that can lead to greater local impacts on water quality.

Erosion and runoff of soils during tillage and farming release significant amounts of sediment and nutrients into the streams and rivers if there are no proper riparian buffer strips in place. In addition, cattle access to streams causes significant damage to the streambank and makes it more susceptible to erosion. Runoff of livestock wastes also releases pathogens into water supplies. Figure 1.4.6-4 illustrates agricultural uses of land within the watershed.

Figure 1.4.6-4 Cows in the Stream and Farming Tillage Impacts on Sediment and Nutrients

Despite the potential for significant negative impacts by agricultural activities, agricultural lands also represent the simplest and cheapest areas for potential restoration and protection. In fact, many farmers are actively pursuing a variety of techniques to help protect and restore local streams. As shown in Figure 1.4.6-5, a number of farmers are installing specially designed cattle crossings and streambank fencing to reduce the impacts of cattle on streams. Other farmers are even establishing riparian buffers to protect the streambank and to filter out harmful nutrients.

Figure 1.4.6-5 Techniques to Prevent the Impacts of Agricultural Activities
Farmers installing cattle crossings (left) and streambank fencing with riparian buffers (right) to limit the impacts of livestock on streambanks and filter runoff from pastures along the Pennypack Creek

1.4.6.5 Development, Construction, and Erosion Runoff

The Delaware River Watershed is developing at a significant rate. With this development comes the construction of homes, highways, and businesses to support that growth. This construction usually entails significant disturbance and moving of earth. The impacts of runoff from construction sites can range from negligible to significant, depending on the characteristics of the construction site, the types of erosion controls that are implemented, and the maintenance of those control structures. There are many types of controls that include the placement of sediment barriers or fences, or bags, which trap sediment in storm drains. Erosion and sediment control plans must be submitted for review to the township and/or county Soil Conservation District. However, the amount of time and personnel available from both the township and county conservation district are limited, compared to the amount of submittals by the numerous developers and developed sites. In addition, the amount of time and staff available to inspect sites in order to observe if the proposed erosion controls are in place are also severely limited, and frequently, priorities are driven by complaints from citizens.

As shown in Figure 1.4.6-6, the impacts of runoff from construction can be severe, releasing significant amounts of sediment into local waterways. The combined impact from the sediment releases at these locations in certain areas can lead to increased dredging and reduced storage capacity in water supply reservoirs. In addition, sediments carry phosphorus into lakes and streams, causing algal blooms. The excess nutrients cause our reservoirs to become eutrophic.

Figure 1.4.6-6 Photographs of the Impacts of Runoff from Construction
Left: Erosion and runoff construction and construction runoff. Right: the impacts of construction runoff that includes increase dredging of reservoirs or decreased water supply storage.

1.4.6.6 Reservoir Operations and Water Releases

There are over a dozen reservoirs in the Delaware River of varying sizes that are used to maintain adequate flow and water supply for all users throughout the watershed. However, these reservoirs can also concentrate contaminants, especially algae. The reservoir can have impacts on water quality in a number of ways. First, it can release concentrated or elevated concentrations of contaminants that will react with the ambient water in the receiving streams and change its characteristics. For example, algae that are growing in a reservoir are released by its operation, that upon entering different water quality conditions can die off releasing chemicals that impact the taste and odor of the water. Also, large releases of nutrients or metals re-suspended in soluble forms by anoxic conditions at lakes into local streams can also cause water quality issues. The second way a discharge from a reservoir can impact water quality is through releases of small quantities of algae that, upon entering the rivers, are now in conditions that are favorable to their overproduction or blooming. Algae once released from a low nutrient reservoir into a nutrient laden stream combined with a long travel time in the river to water intakes downstream could cause an algae bloom that impacts water quality and taste and odor for weeks downstream.

Overall, it is recommended that the operation of these reservoirs, including the levels and quality of releases (bottom/anoxic water vs. top water), be communicated in a real time format to water suppliers. Studies should be conducted to determine how these releases can impact water quality through changing algal populations in their receiving streams.

Figure 1.4.6-7 Reservoirs in the Delaware River Basin - Beltzville Lake

1.4.6.7 Catastrophic Accidents and Spills

At any given time throughout the watershed, an accident that releases contaminants that can directly impact the quality of a water supply can occur. These catastrophic events can require public water supply withdrawals to stop for periods of time ranging from a few hours to several days, limiting available water to affected communities. Water suppliers and communities are prepared to deal with such accidents, because their emergency response planning included preparation for just such occasions. Therefore, the impacts on the public in general are limited. However, when an accident of significant nature does occur under conditions that cannot be anticipated, the impact can be quite dramatic. For example, in the Delaware River Watershed alone during the past several years, there were a number fuel oil spills or discharges into waterways, a railroad tanker car derailment, several major fires along the river at large industrial facilities or abandoned facilities, underground storage tank spills, and various spills of gasoline and oil onto roads and bridges, which leaked into local streams.

One tanker car can contain up to 14,000 gallons of hazardous chemicals. In this area, most railroad lines run along the Schuylkill and Delaware Rivers and pass through Philadelphia. Therefore, given the significant amount of shipping through this corridor, the risk and possibility of a tanker car derailment and release of hazardous material into the Delaware River, though fairly low, is real.

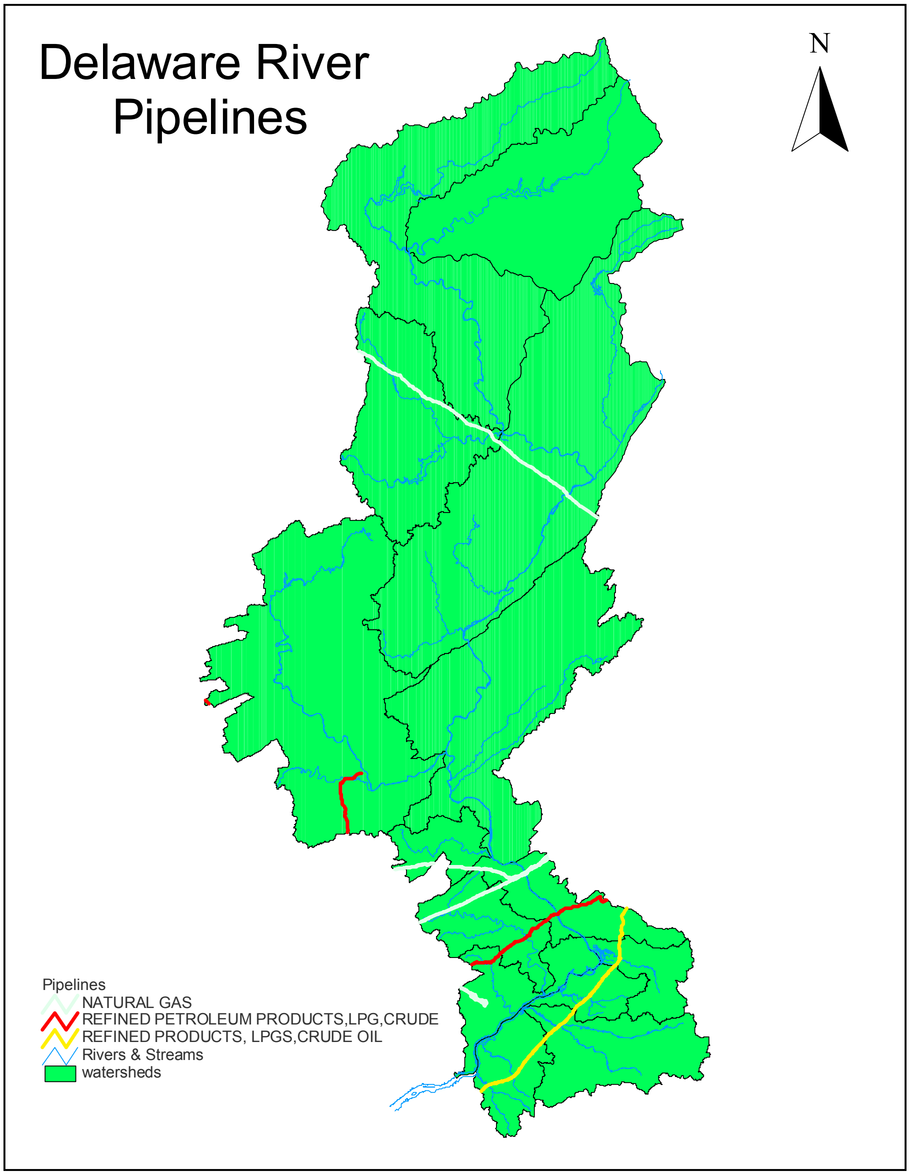
In addition to railroads and other transportation, barge and commercial shipping traffic is quite significant in the tidal Delaware River. An accident from an oil tanker or tanker containing other hazardous materials could have catastrophic impacts on water supplies.

Figure 1.4.6-8 Tanker Car Derailment in Philadelphia
Tanker cars can carry up to 14,000 gallons of hazardous materials.

Beyond the known incidents of this year alone, there are past incidents that continue to concern water suppliers. For example, petroleum pipelines have broken, releasing thousands of gallons of petroleum into local groundwater supplies, streams, and water supplies. The river has many major petroleum pipeline crossings, unknown to the general public. The age and location of these pipelines are largely unknown and the petroleum suppliers are just now voluntarily supplying partial information to local and federal governments. It is believed that these pipelines are of significant age and nearing their service life expectancy. Locations of known pipelines are shown on Figure 1.4.6-9.

The highways and bridges that cross the Delaware River and its tributaries also represent significant opportunities for impacts on water supplies. In the event of an accident, tanker trucks carrying gasoline or fuel oil can spill thousands of gallons of their cargo into storm drains on roads and bridges that discharge directly into the stream or river. In some cases, since many roads follow along the banks of the river and streams, entire trucks can run off the road and into the stream or river, releasing their cargo. In addition to the possibility of impacts due to direct spills from trucks and cars, bridge maintenance activities have been known to release chemicals into the river itself. The painting of bridges can result in the release of paints and solvents if not handled properly and applied with the appropriate controls.

Figure 1.4.6-9 Petroleum and Natural Gas Pipelines in the Delaware River Watershed



Petroleum pipelines cross the Delaware River and its tributaries in many places and may be reaching the end of their service life. Due to voluntary mapping requirements, only a portion of the pipelines in the watershed may be identified on GIS.

1.4.6.8 Road Runoff

In addition to the numerous types of spills and catastrophic impacts from accidents on highways and bridges, maintenance of roadways and parks can also impact water quality. The maintenance of highway shoulders includes spraying of herbicides such as glyphosate to kill weeds growing beside the highway. The evidence of spraying can be observed in summer and fall, when it may be possible to notice a brown swath of dead plant material including portions of nearby trees within 20-50 feet of the highway shoulder. Though the application of these materials is important for the maintenance and protection of the highway, they are sometimes sprayed into storm drains or nearby waterways where they can persist and impact water quality. This effect could be significant given the large number of miles of highway in southeastern Pennsylvania and numerous miles of roadway adjacent to streams and rivers.

Another concern from road runoff is the release of road salts during winter application periods, as illustrated by Figure 1.4.6-10. Concentrations of salts, such as sodium and chloride, have increased significantly over the past several decades at some locations in the watershed. These increasing trends seem to be linked to the increased development and impervious cover in the watershed as more highways, driveways, walkways, and parking lots are built in the watershed. The application of salts to these surfaces to make them safe for travel is important. However, at some time in the future, these practices may need to be addressed in order to reduce impacts on waterways before they significantly impact water supplies or aquatic life. Several water supplies in the Northeastern U.S. have similar issues with the impacts of salt application on water quality and have developed programs to reduce application and mitigate impacts in sensitive areas. Salt mist spraying before storms using special trucks is an example of a new technology that can be used in the Lower Delaware River Watershed to reduce salt application and mitigate salt runoff impacts.

Another example of the negative impacts of runoff can be found in the situation that occurred in the winter of 1994 when some communities ran out of salt and began using fertilizer as a de-icer on sidewalks and driveways. The urea in the fertilizer reacted with the chlorine at a treatment plant and caused major taste and odor problems. This occurrence highlights the need to educate community members about the preventable negative impacts of runoff.

Figure 1.4.6-10 Road Salt Application During the Winter

1.4.6.9 Algae Impacts

The growth and die-off of various types of algae can have significant impacts on water treatment. Diatoms can bloom and clog the filtration process requiring increased filter backwashing. When blue-green filamentous algae die, they release very minute concentrations of chemicals that are not harmful to human health, but which make the water taste and smell unpleasant. The removal of these chemicals requires additional and costly treatment. Algal blooms are caused by excess nutrients in the aquatic system, as well as the loss of shade cover from trees along the stream and river. The reduction of nutrients from agricultural runoff, sewage discharge, and lawn fertilizer application are important components in preventing these situations. Preventing the loss of riparian buffer and shade trees along the stream and river would also keep this problem from worsening. The frequent impacts on taste and odor have involved understanding the sources of these algae blooms. Figure 1.4.6-11 shows one of the instances when the sources were tracked to the Lehigh River.

Figure 1.4.6-11 Picture of Algae on the Lehigh River
The low flows and slow flows behind dams and in reservoirs, large amounts of sunlight, and excessive concentrations of nutrients in the Delaware River provide the proper conditions for algae blooms.

1.4.6.10 Wildlife Management

The Delaware River Watershed provides refuge to many wonderful birds and animals. However, there are certain conditions in which any animal can damage the land and water resources in a given area (see Figure 1.4.6-12). Damage can be caused by a significant and unnatural proliferation of a species, the inhibition of migratory activities, destruction of predatory species, or other factors. The impacts of large and ever-increasing populations of geese in this watershed and nationwide are well known. Figure 1.4.6-12 depicts a local goose population. In the Philadelphia area, geese have been found to impact areas for most major water supplies, which has resulted in the closing of several areas to swimming. Studies by the Philadelphia Suburban Water Company identified that geese were responsible for 70% of the *E. coli* bacteria in one of the regions lakes.

There are a number of techniques that are being employed in order to protect land and water resources from the geese. Some of these involve educating people not to feed the geese in sensitive areas, while others include scaring the geese with noises or dogs. The last resort used in most cases usually involves the active hunting of geese or egg addling to control skyrocketing resident populations in various areas.

Deer have also been identified in various suburban and urban areas as the cause of negative impacts on local land and water resources. Park and land areas that provide habitat for deer, but prevent hunting due to nearby homes, have experienced increasing deer populations. In some cases, the herd becomes unnaturally large and starts to damage the trees and undergrowth through heavy feeding. The loss of undergrowth in old canopy forest areas is significant and leads to increased erosion. In addition, deer can be vectors for many pathogens.

Overall, it is recommended that water suppliers, park managers, golf course managers, state and federal wildlife officials, and wildlife experts should meet in order to develop a deer and geese management plan for impacted areas of the Delaware River Watershed. This would help to combine the resources of various individual efforts into a comprehensive and more effective form of action.

Figure 1.4.6-12 Geese Damaging Land Near a Water Supply Intake
The skyrocketing population of resident non-migratory geese throughout Pennsylvania and the entire United States is damaging land and water resources.

1.4.7 Watershed Monitoring: Current and Future Needs

Key Points

- **Most of the monitoring within the Delaware River Watershed is conducted by over ten water suppliers, government agencies, academic institutions, and community and environmental groups.**
- **Water quality monitoring efforts still need to be better coordinated, and the data should be compiled, organized and shared in a timely fashion.**
- **There are over 2,500 known monitoring locations in the Delaware River Watershed. It is estimated that less than half of these sites have routine or regular monitoring.**
- **Water quality monitoring sites appear to be well distributed within the watershed, with the Middle Delaware River Watershed observing the largest concentration of monitoring locations.**

Understanding the current and future water quality challenges facing water suppliers and the Delaware River Watershed requires analysis of data collected over time at different locations in the watershed. However, the current approach to monitoring has not been coordinated or planned. At any given time, there are five public agencies conducting professional routine monitoring of the Delaware River Watershed. Each of the many water suppliers and businesses in the watershed conducts some form of monitoring at their intakes. In addition, community groups conducting routine monitoring of nearby streams share their data with the Delaware Riverkeeper. Other community organizations conduct monitoring, but do not share it with other organizations due to lack of time, technical capabilities, and resources. Overall, the Delaware River Basin Commission has been the only organization to attempt to track water quality trends, provide limited coordinated of monitoring, and conduct spatial comparisons.

Most of the energy and effort that goes into routine monitoring is focused upon specific issues and projects in particular subwatersheds or areas of the Delaware River. For example, monitoring by the U.S. Army Corps of Engineers is focused on the recreational quality of their various lakes (Beltzville, Francis E. Walter). The Delaware River Basin Commission monitors the tidal Delaware River more heavily for recreational quality considerations. Water suppliers and businesses tend to monitor their intake water quality for process adjustment considerations. Table 1.4.7-1 and Figure 1.4.7-1 provides a description of the organizations that conduct routine monitoring in the Delaware River Watershed and the level of monitoring that is conducted. As shown, almost all of the known monitoring sites in the watershed are conducted by state or federal organizations.

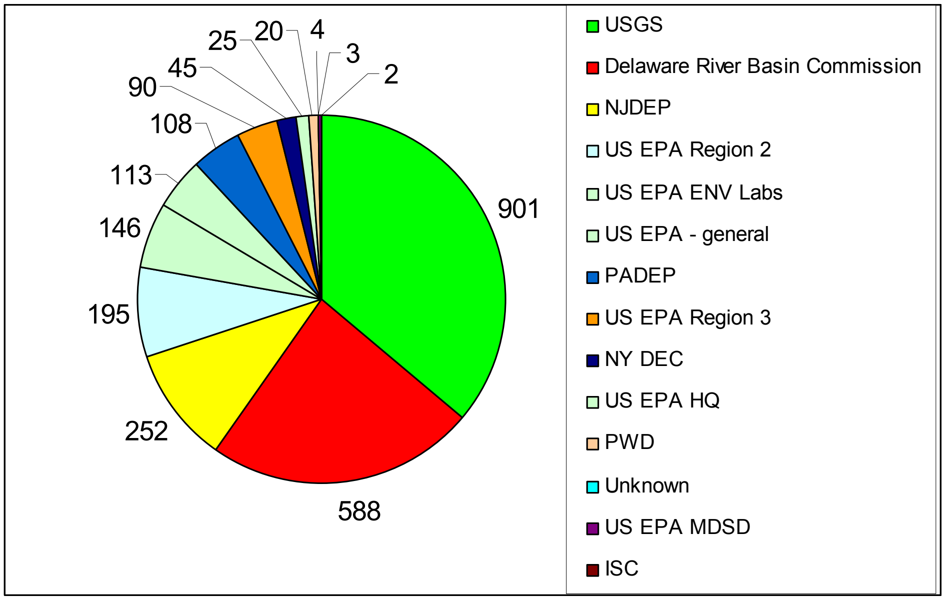
There are almost 2,500 known locations where routine monitoring is occurring in the Delaware River Watershed. Figure 1.4.7-2 provides a breakdown of the number of locations within the various subwatersheds of the Delaware River. This would suggest that there is a routine monitoring location to characterize every 6 to 8 square miles of the approximately 13,000 square-mile watershed. However, this is not the always the case.

As shown in Figures 1.4.7-2 and 1.4.7-3, over 75% of the monitoring sites are located in the Lower/Tidal and Middle Delaware River Watershed, which represent 50% of the total watershed area.

Table 1.4.7-1 Summary of Routine Watershed Monitoring

Organization	Focus Area (s)	Level of Monitoring	Parameter Groups	# of monitoring locations
PADEP	Pennsylvania	Professional	Physical, inorganics, and metals. Limited microbiological	108
USEPA	Watershed wide	Professional	Physical, inorganics, and metals	572
USGS	Watershed wide	Professional	Physical, inorganics, organics, SOCs, and metals parameters	901
US Army Corps of Engineers	Beltzville Lake, Francis E. Walters	Professional	Physical, inorganics, organics, SOCs, microbiological and metals parameters	Unknown
NJDEP	New Jersey	Professional	Physical, inorganics, organics, SOCs, microbiological and metals parameters	252
Delaware River Basin Commission	Watershed Wide	Professional	Physical, inorganics, organics, SOCs, microbiological and metals parameters	588
NYDEC	New York	Professional	Physical, inorganics, organics, SOCs, microbiological and metals parameters	45
Delaware Riverkeeper	watershed wide	Volunteers	Simple physical parameters, limited inorganics and metals	unknown
Water Suppliers	All	Professional	Varies, but mostly inorganics, metals, microbiological Limited organics	< 20 with almost weekly or daily data for many parameters

Figure 1.4.7-1 Breakdown of Organizational Monitoring in The Delaware River Watershed



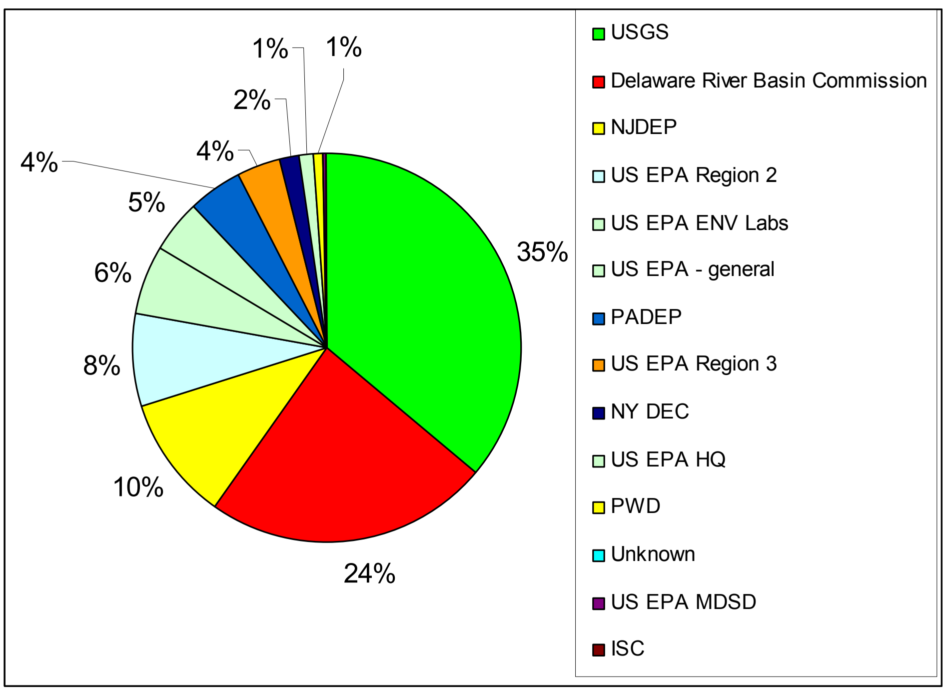
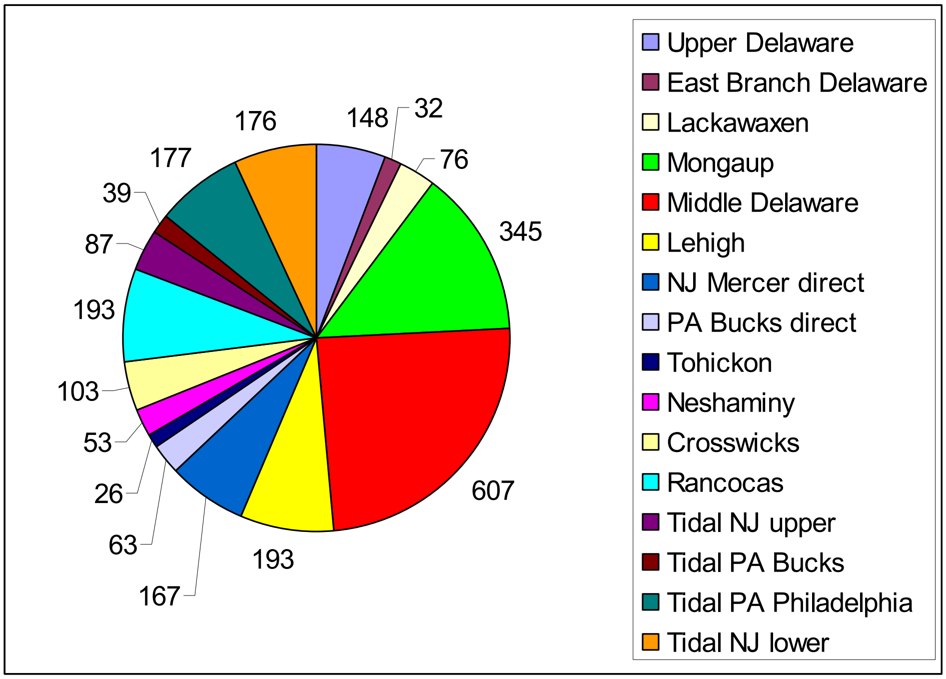


Figure 1.4.7-2 Number of Monitoring Sites in Delaware River Subwatersheds



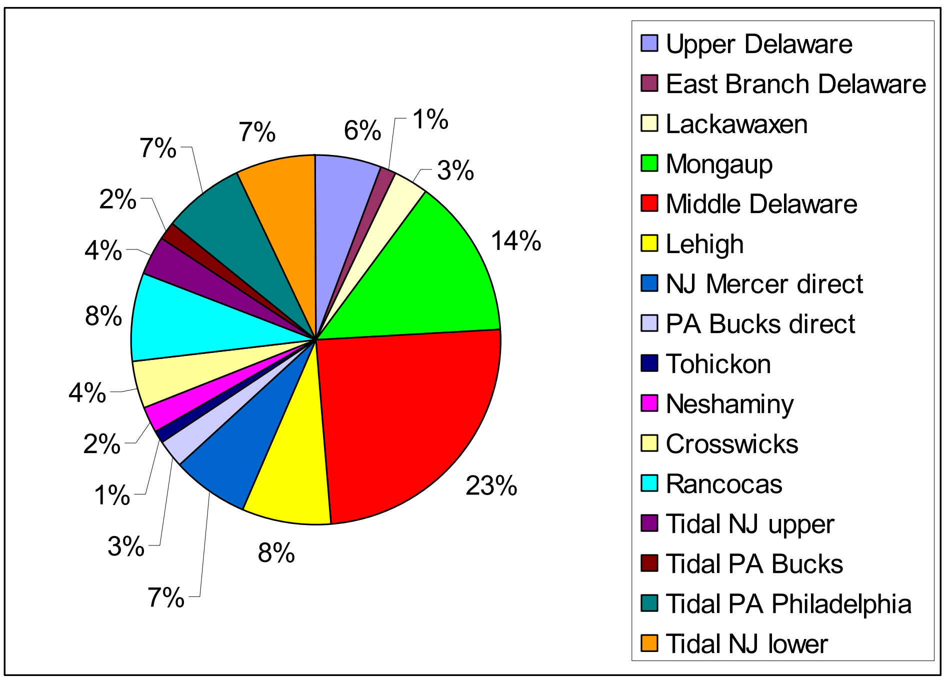
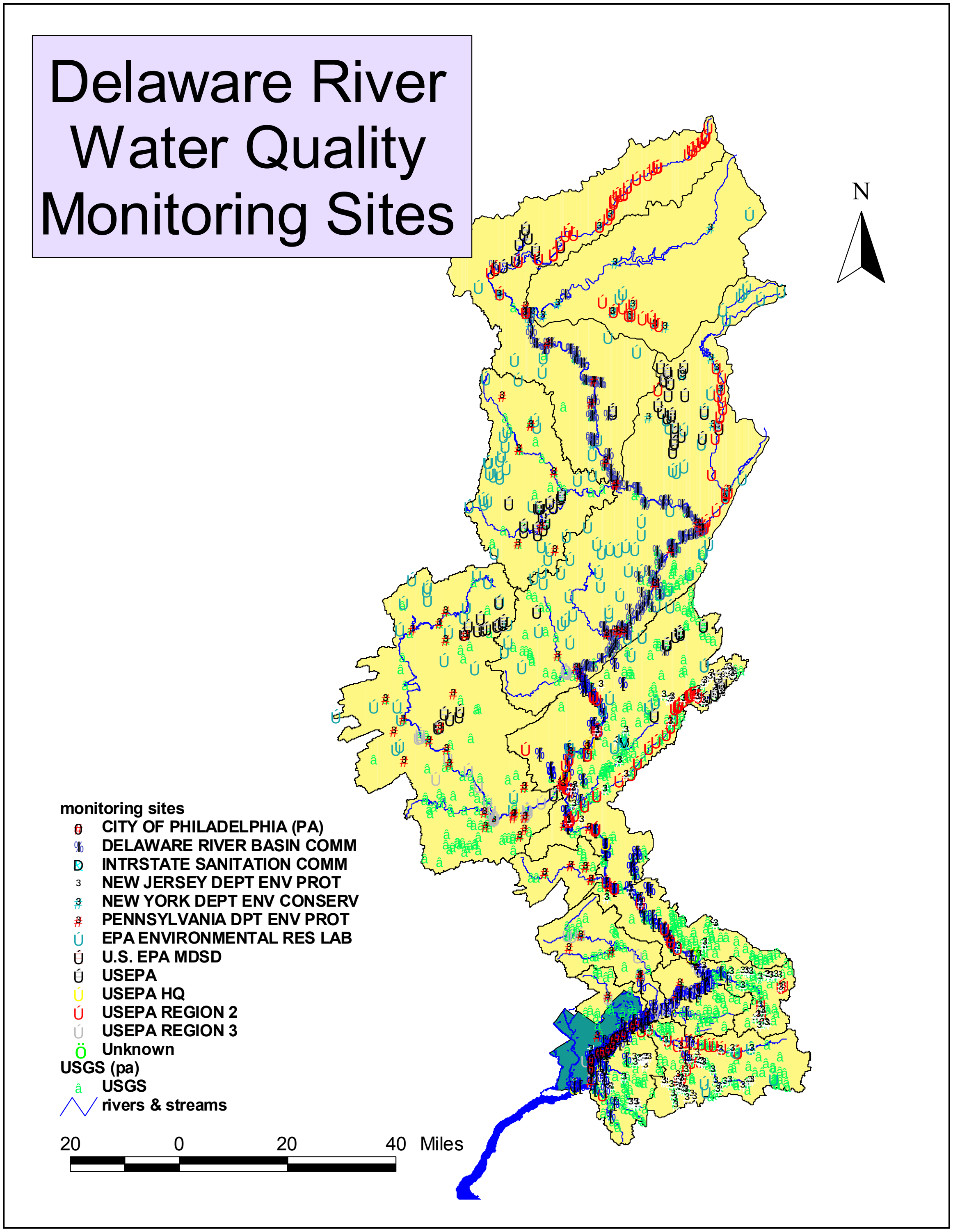


Figure 1.4.7-3 Routine Monitoring Locations by Organizations in the Delaware River Watershed



The quantity and type of monitoring is also important, in addition to the issue of where routine water quality monitoring is occurring. For example, though STORET indicated that a number of sites were monitored by NPS, USGS, and PADEP, that does not always mean that these sites were active for the same periods. For example, the USGS may monitor a number of locations, but it has only collected data from different time periods (70's, 80's, and 90's) for those locations. In addition, as project goals and water quality studies change, so do the selection of parameters. Therefore, monitoring may appear to be continuous at a location, but not for every desired parameter. In order to conduct any meaningful analysis of the water quality for a given watershed, sometimes data from multiple locations has to be pooled together into one data set for analysis.

In addition to the 2,500 potential sites for water quality data, there are numerous special studies conducted by water suppliers, community organizations, universities, county health departments, dischargers, and public agencies with little or no knowledge of one another, or of methods of coordination or data sharing. For example, although Beltzville Lake is extensively monitored by the U.S. Army Corps of Engineers during the spring and summer, it is also studied by other universities, schools, and community organizations. The different monitoring locations and parameters, as well as different seasons and sampling frequencies (USACE tends to conduct most of its monitoring during the summer) lead to various conclusions about the quality of the lake.

Pennypack, Poquessing, and Neshaminy Creeks are another example of locations where a variety of water quality monitoring programs have been conducted in recent years by water suppliers and watershed organizations. At times, dischargers, community groups, and consultants were conducting various levels of monitoring for their own special studies as well. None of this data has been combined to date.

Another important observation is that most of the mainstem river monitoring is conducted by the Delaware River Basin Commission, while tributaries are monitored by either the state environmental protection agencies, USGS, or the USEPA. Though this is a good way to focus resources, it also can prevent organizations from the ability to look at the whole watershed and see connections between water quality in the tributaries and the mainstem river. Therefore, sharing of water quality amongst these agencies is important to increase understanding of watershed issues and connectivity.

Overall, based on the information available from an analysis of the amount, types, and locations of monitoring in the watershed, the following monitoring requirements were identified:

- A data clearinghouse for water quality data needs to be created and made available to all organizations. A format for data reporting should be sent to all organizations that want to participate.

- An organization in the watershed needs to be properly funded in order to be responsible for compiling, organizing, and monitoring the water quality data from the numerous stakeholders in the watershed.

- Organizations that conduct monitoring should form a consortium for the purpose of frequent discussion of monitoring efforts and plans in order to promote better coordination and sharing of data.

- More monitoring locations are needed in locations in the upper watershed or at least monitoring in the upper watershed needs to be conducted more routinely and with more parameters.

- All monitoring organizations should agree on selecting standard monitoring stations for various parameters. It is recommended that the standard locations be placed close to the mouths of the major tributaries to the watershed. The long-term DRBC sites and certain water supply intakes may be the best places to start when selecting these sites. Routine monitoring would be conducted at these stations over long periods of time in order to examine changes and trends in water quality over the years, seasons, or decades. This information will be used as part of a report card system for water quality improvement.

Long term monitoring should be conducted for manganese, aluminum, iron, sodium, chloride, turbidity, total suspended solids, dissolved oxygen, temperature, ammonia, total phosphorus, orthophosphate, nitrate, *E. coli*, and fecal coliforms. Currently, most monitoring does not include coliform measurements except along the mainstem and tidal sections of the river. Efforts should be made to transfer data from hardcopy format in special studies into electronic format. Long term monitoring of the mainstem river at a number of locations is significant, however the same level of effort and quality is not available for many of the Delaware River's tributaries. This prevents the ability to discern the cause and source of water quality issues along the mainstem river. Increased tributary monitoring at special locations linked to long term mainstem monitoring locations can enhance understanding of current and future water quality issues.

1.5 Inventory of Potential Point Sources of Contamination

Key Points

- **Potential point and non-point sources of contamination throughout the watershed were compiled from a variety of databases.**

Based on PADEP guidelines for the statewide Source Water Assessment Program (SWAP), a contaminant inventory of point and non-point sources was developed. The inventory is an essential part of assessing the source water for a drinking water supply intake, because it compiles potential contaminant sources within the 5-hour, 25-hour, and beyond 25-hour time of travel delineation zones. A study area inventory was developed because the zones for the eight water intakes encompass a large portion of the Delaware River Watershed. The study area inventory provides insight into the clustering of sources by major subwatersheds within the Delaware River Watershed.

The focus of this discussion is the study area point source contaminant inventory. Non-point sources are discussed in the land use (section 1.2.5) section of this document and within intake-specific section 2.2.3.

Point source data was compiled from various federal and state databases available on the Internet, as well as from self-assessment data provided by water suppliers. Sources were checked by stakeholders, and verified for correct active status and location. An ACCESS® database was developed to efficiently store and manage information describing the point sources:

The following federal databases were reviewed to identify point sources in the Schuylkill River Watershed:

- Permit Compliance System (PCS)
- Resource Conservation and Recovery Act Information System (RCRIS)
- Comprehensive Environmental Response, Compensation, and Liability Act Information System (CERCLIS)
- Toxic Release Inventory (TRI)

Regulated aboveground storage tanks (ASTs) were also compiled from the PADEP Storage Tank Program. Combined with the information provided by the aforementioned federal databases, the database compilation was complete

The databases were queried for facility, process, and violation information. Facility information included name, facility identification numbers, owner, and location (street address and/or latitude, longitude). Process information included data quantifying on-site contaminants and quantities and/or loading rates. Violation information was related to type (administrative, operation or effluent violation) and frequency.

1.5.1 Point Source Contaminant Inventory

Key Points

- **Over 5,000 potential point sources were identified within the 8,000 square-mile Delaware River Study Area.**

Once the database compilation and population were completed, a study area inventory of potential contaminants was developed for the Delaware River SWAP Study Area. The land area covered by the inventory extends over 8,000 square miles, 500 subwatersheds, and 5,000 point sources. The inventory is sorted by major sub-watershed and will be posted on the Delaware Source Water Assessment project website www.phillywater.org/delaware. The full inventory or an inventory for a subwatershed of particular interest will be available for download from the website or by contacting PADEP.

An example of the inventory for the study area of the Delaware River Watershed is provided in Figure 1.5.1-1. The example shows some of the pertinent attributes associated with the various source types. If a field is blank, then the information was not available. The number of blank fields gives an idea of the incompleteness of much of the downloaded data, especially for SIC codes, contaminants, and quantities.

For PCS facilities, the name, address, NPDES ID, SIC code description, minor/major designation, flow rate, contaminant groups, and violation remark are indicated. A major facility has a flow rate of 1 MGD or greater.

Attributes shown for RCRA facilities are generally the same as for PCS. Instead of minor/major designation, RCRA facilities are differentiated on size as large quantity generators (LQG) or small quantity generators (SMG). A LQG generates more than 2,200 pounds of hazardous waste per calendar month. Flow rates do not apply to most RCRA sites, which are mostly industrial facilities with aboveground or underground storage tanks. An AST download from PADEP is used to supplement the scarce quantity information for RCRA sites. AST data attributes include fairly complete capacity and contaminant information for each site.

TRI attributes include similar fields as the PCS and RCRA facilities. Quantity information is available as ranges, such as 1,000 to 9,999 kg per year. The quantity shown is an average over all available years. If the facility had a release, then the maximum range value is used in the average, otherwise the minimum is used. TRI quantity refers to the amount used or generated on-site. Releases in TRI may be to air, water or land.

Attributes for CERCLA facilities include basic information such as name and EPA ID. In addition, a flag is shown to indicate whether the facility is on the National Priority List (NPL) or not. Quantity and capacity data for CERCLA facilities is limited to two facilities watershed wide. The number of enforced violations is also provided.

Figure 1.5.1-1 Example of Point Source Contaminant Inventory for the Delaware River SWAP Study Area

AST Summary

Name	Address	City	ZIP	Facility ID	Total Tankage (gal)	Releases	Contaminants
1 SVC CTR	1637 W TILGHMAN ST	ALLENTOWN	18102	39-06273	19,000	No	VOC,PH
181 WHEELER COURT	181 WHEELER CT	LANGHORNE	19047	09-44904	7,000	No	PH
24 HOUR STORE	10 STELLA ST	MATAMORAS	18336	52-00672	30,000	No	VOC

CERCLA Summary

Name	Address	City	ZIP	Facility ID	NPL Status	# of Units	# of Enforcements
200 WOLVERTON STREET	200 WOLVERTON STREET	TRENTON	8625	NJD986648129	NOT ON NPL	1	0
2314 N. AMERICAN STREET	2314 N. AMERICAN STREET	PHILADELPHIA	19123	PAD048613368	Not on the NPL		
2514 ORTHODOX STREET SITE	2514 ORTHODOX STREET	PHILADELPHIA	19124	PAN000305658	Not on the NPL		
3200 N. 22ND STREET	3200 N. 22ND STREET	PHILADELPHIA	19145	PA0000569202	Not on the NPL		
3M CO-TAPE DIV	GREEN LN	BRISTOL	19007	PAD981034002	NOT ON NPL	1	0
A & E MFG CO INC	2110 HARTEL ST	LEVITTOWN	19057	PAD042266171	NOT ON NPL	1	0

1.5.2 Inventory Characterization

Key Points

- **Over 5,000 potential point sources were identified within the watershed.**
  - **The highest concentrations of potential point sources were located in the most highly developed subwatersheds such as the Neshaminy Subwatershed.**
- **Sewer systems, dry cleaners, and chemical manufacturers were among the most frequently identified potential point sources.**
  - **The Tidal PA Philadelphia, NJ Tidal Lower and Tidal PA Bucks had the greatest number of dischargers per acre of drainage area.**

1.5.2.1 Entire Watershed Inventory Summary

The inventory has been compiled for the entire Delaware Watershed SWAP study area and its major subwatersheds. With 5000 point sources throughout the area, this characterization highlights the types of sources (PCS, RCRA, etc.) that exist and where those sources are concentrated. Table 1.5.2-1 presents the number of facilities for a particular source type for each major subwatershed.

Table 1.5.2-1 Summary of Point Source Types by Major Watershed

Major Watershed	# of PCS Facilities	# of RCRA Facilities	# of ASTs	# of TRI Facilities	# of CERCLA Facilities
Outside Study Area	58	236	0	7	0
Crosswicks	27	1	2	2	8
Lackawaxen	13	26	59	1	1
Lehigh	81	400	610	91	58
Middle Delaware	134	160	134	56	45
Mongaup	38	78	120	16	22
Neshaminy	43	300	218	42	70
NJ Mercer Direct	54	27	22	40	28
PA Bucks Direct	11	6	18	0	5
Rancocas	47	8	5	17	40
Tidal NJ Lower	113	108	11	51	58
Tidal NJ Upper	32	31	25	8	40
Tidal PA Bucks	32	160	150	39	58
Tidal PA Philadelphia	56	135	111	131	201
Tohickon	24	41	39	5	21
Upper Delaware	11	3	2	1	0
Totals	**774**	**1720**	**1526**	**507**	**655**

Table 1.5.2-1 indicates that for two of the six potential source types – RCRA and ASTs, the Lehigh Subwatershed has the greatest number of sites. This is consistent with the fact that the Lehigh River Watershed encompasses a greater land area than any of the other subwatersheds. The PCS data indicates that the Middle Delaware has the largest amount of facilities while the Tidal PA Philadelphia has the largest number of TRI and CERCLA facilities. These tallies do not necessarily mean that the sources are significant with respect to contamination of the drinking water supplies. The ranking analysis for

each intake determines significance by accounting for other source characteristics, such as time of travel to the intake, water quality impact, or number of violations.

The data from Table 1.5.2-1 is further analyzed based on watersheds with the three highest occurrences of each source type. This compilation is summarized in Table 1.5.2-2. This table clearly shows that the Lehigh, the Tidal PA Philadelphia, and the Neshaminy have high concentrations of sources. Across all source types, with the exception of PCS, the Neshaminy has one of the three highest clusters. This is consistent with the significant industrial land use within the area in which it lies. Both the Neshaminy and the Lehigh have seen a large increase in development during the past decade. Therefore, they also have a significantly large number of facilities.

Table 1.5.2-2 Major Subwatershed Source Type Occurrence

Source Type		Major Watershed	Number of Facilities	Source Type		Major Watershed	Number of Facilities
PCS	1st	Middle Delaware	134	TRI	1st	Tidal PA Philadelphia	131
	2nd	NJ Tidal Lower	113		2nd	Lehigh	91
	3rd	Lehigh	81		3rd	Middle Delaware	56
RCRA	1st	Lehigh	400	CERCLA	1st	Tidal PA Philadelphia	201
	2nd	Neshaminy	300		2nd	Neshaminy	70
	3rd	Outside Study Area	236		3rd	Lehigh/Tidal PA Bucks	58
ASTs	1st	Lehigh	610				
	2nd	Neshaminy	218				
	3rd	Tidal PA Bucks	150				

Table 1.5.2-3 summarizes the most frequently reported types of industrial facilities, based upon SIC codes. The most frequently occurring potential point sources are sewerage systems and gasoline service stations. Using the PADEP land use-based activities defined in the SWAP document, drycleaning plants, water suppliers and industrial inorganic chemicals that are not elsewhere classified are most prevalent in the watershed.

Table 1.5.2-3 Schuylkill Watershed Top Point Sources by Industrial Classification

SIC Code/Description	Number	PADEP Land Use/Activity	Number
4952 - Sewerage Systems	237	Misc. - NPDES Locations	240
5541 - Gasoline Service Stations	53	Industrial - Chemical Manufacturer	227
7216 - Drycleaning Plants, Except Rug Cleaning	37	Industrial – Machine/Metalworking Shops	164
4941 – Water Supply	29	Plastics Manufacturing	110
2819 - Industrial Inorganic Chemicals, Not Elsewhere Classified	27	Electronics Manufacture	99

Although Tables 1.5.2-1 through 1.5.2-3 identify the watersheds in which the groups of source types are located, as well as the most common industries, the drainage areas of the subwatersheds were not considered. By normalizing the number of potential sources in a subwatershed by drainage area, a better representation of clustering and cumulative impacts may be ascertained. Because existing dischargers are more of a concern for cumulative impacts than other potential sources (such as ASTs, RCRA sites or TRI facilities), the data for PCS dischargers was normalized, as described below.

1.5.2.2 PCS Dischargers

Table 1.5.2-4 lists the number of PCS dischargers within each major subwatershed, normalized by drainage area. Although the greatest number of dischargers was located within the Middle Delaware and the NJ Tidal Lower, the normalized data identifies other subwatersheds of concern. A large density of PCS facilities is found within the NJ Tidal Lower, Tidal PA Bucks, and Tidal PA Philadelphia Subwatersheds.

Table 1.5.2-4 Watershed Clustering of Dischargers on a Drainage Area Basis

Major Subwatershed	# of PCS Facilities	Drainage Area (acres)	#/DA (#/acre)
Outside Study Area	58	N/A	
Crosswicks	27	94,455.31	2860E-07
Lackawaxen	13	381,418.14	341E-07
Lehigh	81	871,465.37	929E-07
Middle Delaware	134	633,512.17	2120E-07
Mongaup	38	980,340.74	388E-07
Neshaminy	43	149,395.58	2880E-07
NJ Mercer Direct	54	99,111.98	5450E-07
PA Bucks Direct	11	52,830.14	2080E-07
Rancocas	47	222,547.22	2110E-07
Tidal NJ Lower	113	118,237.15	9560E-07
Tidal NJ Upper	32	69,511.52	4600E-07
Tidal PA Bucks	32	36,160.97	8850E-07
Tidal PA Philadelphia	56	97,317.99	5750E-07
Tohickon	24	83,899.16	2860E-07
Upper Delaware	11	761,835.50	144E-07
Totals	774		

Discharger data is further normalized by median flow in Table 1.5.2-5. Median flow from the period of record at USGS at the nearest gauge to the major subwatershed was used. If more than one gauge was associated with the subwatershed, then a drainage area weighted average value was used. When normalized by flow, as well as by drainage area, clusters of PCS sites are found in the Middle Delaware and NJ Tidal Lower.

Table 1.5.2-5 Watershed Clustering of Dischargers on a DA/Flow Basis

Major Subwatershed	# of PCS Facilities	#/DA (#/acre)	Median Flow (cfs)	#/DA/Flow (#/acre/cfs)
Crosswicks	27	3.E-04	N/A	
Lackawaxen	13	3.E-05	250	1.E-07
Lehigh	81	9.E-05	2090	4.E-08
Middle Delaware	134	2.E-04	N/A	
Mongaup	38	4.E-05	120	3.E-07
Neshaminy	43	3.E-04	140	2.E-06
NJ Mercer direct	54	5.E-04	N/A	
Rancocas	47	2.E-04	N/A	
Tidal NJ lower	113	1.E-03	N/A	
Tidal PA Philadelphia	56	6.E-04	49	1.E-05
Tohickon	24	3.E-04	47	6.E-06
Totals	630			

The inventory of dischargers or PCS facilities throughout the Delaware River SWAP study area is summarized in Table 1.5.2-6. In all, 774 dischargers are found throughout the study area, although only 124 are major dischargers (<1 MGD). Almost of all these are sewerage systems. In fact, sewerage systems comprise the largest component, 326 of 774, for both major and minor dischargers. After sewerage systems, gasoline service stations, water suppliers, elementary and secondary schools, and petroleum bulk stations comprise 122 of the remaining 448 dischargers.

Table 1.5.2-6 PCS Discharger Summary

Total Dischargers	774
Major Dischargers	124
Major Sewerage Systems	81
Top 5 Discharge Types by SIC Code 4952 – Sewerage Systems 5541 – Gasoline Service Stations 4941 – Water Supplier 8211 – Elementary And Secondary Schools 5171 – Petroleum Bulk Stations	 326 53 29 22 18
Dischargers with Available DMR Data	147
Most Common Parameters with DMR Data	Total Suspended Solids pH BOD5 Fecal Coliform Ammonia Nitrogen
Most Common Parameters for Effluent Limits	Total Suspended Solids pH Fecal Coliform Oil and Grease BOD
Discharge Flow Rate Range	0.0 – 40 MGD

Because so many of the dischargers are minor, Discharge Monitoring Report (DMR) data was only available for 147 sites. The most common parameters found in the DMRs and effluent limits are indicated in Table 1.5.2-6. The common DMR parameters – TSS and BOD5 - correlate with turbidity and TOC (DBP precursor), which are of concern from a source water perspective. Metals such as copper, as well as oil and grease, also pose a concern for drinking water supplies.

Discharge Monitoring Report (DMR) data is further summarized in Table 1.5.2-7 based on maximum reported quantities and parameter groups. The parameter groups generally follow those identified in the PADEP SWAP guidance document. These groupings are used to rank potential contaminant sources in the intake-specific report sections. Since the ranking analysis was based on DMR maximum quantity data, the data was compiled in Table 1.5.2-7 to provide a frame of reference. The data also gives an idea, on a pounds-per-day basis, as to the “worst case” order of magnitude of a discharge. This data was available for only 147 of the 774 dischargers in the Delaware River study area and is generally linked to major dischargers. With that in mind, the data truly represents a worst-case estimate of individual loads being discharged into the Delaware River.

Table 1.5.2-7 Summary of Available DMR Data

Parameter Name	Range of Max Quantity Reported			Mean Max Quantity	Count Of Max Quantities
CARBONACEOUS BOD5	0.001	-	11759	383.7751041	1450
CHEMICAL OXYGEN DEMAND, COD	0.090000004	-	1547.102051	189.4572866	136
CHLORINE, TOTAL RESIDUAL	0	-	3191.800049	94.76029557	34
CYANIDE, TOTAL	0	-	795.7670288	157.3065284	25
pH	0.029999999	-	0.029999999	0.029999999	1
SOLIDS, DISSOLVED TOTAL, TDS	85	-	57304	17873.77984	124
SULFATE as SO4	10499	-	30113	14105.88	50
SULFIDE as S	-0.331999987	-	0.583000004	0.014263291	79
TKN (TOT. KIELDAHL NITROGEN)	0.07	-	131	24.03246572	73
BOD, CARBONACEOUS 5 DAY,5 C	28	-	51	39.6	5
BOD5, BIOLOGICAL OXYGEN DEMAND	-4.881000042	-	185656	1509.49896	3275
OXYGEN DEMAND, ULTIMATE	0.800000012	-	486	87.88842852	70
FLOW RATE	7E-05	-	27984	70.44311617	2856
TEMPERATURE	0	-	0	0	1
ALUMINUM, TOTAL	0.289999992	-	66	5.692051282	39
ALUMINUM, TOTAL RECOVERABLE	0.266460001	-	988	104.0015283	13
ANTIMONY TOTAL RECOVERABLE	0.002	-	0.233999997	0.093906976	43
ANTIMONY, TOTAL	0.0038	-	139.1999969	17.51409974	31
ARSENIC, TOTAL	0.002	-	58	11.15967137	7
ARSENIC, TOTAL RECOVERABLE	0	-	58.59999847	9.14406254	32
BARIUM, TOTAL	0.00162	-	151.3000031	17.11456004	27
BERYLLIUM, TOTAL	0.00333	-	11.69999981	3.808360883	12
CADMIUM TOTAL RECOVERABLE	0	-	47.29999924	6.51294108	34
CADMIUM, TOTAL	0.0019	-	5.699999809	0.48664193	31
CHROMIUM TOTAL RECOVERABLE	0.090839997	-	69.59999847	26.22453079	19
CHROMIUM, TOTAL	-0.123000003	-	68.09999847	1.09930143	138
CHROMIUM; HEXAVALENT	0.100000001	-	0.188999996	0.131333331	3
COPPER TOTAL RECOVERABLE	0.0004	-	2387	81.53983143	200
COPPER, TOTAL	-0.363000005	-	340	4.323660717	251
IRON TOTAL RECOVERABLE	9.600000381	-	2999	923.1400002	5
IRON, TOTAL	0.090000004	-	0.326000005	0.143	30

Parameter Name	Range of Max Quantity Reported			Mean Max Quantity	Count Of Max Quantities
LEAD TOTAL RECOVERABLE	0	-	141.8999939	6.986599123	55
LEAD, TOTAL	0.02	-	22.70000076	1.926857597	33
MANGANESE, TOTAL	0.207000002	-	2396.971924	1300.752856	13
MERCURY TOTAL RECOVERABLE	0.002	-	208	21.813348	10
MERCURY, TOTAL	0.0004	-	1.799999952	0.550325001	8
NICKEL TOTAL RECOVERABLE	0	-	561	56.73148915	23
NICKEL, TOTAL	0.001	-	1248	19.20851764	79
SELENIUM, TOTAL	0.002	-	3.599999905	1.626	4
SELENIUM, TOTAL RECOVERABLE	0.025	-	34.79999924	18.4964282	7
SILVER TOTAL RECOVERABLE	0	-	58.59999847	9.936652097	23
SILVER, TOTAL	0	-	69	3.063370561	34
THALLIUM, TOTAL	0.002	-	58.59999847	19.3259994	9
ZINC TOTAL RECOVERABLE	-0.080300003	-	991	59.14021157	256
ZINC, TOTAL	-0.023	-	681	16.76426172	185
AMMONIA (AS N) + UNIONIZED AMMONIA	0.002	-	60	16.42626311	38
AMMONIA-NITROGEN	0	-	1599	53.89651911	1362
NITRATE NITROGEN, TOTAL AS NO3	3.700000048	-	37.40000153	14.36707324	82
NITRATE-NITRITE, NITROGEN	15	-	505	210.25	20
NITRATE-NITROGEN as N	0.159999996	-	0.360000014	0.258888892	9
PHOSPHORUS, TOTAL as P	-2.835999966	-	217	7.037953976	639
DISSOLVED OXYGEN	0.017000001	-	0.017000001	0.017000001	2
HYDROCARBONS,IN H2O,IR,CC14 EXT. CHROMAT	0	-	42.5	4.091238115	21
OIL AND GREASE	0	-	3549	174.3518653	118
PETROL HYDROCARBONS TOTAL RECOVERABLE	0	-	6.730000019	0.541140841	71
PETROLEUM HYDROCARBONS, TOTAL	0	-	42.5	4.091238115	21
(DIOXIN) 2,3,7,8-TCDD	0	-	0.034600001	0.01154	3
1,2,4-TRICHLOROBENZENE	0	-	37.79999924	7.006199885	13
1,2-DICHLOROBENZENE	0	-	37.79999924	7.432576805	13
1,2-DIPHENYLHYDRAZINE	0.0007	-	37.79999924	10.45344429	9
1,3-DICHLOROBENZENE	0	-	29.29999924	5.997884545	13
1,4-DICHLOROBENZENE	0	-	29.29999924	5.658178497	14
2,4,6-TRICHLORO- PHENOL	0.001	-	75.69999695	34.43043878	5
2,4-DICHLOROPHENOL	0	-	37.79999924	9.558022061	9

Parameter Name	Range of Max Quantity Reported			Mean Max Quantity	Count Of Max Quantities
2,4-DIMETHYLPHENOL	0	-	75.69999695	19.12802154	9
2,4-DINITROPHENOL	0	-	37.79999924	9.558422061	9
2,4-DINITROTOLUENE	0	-	37.79999924	7.063964153	14
2,6-DINITROTOLUENE	0	-	37.79999924	9.558022061	9
2-CHLORONAPHTHALENE	0.001	-	37.79999924	17.20443971	5
2-CHLOROPHENOL	0	-	75.69999695	19.12822154	9
2-NITROPHENOL	0	-	37.79999924	9.558066506	9
3,3'-DICHLORO- BENZIDINE	0.001	-	37.79999924	10.83372207	9
4,4'-DDD	5E-05	-	1.169999957	0.287934994	6
4,4'-DDE (P,P'-DDE)	1E-05	-	1.169999957	0.286254994	6
4,4'-DDT (P,P'-DDT)	2E-05	-	1.169999957	0.300594995	6
4,6-DINITRO-o-CRESOL	0	-	37.79999924	9.558066506	9
4-CHLORO-3-METHYL PHENOL	0.001	--	75.69999695	34.43043878	5
4-NITROPHENOL	0	-	37.79999924	9.558066506	9
A-BHC-ALPHA	0	-	0.579999983	0.170639997	5
A-ENDOSULFAN-ALPHA	3E-05	-	0.579999983	0.172376664	6
ACENAPHTHENE	0	-	15.10000038	4.296500045	8
ACENAPHTHYLENE	0	-	15.10000038	3.101530802	13
ALDRIN	0	-	0.579999983	0.18188571	7
ANTHRACENE	0	-	15.10000038	3.118069257	13
B-BHC-BETA	0.017999999	-	0.579999983	0.234549994	4
B-ENDOSULFAN-BETA	3E-05	-	1.169999957	0.31492666	6
BENZIDINE	0.002	-	151	41.29227769	9
BENZO (A) ANTHRACENE	0	-	15.10000038	3.169107725	13
BENZO (A) PYRENE	0	-	15.10000038	3.126614285	14
BENZO(B)FLUORANTHENE	0	-	15.10000038	3.761538488	13
BENZO(GHI)PERYLENE	0.0007	-	15.10000038	4.643190055	10
BENZO(K) FLUORANTHENE	0	-	15.10000038	3.58004617	13
BHC-DELTA	0.009	-	0.579999983	0.213299996	4
BIS (2-CHLOROETHOXY) METHANE	0.001	-	75.69999695	34.43043878	5
BIS (2-ETHYLHEXYL) PHTHALATE	0	-	257.2999878	31.42625706	19
BIS(2-CHLOROISOPROPYL)ETHER	0.001	-	37.79999924	9.843860831	10
BUTYLBENZYL PHTHALATE	0.0007	-	37.79999924	10.30688871	9

Parameter Name	Range of Max Quantity Reported			Mean Max Quantity	Count Of Max Quantities
CHLORDANE (TECH MIX. AND METABOLITES)	7E-05	-	5.800000191	1.41120503	6
CHRYSENE	0	-	276	22.40442145	14
DI-N-BUTYLPHTHALATE	0	-	37.79999924	8.572238284	13
DI-N-OCTYL PHTHALATE	0.001	-	75.69999695	34.43043878	5
DIBENZO (A,H) ANTHRACENE	0.001	-	15.10000038	5.184344509	9
DIELDRIN	1E-05	-	1.169999957	0.279921661	6
DIETHYL PHTHALATE	0	-	75.69999695	13.89251491	13
DIMETHYLPHTHALATE	0	-	75.69999695	12.36159293	15
ENDOSULFAN SULFATE	3E-05	-	1.169999957	0.31309666	6
ENDOSULFAN, TOTAL	3E-05	-	1.169999957	0.270546659	6
ENDRIN	2E-05	-	0.579999983	0.156373329	6
ENDRIN ALDEHYDE	2E-05	-	1.169999957	0.35276166	6
FLUORANTHENE	0	-	37.79999924	6.935242732	14
FLUORENE	0	-	15.10000038	3.21043079	13
GAMMA-BHC	0.001	-	1.090000033	0.296025003	8
HEPTACHLOR	0	-	0.579999983	0.170639997	5
HEPTACHLOR EPOXIDE	0	-	1.50999999	0.457639994	5
HEXACHLOROBENZENE	0	-	37.79999924	7.126199903	13
HEXACHLOROBUTADIENE	0	-	37.79999924	7.130899894	13
HEXACHLOROCYCLO-PENTADIENE	0.002	-	37.79999924	10.49747762	9
HEXACHLOROETHANE	0	-	37.79999924	7.220107575	13
ISOPHORONE	0.001	-	37.79999924	10.32773318	9
N-NITROSODI-N-PROPYLAMINE	0.001	-	75.69999695	34.43043878	5
N-NITROSODIMETHYL-AMINE	0.001	-	75.69999695	20.40585485	9
N-NITROSODIPHENYL-AMINE	0.0004	-	75.69999695	18.0851194	10
NAPHTHALENE	0	-	15.10000038	2.67493849	13
NITROBENZENE	0	-	37.79999924	7.646807608	13
PCB-1016 (AROCHLOR 1016)	8E-05	-	5.800000191	1.628546689	6
PCB-1221 (AROCHLOR 1221)	0	-	5.800000191	1.627033357	6
PCB-1232 (AROCHLOR 1232)	0	-	5.800000191	1.627033357	6
PCB-1242 (AROCHLOR 1242)	0	-	5.800000191	1.627033357	6

Parameter Name	Range of Max Quantity Reported			Mean Max Quantity	Count Of Max Quantities
PCB-1248 (AROCHLOR 1248)	0	-	5.800000191	1.627033357	6
PCB-1254 (AROCHLOR 1254)	0	-	5.800000191	1.627033357	6
PCB-1260 (AROCHLOR 1260)	0	-	5.800000191	1.627033357	6
PENTACHLOROPHENOL	0.001	-	37.79999924	17.20443971	5
PHENANTHRENE	0	-	15.10000038	2.578653355	15
PHENOL	0	-	58.59999847	14.42462457	8
PHENOLS	-0.069200002	-	0.875500023	0.088076296	54
PHENOLS, TOTAL	0.07	-	25.94199944	1.449191165	68
PYRENE	0	-	37.79999924	7.361453722	13
TOTAL BASE/NEUTRAL PRIORITY POLLUTANTS	0.013	-	2.400000095	0.620500023	4
TOTAL PCBs	7E-05	-	5.800000191	1.916454027	5
TOTAL TOXIC ORGANICS (TTO) (40CFR433)	0	-	0.354999989	0.11833333	3
TOXAPHENE	0.0002	-	5.800000191	1.91510002	6
SOLIDS,SUSPENDED TOTAL TSS	-40.04000092	-	22666	374.4907629	4817
FECAL COLIFORM	0.090999998	-	0.090999998	0.090999998	1
1,1,1-TRICHLOROETHANE	0	-	5.800000191	1.890657137	14
1,1,2,2-TETRACHLORO-ETHANE	0.001	-	6.639999866	3.29049001	10
1,1,2-TRICHLOROETHANE	0	-	11.69999981	2.864221439	14
1,1-DICHLOROETHANE	0.0004	-	29.29999924	8.295466545	9
1,1-DICHLOROETHYLENE	0	-	11.69999981	2.713942884	14
1,2-DICHLOROETHANE	0	-	253	26.06299998	10
1,2-DICHLOROETHANE, TOTAL WEIGHT	0	-	11.69999981	2.960972743	11
1,2-DICHLOROPROPANE	0	-	5.800000191	1.294185725	14
1,2-TRANS-DICHLOROETHYLENE	0	-	11.69999981	2.794182157	14
1,3-DICHLOROPROPYLENE	0	-	0	0	4

Parameter Name	Range of Max Quantity Reported			Mean Max Quantity	Count Of Max Quantities
2-CHLOROETHYLVINYL ETHER	0.001	-	58.59999847	26.30869943	6
4-BROMOPHENYL PHENYL ETHER	0.002	-	37.79999924	17.20487971	5
4-CHLOROPHENYL PHENYL ETHER	0.002	-	37.79999924	17.20487971	5
ACROLEIN	0.01	-	189.1999969	59.7657264	11
ACRYLONITRILE	0	-	94.62000275	25.42139995	15
BENZENE	0	-	5.800000191	1.607014308	14
BIS (2-CHLOROETHYL) ETHER	0.001	-	45	14.02624983	10
BROMOFORM	0.0003	-	5.800000191	2.860430015	10
BROMOMETHANE	0.0116	-	58.59999847	24.31015973	10
CARBON TETRACHLORIDE	0	-	11.69999981	3.070138479	13
CHLOROBENZENE	0	-	11.69999981	2.549857155	14
CHLOROETHANE, TOTAL WEIGHT	0	-	58.59999847	14.37121962	10
CHLOROFORM	0	-	21.44000053	7.350373399	15
CHLOROFORM, DISSOLVED	0.236000001	-	34.97999954	8.112599951	10
CHLOROMETHANE	0.0137	-	58.59999847	23.20036974	10
CIS-1,3-DICHLORO PROPENE	0.0074	-	29.29999924	7.652539905	10
DIBROMOCHLOROMETHANE	0.0002	-	5.800000191	2.374741667	12
DICHLOROBROMOMETHANE	0.001	-	67.69719696	2.348946114	65
ETHYL BENZENE	0	-	0	0	4
ETHYLBENZENE	0.0003	-	29.29999924	7.90842988	10
METHYL BROMIDE (BROMOMTHANE)	0.0007	-	0.0008	0.00075	2
METHYL CHLORIDE (CHLOROMETHANE)	0	-	0.0023	0.000542857	7
METHYLENE CHLORIDE	0	-	11.69999981	2.444811122	18
TETRACHLOROETHENE	0	-	5.800000191	1.548650014	20
TOLUENE	0	-	18.20000076	3.544285808	7
TOLUENE, DISSOLVED	0.0003	-	29.29999924	9.312724898	8
TOTAL VOLATILE POLLUTANTS	0.003	-	0.034000002	0.012000001	4
TRANS-1,3-DICHLORO PROPENE	0.0003	-	29.29999924	7.8560199	10
TRICHLOROETHENE	0	-	2.900000095	0.657082122	19

Parameter Name	Range of Max Quantity Reported			Mean Max Quantity	Count Of Max Quantities
TRICHLOROETHYLENE, DISSOLVED	0.0003	-	5.800000191	2.262425019	8
VINYL CHLORIDE	0	-	29.29999924	6.676493253	15
VOLATILE COMPOUNDS, (GC/MS)	19	-	77.19999695	45.37499952	4

Table 1.5.2-7 shows that total suspended solids (TSS) loads are the highest of any parameter and have the greatest number of reported quantities. Total suspended solids are related to the turbidity parameter group. Turbidity is another indicator of particulates in the water supply, but it is a more meaningful measure of performance in drinking water treatment. Maximum and average ammonia loads are greater than phosphorus loads. The table also indicates the various volatile organic compounds (VOCs) and synthetic organic compounds (SOCs) discharged into the Delaware River. Vinyl chloride has the single greatest VOC discharge of 6.7 pounds per day (lbs./day). Relative to the other VOC discharges, acrylonitrile and acrolein are also large average quantities. Total phenols are the largest discharged quantity for the SOCs. Otherwise, quantities of SOC discharges are similar. Of the metals, iron is clearly the largest discharged quantity. High maximum quantities are also reported for aluminum, total chromium, total copper, total lead, total nickel, and total zinc. Chromium and lead pose the greatest risk in drinking water.

1.5.2.3 RCRA/AST Facilities

As summarized in Table 1.5.2-8, RCRA facilities comprise many of the point sources in the Delaware River study area. However, only 387 of the 1,685 RCRA facilities are designated as large quantity generators (LQGs). Data describing the industry type or capacity of the facilities is limited. Taking into account the limited number of SIC codes, most RCRA facilities are dry cleaning plants, followed by chemicals and chemical preparations not elsewhere classified, and automotive transmission repair shops, electroplating, plating, polishing, etc., and top, body, and upholstery repair shops and paint shops. Relatively few RCRA sites were cited for violations. Capacity information for use in ranking sites is available for merely 58 sites, and contaminant information was not available. Reported capacities ranged from 2 to 25,000,000 gallons for the RCRA sites with available data.

Table 1.5.2-8 RCRA Facility Summary

Total RCRA Facilities	1685
Large Quantity Generators	387
Facilities with SIC Codes	265
Top 5 RCRA Industry Types by SIC Code 7216 – Dry Cleaning Plants 2899– Chemicals And Chemical Preparations, Not Elsewhere Classified 7537 – Automotive Transmission Repair Shops 3471 – Electroplating, Plating, Polishing, etc. 7532 – Top, Body, And Upholstery Repair Shops And Paint Shops	 37 10 8 7 7
RCRA Facilities with Violations	282
RCRA Facilities with Capacity/Volume Data	58
Range of Capacity	2 – 25,000,000 gallons 1 – 3,456,000 gal/day
Most Common Parameters/Contaminants	Not Applicable – no contaminants linked to RCRA downloads

As mentioned previously, RCRA data was supplemented with AST information from PADEP. PADEP AST data included useful and detailed information relating to tank age, contaminants, and volumes. AST data is summarized in Table 1.5.2-9.

Table 1.5.2-9 AST Facility Summary

Total AST Facilities	1526
AST Facility Overlap with RCRA Facilities	73
Total Number of Tanks	4674 Total/1904 ASTs
Tank Capacity Range	200 gal – 8 MG
Tank Age Range (years)	1 – 75
Number of Different Parameters/Contaminants	138
Most Common Parameters and Quantities by Number of Tanks Misc. Hazardous Substance Diesel Fuel Gasoline	 609 tanks/5.1 MG 235 tanks/6.7 MG 192 tanks/18.1 MG
Most Common Parameters/Contaminants and Quantities by Total Volume Heating Oil Gasoline Diesel	 78 MG 18 MG 7 MG

Table 1.5.2-9 shows that 1,526 facilities throughout the Delaware River SWAP study area have aboveground storage tanks on-site. Of those facilities, only 73 overlap with the RCRA facilities. This may be due to RCRA sites also having underground storage tanks on-site. The AST data is useful for characterizing potential contaminant sources in the watershed. Tanks range in capacity from 200 gallons to 8 million gallons and range in age from 1 to 75 years old. Older tanks may pose a greater risk for spills and leaks. The tanks contain 138 different substances. The most common of these by volume is an unidentified hazardous substance, followed by diesel fuel, and gasoline. The significance of these tanks as contamination sources depends on factors such as the total volume of substance at any one site, tank age, and the time of travel to the drinking water intake. These factors are considered in the intake-specific susceptibility ranking.

1.5.2.4 TRI Facilities

A summary of TRI sources is presented in Table 1.5.2-10. A facility is listed in the TRI if a chemical from the inventory is used or manufactured on site. These sites do not necessarily discharge the listed chemical(s). Data describing on-site chemicals, quantities of chemicals used or manufactured in a given year, and releases to air, water or the ground is available for the TRI sources.

Table 1.5.2-10 indicates that 507 TRI facilities are found in the Delaware River SWAP study area. A SIC code is identified for 504 of these industries. SIC codes are linked to activities that PADEP identified in the state SWAP document. Based on activity, most

TRI facilities are chemical manufacturers, machine/metalworking shops, or plastics manufacturers.

Chemical and quantity data is very complete for the TRI facilities, however quantities are presented as ranges. Ammonia, copper, toluene, phosphoric acid and nitric acid are the most common chemicals listed by the various TRI sites. Release information was available for 312 of the TRI facilities. A company by the name of Horsehead Development Co. Inc. has the greatest number of reported releases. The Zinc Corp. of America and Ashland Chemical Inc. have the next highest numbers of reported releases.

Table 1.5.2–10 TRI Facility Summary

Total TRI Facilities	507
Facilities with SIC Codes	504
Top 3 Industry Types by Activity Chemical Manufacturing Machine/Metalworking Shops Plastics Manufacturing	 115 83 63
Top 3 TRI Industries by SIC Code 2819 2899 2851	 15 15 15
Facilities with Quantity Data	12
Most Common Parameters for Facilities with Quantity Data Ammonia Copper Toluene Phosphoric Acid Nitric Acid	 37 20 17 16 14
Facilities with Release Data	312
Facilities with Greatest Number of Releases Horsehead Development Co. Inc. Zinc Corp. of America Ashland Chemical Inc.	 168 releases to water 168 releases to water 105 releases to water

1.5.2.5 CERCLA Facilities

Although data characterizing CERCLA facilities in the SWAP study area is limited, Table 1.5.2-11 summarizes the available information. While 655 CERCLA facilities are located within the study area, only 34 are on the final National Priority List (NPL). Information for 35 of the CERCLA facilities is available through the RCRA and TRI databases, where those facilities are also listed. Only 63 sites are found in the floodplain. Since information on the Superfund sites is so limited, these sites are screened or ranked subjectively for the intakes. The low number of NPL sites and sites in the floodplain is considered in the subjective screening.

Table 1.5.2–11 CERCLA Facility Summary

Total Number of CERCLA Facilities	655
Number on the NPL List	34
Number also listed as RCRA	29
Number also listed as TRI	6
Number in Flood Plain	63

1.6 Identification of Restoration Efforts

Key Points
- **Federal, State and private grants have provided almost $20 million for environmental projects within the Delaware River SWAP study area over the past several years.**
- **Grants were awarded to 54 recipients, with county and municipal groups receiving the majority of funds.**
- **Almost 60% of the grants awarded were used for protection projects.**

In order to gain an understanding of the current levels of environmental stewardship and awareness within watersheds, a compilation of grants and restoration projects was completed. State, Federal and private grant sources identified the levels of funding that they provided through various programs to respective watersheds within the Delaware River SWAP study area from 1995 to 2001.

These programs include the Pennsylvania Department of Environmental Protection's (PA-DEP) 319 Nonpoint Source Program, the Growing Greener Program, the Pennsylvania Department of Conservation and Natural Resource's (PA-DCNR) Rivers Conservation Plan Program, and Pennsylvania's Coastal Zone Management Program. Also included were Pennsylvania's Natural Resources Conservation Service's (NRCS) Conservation Reserve Program (CRP), Wetlands Reserve Program (WRP), Watershed Protection and Flood Prevention Act (PL-566) Program, and the Environmental Quality Incentives Program (EQIP). In addition, private sources of funding were also compiled, including the William Penn Foundation, the Pew Charitable Trusts and The Pennsylvania League of Women's Voters. Additional sources of funding included New York State DEP, New York City DEP, and New Jersey DEP funds. Federal funds via the Army Corps of Engineers (USACOE), the United States Environmental Protection Agency (EPA), the United States Fish and Wildlife Service (FWS), and the National Science Foundation (NSF) were also investigated.

From the data received, the Delaware River SWAP Study Area had a total of $19,167,802 awarded within its boundaries for the time period of 1995 to 2001, with most of the grant dollars being awarded post-1997.

Figure 1.6-1 Distribution of Grant Dollars Within the Delaware River SWAP Study Area

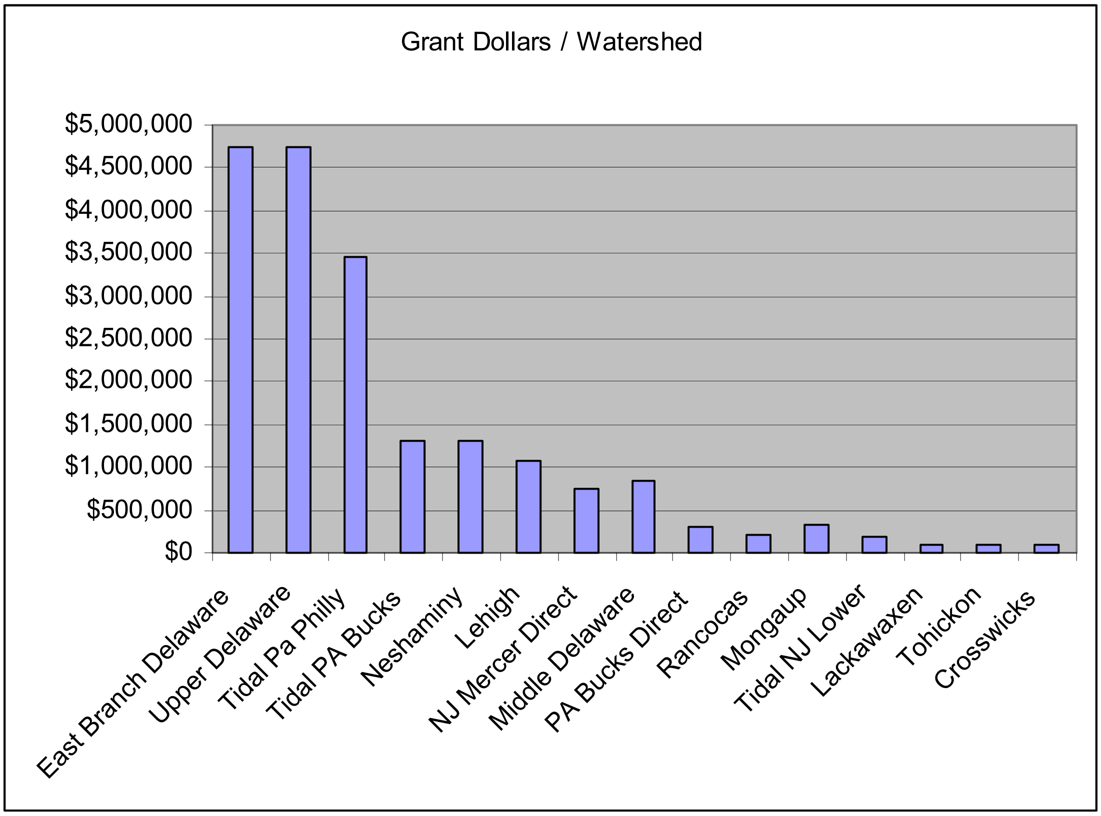


Figure 1.6-2 shows the grant dollars broken up by dollars for each study area subwatershed. The East Branch Delaware and the Upper Delaware Watersheds both ranked first in terms of grant dollars, with a total of $4,751,250 awarded to each. These watersheds are the location for two large reservoirs, Cannonsville and Pepacton, which provide an unfiltered source of drinking water for New York City. In order for New York City to use this supply as an unfiltered source, they must provide an extreme level of watershed protection. This effort is reflected in the amount of restoration and protection money spent in these watersheds.

Figure 1.6-2 Grant Money per Capita Awarded Within Each Delaware River SWAP Study Area

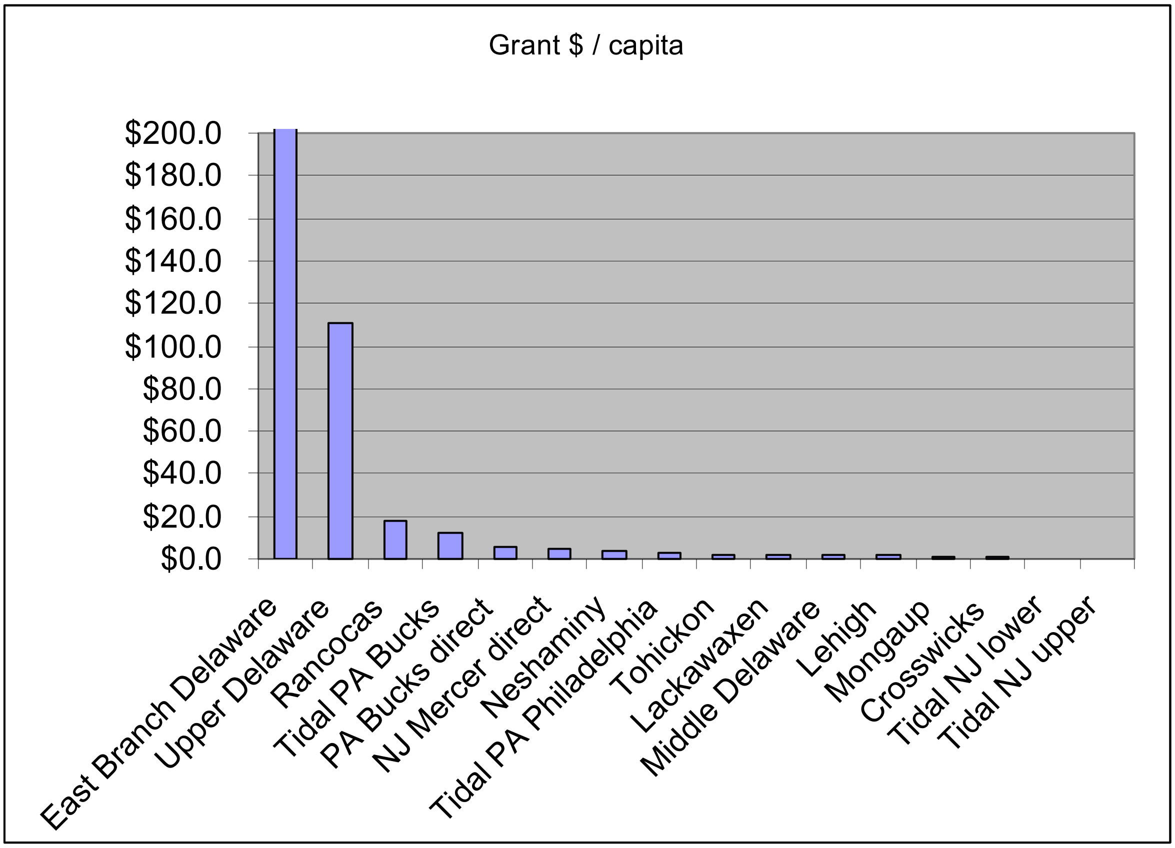
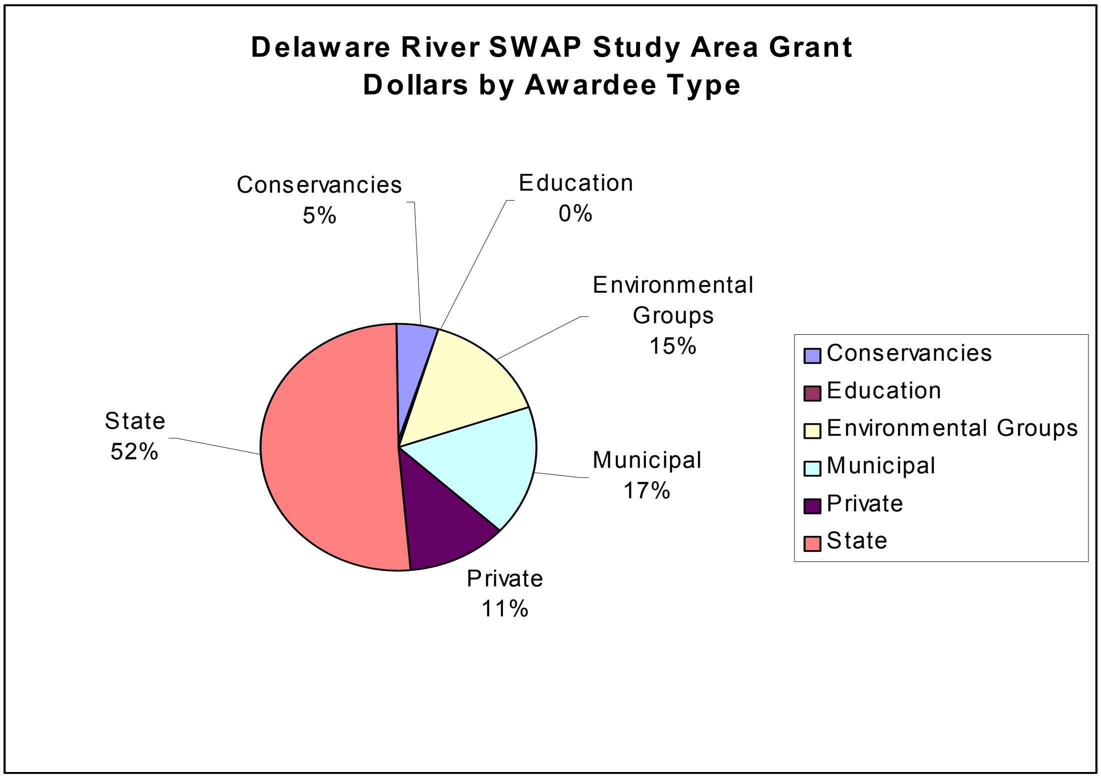


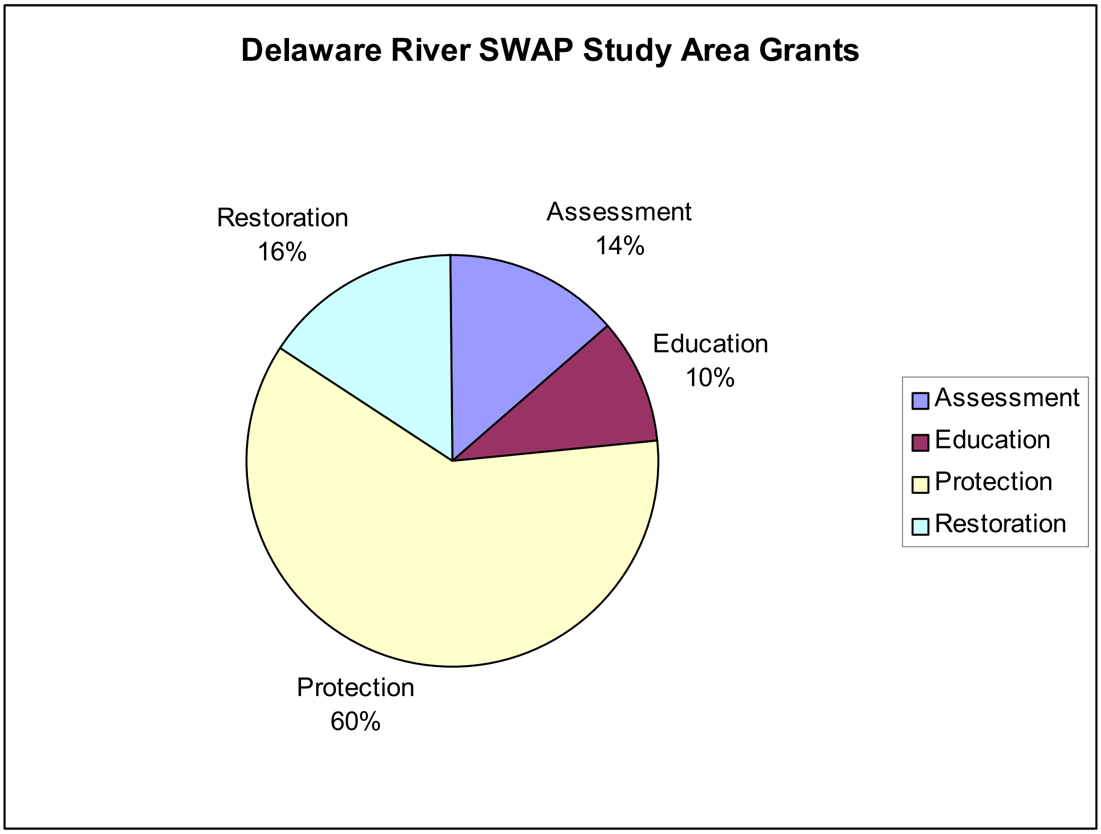
Figure 1.6-2 shows the amount of effort that New York City/State have done in the headwaters of the Delaware River. These areas are not heavily populated, but provide the majority of water for the citizens of New York City. This tends to skew the results, because more people benefit from protection efforts in those areas than depicted because they are located outside of that watershed (New York City).

Figure 1.6-3 Distribution of Delaware River SWAP Study Area Grants by Recipient Type



This figure shows that a majority of funds (52%) were given to state agencies. The vast majority of these funds are related to New York City transferring funds to New York State to provide protection efforts in the headwaters of the Delaware River for Canonsville and Pepacton Reservoirs.

Figure 1.6-4 Distribution of Delaware River SWAP Study Area Grants by Project Type



1.7 Public Participation Process

Key Points

- **Public kick-off meetings, Technical Advisory Group meetings, media articles and a web site are some of the methods used to involve the public in the SWAP.**

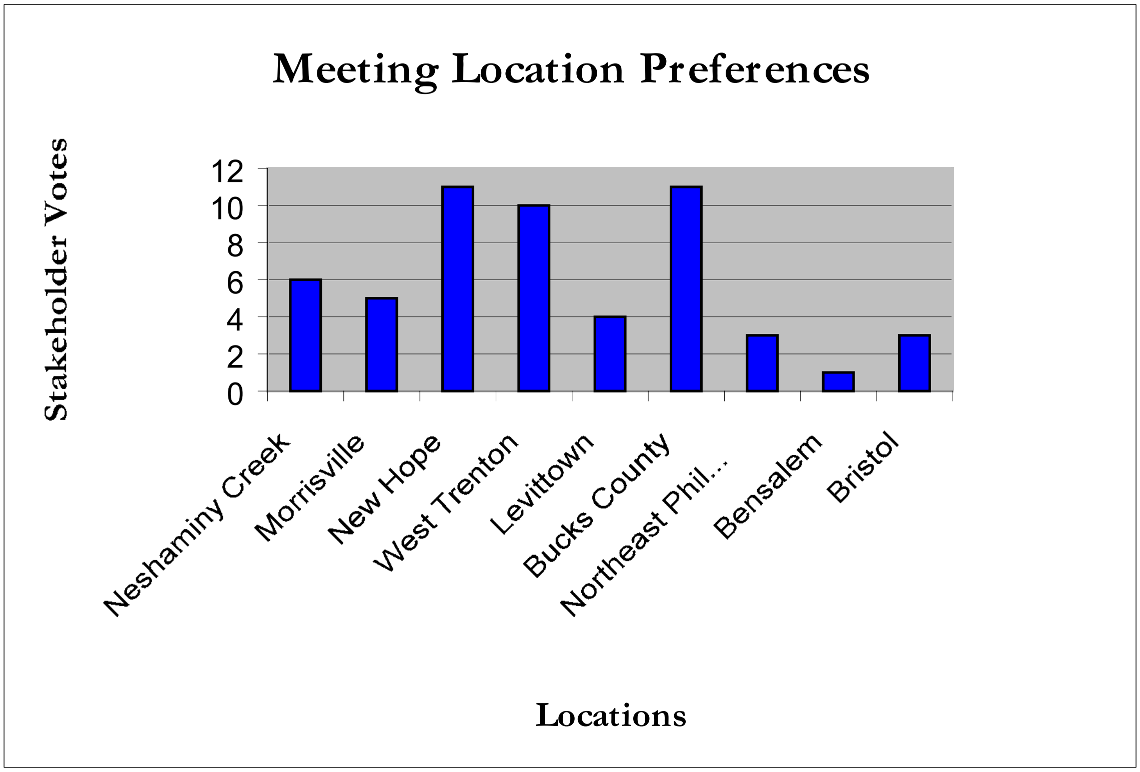
Several avenues will be available for stakeholder and public involvement throughout the Delaware Source Water Assessment Program. These include:

- Public kickoff meetings
- Public wrap-up meetings
- Technical advisory group meetings
- Legal notices
- Newspaper articles
- SWAP web site

This multi-faceted approach provides opportunities for the partnership to introduce the public and stakeholders to the source water assessment program and process, and for the partnership to obtain information and feedback from the public. In the past, these avenues appear to have been moderately successful at reaching interested public and stakeholders. One public meeting has resulted in 34 attendees, two advisory group meetings resulted in 23 attendees, 12 legal notices have been published, two newspaper articles have been published about the project, and the web site has been accessed 146 times to date. More public meetings discussing the ongoing assessment will take place in the near future

One of the important goals of gathering stakeholder input during the initial stages of the public participation process is to develop a framework for the meetings to ensure that they are optimally effective. According to the results of the first round of surveys distributed to gather stakeholder input, the best time for the stakeholders to meet is during the day (either morning or afternoon) and most would prefer to meet in the New Hope, West Trenton, or Bucks County areas. The following figure illustrates the amount of stakeholder votes each location received.

Figure 1.7-1 Meeting Location Preferences



1.7.1 Advisory Groups

Key Points

- **An open Technical Advisory Group (TAG) has been established to facilitate communication among stakeholders and to gather information about the watershed.**
- **The TAG meets quarterly to assist the Source Water Assessment Partnership in the SWAP process.**

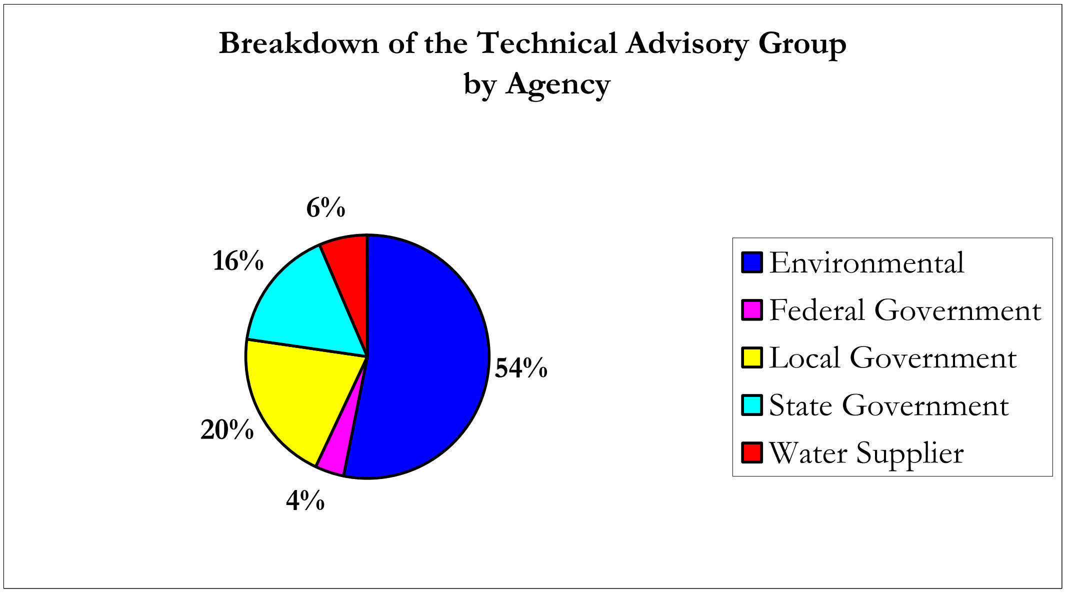
To better facilitate communication among the Source Water Assessment Partnership and the regions of the Delaware River Watershed to be assessed, an open Technical Advisory Group (TAG) has been formed. This TAG was developed by the partnership as a way to closely interact with the stakeholders, and in turn, to gather integral information about each region of the Delaware River Watershed. All of the stakeholders have been invited by the partnership to participate. Meeting quarterly, it is the primary responsibility of the TAG to inject public interest into the SWA process. Other duties of this group include:

- Sharing information with stakeholders
- Verifying the information put forth by the partnership
- Providing input on the assessment techniques and criteria used by the partnership
- Offering general information regarding the areas local to each TAG
- Participating in public outreach and education
- Describing current protection activities
- Identifying "potential" sources of contamination and preservation
- Assisting in the development of summary reports

Technical Advisory Group Participants

Composed of watershed organizations, public interest groups, dischargers, suppliers, and local government agencies, the TAG offers a broad variety of perspectives and visions. The following graph is illustrative of the various types of agencies participating in the Technical Advisory Group (see Figure 1.7.1-1).

Figure 1.7.1-1 Technical Advisory Group Breakdown



The following is a summation of some of the TAG's participants:

It is the mission of the ***Department of Environmental Protection (DEP)*** to protect the air, land, and water of Pennsylvania from pollution, and to provide for the health and safety of its citizens through a cleaner environment. DEP works as a partner with individuals, organizations, governments, and businesses for the prevention of pollution and the restoration of natural resources. It achieves these goals via public service, protection, teamwork, communication, and pollution prevention. DEP is the state agency largely responsible for administering Pennsylvania's environmental laws and regulations. Its responsibilities include: reducing air pollution; making sure that drinking water is safe; protecting water quality in Pennsylvania rivers and streams; making sure waste is handled properly; managing the Commonwealth's recycling programs and helping citizens to prevent pollution and comply with the Commonwealth's environmental regulations. DEP is committed to general environmental education and encouraging effective public involvement in setting environmental policy.

PennFuture is an organization that takes pride in defending the environment. In achieving its mission of defending nature, PennFuture effectively resists those who attack the environment and rallies against those who fail to do their duty to protect it. By combating global warming, smog, acid rain, and illness, and by advocating the increase of desperately needed funding for farmland preservation, among other things, PennFuture is making great strides in assuring that polluters and their allies no longer decide the fate of the environment and the economy. Comments and concerns may be voiced to Brenna Herpmann at (800) 321-7775. PennFuture's mailing address is 212 Locust Street, Suite 410, Harrisburg, PA 17101.

In order to share the responsibility of managing the water resources of the Delaware River Basin, the ***Delaware River Basin Commission (DRBC)*** was formed by the signatory parties of the Delaware River Basin Compact (Delaware, New Jersey, New York, Pennsylvania, and the United States). Since its inception on October 27, 1961, the very day that Compact became law, DRBC has been a pacesetter in environmental protection. As mentioned in its mission statement, DRBC focuses mainly on protecting, enhancing, and developing the water resources of the Delaware River Basin for the benefit of present and future generations. In achieving their mission, DRBC has developed such programs as water pollution abatement, water supply allocation, regulatory review (permitting), water conservation initiatives, regional planning, drought management, and flood control. Questions, comments, and concerns may be forwarded to Jon Zangwill via e-mail, zangwill@drbc.state.nj.us or telephone, (609) 883-9500 x 307. DRBC's mailing address is 25 State Police Drive, West Trenton, NJ 08628.

Clean Water Action (CWA) is a national citizens' organization that works toward the following goals: affordable water, prevention of health-threatening pollution, creation of environmentally safe jobs and businesses, and the empowerment of people to make democracy work. In addition, CWA organizes grassroots groups, coalitions, and campaigns with the common interest of protecting health and quality of life, so that they may better promote environmental well-being within a community. The mailing address of the CWA National Office is 4455 Connecticut Avenue NW – Suite A300, Washington, DC 20008-2328 (Telephone: (202) 895-0420). The mailing address of the CWA Philadelphia Office is 1201 Chestnut Street, #602, Philadelphia, PA 19107. All inquires may be directed to Bob Wendelgass at the Philadelphia Office via e-mail, bwendelgass@cleanwater.org or telephone, (215) 640-8800.

It is the mission of the ***Pennsylvania Environmental Council (PEC)*** to improve the quality of life for all Pennsylvanians. In doing so, PEC enhances the Commonwealth's natural and man-made environments by integrating the advocacy, education, and implementation of both community and regional action programs. Director of Watersheds Programs, Ann Smith, will be accepting questions, concerns, and comments at (215) 563-0250. The mailing address of the PEC is 117 South 17th Street, Suite 2300, Philadelphia, PA 19103-5022.

Founded in 1989, The ***Delaware River Greenway Partnership*** (DRG) promotes awareness and protection of the river and other natural resources by encouraging both public and private stewardship of the Delaware River and the greenway that surrounds it. Among the DRG's current projects are: *Bridging Our Lower Delaware*, *Delaware River Heritage Trail*, and *Annual Education Reform*. The DRG also publishes a quarterly newsletter, the *Delaware River Greenway News*. The DRG can be contacted by telephone at (908) 996-0230.

The ***Bucks County Sierra Club*** is an organization that works to protect the county's land, air, and water resources by encouraging Bucks County residents to take an active role in making elected officials recognize the importance of these resources and prevent further damage to them.

The mission of the ***Bucks County Water and Sewer Authority*** is to provide quality service in an environmentally safe manner at an affordable rate, and to educate their current and future customers on water conservation. The authorities' ongoing goals include: maintenance of their commitment to affordable rates and excellent service levels, meeting or exceeding all environmental and public health standards, continual seeking and identification of cost saving procedures without the sacrifice of quality, and the education of customers, neighbors, and the communities' children in that water is a limited resource and should be treated as one of our most valuable commodities. The *Bucks County Water and Sewer Authority* was founded by the Bucks County Commissioners in 1962 to support local municipalities with the installation of water and sewer service. As a non-profit agency carrying out an enterprise role, no tax money is involved in the operation of this (or any) authority; all income is derived by billing the people who utilize their services. Consequently, those not making use of the service do not pay towards it; also known as "user pays." The good news is, as an "Authority", it only charges its customers the cost to operate the service.

The ***Stroud Research Center*** uses its advanced knowledge of stream and river ecosystems to provide solutions for water resource problems around the world. The center uses extensive education programs, conservation leadership, and its professional services to promote public understanding of freshwater ecology and to develop new ideas and hypotheses to improve the environment. Included in Stroud's mission statement are: the advancement of knowledge of stream and river ecosystems through interdisciplinary research, the development and communication of new ecological ideas, hypotheses or theories, the provision of solutions for water resource problems worldwide, and the promotion of public understanding of freshwater ecology through education programs, conservation leadership and professional service. The Stroud Center can be contacted via telephone at (610) 268-2153 or fax at (610) 268-0490. The mailing address for the center is 970 Spencer Road, Avondale, PA, 19311. Comments and concerns may also be voiced via e-mail at Webmaster@Stroudcenter.org.

Since it's beginning in 1969, the ***Catskill Center for Conservation and Development*** has worked as a non-profit organization to inform the public of issues concerning the conservation of the resources of their area. Public forums are used to encourage the public to get involved with these issues, and to help foster a deep appreciation for the environment in which they live. Centering on environmental protection and sustainable economic development has helped the organization to protect the cultural, historic, and natural resources of the Catskill Mountains. Merging both environmental protection and sustainable economic development, the organization is a campaigner for the region's vital main streets, valuable natural resources, artistic and historic assets, and working landscapes. They achieve this through four main program areas; *Natural Resources and Land Conservation, Education, Community Planning and Development, and Regional Culture and Arts.* The Catskill Center can be reached via telephone at (845) 586-2611. It is located in Arkville, New York.

Funded in 1959, ***Trout Unlimited's*** mission statement is "to conserve, protect and restore North America's trout and salmon fisheries and their watersheds." The organization accomplishes this mission through an extensive volunteer network. With 125, 000 volunteers in 500 chapters nationwide, the organization works directly through professionals who testify before congress and intervene in federal legal proceedings to ensure they are involved in conservation issues. The drive of the organization is to protect our rivers and fisheries for generations to come. Trout Unlimited can be reach by telephone at (703) 522-0200 and by fax at (703) 284-9400. The mailing address is 1500 Wilson Blvd., #310, Arlington, VA, 22209-2404. Questions and comments can also be sent via e-mail at trout@tu.org.

The ***Heritage Conservancy***, formerly known as the Bucks County Park Foundation, was founded in 1958 when concerns about the rapid loss of open space in Bucks County started to arise. Since that time, the conservancy has been dedicating its time and efforts to protecting the counties natural and historic heritage. By partnering with citizens, businesses, and government agencies, the conservancy has become a leader in land conservation and historic preservation. The organization achieves these environmental goals through a process of assessing potential sites, educating the public, and implementing actions to improve our natural habitats. The Heritage Conservancy can be contacted by phone at (215) 345-7020 and by fax at (215) 345-4328. The mailing address is 85 Old Dublin Pike, Doylestown, PA, 18901.

Created as a chapter of the National Audubon Society in 1969, the ***Bucks County Audubon Society*** has set out to create a sense of need for environmental change. Since their start, the BCAS has been protecting the environment, educating the public on ways to better conserve their natural resources, and promoting the wise use of land, water, and air. With over 2300 members, BCAS is one of the chief citizen membership groups representing environmental and ecological interests in Bucks County. The mailing address for the Bucks County Audubon Society is 6234 Upper York Road, New Hope, PA, 18938. BCAS can also be reached by phone at (215) 297-5880 or by fax at (215) 297-0835. All e-mail can be directed to bcas@bcas.org.

The ***New Jersey Audubon Society*** works to instill a sense of environmental conservation in New Jersey's citizens to protect the plants, animals, and natural resources of their state. Though not associated with The National Audubon Society, the NJAS has set forth to conserve the natural environment through education programs and information services, as well as to increase the public's knowledge of New Jersey's flora and fauna through extensive field work. As one of the oldest independent audubon societies, the NJAS has made every effort to protect threatened and endangered species and has also established and maintained wildlife sanctuaries and education centers. The mailing address for the NJAS is: New Jersey Audubon Society Headquarters, 9 Hardscrabble Road, PO Box 126, Bernardsville, NJ 07924. Questions and concerns can also be direct via telephone at (908) 204-8998 and through e-mail at hq@njaudubon.org.

The ***National Audubon Society of New York State*** works on local, state, and national levels to provide protection for birds, forests, wetlands, and wildlife. The statewide council advocates and educates the proper management of wildlife and their habitats to help improve the environment. The National Audubon Society of New York has, since its foundation, significantly increased its financial and staff commitments to centers and education. They are looking at the broadest possible range of opportunities to meet their goals of continued growth in the area, under the principle that realistic center growth must provide results that are fiscally advantageous, operationally practical and educationally sound. The society can be reached via telephone at (518) 869-9731, fax at (518) 869-0737, and by means of e-mail at nasnys@audubon.org. The mailing address is 200 Trillium Lane, Albany, NY 12203.

The ***New Jersey Farm Bureau*** represents the agricultural producers and enterprises of New Jersey. Their goal is to create positive public relations, influence laws and regulations, and to seek out activities and ventures that benefit the welfare of the producer members. In their mission, the New Jersey Farm Bureau states that their mission is to represent the agricultural producers and enterprises of New Jersey at all levels of government – local, county, state, federal, and international. The bureau's mailing address is 168 West State Street, Trenton, New Jersey, 08608. They can also be reached by phone at (609) 393-7163 and by fax at (609) 599-1209.

Pennsylvania-American Water Company is committed to providing quality water, services, and products to their customers while trying to maintain the environment in which we live. The company works hard to focus on personal solutions and to exceed the expectations of their clients in the services they provide. In their mission they state that they will "continually build ever-increasing value for their shareholders and their customers in the business of water resource management." The PAWC can be reached via their toll-free number at (800) 565-7292.

It is the mission of the ***Wildlands Conservancy*** to protect vital open spaces, watersheds, wildlife, and farmlands in Pennsylvania. The organization is dedicated to the preservation of rivers, land, and trails through public education programs. The efforts of this member-supported organization have produced over 31, 000 acres of permanently protected open spaces in eastern Pennsylvania. The Conservancy is also working to protect Pennsylvania's waterways and care for injured or orphaned wildlife. Questions and concerns can be voiced through phone at (610) 965-4397 or fax at (610) 965-7223. The mailing address for the conservancy is 3701 Orchid Place, Emmaus, PA 18049.

Established in 1996, the ***Partnership for the Delaware Estuary*** was created to coordinate the protection and enhancement of the Delaware River Estuary. The partnership has taken a leadership role in promoting the conservation of this natural resource to help contribute to the usefulness of the estuary for environmentally friendly recreational purposes. By increasing the publics awareness and understanding of this important natural resource, the partnership is encouraging enhancement and protection throughout the Delaware Estuary. Comments, questions and concerns can be directed to Kathy Klein via e-mail at partners@udel.edu. The Partnership for the Delaware Estuary may also be reached through its toll-free number at 1-800-445-4935.

New Jersey Futures was formed in 1987 to serve as the watchdog over the state's development and redevelopment plans. This nationally recognized promoter of open space protection has become a leader in the fight for smarter land use. NJF is also working with the state of New Jersey on a plan to become the nations first "sustainable state:" a plan that incorporates the balance of economic, environmental, and social goals of the state. The organization is working hard to develop a strong economy, and a healthy natural environment. The mailing address for NJF is New Jersey Future, 114 West State Street, Trenton, NJ, 08608. Questions and concerns can be voiced via e-mail to njfuture@njfuture.org. The organization can also be reached by telephone at (609) 393-1189 and by fax at (609) 393-1189.

Technical Advisory Group Meetings

Three TAG meetings were held as of April 2001. The following table outlines the date, location, and number of attendees at each meeting.

Table 1.7.1-1 Summary of Technical Advisory Group Meeting Dates and Locations

Meeting	Date	Location	Number of Attendees
1	May 16, 2001	Delaware River Basin Commission Offices West Trenton, NJ	14
2	November 8, 2001	Bucks County Water & Sewer Authority Offices Warrington, PA	9
3	May 14, 2002	Bucks County Water & Sewer Authority Offices Warrington, PA	
			Total Attendees 23

Summarization of Technical Advisory Group Meeting Minutes

These meetings are, in essence, forums for discussion during which local stakeholders are encouraged to voice their concerns and share their opinions of the project. The following is a summation of the minutes from the first two meetings:

MEETING 1

This meeting acted as an introduction to the Delaware River Watershed as well as to the Source Water Assessment Program. The meeting both summarized the Delaware River and its intrinsic values as well as reviewed the operation and challenges of a water treatment plant. The watershed of the Delaware River was said to be a home to over seven million people, composed of 1,450 industrial and municipal dischargers in which wastewater treatment accounts for 98% of the total discharge to the estuary. It was also stated that 17.5 million people rely on the Estuary's surface water intakes for drinking water; most of the water being distributed throughout New York City. The estuary was cited as a source of heritage, history, culture and recreation for the region. In evaluating the operation and challenges of a water treatment plant, the Baxter WTP was broken down and analyzed. The plant was undergoing capitol construction; therefore, a review of its current and future conditions took place.

The specific aspects of the Delaware River Watershed as a source of drinking water supply are as follows:

- It is comprised of eight large surface water intakes.
- Over 600,000 MGD is withdrawn on average from the river and its tributaries (not allocated)
- It serves over 17.5 million people

The Source Water Assessment (SWA) was explained to be an iterative, continuous, and multi-phase process. The process aids in the identification of "potential" and/or existing sources of contamination, evaluates the vulnerability/susceptibility of the water supply to contaminant sources, and determines protection priorities and activities for the water supply. The ultimate goal of the SWA was specified as developing local sources of water protection initiatives involving both water suppliers and the public and educating the public about the source of their drinking water as well as its pertinent challenges.

Utilities and stakeholders were encouraged to become interested in the SWAs because the program was based on federal regulations mandated by Congress. Responding to requests by the public to know more about their water supply and how to protect it, Congress included provisions for a SWA within the Safe Drinking Water Act Reauthorization of 1996. It is the goal of Congress to have 50% of the United States population enveloped under Source Water Protection Plans by 2005.

The SWAs were said to benefit the stakeholders present at the meeting because stakeholders of the TAG would be directly involved by:

- Identifying sources of contamination and areas for protection
- Having their organization highlighted for interested persons to contact/join
- Determining potential linkages between their efforts and protection efforts
- Increasing potential funding opportunities for communities and watershed groups by incorporating projects into approved SWA plans

The point was made that source water advisory group participation is an integral piece in determining the success of the project. This group meets quarterly throughout the length of the project, provides public input into the process, and helps determine public outreach. A number of tasks that the stakeholders can do in order to assist in the source water assessments were also listed. These tasks, such as listing water source issues, providing pictures or tours of areas of concern, and providing input on ranking criteria were summarized. Final products and purposes of the project were also reviewed. The following table illustrates these specific final products.

Table 1.7.1-2 Final Products and Purposes

Product	Type	Audience
SWA Report	Technical	Water Supplier & Public Agencies
Summary Report	Educational/Motivational	Public
Maps/Coverages	Technical	Water Supplier & Public Agencies Watershed
Source Water Partnership	Educational/Motivational/Technical	All Stakeholders

It was also stated at the meeting that due to an inaccuracy in the federal databases, source issues must be "groundtruthed". In doing so, many things will be looked at including:

- Thousands of point sources and regulated facilities
- Dozens of wastewater plants
- Hundreds of farms
- Non-point source potential
- Numerous other sources typically identified

Another topic of consideration is source water protection issues. The following table outlines various issues as well as their possible sources:

Table 1.7.1-3 Source Water Protection Issues

Issues	Possible Sources
Pathogens-*Giardia/Cryptosporidium*	Sewage, livestock, & wildlife
Algal Blooms/Nutrients	Sewage, agriculture, lawncare, golf courses
Metals-Manganese	Acid mine drainage
Chloride & Sodium	Road salts/highways
Pesticides/Herbicides	Lawn care, right of ways, agriculture
MTBE/Bromide/DBP Precursors	Cars & recreational watercraft

Operation and challenges of a water treatment plant were also discussed at the meeting. Specifically, the challenges of optimized water treatment during capitol construction and increased regulatory requirements. The Baxter WTP was broken down in order to assess the challenges it faces. Its current condition and historical treatment were outlined in detail and the areas for improvement were identified. Baxter, scheduled to undergo capitol construction for seven months, finished in June 2001.

The meeting finished with a series of questions and answers in which the stakeholders were able to voice their concerns and comments as well as inquire about the assessment.

A schedule and timeline were presented. The deadlines for the draft reports, which begin in April 2002, are marked for completion by January 2003. The following figure displays the breakdowns of the assessment and the schedule.

Figure 1.7.1-2 Assessment Schedule

Intakes Assessed

Water Supply	Draft Reports
PWD – Baxter	April 2002
PSWC – Bristol	October 2002
Morrisville	October 2002
Lower Bucks JMA	October 2002

Non-tidal/Tributary Intakes

Water Supply	Draft Reports
PSWC – Neshaminy	July 2002
Middletown – Chubb Run	July 2002
PA American – Yardley	January 2003
Bucks County Water	January 2003

MEETING 2

Meeting two was broken up into three main sections. They were:

1. *Delaware River Source Water Assessments*
2. *Contaminant Source Inventory*
3. *Susceptibility Analysis*

Zone Delineation's for tidal and non-tidal areas were covered under the Delaware River SWAs. Determining the zone delineation for the intakes is a difficult task due to their considerably large size. The zone delineation was therefore broken down into several sections for simplification. These sections that compose the breakdown are:

- Intakes (the eight intakes were broken down into tidal and non-tidal influence and by intakes on tributaries)
- Zone definitions (Zones A, B, and C)
- Time of travel for tidal, non-tidal, and tributary intakes
- A further breakdown of tidal intakes
- Additional incorporation of tributaries in tidal zone, non-tidal river intakes, tributary delineation, and water quality data were also present in the analysis

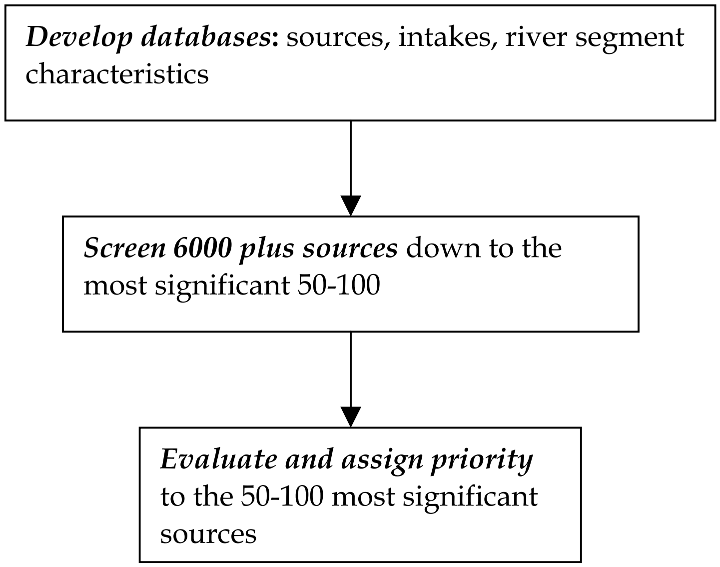
The next steps to take in the delineations were also discussed and include:

- Cleanup and refinement of the zones
- Beginning of data analysis
- Searching for electronic data or water quality studies to "groundtruth" suspected potential sources
- Working on stream impairment GIS and data for NJ

A contaminant inventory database compilation had been completed and was discussed at the meeting. Main web sites such as the "Right To Know Network" (RTK) and "Envirofacts" were utilized in the contaminant source compilation. Federal databases were accessed and data was downloaded. The data was downloaded by county, the data sites were then "clipped" in GIS to eliminate those outside of the watershed boundaries, missing "x-y" coordinates were filled in, facility data was cross-referenced, and quantity/contaminant data was populated.

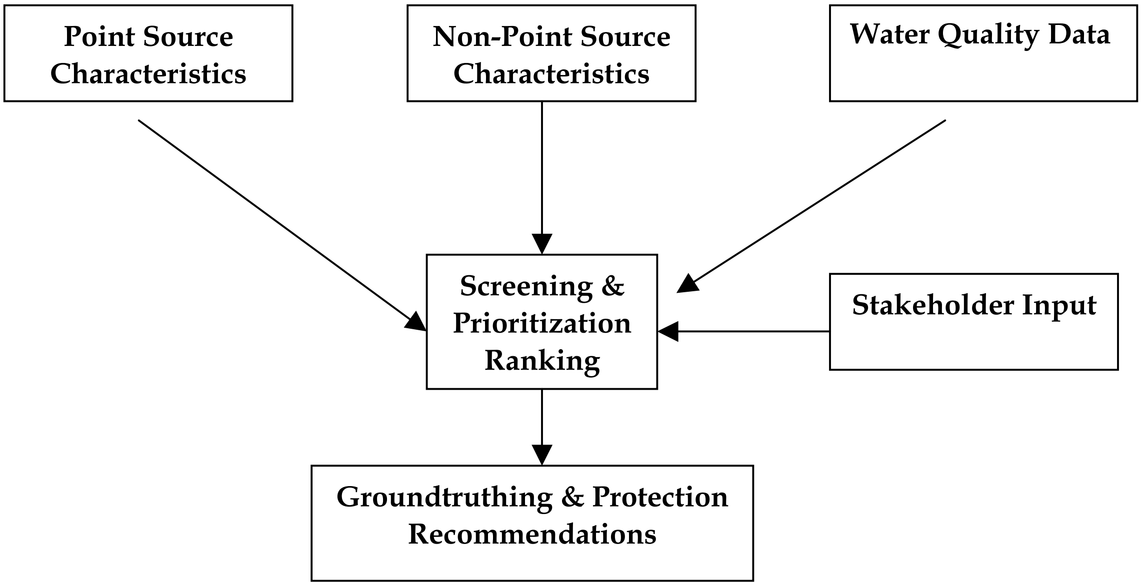
A susceptibility analysis overview was also presented at the meeting. The Delaware River Source Water Assessment proved to be a complex undertaking with the watershed covering 300 miles of river, as well as a 13,000 square mile watershed with more than 6,000 potential sources. The overall goal of the project is to understand which sources are most critical and which are less serious, understand present water quality concerns, focus energy on important sources, and result in a limited number of high priority sites. The general approach is comprised of three main steps, which are illustrated in the following figure (Figure 1.7.1-3):

Figure 1.7.1-3 Main Steps in the General Approach



This approach is based on and includes the approach of the Source Water Assessment and Protection Program of PADEP. It has been modified and formalized into the process that includes point sources, non-point sources, and "special categories" such as acid mine drainage, spills from railroads, and pipeline breaks. A technical approach or state approach was presented at the meeting and includes surface water and zone delineation, water quality analysis, a susceptibility analysis for the state which includes qualitative measures as well as available qualitative data. The Delaware River approach is inclusive of all the elements of the state approach but is more extensive. For example, the Delaware River approach is more quantitative than the state approach and is designed to handle thousands of potential sources. An illustration of the source water assessment simplified approach follows (see Figure 1.7.1-4). In this approach, stakeholder input is included in the "Screening and Prioritization Ranking" along with "Point and Non-Point Source Characteristics" and "Water Quality Data". After all four go through the "Screening and Prioritization Ranking", "Groundtruthing and Protection Recommendations" are then developed.

Figure 1.7.1-4 Source Water Assessment: Simplified Approach



A source priority ranking was completed utilizing the Evamix Evaluation Criteria Groups. The groups are comprised of:

- River Flow Related Criteria (2)
  - Location
  - Time of Travel
- User Related (1)
  - Potential Health Impact (combined ranking only)
- Intake Criteria (3)
  - Relative Impact (both intake and source related)
  - Removal Capacity (combined ranking only)
  - Impact on Treatment Operations (combined ranking only)
- Source Related (3)
  - Potential for Release/Presence of Controls
  - Potential Release Frequency
  - Violation Type/Frequency

Based on these, the stakeholder's criteria weightings are illustrated in the following table (Table 1.7.1-4):

Table 1.7.1-4 Stakeholder Criteria Weightings

Criteria	Min	Max	Average	Agreed
Relative Impact at Intake	5%	25%	13%	12
Time of Travel	2%	15%	7%	5
Existing Removal Capacity	3%	30%	13%	10
Impact on Treatment Operation	2%	30%	10%	10
Potential Health Impacts	10%	30%	20%	20
Potential for Release/Controls	3%	20%	10%	14
Potential Release Frequency	3%	20%	9%	14
Violation Type/Frequency	3%	20%	9%	10
Location	2%	20%	8%	5

The Delaware River approach employed four linked databases. In regards to the intake; location, stream segment, withdrawal data, and a list of contaminants where 50% MCL exceeded were included. In the stream segment were segment ID, position in stream, flow, and velocity. Lastly, the source included ID, location, stream segment, zone, quantity, concentration, contaminants, and likelihood of release.

Within the Delaware River approach it was necessary to assign pollutant categories. These categories are essential because the approach used cannot deal with thousands of sources, 42 intakes, and try to do this for all types of pollutants. The purpose of this approach is to assign one or more 10-pollutant categories to each source. This may be done using data from Federal or State Databases or through the use of SIC code and standard assumptions of pollutants related to SIC codes.

Advantages to the Evamix approach are that it helps to clearly define the alternatives under consideration, it requires a clear set of evaluation criteria, and it does not lose information because it accepts quantitative and qualitative data. Additionally, it organizes objective information into a clear set of scores, it segregates the subjective part of the evaluation into criteria weights, and it is flexible and simple in that it handles new data easily. Finally, the process is clear, defensible, and reproducible.

For this Delaware River approach, the Evamix results will be reviewed and "reality checked." Results for high-ranking sources will be added to other sources outside of the analysis (e.g., highway spills, pipelines, etc.). Furthermore, high-ranking sources will be flagged for follow-up data collection in a later phase to verify results.

The meeting again closed with questions and answers in which the stakeholders were able to present their concerns and provide input on the assessments.

1.7.2 Public Meetings

Key Points

- **Thirty-four people attended the first of several public kick-off meetings being conducted to introduce the SWAP.**

To date, one public kick-off meeting has been conducted to educate the public about the importance of the Delaware River Source Water Assessment Program (SWAP). This, along with each future public kick-off meeting will utilize the following general approach in order to generate public interest:

- Press releases produced by the Philadelphia Water Department and the local stakeholders will be sent to the local media and newspapers
- Legal notices will be sent to the local media and newspapers
- Advertisements will be published in the Pennsylvania Department of Environmental Protection (PADEP)'s *Update*

Hosted by local watershed organizations to promote a sense of credibility as well as to establish a connection with local residents, these meetings are, in essence, informational forums where members of the public are enabled to voice their concerns as well as share their visions for the project. The first public meeting held on November 15, 2001 sponsored by the Friends of the Pennypack Creek at the Holmesberg Baptist Church, yielded 34 attendees.

Standard meeting agendas have been developed and are followed at each meeting. This agenda generally consists of an introduction and an explanation of the purpose of the meeting. Another component of this agenda is an overview of source water assessments, which includes a brief, yet thorough, description of the SWAP as well as the areas to be assessed, i.e., the Delaware River Watershed. In addition, a discussion of contaminant source issues and water quality concerns is a keynote feature of the agenda. Finally, each meeting is concluded with an exercise in identification of potential contaminant sources, in which the attendees are asked to identify local sites that may impact the water supply. Examples of source water assessment issues are presented and photos of these examples are shown to aid the public in identification. Questions, concerns, and comments are addressed as they are raised.

Prior to these kick-off meetings, several avenues are pursued in an attempt to notify the public of their occurrence. Letters produced by the Philadelphia Water Department, local stakeholders, and watershed groups specifying the location and directions, date, time, and nature of the meetings are mailed to numerous stakeholders, including many of the businesses, government agencies, and environmental organizations located within or affected by the Delaware River Watershed. The information contained in these letters is also posted on the SWAP website, www.phillywater.org/delaware. To further generate public interest, various watershed groups and local stakeholders post fliers throughout their respective areas and send press releases to their local newspapers. Many of these local newspapers will feature articles describing the nature of the meetings as well as the outcome, when applicable. Legal notices detailing the location, time, and date of each meeting are printed in the local newspapers in each area with which the SWAP is affiliated, for the purpose of opening the meetings to everyone within the watershed. Table 1.7.2-1 is illustrative of the publications in which the legal notices have appeared thus far, the dates of publication, and the general areas reached.

Table 1.7.2-1 Legal Notices Published for Public Kickoff Meetings

Date of Notice	Publication Name	Area Reached
11/14/01	*Northeast Times Newsweekly*	Philadelphia, PA
11/14/01	*Far Northeast Times*	Philadelphia, PA

The articles featured in each newspaper clearly state the purpose of the meeting as well as the date and location of each meeting. The function of the SWAP is described as well as its derivation. The articles invite the public to share their visions of the project and the opportunity for attendees to contribute what they would like to see develop throughout the duration of the assessment. A contact number is also provided in the event that anyone might want to pursue more information on the source water assessments.

1.7.3 Website

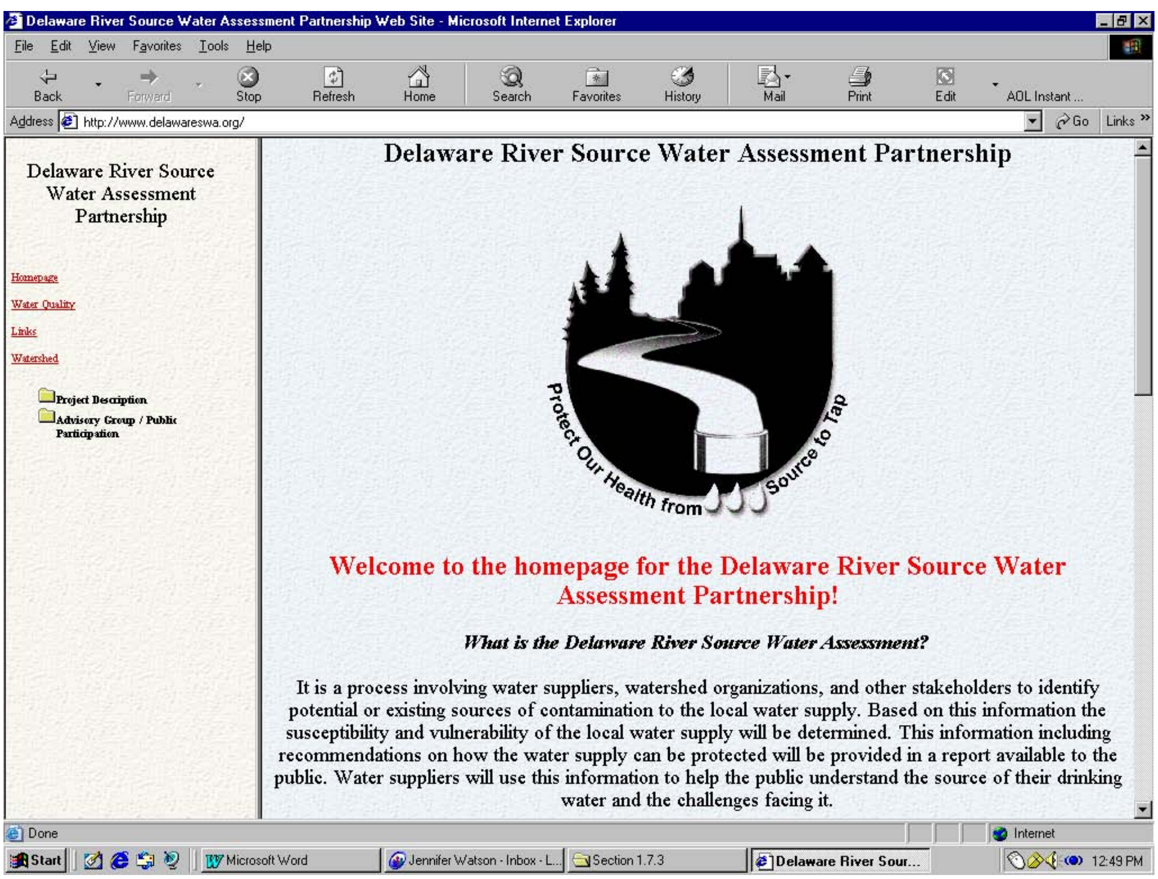
Key Points

- **SWAP project information is available through the project website, www.phillywater.org/delaware.**

A website has been developed for the project (www.phillywater.org/delaware*)* to provide a location where information about the project can be easily accessed by the public and stakeholders (see Figure 1.7.3-1). Although, this is a task beyond the scope of the contract, it is considered a necessary form of information delivery. Most importantly, the website is considered the most efficient way of providing the advisory group meeting information, meeting handouts, and meeting minutes without producing a significant burden of production on staff, given that there are many stakeholders to whom information must be mailed on at least a quarterly basis.

The website has been set up to provide general information about the purpose of the SWAP as well as contact information. It also provides links to information about public meetings, advisory group meetings, meeting materials, general watershed information, limited maps, watershed organizations, and general water quality information. Another special feature is an on-line stakeholder survey that stakeholders can fill out to provide information about their water quality issues.

Figure 1.7.3-1 Delaware River SWAP Website (www.phillywater.org/delaware)



1.8 General Recommendations for the Delaware River Watershed

The compilation of extensive field surveys, interviews with numerous stakeholders, and the examination of water quality, land use, and impaired stream information was compiled into the recommendations listed below for the Delaware River Watershed. These recommendations address 12 different categories, including general watershed protection ideas and specific activities related to watershed issues.

1.8.1 Grant Funding and Watershed Organizations

Based on the protection priority areas, restoration projects, and grant funding information available, it is apparent that there is a need for more restoration projects and watershed organizations for protection of the mainstem of the Delaware River between Trenton and Port Jervis. Efforts should be made via the Delaware Riverkeeper to promote development of local sponsors in these areas more effectively.

- Current grant funding appears to be focused appropriately on restoration with most of the grant money going to state organizations. It is recommended that the states make this money available to local municipalities to implement local protection efforts if these monies are not already available.

1.8.2 Protection and Preservation

- A coordinated regional protection plan needs to be developed and adopted by water suppliers, planning commissions, and municipalities for establishment and protection of sensitive and high priority protection areas to the multiple and overlapping water supply areas between Camden and Easton.

- Conservation easements should be acquired, zoning areas adjusted, or local ordinances enacted in order to reduce stormwater impacts from future development between Camden and Easton.

- The TMDL process and requirements along the Delaware River should include components to address drinking water impacts.

Priority for funding of Growing Greener and DCNR grants for projects in priority water supply protection areas should be given to projects that address sustainable mitigation of stormwater impacts and restoration or preservation of areas. In addition, agricultural land within the protection priority corridor would also be given easier access and higher priority for USDA funding, such as EQUP or CRP, in order to keep sensitive land areas out of production and protect local streams. PADEP and USDA could designate farms within the priority protection area as high priority for development of nutrient management plans. Townships located within a priority protection area should also be required to adopt a uniform ordinance to address stormwater impacts from current and future activities.

1.8.3 Sewage Discharge and Regulatory Enforcement

- Overall, both the sewer system capacity and integrity and the treatment plant capacity during wet weather periods represent the greatest and most difficult sewage-related issues in the watershed. Infrastructure improvements for adequate wastewater collection and treatment systems are needed to address infiltration and inflow or system capacity issues. These improvements will eliminate events such as overflowing manholes of raw sewage into downstream water supplies.

- Raw sewage discharges upstream of water supply intakes by communities through CSOs or SSOs need to be monitored, evaluated, and improved. These discharges can significantly impact pathogen concentrations in downstream water supplies.

- Wastewater dischargers should be encouraged and given incentives to switch to ultraviolet light disinfection and/or filtration of effluents in order to reduce C*ryptosporidium* pathogen levels and viability from discharges. Permits for discharge from new wastewater facilities or plant expansions should include ultraviolet light disinfection requirements.

- It is recommended that the DRBC and the PADEP regions covering the Delaware River Watershed develop a watershed-wide approach to addressing permit requirements. One suggestion would be a uniform fecal coliform discharge limit for any wastewater discharge upstream of a drinking water intake in the watershed.

- Compliance requirements for industries and municipalities discharging wastewater into the protection priority corridor between Camden and Easton should be enforced.

- Encouragement of rigorous and regular revision and implementation of ACT 537 Sewage Facilities Management Plans in Montgomery, Bucks, Mercer, and Lehigh counties. In addition, the sewage facility related issues from the SWAs should be incorporated into the ACT 537 plan with emphasis on monitoring and measuring progress towards addressing identified problems.

1.8.4 Stormwater Runoff Impacts

- Incentives for townships and communities in priority runoff areas are needed to mitigate stormwater impacts on water supplies.

- The Phase II stormwater regulations should be fully implemented and enforced throughout the watershed, with first priority for compliance monitoring and inspections recommended for communities discharging into protection priority areas for drinking water supplies.

- The Delaware River Basin in coordination with the Delaware Riverkeeper, PADEP, and NJDEP should set a goal for achieving a certain number of specific BMPs within the next 10 years. For example, the goal could be to implement 100 BMP projects or build 100 infiltration trenches or wetlands, or mitigate/treat one billion gallons of stormwater runoff in 10 years or by 2010.

1.8.5 Spills and Accidents/Emergency Response

- Interaction and communication with petroleum pipeline owners and operators, as well as railroad, road and bridge construction crews needs to be developed and improved. It is important for these stakeholders to understand water supply issues and impacts from catastrophic accidents and spraying of herbicides on rights-of-way. Therefore, a series of emergency response workshops needs to be coordinated to include the following parties:

    - PEMA
    - PECO
    - CSX/Conrail
    - PennDoT
    - Local Street Department Construction and Maintenance Managers

- Given the potentially catastrophic impacts from spills and accidents, an early warning system similar to that on the Ohio River should be installed along the mainstem of the Delaware River to provide water suppliers warning and accurate real time data when spills and accidents occur. It is recommended that the USGS be involved in the implementation of the early warning system.

- New permits should be banned for new storage tanks and facilities that use or store toxic chemicals including petroleum products within the 100 year floodplain of the river and its tributaries. The PADEP should also develop and implement a long-term plan to relocate, reduce, or eliminate tanks and sources with toxic chemicals that are currently located within the floodplain.

- An accurate time-of-travel study needs to be conducted on the Lower Delaware River to determine the time various spills will take to arrive at various water supply intakes and the amount of dilution under various flow scenarios. This should be incorporated into a computer model for emergency planning simulations using various chemicals and scenarios. This is also an important component necessary to make information from the early warning system more useful. The USGS should be involved in the implementation of this effort.

- In sensitive water supply areas along roadways and bridges, signage should be erected, which would include phone numbers to contact water suppliers during emergencies and spills. The signs should include a unique identification number corresponding to a known location for the water supplier.

- A special workshop with street departments and PennDoT should be held in order to develop a strategy to reduce salt impacts from road salt application. This may include strategies to acquire special funding for salt misting trucks to reduce salt application in sensitive areas.

1.8.6 Agricultural Impacts

- Agricultural land that is preserved should have specific riparian buffer and streambank fencing requirements included in its preservation status.

- Additional incentives and efforts should be allocated to develop nutrient management plans for farms in sensitive water supply areas.

- Active agricultural lands adjacent to streams in sensitive water supply areas should be required to have riparian buffers or streambank fencing to reduce impacts from livestock activity, pasture runoff, and crop runoff. Livestock releasing fecal material directly into a stream represent a direct waste discharge to a water body and therefore, should be subject to the similar regulations and permit requirements as other dischargers.

- The targeting of USDA funding for water quality protection under EQIP and enrollment of CRP lands should give consideration to sensitive water supply areas, and the programs should be made more accessible to farmers. To maximize water supply protection, water suppliers should be consulted in connection with the allocation of EQIP and CRP funds. A goal should be set by the USDA, DRBC, PADEP, and NJDEP to have approximately 25-50% of all agricultural lands in sensitive water supply areas to have streambank fencing or riparian buffers by 2010.

- Areas of intense or concentrated agricultural activity should also be prioritized for protection and mitigation efforts.

1.8.7 Erosion and Sedimentation Issues

- Special erosion controls and ordinances to reduce stormwater impacts from future development and erosion are needed in protection priority areas for water supplies.

- Conservation Districts need more assistance in addressing erosion control and stormwater runoff issues from development.

- The operation and discharge of contaminants and algae from the many reservoirs in the watershed are suspected of having impacts on water supplies. These areas need to be monitored and investigated or communication about these discharges and the timing of their impacts needs to be better understood.

1.8.8 Wildlife Impacts

- The U.S. Fish and Wildlife, state game commissions, park managers, golf course managers, and water suppliers should develop and implement a regional management plan to address the exploding population of non-migratory Canada geese.

1.8.9 Public Education

- Township officials in priority protection areas should be educated about stormwater impacts on water supplies through meetings, workshops, or mailings.

- The results of the local source water assessments need to be presented directly to local township officials. Common issues from multiple water supplies should also be provided to show how everyone lives downstream and feels the impact from pollution.

1.8.10 Data and Informational Needs for Improved Protection and Assessment Efforts

- A combined and coordinated effort to establish data protocols for proper data comparison (GIS or otherwise) between the various states in the Delaware River Basin needs to be established. Currently most data cannot be compared between states.

- An accurate watershed-wide land use GIS coverage is necessary for TMDLs and runoff impact estimates.

- GIS coverages of farms, types of agriculture, farming density, and EQUP/CRP lands, or lands with conservation easements, should be developed for the entire watershed.

- GIS coverages of the sanitary and stormsewer collection systems and outfalls in watershed communities should be developed.

- Updated and accurate locations of the many known point sources, as well as their outfall locations are necessary since many are currently off by far distances in comparisons between GIS and reality.

- Detailed GIS coverages of the age and location of petroleum pipelines in the watershed should be developed.

- Detailed GIS coverages of location, type of activity, and dollar amounts spent on various restoration, education, and protection efforts in the watershed should be compiled.

- A GIS coverage of the land use zoning for various townships and proposed future development corridors should be created to prioritize future protection and preservation efforts.

- Violation information for dischargers on the E-facts and Envirofacts websites for PADEP and EPA are incorrect and outdated. Efforts should be made to make this information more accurate and up-to-date.

- Updated information regarding the status and impacts from CERCLA sites and abandoned industry in the watershed should be compiled.

- A cumulative loading analysis of various discharges and runoff in the watershed should be performed.

- Actual and accurate estimates or reported values of contaminant concentrations from dischargers should be electronically available.

1.8.11 Water Quality Monitoring and Data Recommendations

Overall, based on the information available from an analysis of the amount, types, and locations for monitoring in the watershed, the following is needed:

- More comprehensive routine monitoring locations are needed in the major tributaries of the Delaware River Watershed.

- All monitoring organizations should agree on selecting standard monitoring stations for various parameters. It is recommended that the stations be placed close to the mouths of the major tributaries to the watershed. The long-term DRBC sites and certain water supply intakes may be the best place to start in selecting these sites. These standard stations would have routine monitoring conducted over long periods of time in order to examine changes and trends in water quality over years, seasons, or decades. This information will be used as part of a report card system for water quality improvement.

- Long term monitoring should be conducted for manganese, aluminum, iron, sodium, chloride, turbidity, total suspended solids, dissolved oxygen, temperature, ammonia, total phosphorus, orthophosphate, nitrate, E. coli, and fecal coliform. Currently, most monitoring does not include coliform measurements.

- Efforts should be made to transfer data from hardcopy format in special studies into electronic format.

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Delaware River Source Water Assessment
List of Acronyms

ACCESS	Microsoft Access Database Software
AMD	Acid Mine Drainage
AST	Aboveground Storage Tank
BOD	Biological Oxygen Demand
BG	Billion Gallons
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Act Information System
CFS	Cubic Feet per Second
COWAMP	Pennsylvania's Comprehensive Water Quality Management
CRP	Conservation Reserve Program
CSO	Combined Sewer Overflow
CSX	CSX Transportation Rail Company
CWA	Clean Water Act
CWA	Clean Water Action
DBP	Disinfection by-product Precursor
DCNR	Department of Conservation and Natural Resources
DEP	Department of Environmental Protection
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
DRBC	Delaware River Basin Commission
DVRPC	Delaware Valley Regional Planning Commission
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESRI	Environmental Systems Research Institute
EVAMIX	Mixed Data Multi-criteria Evaluation Software Program
FBRR	Filter Backwash Recycling Rule
FHWA	Federal Highway Administration
FWS	Fish and Wildlife Service
GIS	Geographic Information System
GPD	Gallons Per Day
INCODEL	Interstate Commission on the Delaware River Basin
LQG	Large Quantity Generators
MCPC	Montgomery County Planning Commission
MGD	Millions of Gallons per Day
MSL	Mean Sea Level
MTBE	Methyl Tertiary Butyl Ether
NAWQA	National Water Quality Assessment
NCDC	National Climatic Data Center
NJDEP	New Jersey Department of Environmental Protection
NLCD	National Land Cover Data Set
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System Permit Program

NPL	National Priority List
NPS	Non-Point Source
NRCS	Natural Resources Conservation Resources
NSF	National Science Foundation
NURP	National Urban Runoff Pollutants Study
NWR	National Wildlife Refuge
NWSRS	National Wild and Scenic River System
PADEP	Pennsylvania Department of Environmental Protection
PAWC	Pennsylvania American Water Company
PCB	Polychlorinated Biphenols
PCS	Permit Compliance System
PEC	Pennsylvania Environmental Council
PECO	Pennsylvania Electric Company
PEMA	Pennsylvania Emergency Management Agency Program
PWD	Philadelphia Water Department
PWS	Public Water Supply
RCRA	Resource Conservation and Recovery Act
RCRIS	Resource Conservation and Recovery Act Information System
RTK	Right To Know
SDWA	Safe Drinking Water Act
SOC	Synthetic Organic Compounds
SQG	Small Quantity Generators
SSO	Sanitary Sewer Overflow
STEPS	Student Technical Experience in Problem Solving
STORET	USEPA's Environmental Data System of STORage and RETrieval
STP	Sewage Treatment Plant
SWA	Source Water Assessment
SWAP	Source Water Assessment Program
TAG	Technical Advisory Group
TDS	Total Dissolved Solids
TM	Thematic Mapper
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TRI	Toxic Release Inventory
TS	Total Solids
TSS	Total Suspended Solids
USACE	US Army Corps of Engineers
USACOE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	Volatile Organic Compounds
WHP	Wellhead Protection Program
WRP	Wetlands Reserve Program
WWTP	Wastewater Treatment Plant

APPENDIX

Figure A:

ZONE 5 — TIMES NEWSPAPERS, WEDNESDAY, NOVEMBER 14, 2001

Drinking water is the hot topic

The Friends of Pennypack Creek will host a public meeting from 7:30 to 9 p.m. tomorrow at the Holmesburg Baptist Church, at Frankford Avenue and Rhawn Street, to discuss potential sources of contamination to the Delaware River.

The Delaware River Source Water Assessment Project (SWAP) is a public-private initiative facilitated by the Philadelphia Water Department.

The SWAP is designed to explore and understand the environmental challenges to the Delaware River watershed as a means to identify its existing and potential pollution sources to drinking water supplies.

In 1986, amendments were passed to the federal Safe Drinking Water Act that required state agencies and water suppliers to survey drinking water sources for contaminants and to make the information available to the public.

This meeting is an opportunity for individuals and organizations to become involved and to add their vision to the project.

For more information, call 215-685-4944. ••

Figure B:

Meeting will discuss study of drinking water supply

The Friends of Pennypack Creek will host a public meeting on Thursday, Nov. 15, from 7:30 to 9 p.m. at the Holmesburg Baptist Church, at Frankford Avenue and Rhawn Street, to discuss potential sources of contamination to the Delaware River.

The Delaware River Source Water Assessment Project (SWAP) is a public-private initiative facilitated by the Philadelphia Water Department.

The SWAP is designed to explore and understand the environmental challenges to the Delaware River watershed as a means to identify its existing and potential pollution sources to drinking water supplies.

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This meeting is an opportunity for individuals and organizations to become involved and to add their vision to the project.

For more information, call 215-685-4944. ••

Cannot identify source of this article. (Possibly News Gleaner)

Figure C:

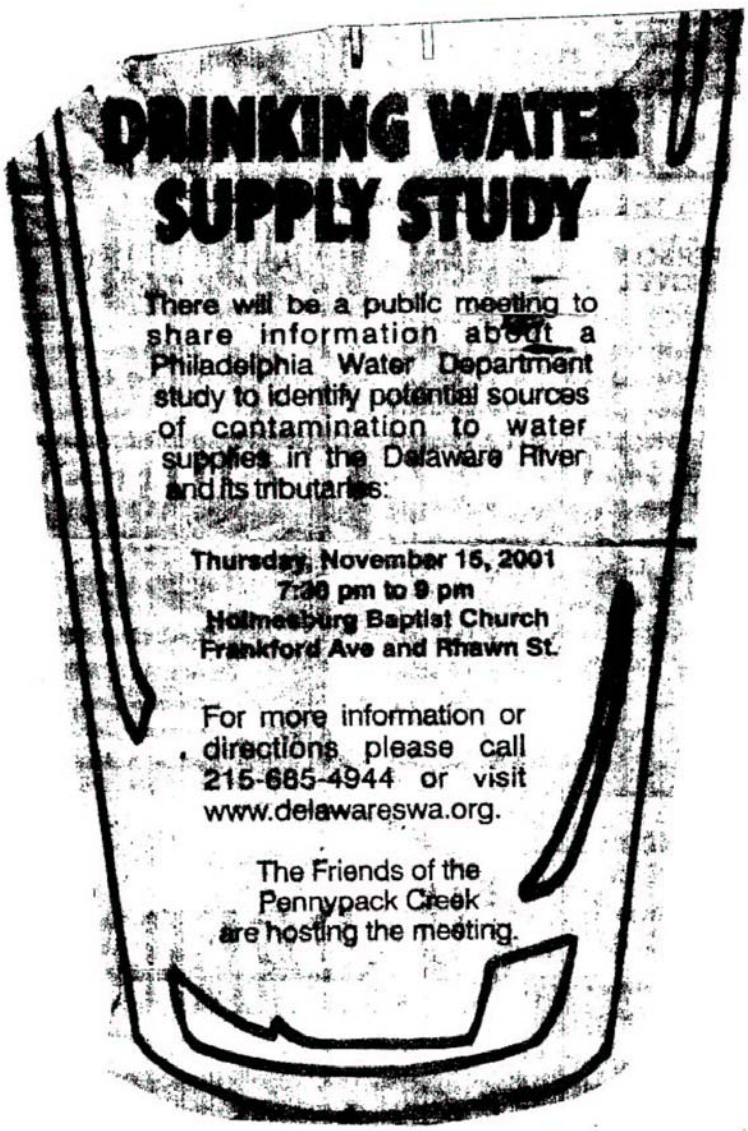
DRINKING WATER
SUPPLY STUDY
There will be a public meeting to share information about a Philadelphia Water Department study to identify potential sources of contamination to water supplies in the Delaware River and its tributaries:
Thursday, November 15, 2001
7:30 pm to 9 pm
Holmesburg Baptist Church
Frankford Ave and Rhawn St.
For more information or directions please call 215-685-4944 or visit www.delawareswa.org.
The Friends of the Pennypack Creek are hosting the meeting.

Figure D:

Drinking Water Supply Study

There will be a public meeting to share information about a Philadelphia Water Department study to identify potential sources of contamination to water supplies in the Delaware River and its tributaries:

Thursday, November 15, 2001
7:30 p.m. to 9 p.m.
Holmesburg Baptist Church
Frankford Avenue and Rhawn Street

For more information or directions, please call 215-685-4944 or visit www.delawareswa.org.

The Friends of the Pennypack Creek are hosting the meeting.

Figure E: *The Northeast Breeze,* December 6, 2001

Water Department to test quality of creeks

BY NICOLE CLARK
Staff Writer

Ever wonder what's floating in your drinking water before it's decontaminated?

At a recent meeting of the Friends of Pennypack Park, Christopher Crockett, an engineer and manager of the Philadelphia Water Department Office of Watersheds Source Water Protection Program discussed the Delaware River Source Water Assessment Partnership, also called SWAP, a new plan to identify existing and potential pollutants to drinking water supplies.

Funded through a grant from the Pennsylvania Department of Environmental Protection, the study will survey the Delaware River watershed, a 330-mile stretch of river encompassing 13,500 square miles of area and running through 42 counties. The watershed includes the Tookany, Tacony, Frankford and Pennypack creeks.

Crockett stressed our tap water is already safe. The survey's purpose is to make the water easier and less expensive to treat.

"These are not evaluations or indications of your drinking water quality or safety," Crockett said. "We evaluate it before it goes to the plant. We don't want you to get worried that water goes straight from the river into your glass."

Philadelphia, he said, is home to award-winning treatment plants and is one of the most aggressive cities in the country in ensuring water safety.

A public-private initiative comprised of regulatory agencies, water suppliers, watershed and environmental organizations, the Delaware River SWAP was implemented after 1996 amendments to the federal Safe Drinking Water Act passed in 1974.

In response to the public's desire to know more about water supplies and how to protect them, the amendments required state agencies and water suppliers to survey their drinking water sources for origins of contamination and to make the information public in annual Consumer Confidence Reports. The reports, which currently document the quality of tap water, were first published in 1998. Source water information will be the most recent addition.

Crockett said PWD was hired by the state rather than a private consultant because of its knowledge of the area. But the department still needs citizen input.

"It's simple things like calling in if you see (short) dumpers or oil spills," he said, "broken water mains or developers without fences allowing (pollutants) to fall in." Overflowing sewers and manholes, runoff and eroding streambanks are other targets.

The Pennypack Creek empties into the Delaware River behind the Baxter Water Treatment Plant, 9001 State Road. Baxter provides water to almost 60 percent of the city's population. The Belmont and Queen Lane water treatment plants supply the rest.

A watershed, Crockett said, is an area where rainwater runs off the land and drains into a river or creek. "Unit" watersheds, like the Pennypack, can make up a larger watershed, such as the Delaware River.

The protection plan's first step is to determine which areas drain into the surface water intakes. Those pull water from creeks or streams, not the ground. The Delaware River and its tributaries provide drinking water to about 17 million people, including those in New York

(Continued on page 21)

Figure E (continued): *The Northeast Breeze*, December 6, 2001

December 6, 2001 The Northeast Breeze 21

Water Department to test quality of Tacony and Pennypack creeks

(Continued from page 10) City, Trenton and Philadelphia.

A water quality data review will pinpoint exactly what lives in the water. "We'll be looking for trends," Crockett said. "Is the stream getting better or worse?"

Potential sources of contamination, such as gas stations, dry cleaners and parking lots, are everywhere. Through surveys, interviews with water suppliers and stakeholders, public meetings and water analysis, PWD will identify each one, then rank them according to hazard level.

Among the pollutants they'll be searching for are pathogens contained in sewage, livestock and wildlife waste, algal blooms that release non-harmful but fishy-smelling chemicals that must be treated with carbon, and nutrients from lawncare and golf courses.

Others on the list are metals and manganese created by acid mine drainage, chloride and sodium from highways and road salt, pesticides and herbicides used in lawncare products and agriculture methods, MtBE, a gasoline additive leaked from cars and watercraft, and natural elements in the river, such as bromide, that can chemically react with other elements to create potential cancer-causing compounds.

Once those spots are identified, a protection plan will be developed. The hope is that neighborhood organizations will hold meetings and workshops to educate people on issues such as safer alternatives to road salt and how to properly use lawncare products. Crockett said groups could also acquire grants for water protection by incorporating projects approved in SWAP plans.

The state deadline for PWD's draft report on the Baxter plant's supply is April. Crockett said he will probably return to a meeting of the Friends of Pennypack Park in winter to report the plan's progress.

If you would like to provide PWD with information regarding pollution in the Delaware River watershed, call Christopher Crockett at 215-685-6234 or email him at chris.crockett@phila.gov. More information and an opinion survey are available at www.delawareswa.org.