DURHAM TOWNSHIP ENVIRONMENTAL ADVISORY COUNCIL

Cooks Creek Watershed Monitoring and Planning Program

Cooks Creek Watershed Conservation Plan

Bucks County, Pennsylvania

Funded through a grant from Pennsylvania Department of Conservation and Natural Resources

Prepared by

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with the assistance of

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A CASE FOR PROTECTION OF THE COOKS CREEK WATERSHED

A recent USGS publication stated, "As the Nation's concerns over water resources and the environment increase, the importance of considering groundwater and surface water as a single resource has become increasingly evident" (T.C. Winter, USGS -- Water Resources of the United States – Circular 1139). This certainly applies to the existing and future water supply and water quality issues in Pennsylvania. Whether the concern is source-water protection, drought management, wetland preservation, in-stream aquatic habitat, spring-water withdrawals, or total maximum daily loads (TMDL), an understanding of the interactions between groundwater and surface water is needed for resource management.

The issues surrounding growth patterns and overall water resources are not limited to municipal boundaries. The Pennsylvania Municipalities Planning Code enables water resources to be integrated into the overall land use and land management schemes. Individual municipalities within the Cooks Creek area (and elsewhere) have not been able to technically cope with matters that extend beyond their respective jurisdictions.

The geographical scope of the Cooks Creek Rivers Conservation Plan must be watershed-wide considering all aspects of water resources including: aquifers, quality and quantity, water supply, wastewater, and stormwater. It is the objective of this study to build on prior knowledge and formulate a resource management capability that sustains these resources for future use. Due to the unique and sensitive nature of the Cooks Creek system, it is important to manage and protect the creek, aquifer, springs, and wetlands as a whole. A holistic or watershed-based management approach is needed to address these concerns.

Watershed analysis is a unique approach that provides the basis for a sound understanding of watershed conditions and management options. Independent components influence watershed conditions, such as geology and climate. Within the confines of a watershed, the specific site geology may control vegetation, soils, hydrology, and stream morphology. Climate affects each of these variables, which in turn may affect watershed conditions. As land use and water consumption increase, the influence of man on the environment and watershed will be more profound and immediate.

In order to facilitate a holistic management plan, existing conditions within the Cooks Creek Watershed have been evaluated. Included in the evaluation were studies related to surface water quality, stream bank conditions and characteristics, groundwater availability and flow, geology, hydrogeology, and soil characteristics and types. A review of previous studies and assessments was also conducted.

The geology, hydrogeology, and soil study results were used to develop a management plan with respect to water use, stormwater and wastewater management, and to provide guidance for future development within the watershed.

Funded through a grant from Pennsylvania Department of Conservation and Natural Resources

Foreword

This Watershed Conservation Plan (WCP) is a compilation of numerous studies that have been conducted within the Cooks Creek watershed. These studies include: geologic and wetland surveys, well water level monitoring, stream gauge data collection, water quality chemistry, bioassessment surveys, stream corridor evaluations, and GIS database development. This WCP references all these studies and the appendices to this report include the results of many of the studies performed. The notable exception being the results of studies performed in support of the *Wetlands Management Plan* that was prepared for the USEPA (published under separate cover). Those wishing to obtain a copy of the Wetlands Management Plan should contact the Durham Township EAC. This WCP was funded in part from the Community Conservation Partnership Program, administered by the Bureau of Recreation and Conservation, Pennsylvania Department of Conservation and Natural Resources. Special thanks to the members of the Cooks Creek Watershed Association, the Durham Township Environmental Advisory Council, and the Springfield Township Environmental Advisory Council who provided hundreds of hours of volunteer time toward the development of this Plan.

Executive Summary

Overview

This Watershed Conservation Plan is for the Cooks Creek Watershed, located primarily in the Townships of Durham and Springfield, Bucks County, Pennsylvania. This plan is based upon several years of intensive research and analysis of watershed conditions and was developed to provide the basis for plans and ordinances that will protect the resource value of the watershed for the residents of the area. A list of recommendations has been prepared to implement this plan consistent with the results of these studies.

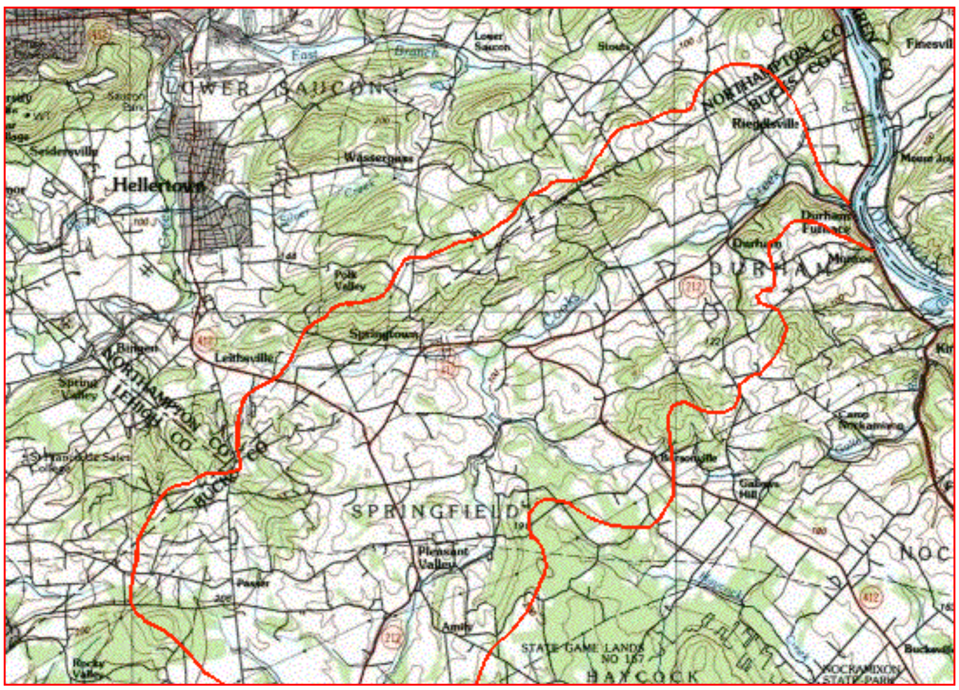

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Figure ES1 - Cooks Creek watershed area.

The Cooks Creek Watershed is located in upper Bucks County, Pennsylvania and is a tributary to the Delaware River. Approximately 40 miles of stream corridor drain about 30 square miles of terrain primarily in the townships of Durham and Springfield, but also including small portions of

Haycock and Richland Townships, as well as Upper SauconTownship, Lehigh County and both Lower Saucon and Williams Townships, Northhampton County.

The Cooks Creek Watershed corridor is comprised of scenic hills, valleys, and open areas where the waterways flow. Cooks Creek has a diverse watershed corridor. The watershed corridor is comprised of broad open valleys, valley bottoms, and gentle stream gradients dictated by the underlying geology of the area. Land use is primarily residential and agricultural, providing for a scenic and bucolic setting.

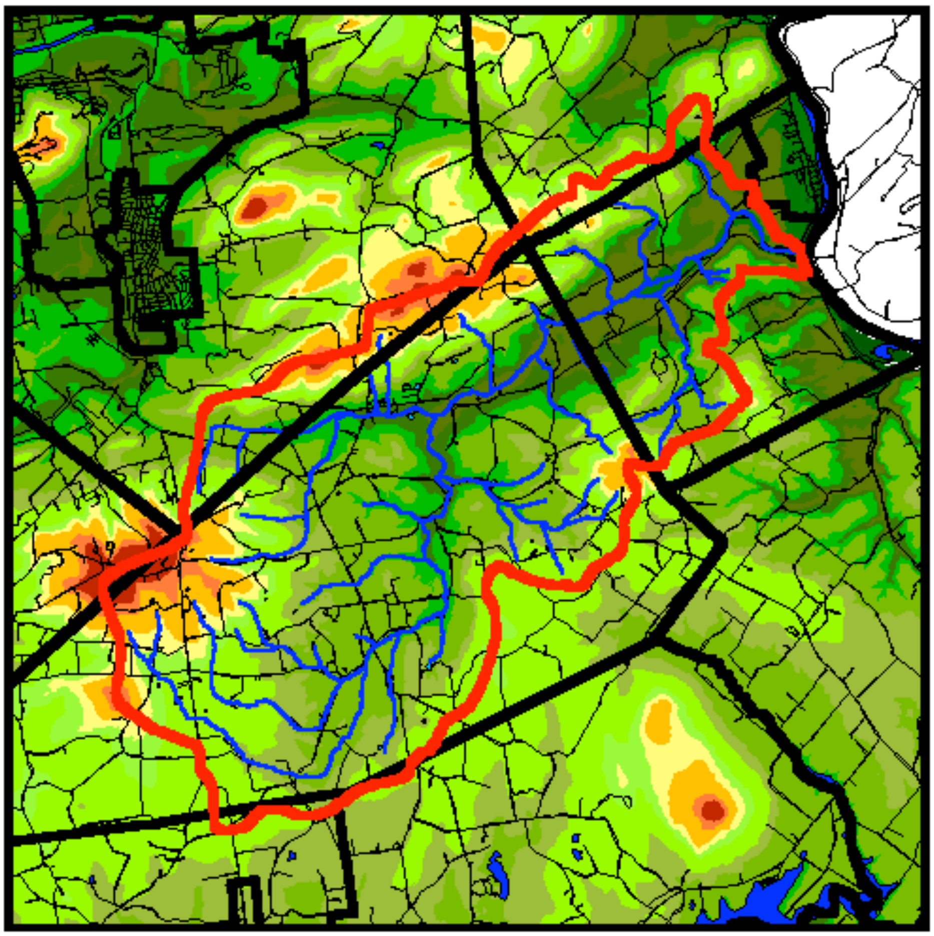


Figure ES2 – Watershed Topographic Map

Cultural/Historical

The Cooks Creek Watershed, positioned as it is in upper Bucks County, is an area steeped in colonial history. There are numerous colonial period homes, public houses, and inns still surviving and both Durham and Springfield Township have active historical societies. The Durham Iron Works and Mine in Durham Furnace, provided pig iron and iron products for the colonies and armaments for the Revolutionary Army. The mine entrance and airshafts on Mine Hill are still easily seen. In fact, the mine provides a refugee for the endangered Indiana Bat, resulting in the entrances being blocked to the public in 1995. The Durham Gristmill stands on the site of the original Durham Furnace, and is a fine illustration of the importance of waterpower to the colonists. Cooks Creek was diverted using a system of wing dams and raceways, still being maintained by Durham Township. The mill itself ceased operations only in recent years (1960s) but is no longer operational. Plans are in place to restore the building and water wheel. In addition to the iron, the area was well known as a good source of lime for agricultural purposes, and numerous limekilns, in various states of disrepair, can be found throughout. Although historically, the pervasive network of tributaries resulted in a host of covered bridges being built, only one of these quaint structures still remains. Fire and flood have taken their toll, but the Knecht's Bridge off Slifer Valley Road in Pleasant Valley still provides a touch of historic class to Springfield Township.

Geology

The geology of a region, while predominantly unseen, is the foundation for all the natural resources. Soils, groundwater, surface water and through these the flora and fauna of a region are all dictated on a fundamental level by geology. The underlying geology of the Cooks Creek Watershed is primarily of three types: crystalline (granite and schist) in the ridges to the north and south, diabase (red shale) in the headwaters, and a carbonate (limestone) central valley.

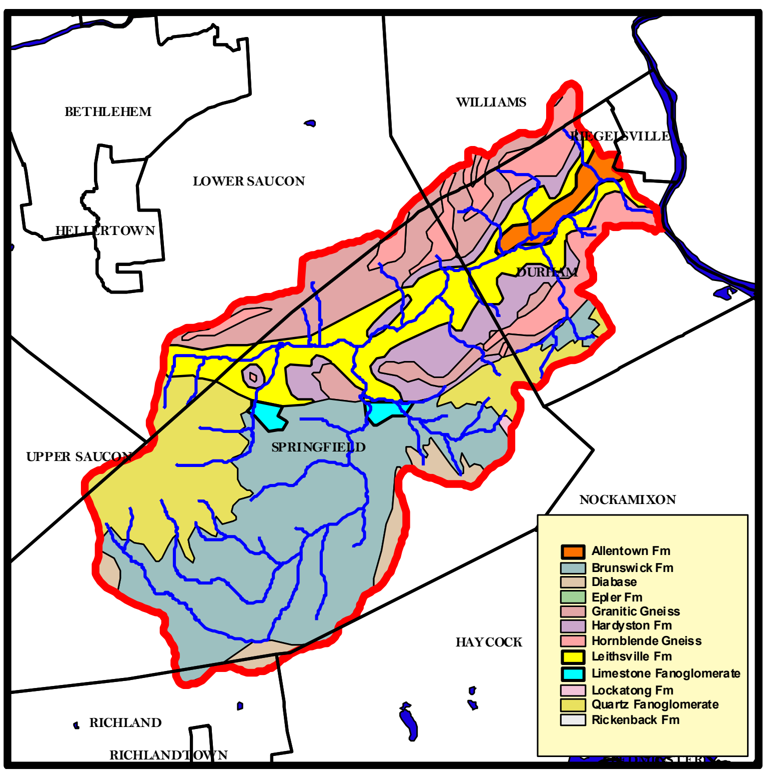


Figure ES3 – Geology Map.

In order to fully understand the geology of the Watershed, professional geologists were commissioned to study the area. The geologists used a combination of aerial survey and field confirmations to develop geology overlays and three dimensional model depictions of the major geologic units.

The geologic units of the entire watershed were grouped into four geologic categories:

- Category I: Diabase
- Category II: Brunswick and Lockatong Formations; and Quartz Fanoglomerates
- Category III: Carbonate Rocks including Allentown and Leithsville Formations and Limestone Fanoglomerates
- Category IV: Crystalline Rocks including Hardyston Formation and Gneiss Formations

These classifications were used in determining groundwater contributions to the baseflow of the basins and/or sub-basins within the watershed. Sub-basins are the drainage areas of various tributaries to the main stem of Cooks Creek Watershed. This ranking of sub-basins was necessary for extrapolating water production yields from each sub-watershed area. This information was used to assess water balance and groundwater resource evaluations.

Hydrology

The unique geologic characteristics noted above dictate the surface water hydrology of the Cooks Creek Watershed. The 37 miles of Cooks Creek and its tributaries drain a watershed that is 30 square miles in size, approximately 9.5 miles long and 4 miles wide. Cooks Creek flows 18 miles in a southeasterly direction from Flint Hill to the Delaware River with a vertical elevation drop of 625 feet.

The watershed headwaters are primarily in the western portions of Springfield Township, where large, flat open farm fields are punctuated by springs. Emergent wetlands surround the streams, indicating their location to the observant and protecting the minute flows that eventually gather to become the Cooks Creek. The streambed in this area meanders through farm fields or mature secondary growth forests of oak, ash and walnut. Along the northern and southern boundaries of the watershed are the crystalline ridges of Buckwampum Hill, Mine Hill, Flint Hill and Steely Hill. Springs punctuate the ridges, bursting forth where the plates of limestone and crystalline rocks meet and rushing down to the limestone valley through mature hardwoods, often with steep slopes. Due to the small size of the watershed, however, none of these tributaries is very large, rarely exceeding 4 feet in width. Two (2) of these tributaries are of special note: Silver Creek in Springtown and Coon Hollow Run in Durham.

Understanding the hydrology of Cooks Creek was seen as a priority to being able to protect the stream's Exceptional Value (EV) status. There is a finite amount of water in the watershed, and a theoretical minimum required for the sustenance of the Creek, both for its beauty and as habitat for wildlife. The water in the Creek comes from two sources: storm water/snowmelt runoff and groundwater. While weather plays its hand as far as runoff is concerned, the groundwater comes from springs and seeps and is virtually continuous. This flow is termed the *baseflow*, and is the most important hydrologic characteristic of the watershed.

In order to better understand the hydrology of Cooks Creek, the United States Geologic Survey (USGS) had installed a stream flow monitoring station, or stream gauging station at Red Bridge Road in Durham, but it was abandoned in 1993. The Durham Environmental Advisory Council (DTEAC) obtained the stilling well in 1995 and reactivated it with new equipment in May of 1999. The DTEAC plans to continuously monitor the flow in Cooks Creek for 10 years to better understand the baseflow of the Creek through development of a Q_{7-10} statistic. The Q_{7-10} is a hydrologic statistic representing the weekly average of the lowest flow expected during a 10-year period. This statistic has legal precedence for its use in the establishment of planning parameters for baseflow and wellhead protection. In addition to this station, which effectively monitors the entire watershed, a second station above the confluence of Silver Creek in Springtown is planned in order to more effectively characterize the diabase/sandstone headwaters portion of the watershed.

Groundwater hydrology or hydrogeology is the linkage between the geology and the groundwater of a watershed. As mentioned above, Cooks Creek is a complex, interdependent system that relies on groundwater for its baseflow. It is absolutely necessary to understand these linkages and the linkages between hydrogeology and hydrology fully before one can truly manage the available resources to ensure that there is adequate high quality drinking water for citizens as well as water for sustaining Cooks Creek.

To better understand the amount of water in the aquifers of the Watershed, DTEAC commissioned a field study to develop a groundwater contour map. This map is a synoptic picture of the groundwater level as measured through drinking water wells.

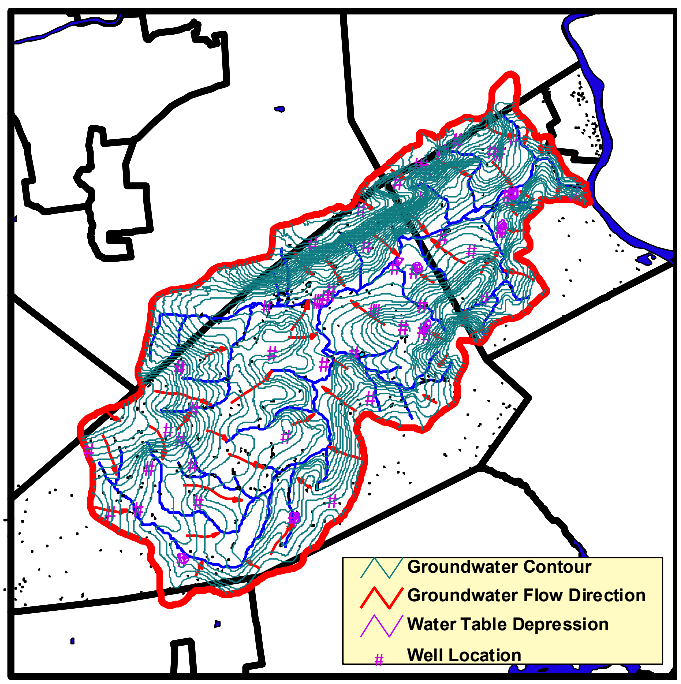


Figure ES4 – Groundwater Contour Map.

Over 75 wells were surveyed in this study and a contour map developed. In order to understand how the aquifer responds over time, several locations throughout the area were monitored for water level on a monthly basis. This "dynamic range" illustrates how the aquifer responds to use and rainfall. When combined with data from the stream gauge, a complete picture of the hydrologic system of the watershed begins to appear.

It appears that current water withdrawals are not jeopardizing the baseflow of the Creek. However, additional modeling studies currently underway will enable managers to determine the amount of groundwater available for development that will not jeopardize this baseflow. It is important to note here that these calculations are based on assuming that water quality conditions remain constant. If water quality continues to be threatened by nutrients and erosion, additional baseflow may be needed in the Creek in order to maintain the necessary water quality during periods of low flow.

Water Quality

Cooks Creek boasts good to excellent water quality, a diverse macro-invertebrate benthic community, and a Class A wild brown trout (*Salmo trutta*) population. In addition, tributaries to Cooks Creek support both Class A wild brown trout populations and Class A native brook trout (*Salvelinus fontinalis*) populations. The entire Cooks Creek drainage basin is classified as an *Exceptional Value (EV) coldwater fishes (CWF)* waters. These standards are based upon the health of the biological communities present in the stream, the natural resources, and the scenic beauty of the watershed as well as the recognition of the local community as to their inherent value. Special status is granted only by petition to the Environmental Quality Board of the State of Pennsylvania.

The watershed is not without water quality issues, however. A literature search and a field survey revealed that both suspended sediments and nutrient runoff have contributed to apparent stress in various locations throughout the watershed. While the data collected to date do not indicate a definitive management action, they do indicate the need for a more detailed investigation into the reasons for their presence and to suggest appropriate management action.

Land Use

Land use issues are directly linked to the ways in which human impacts effect the hydrologic system of the watershed. Land use in the watershed varies tremendously from open unused forested lands to intensively residential village centers. One way to manage the diversity in this system is to divide the watershed into sub-watersheds based on tributaries. The Cooks Creek Watershed includes a total of 40 sub-watersheds. It is these watershed units that must be understood in order to maintain water quality and quantity in the watershed. Hydrologists will be using these sub-watersheds as the modeling of our watershed continues in the next several years. However, considerable effort must be made to better understand current land us and to characterize the land use in each of these sub-watersheds. In addition, the comprehensive plan and zoning ordinances should be developed utilizing the sub-watershed system to incorporate the results of this study in the most effective manner.

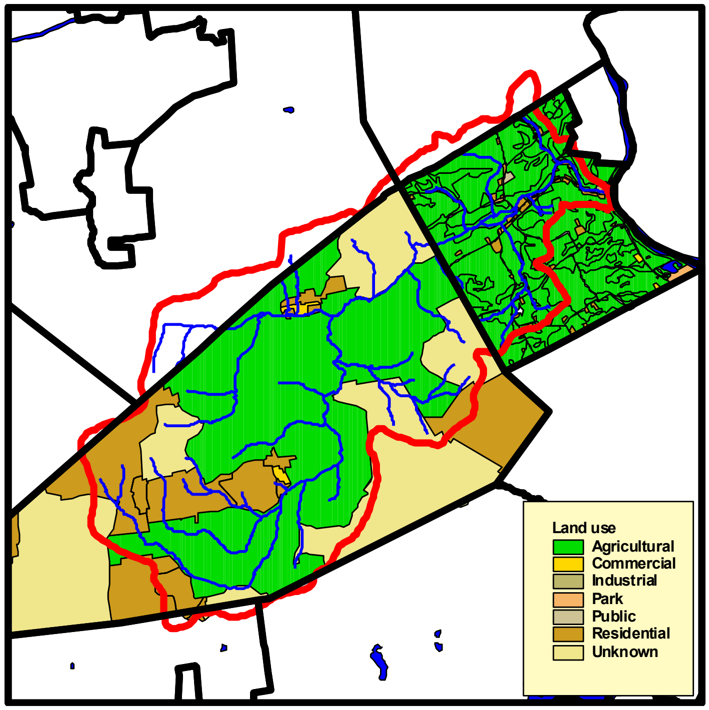


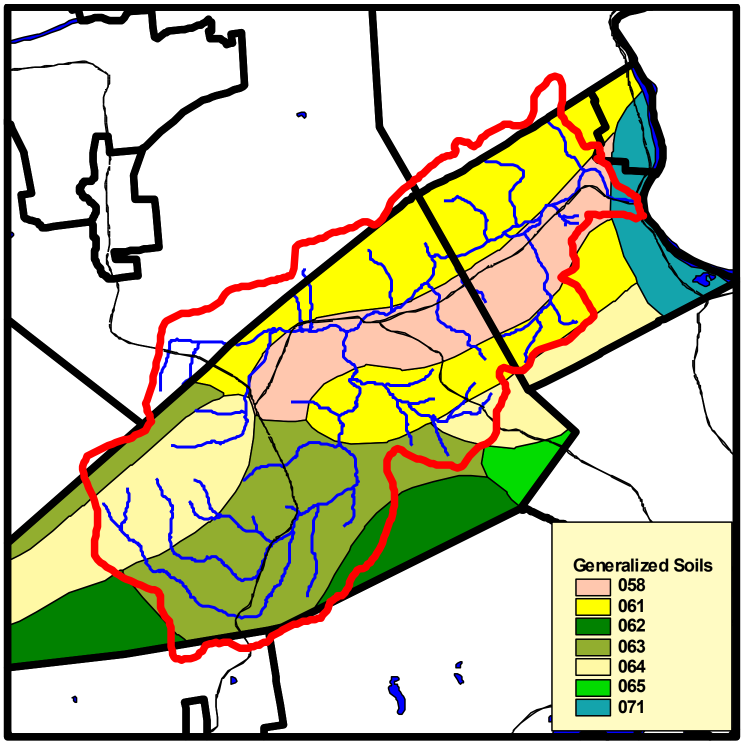
Figure ES5 – Existing Land Use Map.

While both Durham and Springfield townships have progressive land use regulations that take resource protection into account, these documents are outdated and have relatively weak scientific underpinning. There is an immediate need to bring the Comprehensive Plans and Zoning Ordinances up to date in both townships. This need has been recognized and is currently being acted upon. This Watershed Conservation Plan, and the information it contains, is envisioned to be an invaluable asset in the process of updating these documents.

Soils

The Cooks Creek Watershed boasts some of the finest agricultural soils in Bucks County, with over 65 % of the land considered prime agriculture. In addition, included are some highly sensitive shallow forest soils along the higher ridges as well as poorly drained hydric soils in the lowlands.

Soils are the link between the underlying geology and the surface features such as topography, stream morphology, surface water hydrology, vegetation, and land cover. Soils are not only the primary resource governing plant communities and agricultural productivity of the watershed, but they also control the permeability of surface runoff and are instrumental in recharging the groundwater that sustains the Cooks Creek. Soils also provide a critical biological filter for pollutants such as pesticides, hydrocarbons and nutrients that are the main threats to water quality.



3 ***Figure ES6 -*** *Generalized Soils Map for the Watershed.*

Three main generalized soil groups exist in the Cooks Creek Watershed. These groups are:

- Deep soils that have a medium-textured surface layer and a medium textured or moderately fine-textured subsoil. (Associations: Allenwood Chester (061 and 064) , Duffield-Washington (058), and Towhee-Neshaminy-Mount Lucas (062));

- Deep soils that have a medium-textured surface layer and a firm friable, but mainly firm and compact, subsoil; shallow to deep over shale or sandstone. (Associations: Abbottstown-Readington-Reaville (065) and Penn-Klinesville (063)); and,

- Deep soils that have a medium-textured surface layer and a medium-textured or moderately coarse-textured subsoil (Association: Alton-Pope (071)).

Recommendations and Management Options

The overall goal of this Cooks Creek Watershed Conservation Plan is two fold: 1) to formulate a management program that truly sustains water resource through utilization of Best Management Practices (BMPs) and 2) to highlight those characteristics or critical issues in the watershed that require further study. This can be achieved through projects conducted in cooperation with watershed associations, agricultural organizations, various governmental agencies and others. Management options will include maintenance, enhancement and restoration activities. The following management options and recommendations should be considered for protecting, enhancing, and preserving the Cooks Creek Watershed resources:

1. Develop a Water Management Plan

Using data developed from ongoing and future studies, develop a Sustainable Watershed Management Plan that provides for wellhead and baseflow protection in the Cooks Creek Watershed.

2. Monitoring Cooks Creek Flow

The critical baseflow condition $Q_{7\text{-}10}$ values are used in the Water Balance Model. The $Q_{7\text{-}10}$ has not been collected from the Cooks Creek Watershed using data from a ten-year period. Less than four years of data have been collected for this calculation. This equation requires the collection and use of 10 years of data, therefore, continued monitoring of the "Red Bridge Road" bridge location gauging station should be conducted to obtain the additional data required. The following maintenance actions should be conducted:

- *Maintenance of Red Bridge Gauge* – Continue to maintain and periodically download the computer at the Red Bridge Road monitoring station and upload into WAMOS;

- *Maintenance of the Rating Curve for the Red Bridge Road Gauging Station*. The Rating Curve requires annual riverbed profile measurements and periodic stream velocity measurements; and,

- *Install a Second Stream Gauging Station* – A second stream gauge station should be installed in the eastern edge of the watershed. Preferably this station should be upstream of the confluence of Silver Creek with the main stem of Cooks Creek, in the village of Springtown.

3. Monitoring Aquifer Levels

Water levels should be measured monthly at 4 to 6 residential wells. This data is used in groundwater storage and water budget calculations in WAMOS computer interface.

4. Generate an Upgraded Water Table Map.

In this study approximately 75 residential wells were utilized to establish the water table map. An additional 30 residential wells are suggested to measure for depth to water to upgrade the water table map.

5. Expand the GIS Database

As more watershed related data becomes available, expand and incorporate all data into GIS and computer applications. Train municipal officials in the use and maintenance of GIS databases. Develop and maintain current land use maps.

6. Continue to Develop the Hydrologic Database managed using the computer interface WAMOS

As more hydrologic data becomes available, continue to incorporate, expand, and enhance the hydrologic database and facilitate its use in planning activities.

7. Develop a Nutrient Management Plan

Low level, chronic nutrient pollution has been observed in the watershed and has been shown to impact water and habitat quality. Perform a comprehensive nutrient balance to determine the sources and causes of nutrient enrichment in the Cooks Creek Watershed. Use this information to pinpoint appropriate management actions.

8. Develop a Township Level Storm water Management Plan

Extremely local erosion problems have been observed contributing to siltation in the streambeds. Given the sensitivity of the wildlife and fisheries of the watershed these problems should be carefully examined and controlled, if possible. Although a county-wide storm water management plan exists a specific township level plan should be developed to determine the locations and magnitude of storm water runoff in the watershed. Monitor erosion throughout the watershed and determine its causes. Develop a plan to manage both storm water and erosion and determine appropriate management actions.

9. Develop a Comprehensive Biological Inventory

Considerable biological resources exist in the watershed. In order to monitor the success of this plan and to alert officials to any future problems, work with local watershed groups to establish and monitor the health of the biological resources of the watershed including but not limited to:

- Fish population surveys;
- Rare and endangered species (flora and fauna);
- Wetland plant inventory;
- Bats of Mine Hill; and,
- Benthic invertebrate diversity and health.

10. Expand and Maintain a Water Quality Monitoring Program

In order to expand water quality monitoring information and track improvement, the following community programs should be encouraged:

- Stream Watch Program (Philadelphia Academy of Sciences program or equivalent);
- Nutrient Survey and Management Plan; and,
- Visual assessment (Delaware River Basin Commission method or equivalent).

11. Educational Activities

Educational programs are necessary to change misconceptions regarding watershed resources and to encourage future protection and enhancement of Cooks Creek Watershed. The following educational programs or forums should be considered:

- Water Quality Seminars for Local Government Officials:
    - Maintaining current or limited ground water levels in order to protect against excessive groundwater drawdown that would result in adverse effects to wellheads and stream baseflows;
    - Suitability of soils for on-site septic systems including:
        - Soils feasible for conventional systems;
        - Soils feasible for alternative systems;
        - Soils not feasible for any type of on-site system;
        - Carbonate derived soils, not feasible in Bucks County for any on-site system; and,
        - Soils subject to flooding, not feasible for any on-site systems.
    - Minimization practices for point and non-point source pollutants; and
    - Improving riparian buffer management along tributaries.
- Public Workshops
    - Public awareness of non-point source pollution;
    - Implementation of animal nutrient management plans;
    - Improving farming practices especially with respect to livestock stream crossings and stream corridor livestock fencing initiatives; and,
    - School outreach.

12. Riparian Buffer Improvements

A complete assessment of current stream bank conditions should be conducted to determine priority sites within the watershed requiring riparian buffer enhancements. Riparian buffer improvement and management programs should be employed.

13. Ordinances and Planning Documents

Update the Comprehensive Plans for both Durham and Springfield Townships. Include the data in this plan, and referenced studies. Work to ensure that water quality and quantity are sufficient to support local vision for the future of the watershed.

The following critical areas should be considered for zoning ordinance and Comprehensive Plan preparation:

- Storm water management and erosion control;
- Wetlands protection;
- Baseflow protection;
- Conservation easements and open space;
- Endangered and/or threatened species habitat protection;
- Karst and sinkhole land development standards;
- Overlay districts of critical areas (first order sub-basins; wetland buffers; riparian (flood plain); and, lakes and ponds);
- Septic systems types based upon soil districts;
- Steep slopes;
- Stream or riparian buffers; and,
- Wellhead protection.

I. HISTORY

Durham Township

Durham Township comprises 6,410 acres and is one of the smallest of the 31 townships of Bucks County. It is located in the extreme northeast corner of the county. It is bounded northwest by Northhampton County, northeast by the Delaware River, southeast by Nockamixon Township, and southwest by Springfield Township.

Prior to its establishment as a township on June 3, 1775, it was a quasi-organization known as the Durham Tract. This land tract shares virtually the same boundary lines of the township today. Evidence points to settlement as early as 1698. Durham Tract was populated faster than surrounding counties due to the iron deposits located in the Durham Hills. Even though this area was growing at a fast pace, private ownership of the land by Durham Iron Company hindered its development into a “township”.

It was not until 1727 that a blast furnace was erected in the village of Durham. Power for the furnace was derived from the nearby Durham Creek. This historic landmark is preserved at the Mercer Museum in Doylestown, Pennsylvania. The Iron Works provided cannon shot for the Provincial government, presumably for the French and Indian War. The Continental Army was also supplied shot shells and cannon from Durham. The great chain stretching across the Hudson at West Point in the Revolution was made here. Each link weighed 250 pounds.

Little is know about the operations at Durham Iron Works. It began operations sometime in 1727 and on December 24, 1773, the owners of the company decided to partition the land. The partition divided the land into forty-four (44) tracts. One tract included the Durham Furnace itself and was apportioned to Joseph Galloway, his wife Grace, and daughter of Lawrence Growden. Mr. Galloway leased the iron works to George Taylor, who operated it from 1774 until 1780. During this time, Galloway had become the leader of the Tory side of the movement opposing Independence, and promptly sided with the British. He was accused of treason; his properties were seized and sold in 1779 to Richard Backhouse. Mr. Backhouse and his associates operated the furnace from 1780 through 1789. Thereafter, the furnace was not in operation and was sold to Judge William Long in 1819. The original furnace was demolished and replaced by a gristmill, which still stands.

In 1847 Joseph Whitaker and Company purchased the remaining 894 acres of the furnace tract. They built two (2) new blast furnaces located near the mouth of Durham Creek where it empties into the Delaware River. This company produced mainly pig iron and shipped their product by water and by train from Riegelsville, NJ. In 1864 the Whitakers sold the property to Edward Cooper and Abram Hewitt. Mr. Cooper was an engineer and inventor, who designed the hot blast stoves, double bell and hopper used at Durham.

After only 17 months, the property again changed hands and was deeded to Lewis Lillie & Son of Troy, NY. Lillie & Son then transferred their safe making operation to Durham. They enlarged the plant and derived power by damming the Durham Creek and digging a mile long race. Lillie & Son continued operating both blast furnaces in conjunction with local mines and quarries. Financial difficulties led to the take-over by creditors who operated the company under the name of The Lillie Safe and Iron Company. The Company was later sold to its previous owners, Cooper and Hewitt, on October 1, 1870. The new owners modernized the plant and added two (2) new blasts.

On December 27, 1901, the property was transferred to Col. John Jamison and Aaron F. Baker, who transferred the property in one (1) week to the newly chartered Durham Iron Company. This Company was in operation for approximately 7.5 years, prior to shutting down on June 23,1908. The plant was dismantled in 1912 and the real estate was later divided and sold. The history of the Durham Iron Works spanned 181 years, including suspensions. This company took its place in history from supplying shot in the Revolutionary War to discovery and invention of new metallurgy processes.

Other early industrial efforts throughout the region directly related to the agricultural economy. Scores of gristmills and sawmill operations were erected along the streams of the county that provided the necessary power for the mills. The great abundance of forests provided a natural lumber resource. The lumber was shipped downstream, where shipbuilding became an important industry in Philadelphia and other cities along the Delaware River. Robert Durham built the first Durham Boat in Durham Township, which was used to ship the iron product to Philadelphia. He is also credited with building the ship George Washington used in his famous crossing of the Delaware.

Durham Creek flows through the valley and is bounded on either side by high hills. There is a gradual ascent to the hills that permit cultivation of the land. There have been frequent discoveries of Indian relics in this area, suggesting the early occupation of the American Indian race.

The "Old Durham Furnace School", erected in 1727, was the first school built in the Upper Bucks area. Children met in this small log house, located on the east side of the road leading from Easton to Philadelphia, approximately 100 yards north of Durham Creek. Many other schools were then built in the area, including the present-day Durham School built in 1865. The original school consisted of 2 rooms. In the 1920's, two (2) more rooms and an all-purpose room were added.

Springfield Township

Springfield Township lies in the extreme northern area of Bucks County and borders Northampton and Lehigh counties, along Route 212. It is one of the largest and one of the least populous townships. In the southeastern portion of the township, the Indians settled a considerable hill, called "Buckwampum". In this area near Stony Point, a great number of arrowheads and Indian implements have been found.

In 1735, William Penn's sons sold about 4,000 acres of their best land in southeastern Pennsylvania by lottery. These acres became known as the Lottery Lands of Springfield Township. Persons of German descent almost exclusively purchased the lottery tract. It is one of the last townships to be organized. It is assumed the early settlers found their way to this area during the time of settlement of the Durham Tract. Durham was an English settlement and the first purchasers of land in Springfield were of the same descent. It is recorded that some English settlers reached this area through the “Swamp” and “Richlands”. The Germans followed the same route. Springfield Township is a valley where immigrants up the Delaware and Perkiomen Rivers met.

The earliest purchase of land in this area was in 1737, although settlers were in the area prior to this time. The land consisting of 651 acres on Cook’s Creek was patented to William Byran.
One of the first German settlers, George Bachman, purchased 213 acres at the branches of the Tohickon and Saucon Creeks in the northwest part of the township. One of the oldest dwellings in the township can be dated to 1738.

A prominent citizen of Springfield Township was the Reverend A.R. Horne (1834-1902). The Reverend established the Bucks County Normal School at Quakertown, and remained in charge for five (5) years. He established *The National Educator* and was the proprietor and editor.

On June 16, 1743, the settlers of Springfield petitioned the court to permit their settlements to be “comprehended in a new township”. The township was then surveyed and laid out immediately after this petition was filed. At this time there were 56 “dwellers”, presumably heads of families. Springfield was given its name due to the vast number of springs and seeps that gushed out of its hillsides that formed brooks and creeks. The original boundary of the township did not extend quite to the line of the two Saucon Townships. The intervening strip of land was left between these three townships. This area was later added into Springfield Township borders, which closely resemble its borders today.

The first gristmill in Springfield was built by Stephen Twining in 1738. In 1861 Springfield’s public school system was operational, comprising eleven (11) schools. The Springfield Church, known as Trinity, Reformed and Lutheran was established prior to 1745 and is one of the oldest in the northern townships of Bucks County. The first house was built of logs and served as both church and schoolhouse. The Mennonite congregation in Springfield built their first meetinghouse in 1780.

Several roads in Springfield were constructed dating to 1742. These roads connected key areas both in and around Springfield. Key areas included: Bethlehem, Houpt’s mill, Durham, Strawns Tavern, and Fretz’s gristmill. It is thought that the “Indian Walk of 1737” passed through Springtown. The post office was established here in 1823, with Joseph Afflerbach appointed as postmaster.

Today Springfield boasts many historic landmarks including: Springtown Hotel, Springfield Union Church, Liberty Bell Trolley, Pleasant Valley Bridge, and Pleasant Valley Grist-Mill.

Information gathered from various resources was used to create a map of the locations of historic significance throughout the watershed (Figure A). Current records reflect that:

- 186 historic places or agricultural resources are located within Springfield Township;
- 13 historic places or agricultural resource areas worthy of further study are located within Durham Township;
- 19 sites within the watershed are eligible for placement on the National Register;
- 2 sites are National Historic Landmark sites; and,
- 15 sites are suggested for further study for their potential historical or cultural significance.

Several scenic roadways (19.5 miles) are also present within the watershed. These are also shown on Figure B.

Numerous colonial period homes, public houses, and inns still survive in both Durham and Springfield Townships. The Durham Gristmill stands on the site of the original Durham Furnace, and is a fine illustration of the importance of waterpower to the colonists. Cooks Creek was diverted using a system of wing dams and raceways, still being maintained by Durham Township. The mill itself ceased operations only in recent years (1960s) but is no longer operational. Plans are in place to restore the building and water wheel. In addition to the iron, the area was well known as a good source of lime for agricultural purposes, and numerous limekilns, in various states of disrepair, can be observed. Although historically, the pervasive network of tributaries resulted in a host of covered bridges being built, only one of these quaint structures still remains. Fire and flood have taken their toll, but the Knecht's Bridge off Slifer Valley Road in Pleasant Valley still provides a touch of historic class to Springfield Township.

II. PROJECT AREA CHARACTERISTICS

Location

Cooks Creek Watershed is located in southeastern Pennsylvania, between 40 ° 23' 13.90" and 40 ° 3 6' 24.20" north latitude and 75°11' 50.40" and 75°20' 57.00" west longitude. Cooks Creek is a tributary to the Delaware River and is located primarily in the northern part of Bucks County (Figure 1). Most of the watershed areas are located in Springfield (70.29%) and Durham (19.39%) Townships. Small portions of the watershed are located in the neighboring Townships of Richland (0.72%), Haycock (0.21%), and Riegelsville Borough (0.03%). Minor portions of the watershed basin are also located within Lehigh County (Upper Saucon Township, 0.28%) and Northampton County (Lower Saucon Township, 6.83% and Williams Township, 2.25%). The watershed has a vertical elevation drop of 625 feet from the headwaters to its confluence with the Delaware River.

Size

The stream originates along the southern slopes of Flint Hill in Springfield Township. Cooks Creek flows approximately 18 miles in a northeasterly direction to its confluence with the Delaware River at Durham Furnace. The entire Cooks Creek basin, including its 37 miles of unnamed tributaries, drains approximately 30 square miles of predominantly private lands.

Topography

The watershed is approximately 9.5 miles long and 4 miles wide with an elevation ranging from 140 feet above mean sea level (MSL) at the mouth to approximately 1,000 feet above MSL on Flint Hill along the northern boundary with Lehigh County. Approximately 36 % of watershed is too steep (15% or greater) for development according to the Bucks County Conservation District criteria.

In order to better understand the unique topographic characteristics of the watershed Figures 2, 3, and 4 have been prepared. Figure 2 presents the topographic contour map of the region. This map was digitized and compiled from the Riegelsville, PA-NJ, 1990, Hellertown, PA, 1992 Quakertown, PA, 1973, and Bedminster, PA, 1990 USGS 7.5 minute Quadrangle Maps. Figure 3 was developed to easily identify elevations within the watershed utilizing a Digital Elevation Model (DEM). Figure 4 illustrates the main tributaries of the Cooks Creek Watershed and the drainage pathways of the tributaries, utilizing hill-shaded rendering data. This presents a three-dimensional image of Cooks Creek Watershed, by simulating the sun on the northern horizon casting shadows on hills and valleys.

Major Tributaries

The Cooks Creek Watershed includes a total of 40 sub-watersheds that were delineated by the outline of the drainage basin divides pattern (Figure 5). Figures 5-1 through 5-7 present sub-basin identification information. The *stream order* of these sub-watersheds are important to note, as *first order* sub-watersheds account for 66% of the land surface in Cooks Creek Watershed. Based upon the geologic sub-basins, *first order* stream regions (Area 1, Area 3, Area 4, Area 6, and Area 7) and all higher order stream regions (Area 2 and Area 5) were established in this study (Figure 6.1 and Figure 6.2).

A *first order* stream is the original headwater tributary that flows from a spring or seep. This area is usually the steepest portion of the watershed and therefore can be severely impacted by the loss of vegetation. A perennial stream that flows year round is considered a *first order* stream, while an ephemeral or temporary stream (i.e., storm flow channels etc.) is not. When two *first order* streams converge, they form a segment known as a *second order* stream. Two *second order* streams merge to form a *third order* stream, and so on. *First* and *second order* headwater streams generally provide the greatest surface area of the watershed system and they also allow the greatest exposure to pollutants within the system.

It is also important to note that Pennsylvania Department of Environmental Protection (PADEP) has established a system for classifying streams in the State as specified in Chapter 93, Title 25 of the Pennsylvania Code. The standards are based on water uses which are to be protected and will be considered by PADEP in its regulation of discharges from sewage treatment plants, industrial plants, and stormwater management facilities. Current Water Quality Classifications for the Cooks Creek Watershed are shown on Figure 7.

The highest quality designations for a streams or watersheds are considered Cold Water Fishes (CWF). Cooks Creek Watershed has been designated a CWF. Additional classifications and uses of streams are summarized below:

- CWF – *Cold Water Fishes* – Maintenance and/or propagation of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat.

- MF – *Migratory Fishes* – Passage, maintenance, and propagation of anadromous and catadromous fishes and other fishes which ascend to flowing waters to complete their life cycle.

- TSF – *Trout Stocking* – Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna, which are indigenous to a warm water habitat.

- WWF – *Warm Water Fishes* – Maintenance and propagation of fish species and additional flora and fauna, which are indigenous to a warm water habitat.

Chapter 93 also includes two categories of Special Protection Waters:

- HQ – *High Quality Waters* – A stream or watershed that has excellent quality waters and environmental or other features that require special water quality protection.

- EV – *Exceptional Value Waters* – A stream or watershed which constitutes an outstanding national, State, regional, or local resource, such as waters of national, State, or county parks or forests, or waters which are used as a source of unfiltered potable water supply, or waters which have been characterized by the Fish Commission as "Wilderness Trout Streams", and other waters of substantial recreational or ecological significance.

The entire Cooks Creeks basin has been designated as an *Exceptional Values (EV) CWF* Waters.

The major tributaries to Cooks Creek are: Silver Creek (Silver Creek) and Hollow Coons Run.

Watershed Corridor

The watershed corridor consists of the tributaries and drainage channels that comprise the watershed as a whole. "Waters of the United States" or "Waters of the Commonwealth" include all wetlands, ponds, lakes, streams impoundments, and intermittent drainageways that can eventually be linked to interstate or foreign commerce. Almost all tributaries above the intermittent stage are considered "Waters of the United States".

The Cooks Creek Watershed corridor is comprised of the hills, valleys, and open areas where the waterways flow. Cooks Creek has a diverse watershed corridor comprised of broad open valleys, valley bottoms, and gentle stream gradients dictated by the underlying geology of the area.

The stream morphology or the characteristics, patterns, and profiles of the stream are typical of eastern Pennsylvania waterways. Land use along the corridor is a mixture of agricultural, residential and forested lands, with almost no industrial land use. The overall condition of the watershed corridor is good with the need for riparian buffer zones and stabilization in limited areas resulting from historical agricultural practices.

Climate

The region is part of the Eastern Broadleaf Forest Ecoregion (Bailey 1995). The climate of the area is classified as cool temperate, with an average growing season length of 160 days. The average annual precipitation of 42 inches occurs throughout the year, but precipitation rates are slightly higher in the summer months (Cuff et al. 1989).

Watershed Land Use

The Cooks Creek valley is predominantly rural/agricultural, in fact, 58 % of the Durham Carbonate Valley is used for agricultural purposes. Woodlands represent 15 % of the land area. The residential (15 %) and commercial, manufacturing, and institutional land uses (2 %) are located mainly along Route 212 and are concentrated in the villages of Springtown and Durham.

The vacant undeveloped area of this valley comprises the remaining 10 % of the land area (Figure 8).

Land Use Patterns and Trends (Bucks County)

The following natural features characterize the Cooks Creek Watershed. Future planning solutions for development and conservation can be derived from this information.

Historically, farms, villages, and country towns characterized Bucks County. However, the period just after World War II marked a mass migration from Philadelphia and the sub-urbanization of many parts of the county (especially in the lower Bucks County region). Since that time, Bucks County has been one of the fastest growing counties in the state. This can be attributed to several factors including: proximity to major metropolitan areas, accessibility to regional highway and transit systems, availability of developable land, extensive environmental and cultural resources, significant business and economic activity, and continued migration of population from cities to suburbia. Today, Bucks County is a diverse community with decentralized population and employment areas. Notwithstanding past growth, over half of the county currently consists of agricultural, rural residential, or vacant land uses (located primarily in the central and upper Bucks County regions).

Despite the continued high levels of growth during the past decade, land consumption for residential development generally appeared to be occurring at a slower pace. The reduced consumption of land can be attributed to: the slower rate of growth for housing development, the nearly built out stage of certain areas, and the trend for the concentration of the development of reduced lot size and cluster housing. The reduction in land consumption is reflected in the county's average acreage per dwelling unit statistics. These statistics indicate that land consumption reduced from 0.718 acres/unit in 1970 to 0.537 acres/unit in 1990. The consumption of land for non-residential development in the county has been steady over the past three decades, resulting mainly from construction of industrial parks, office parks, shopping centers and expansion of existing commercial areas.

As lower Bucks County approaches build out capacity, development pressures have crept into central Bucks County. This region is expected to receive the majority of future residential and non-residential growth. Central Bucks County is expected to grow at a faster pace than in previous decades, with Upper Bucks County following close behind.

The Upper Bucks County region is the most rural area of the county. The total land area for the region is approximately 263 square miles or roughly 43% of the total county area. With the exception of several small areas of concentrated development in and around the nine existing Boroughs and numerous villages, it has the highest percentages of rural residential (64%) and vacant land (52%) use in the county.

A significant portion of this region contains natural resources, which may limit development, including: steep slopes, wetlands, floodplains, and soils with shallow depths to bedrock. In addition, recreation and tourism constitute a significant portion of the region's vitality and provides visitors with an ample supply of recreational land and numerous historic inns. In fact, this region has the highest concentration of park and recreational acreage, and State Game Lands in the county. The Pennridge and Quakertown planning areas of the region have public water and wastewater systems throughout its Boroughs and adjacent areas under development. In contrast, all of the Palisades planning area within the watershed, including Durham and Springfield Townships are serviced by on-lot sewage treatment systems. Springfield Township does provide wastewater treatment for the village of Zion Hill, however, this area is not in the watershed. Finally, the region is served by the Quakertown, Palisades, and Pennridge School Districts.

Various townships and municipalities other than Durham and Springfield have limited lands within the watershed. These lands account for a minimal area of the watershed, therefore, only the Springfield and Durham Township zoning districts have been included within this study.

Zoning -- Durham Township

The Durham Township Natural Resources Plan identifies the township as prime agricultural land, forest, steep slopes, scenic areas, wetlands, streams, floodplains and ponds (Figure 9).
Agricultural land is most valuable to society when it is cultivated. It is crucial that it be preserved in parcels large enough to permit efficient farm operations and to allow adequate separation or buffer from non-farm activities. If prime agricultural soils are to remain productive, their extreme low tolerance to extensive development must be recognized. Agricultural lands comprised 36% of the Township land in 1994 (Bucks County Continuum, Bucks County Planning Commission, January 1994).

Other natural resources such as forests, steep slopes, scenic areas, wetlands, streams, floodplains, and ponds have evolved over time and are a part of the ecologic systems of the region. They also represent the areas of the greatest aesthetic beauty within the Township. Individually and collectively these natural resources are highly interdependent. The destruction of any one resource could have far reaching effects, not only on the natural systems in Durham Township, but in surrounding municipalities as well.

The following is a list of primary zoning districts within Durham Township (Zoning Ordinance, December 1992):

- *Resource Protection (RP)*. The land in this district is identified in the Durham Township and Bucks County Comprehensive Plans. These lands contain important resource features and historic areas. The two-fold purpose of this ordinance is to: 1) maintain the agricultural industry and preservation of farmland and 2) to protect the valuable natural resources.

- *Village Center (VC).* This area is designed to preserve the character and integrity of Durham Village. Specific development and construction criteria must be maintained in order to protect the historic nature of the Village.

- *Development Districts.* These areas are designed to accommodate the anticipated growth within the Township. The purpose of development areas is to control and regulate development in order to coordinate the provision of public services. Residential development is encouraged in these concentrated areas, which will promote the most efficient use of land. The two development districts are outlined below.

    - *Rural Residential Area (RR).* The purpose of this district is to accommodate all types of residential structures to ensure a balanced community. The district encourages continued development of Riegelsville Borough as the regional center.

    - *Planned Industrial-Commercial Area (PC-I).* This area is designed for planned industrial and commercial uses in an appropriate location with access to arterial highways and public services. The intent of this area is to encourage high quality industrial and commercial development. This development enhances the employment opportunities within the Township. These areas are designed with adequate road access and public utilities to minimize adverse impacts on the surrounding natural resources and residential areas.

- *Limestone Region*. This is not a separate zoning district but it is an area that extends through various districts within the Township. Careful consideration during design and construction is required to protect against future damage or destruction (i.e. sinkholes, fissures, etc.).

- *Floodplain Conservation District*. The purpose of this area is to prevent the loss of property and life through restrictive zoning. It also provides for flood protection and relief.

- *Steep Slope Areas*. This area provides for permitting uses of steep slopes in areas which are compatible with preservation of natural conditions and which maintain stable soil conditions.

Zoning -- Springfield Township

The zoning ordinance for Springfield Township was reviewed (Zoning Ordinance, August 1990). A brief description of these areas is presented in the following list of primary zoning districts:

- *Agricultural District (AD).* The purpose of the Agricultural District is to recognize and protect the area designated as a significant agricultural area by Bucks County in its Natural Resources Plan and the areas of the Township where farming predominates.

- *Watershed District (WS).* This district is designed to protect the existing watershed. It provides for low intensity development compatible with the natural features of the watershed.

- Res*ource Protection District (RP).* The purpose of this district is to protect areas consisting largely of natural features such as: forest, steep slopes, scenic areas, wetlands, streams, floodplains, and ponds.

- *Rural Residential District (RR).* The purpose of this area is to preserve the rural character of the Township. This area provides for the residential growth of the Township. All types of residential uses are permitted at various densities according to the underlying geology of the site. Development will relate to the natural physical characteristics such as waterways, woodlands, topography, and soils in order to protect and preserve these natural features and the open character of the countryside. Areas underlain with limestone must employ development practices and designs that will not adversely affect the structural integrity of the underlying strata.

- *Development District (DD).* This area is established to accommodate anticipated growth of the township. These areas are served by public sewers and include high-density housing.

- *Village Commercial District (VC).* Village centers are specifically structured to accommodate municipal, retail, and institutional uses considered to be essential to the function of residential neighborhoods. The village center is located within a limestone region; therefore, appropriate siting of sewage disposal systems is mandatory to prevent pollution of groundwater sources.

- *Planned Industrial District (PI).* This area is designed for planned industrial and commercial uses in an appropriate location with access to arterial highways and public services. The intent of this area is to encourage high quality industrial and commercial development. This development enhances the employment opportunities within the Township. These areas are designed with adequate road access and public utilities to minimize adverse impacts on the surrounding natural resources and residential areas.

- *Highway Commercial District (HC).* This district was specifically designed to provide for highway commercial uses along Route 309. The Route 309 corridor is not within the boundaries of the Cooks Creek Watershed.

- *Floodway Protection Overlay (FP).* This area is an overlay district and as such it adds to existing regulations in the district affected. This area provides for the protection of stream corridors subject to flooding.

- *Scenic District Overlay.* The purpose of this district is to protect the unique visual character of the township. It is designed to minimize adverse visual impacts.

Socioeconomic Profile

Population Centers

The information was derived from the Bucks County Planning Commissions Municipal Demographic Profile of Bucks County (February, 2000) and the Bucks County Continuum

(January, 1994). These records were used to illustrate changes in population over time. Population and housing unit projections are important as they help to identify future water needs.

Durham and Springfield Townships and Riegelsville Borough were utilized to demonstrate the growth rates and the socioeconomic profile of the watershed. The watershed is relatively undeveloped, with pockets of urbanization along the Silver Creek and Cooks Creek Valleys.

Durham Township and Riegelsville Borough experienced a population growth of less than 100% from the period of 1930 through 1990, while the surrounding municipalities, including Springfield, experienced a population growth of 100 to 499% for the same time frame. In fact Riegelsville has experienced a decrease in the population.

Adjustments to municipal population projections were based upon potential growth scenarios and stages of development of each municipality. Population projections for the three areas show a steady increase in the numbers of residents for the area. The table below presents these projections.

	Population 2000	Projected Population 2020	% Growth
Durham Township	1,420	1,970	38.7%
Springfield Township	5,660	7,760	37.1%
Riegelsville Borough	1,020	1,240	21.6%

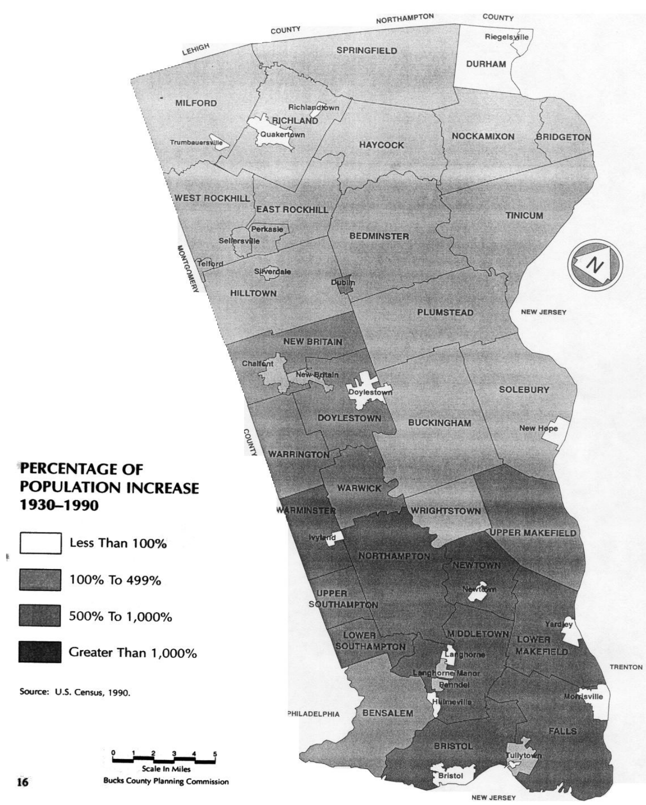


Figure 10. Percentage of population increase 1930 – 1990.

Housing projections were developed for the county as a whole and served as a control total for municipal projections, which were produced separately. By the year 2020 housing units in the three major municipalities within the watershed are expected to increase. The table below presents the projections in housing units for the watershed.

	Housing units 2000	Projected units 2020	% Growth
Durham Township	~600 units	720 to 810 units	20 to 35%
Springfield Township	~2,220 units	2,530 to 2,860 units	14% to 29 %
Riegelsville Borough	~430 units	440 to 500 units	2% to 16%

These projections are designed as tools to plan for what may occur if the demographic characteristics and trends remain constant to the year 2020. The projections for specific areas are discussed below. The Cooks Creek Watershed is primarily within the *Palisades Area.*

Palisades Area Profile

The Palisades planning area, which includes Durham and Springfield Townships, is predominantly rural and constitutes approximately 38% of the region and 16% of the total county land area. The area contains a high concentration of natural resources including: streams, the Delaware River, floodplains, wetlands, steep slopes, significant agricultural areas, and woodlands. Significant geologic features such as Ringing Rocks, Durham Caves, High Rocks, and Nockamixon Cliffs are located in the planning area. There are several high quality streams in this area, including Cooks Creek and portions of Rapp and Tinicum Creeks. The planning area also contains several county parks, various state game lands, and approximately one third of the Delaware Canal State Park. Water and sewer facilities are almost exclusively on-lot.

Palisades Area Development Trends

In the past, growth in the upper Bucks region was slow, with only limited residential and non-residential subdivision and land development located predominately in or around the existing boroughs. Currently agricultural, vacant, and rural residential land uses constitute approximately three quarters of the total regional land area. The densest development is centered around Quakertown Borough and the corridor between and including Telford, Perkasie, and Sellersville boroughs. The upper Bucks region is projected to grow at a faster pace than in previous decades. The economic stability created by public water and wastewater systems and the strong commercial and industrial presence makes the Quakertown and Pennridge planning areas very attractive for future growth. Improved access to Route 611, Route 309, and Interstate 78 may facilitate increased growth pressure throughout the region.

Durham Township Development Trends

The Bucks County Housing Plan projected that Durham Township will need an additional 1,820 housing units to reach its full development capacity. The county presented two alternative approaches that the Township could take in planning for future growth. One alternative is the comprehensive plan with the traditional zoning techniques. The other alternative is the Development Area concept. Both provide for the same degree of development, but each utilizes a different approach.
The traditional approach divides the entire township into different use districts, (i.e., residential, commercial or industrial, etc.). In this approach development is controlled by the availability of adequate roads, sewers or other essential facilities necessary for development. This approach encourages scattered, sprawling development patterns and does not preserve open space or agricultural land. The Development Area concept, allows for farmland and open space preservation by realizing that most development should occur in areas where services already exist or where they can be reasonably provided.

Transportation Facilities

Transportation access to employment centers throughout upper Bucks region is relatively good through highway access. These highway systems include: Routes 113, 212, 309, 313, 663, 412, 413, 611 and the Northeast Extension of the Pennsylvania Turnpike. Primary transportation access to the Cooks Creek Watershed is gained from Routes 212, 611, and 412.

Three airports are located in the region, however there are no airports within the watershed.

Historically, rail access was important to the mining and metallurgy industries of Durham Township. While the remains of several trestles exist within the bed of Cooks Creek and historical railbeds can be seen along the Creek, there are no functioning railways in the Watershed.

Major Sources of Employment

According to the Bucks County Continuum (January, 1994) and the Municipal Demographic Profile of Bucks County (February, 2000), the major sources of employment within the area are: mining and manufacturing (34 to 35%), service industry (28 to 31%), and wholesale/retail trade (17 to 23%). Labor force and employment estimate projections also show a steady increase over time within the area of the watershed. However, there are no specific businesses that have a significant impact on the watershed, nor are any businesses located in the watershed itself that employ significant numbers of people.

Outstanding or Unique Features

Cooks Creek boasts good to excellent water quality, a diverse macro-invertebrate benthic community, and a Class A wild brown trout (*Salmo trutta*) population. In addition, tributaries to Cooks Creek support both Class A wild brown trout populations and Class A wild brook trout (*Salvelinus fontinalis*) populations. The entire Cooks Creek drainage basin is classified as an *Exceptional Value (EV) coldwater fishes (CWF)* waters. These standards are based upon the health of the biological communities present in streams and rivers.

The main stream is a moderately alkaline, well-buffered limestone stream that supports excellent aquatic macro-invertebrate populations and a Class A wild brown trout population. Class A wild trout populations are also present in Silver Creek and Coon Hollow Run (tributaries to Cooks Creek). The wild brown trout populations in the Cooks Creek basin are unique in Bucks County. The wild brook trout population in Coon Hollow Run is not only unique in Bucks County, but is also very rare in the Pennsylvania Fish and Boat Commission (PFBC) fisheries management region Area 6. Surface and groundwater resources in the basin, upon which the Class A wild trout populations depend are very susceptible to contamination due to the underlying limestone geology.

The wild brown trout populations in Cooks Creek are probably limited by two factors: seasonal elevations in water temperatures and restricted physical habitat. Cooks Creek was divided into three sections, describing stream characteristics influencing the wild trout population (Figure 11).

- **Section 1** of Cooks Creek (headwaters section) lies upstream from the major limestone influences. Relatively poor physical habitat combines with a lack of riparian buffers in many areas (resulting in warming of the water). These characteristics make this part of the watershed unsuitable for supporting a wild trout population.

- **Section 2** of Cooks Creek (middle section) supports a Class A biomass and has somewhat restricted physical habitat for adult trout.

- **Section 3** (located toward the mouth of the creek) has less physical habitat than Section 2, and therefore supports less biomass.

Wild trout populations in Sections 2 and 3 are probably at their physical carrying capacities. Electro fishing in both sections, particularly in Section 3, detected adult trout. The PADEP should continue to protect the EV-CWF status of the Cooks Creek basin. This is necessary to protect the uniqueness of this area and its' scenic and historical qualities.

III. Issues, Constraints, and Opportunities

This section identifies recommendations from previous studies and investigations performed for assessing watershed conditions and/or resources that will aid in the protection and management of watershed resources. In addition, a summary of existing data gaps which may require further study or investigation to address watershed concerns is presented.

Previous watershed investigations performed by PADER (1990), PA Fish and Boat Commission (1992 & 1993), Township of Durham (1995), Symbiosis Environmental (1998), Morris Arboretum (1999), and DTEAC / MJE (2000) on Cooks Creek Watershed have been reviewed. The following is a list of the recommendations made based upon this literature review. See Appendices A for a summary of each report.

Recommendations presented in the PADER 1990 Report

- Based on the Department's evaluation of the Cooks Creek Watershed, a change in the basin's water use designation to EV status is appropriate. Justification for a basin wide EV designation, include:

    - The excellent water quality of Cooks Creek and its tributaries have better than applicable standards. The limestone influenced water quality and associated aquatic biota of Cooks Creek are rare in this part of the state.
    - Redesignation as EV would provide a degree of protection for this water source.
    - Due to the carbonate lithology, a number of geologic formations found in the basin have been identified by the Department as having aquifers that are easily contaminated. The association of surface water and groundwater typically found in limestone influenced streams, makes the protection of groundwater quality highly dependent upon the protection of surface water quality. This is especially important due to the widespread use of groundwater for domestic use.
    - Local planning agencies have documented their desire to preserve the unique resources found within the Cooks Creek Watershed. Local zoning is compatible with and would be complemented by an EV designation.
    - Naturally reproducing brook and brown trout populations, as well as the migratory American eel (*Anguilla rostrata*), have been documented in the Cooks Creek basin by both the PFBC and the Bureau of Water Quality Management.
    - The Cooks Creek Watershed, because of its juxtaposition to the Delaware River corridor, is utilized by a number of migratory avian species. Not only are resident species dependent upon the continued excellent water quality, but also so are migratory species, which utilize the basin as an important stopover point during the spring and fall.
    - Cooks Creek is a 1-A candidate in the Scenic Rivers System Inventory. The basin provides a variety of outdoor recreational opportunities which do not require

modification of the existing natural setting including fishing, hunting, birding, horseback riding, cross country skiing, hiking, and sight-seeing.

- More than 150 delineated wetland areas exist in the Cooks Creek basin. At least one wetland in the basin is of exceptional ecological significance, supporting numerous rare and endangered wildlife and plant species.
- Ten species of special concern in Pennsylvania have been recorded in the Cooks Creek Watershed. The Nature Conservancy has documented the current existence of several endangered herpetofaunal species within the basin, including the bog turtle (*Clemmys muhlenbergii*), the eastern mud salamander (*Pseudotriton montanus*), and the red-bellied turtle (*Chrysemys rubriventris).*

Recommendations presented in the PA Fish and Boat Commission (PFBC) 1992 Report

- The Pennsylvania Department of Environmental Resources (PADER) should continue to protect the entire Cooks Creek basin with the EV-CWF designation.
- The Bucks County Conservation District (BCCD) should investigate the sources of the moderate siltation of Cooks Creek, noted by the PFBC and pursue corrective actions. These areas are described in Section 01 of the report. They include: the area downstream from the State Road 4067 bridge, the downstream side of a private farm road bridge in Gruversville vicinity, the area downstream from the Township Road 485 bridge, and the area downstream from the State Road 4069 (Slifer Valley Road) bridge.
- Bank erosion in a pasture immediately upstream from the village of Pleasant Valley was noted. Measures should be taken to correct this problem.
- Best management practices on farmlands upstream from Springtown should be implemented to better control surface runoff into tributaries and the main stem.
- The BCCD should investigate the PADER report that livestock have free access to unnamed tributaries within the Cooks Creek basin and pursue corrective actions.
- The PFBC should continue to manage the wild trout populations in Sections 02 and 03 (downstream from the State Road 212/State Road 412 bridge to the mouth of the creek at the Delaware River) with conventional, statewide angling regulations.
- The Springtown Rod and Gun Club should restrict plantings of adult trout in Cooks Creek. Plantings should be restricted to the sections upstream from Springtown and downstream from Durham, contingent upon landowner permission.
- If interested, the Bucks County Chapter of Trout Unlimited should pursue habitat improvement projects in Section 03 (downstream of Red Bridge Road bridge) of Cooks Creek.
- The PFBC Area 6 Fisheries Management staff should reconnoiter Section 03 of Cooks Creek to determine whether or not the site's habitat was representative of the entire area. If not, a second, more representative site for a trout population estimate should be selected.
- Township officials should consider enacting ordinances that will prevent future development from denuding stream banks of trees and natural vegetation. Trees and vegetation provide the necessary shade to maintain cold-water habitat for Cooks Creek's trout population and will protect against further bank erosion. Bank erosion contributes sediments to the stream, which negatively impact fish and aquatic insects, resulting in the stream becoming wider and shallower.

Recommendations presented in the PFBC 1993 Report

- The BCCD should investigate the sources of heavy siltation in Coon Hollow Run and take corrective action. Probable sources are from agricultural and dirt road run-off.
- Local land use planning agencies should recognize the unique and sensitive nature of Coon Hollow Run in Bucks County. Township officials should enact zoning laws and other restrictions that will protect the stream from degradation.
- The PFBC should continue to manage Coon Hollow Run under conventional, statewide angling regulations.

Recommendations presented in the Symbiosis Environmental 1998 Report

- Both Coon Hollow Run and Cooks Creek appear to be in excellent health and continue to be worthy of their EV status.
- The benthic communities within Coon Hollow Run and Cooks Creek are sensitive to low flow conditions, and should be considered carefully when planning water usage within the Township. This can be accomplished by: restricting over-utilization of groundwater and surface water resources, avoiding permanent degradation of the stream ecosystem, and increasing regulation of land use practices.
- The PFBC 1993 report mentions siltation in the downstream reaches of Coon Hollow Run, and that this siltation is likely due to the presence of an unpaved road crossing the stream. Siltation can result in decreased habitat for benthic invertebrates and decreased sites for trout spawning. In an effort to protect the sensitive benthic and fish communities, the Township may wish to consider streamside erosion management at the Coon Hollow Road crossing.

Recommendations presented in the Morris Arboretum 1999 Report

- Several stream valleys including Cooks Creek were deemed as high-priority sites due to their high quality aquatic resources. Township managers should continue to strive to protect these areas with open space protection areas.
- The regions continuous forest cover and unusual geology should be protected. This area provides a habitat for birds and other species that are dependent upon extensive tree-covered areas.

Recommendations presented in the DTEAC / MJE 2000 Wetlands Conservation Plan Report

- Possible actions for the maintenance and preservation of the wetlands and the unique natural resources within the Cooks Creek Watershed include:

    - *Watershed Management*. Because of the unique and sensitive nature of the Cooks Creek system, it will be important to manage and protect the creek, aquifer, springs, and wetlands as a system. A holistic management approach that recognizes the connections between various elements and uses a number of different approaches is recommended.

- *Comprehensive Plan, Environmental Element*. One important step is to develop an element of the Comprehensive Plan that discusses the valuable social and environmental benefits of the Cooks Creek Watershed. This is important because the Comprehensive Plan serves as the blueprint for Township decisions on land use and development. A thorough discussion of environmental considerations should be included in the Comprehensive Plan. The Environmental Element should include a discussion on the natural resources inventory as well as goals, objectives, and strategies for protecting valuable environmental resources.

- *Cooks Creek Overlay District or Environmental Ordinance*. One option to consider is an "overlay" ordinance for Cooks Creek that would require new development projects to identify sensitive resources, and use best management practices to protect these resources. An overlay district is a special designation within the Zoning Ordinance that contains additional requirements beyond those required by current zoning, focusing on protecting special resources. Overlays are typically used for valuable river systems, public water supply reservoirs, historic areas, etc. As an alternative, a Township-wide environmental ordinance could be developed that has similar requirements to the overlay district. Some of the basic features included in such ordinances are described below:
  - Identification or inventory of sensitive resources such as karst or aquifer recharge areas, wetlands, springs, steep slopes, highly erodible soils, highly permeable soils, and 100-year floodplains within the overlay zone.
  - Inclusion of a vegetated buffer within the overlay zone. This buffer of vegetation extends landward (approximately 100 feet) from streams and creeks. This vegetated buffer is important for the protection of water quality because it traps some of the pollutants that would otherwise be transported into the stream with stormwater.
  - A requirement for evaluation of the impacts to sensitive resources and water quality (surface water and groundwater) from proposed development. This approach can be broadened to require an analysis of the natural, physical and socio-economic environment for new development projects anywhere in the jurisdiction. For example, Tinicum Township has an ordinance that requires an Environmental Impact Assessment Report with similar broad ranging requirements for new development.
  - Mitigation steps to avoid, minimize, or mitigate for the impacts to sensitive resources described above.

- *Growth Management*. Other planning tools that could be considered include growth management ordinances that promote cluster development, preservation of open space and riparian corridors, and transfer of development rights to protect rural areas.

- *Education*. Continue to expand public outreach efforts that emphasize the public benefits of environmental stewardship and watershed management. This approach could involve seminars or newsletters for residents, industries, and farmers on the importance of protecting the watershed and how they can help.

- *Water Monitoring Program*. Consider developing a water quality-monitoring program of the stream and the primary water supply aquifer. Several stream monitoring programs have been implemented elsewhere including one developed by the PADEP and a nationwide program by the Isaac Walton League, which relies on citizen efforts. A similar program has been developed by the Alliance for the Chesapeake Bay, within the Chesapeake Bay Watershed. One option is to consider a program that uses remote sensing to track the health, type, and extent of wetlands in the watershed and water quality. Such programs have been implemented in other important watersheds such as the Everglades and Chesapeake Bay. Remote sensing has the ability to cost-effectively identify many water quality problems, drought stress in vegetation, and plant community changes. This effort would require a source of funding or a collaborative effort with a research institution or consultant with the capability to perform such analysis.

- *Funding*. Consider seeking additional funds to develop a watershed approach for management and preservation of the Cooks Creek natural resources, water quality, and groundwater resources.

- *Protection of Sensitive Areas and Vulnerable Wetlands*. Promote the protection of sensitive segments of the watershed (i.e. riparian zones) and wetlands through fee simple acquisition, use of conservation easements, and re-establishment of vegetated buffers. The focus of this effort should be wetland areas that are important to aquifer recharge, wetlands that are disturbed or impacted, springs and seeps that contribute base flow to the stream and wetlands, and habitats that support rare species, and headwaters segments of the Cooks Creek tributaries. The following wetland areas should be targets of this effort:
  - Wetlands within karst-prone geologic formations;
  - Wetlands with potentially suitable habitat for endangered and threatened species such as Area D, Area P, Area X, Area Y, Area AA, Area AC, Area AD; and,
  - Disturbed wetlands included in Area J, Area M, Area T, Area W, and Area X.

Other Critical Issues for the Watershed

- Nutrient pollution;
- Stream bank erosion;
- Loss of stream bank cover;
- Outdated planning documents and accompanying zoning ordinances;
- Baseflow loss (stream water level decreases);

- Loss of habitat for flora and fauna especially threatened and/or endangered species;
- Karst topography related issues.

Data Gaps

Additional studies or investigations required to aid in the protection, preservation, and enhancement of the watershed may include:

- Development of a comprehensive watershed management tool for Cooks Creek Watershed;
- Stream watch – volunteer stream monitoring program;
- Conducting ongoing groundwater elevation contour mapping for the watershed;
- Further refinement of the water table data with additional monitoring point(s) to improve the water table maps and more fully understand the hydrology of the watershed;
- Stream water quality sampling for continued evaluation of water resources;
- Permeabilities, transmissivities, storage coefficients, hydrochemical characteristics and the characteristics of the water table (piezometric surface) should be assessed;
- A watershed wide nutrient management plan to protect the exceptional value status of the watershed;
- Zoning ordinances that are consistent with comprehensive plans to protect vital resources and high-risk areas (i.e., karst, hydric soil, steep slopes, etc.)
- Preparation of updated land use maps to evaluate current conditions and management strategies within the watershed;
- Watershed wide stormwater management plan;
- Watershed wide stream bank evaluation and erosion control plan to assess conditions and provide stream bank restoration management plans;
- Maintenance of the GIS database and Township development of the GIS as an implementation tool to assist in planning and protection of the resources (e.g. streams, karst, hydric soils, etc.) within the watershed;
- Wellhead protection scheme for public and private wells; and,
- Karst geology protection plan for the limestone valley.

IV. Land Resources

Geology

The geology of a region, while predominantly unseen, is the foundation for all the natural resources. Soils, groundwater, surface water and the flora and fauna of a region are all dictated on a fundamental level by geology. The underlying geology of the Cooks Creek Watershed is primarily of three types: crystalline (granite and schist) in the ridges to the north and south, diabase (red shale) in the headwaters, and a carbonate (limestone) central valley.

In order to fully understand the geology of the Watershed, professional geologists conducted studies of the area. The geologists used a combination of aerial survey and field confirmations to develop geology overlays and three dimensional model depictions of the major geologic units.

The geologic units of the entire watershed were grouped into four geologic categories:

- Category I: Diabase
- Category II: Brunswick and Lockatong Formations; and Quartz Fanoglomerates
- Category III: Carbonate Rocks including Allentown and Leithsville Formations and Limestone Fanoglomerates
- Category IV: Crystalline Rocks including Hardyston Formation and Gneiss Formations

These classifications will be used in determining groundwater contributions to the base flow of the basins and/or sub-basins within the watershed (Refer to Figure 5). Sub-basins are the drainage areas of various tributaries to the main stem of Cooks Creek Watershed. Figure 12 depicts the sub-basin geology for the entire Cooks Creek Watershed. The sub-basins were grouped into seven areas determined of the dominant local geology.

Figures 12-1 through 12-7 provide in-depth detail of the geology of each sub-basin area (Areas 1-7). Each area is again divided into sub-watersheds. The designations are identified as: Cooks Creek (CC), Silver Creek (SC), Tributary (T), North (N), South (S), while numbers identify each individual sub-watershed, with *first order* streams labeled as “a”. This ranking of sub-basins is necessary for extrapolating water production yields from each sub-watershed area. This information is used later to assess water balance and groundwater resource evaluations.

The topography of Cooks Creek drainage basin is defined by geologic characteristics of harder, more resistant rocks, which occupy highlands. These highlands may rise to elevations as high as 300 feet above the lowlands. The softer, less-resistant rocks tend to erode easily and occupy the lowlands as broad open valleys, valley bottoms, or gentle stream gradients. With harder, more resistant rocks, the valleys are narrower and steeper. Many of the streams draining the ridges surrounding the valley of Cooks Creek flow down more resistant rocks that underlie the ridge crest and mid slopes. These streams occupy steeper and narrower valleys. Cooks Creek occupies the broad, open, lowland valley bottomlands called the Durham Carbonate Valley (Figure 13). Much of this land is currently under agricultural use. The natural diversity of Cooks Creek basin is due largely to the fact that the watershed spans two physiographic provinces: the Reading Prong and the Piedmont.

Reading Prong

The northern portion of the basin is part of the New England Geologic Province, locally known as the Reading Prong. Separated from the Triassic formations to the south by the Monroe Border Fault; the Reading Prong is composed of parallel ridges of Precambrian gneiss separated by a Cambrian limestone valley.

The northern portion of Cooks Creek basin, along Kohlberg-Steelys-Bougher Hills, has narrow ridges of granite gneiss, and Hardyston Quartzite. Rugged terrain with steep slopes precludes much development. This area is predominantly forested. Local streams occupy steep and narrow valleys that serve as the discharge areas for groundwater.

The southern portion of Cooks Creek basin from Bitts Hill to Mine Hill is a highland. It consists of a series of stacking thrust fault bounded blocks of Hardyston Quartzite and granite gneiss. This area is above the Musconetcong Thrust Fault. Steep slopes have precluded development and the area remains forested. The gentler sloped areas of the area are farmed.

Piedmont

The southern half of the Cooks Creek basin lies within the Piedmont Geologic Province. This area is in the Triassic Lowlands, a region of gentle rolling ridges and alternating bands of sedimentary Triassic shale, sandstone, argillite, and conglomerate of the Brunswick, quartz Fanoglomerate and Lockatong Formations. The shales and sandstones produce good to excellent agricultural soils and which are farmed. Only stream valleys, steep slopes, poorly drained areas, and scattered farm woodlots remain forested.

Buckwampum Hill and Flint Hill contain massive sills and dikes of diabase rock. This was formed when molten magma intruded during the late Triassic or early Jurassic period formations. Subsequent erosion has produced a series of ridges and hills. A boulder-strewn landscape with numerous perched wetlands is common. The rocky landscapes created by diabase intrusions have remained mostly forested due to their ruggedness and unsuitability for agriculture.

Flint Hill ridge occurs as a broad, plateau-like upland that serves as the western drainage divide for Cooks Creek basin, while the prominent ridge of Buckwampum Hill serves as the southeastern drainage divide. Both of these areas are utilized for agriculture.

Karst-prone Areas

Karst-prone areas consist of closely spaced sinks or sinkholes including caverns. These sinks are the result of exceptionally soluble rocks, where sinks and caverns form. In this type topography, the drainage pattern is irregular and/or streams disappear abruptly into the ground. These sinks are a direct result of solubility of carbonate rock, such as limestone. Karst-prone areas are mature karst systems of limestone bedrock in which old sinkholes are masked by extensive soil coverage.

Most of the carbonate rocks in Durham Carbonate Valley are dolomitic, therefore, they would be less likely to have large sinkhole occurrences and massive cavern networks that may exist in areas with calcitic carbonate rock such as those found in Florida, Kentucky, and Missouri. Nevertheless, as shown by the number of sinkholes occurrences, there is obviously a need for concern (Figure 14). Figure 15 depicts the karst-prone areas of the watershed.

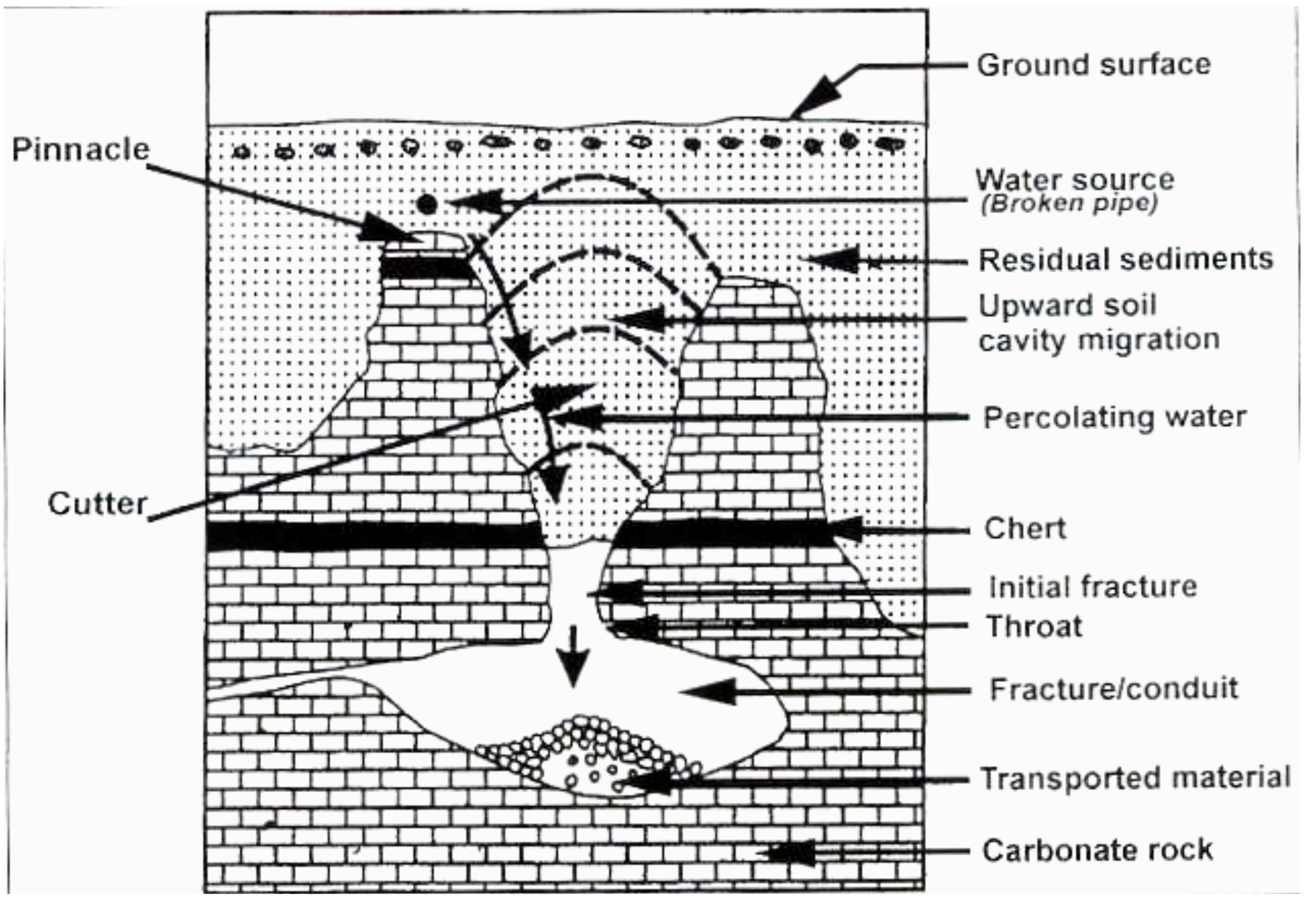


Figure 16. Conceptualization of Sinkhole Formation (Foundation Engineering Problems and Hazards in Karst Terranes, Fact Sheet 11, Maryland, Geologic Survey, Figure 4)

Karst prone areas present many challenges to the watershed. Current mapping of the karst geologic topography reveals numerous areas within the watershed that must be properly evaluated and protected to avoid loss of property and life.

Soils

Soils are formed over thousands of years from weathering bedrock and decaying plant growth or organic matter. Soils are the link between the underlying geology and the surface features such as topography, stream morphology, surface water hydrology, vegetation, and land cover. Soils control the permeability of surface runoff and the recharge within the watershed. Soils also control the plant communities and agricultural productivity of the watershed. Prime agricultural areas are typically established in deep soils along valley bottoms. Forested areas typically exist where thin soils are encountered.

Soils are important in the filtering of pollutants that may affect the water quality of the watershed. This is especially important when considering the placement of on-site septic systems within the watershed. The correlation between the soils and septic system type and placement are discussed in greater detail in Appendix E.

Three main generalized soil groups exist within the watershed. These groups are:

- Deep soils that have a medium-textured surface layer and a medium textured or moderately fine-textured subsoil. (Associations: Allenwood Chester, Duffield-Washington, and Towhee-Neshaminy-Mount Lucas);
- Deep soils that have a medium-textured surface layer and a firm friable, but mainly firm and compact, subsoil; shallow to deep over shale or sandstone. (Associations: Abbottstown-Readington-Reaville and Penn-Klinesville); and,
- Deep soils that have a medium-textured surface layer and a medium-textured or moderately coarse-textured subsoil (Association: Alton-Pope).

Figure 17 presents the Generalized Soils Map for the watershed. As shown on Figure 17, the area near the Delaware River is comprised of Alton-Pope Association soils. These are nearly level to gently sloping, well-drained soils on terraces or floodplains. The central portion of the watershed consists of Duffield-Washington and Allenwood Association soils. These are gently sloping, well drained upland soils. On either side of the Duffield–Washington Association soils are the Chester soils. Chester Association soils contain nearly level to moderately steep, well-drained upland soils. On either side of the Allenwood soils are the Penn-Klinesville Association soils. Penn Klinesville Association soils are comprised of nearly level to moderately steep, shallow and moderately deep, well-drained upland soils. Figure 18-A and Figure 18 presents the entire watershed soil types.

Natural constraints resulting from soil related issues include: poor water recharge areas, high groundwater table, steep slope soils (Figure 18B), shallow soils and highly eroded soils. Figures 18-1 through 18-7 present the soils maps for Areas 1-7 that were digitized for the watershed during this project. Specific soil types are mapped and utilized later in the report to outline areas of concern with respect to septic system design and placement within the watershed. For instance, Towhee-Neshaminy-Mount Lucas soils are typically found over diabase. These soils are rated as

having moderate to severe limitations for on-site septic systems due to their shallow depth to bedrock and low water yields. Consideration should be given when existing groundwater wells and water quality require protection.
Hydric soils are present in the watershed especially along the stream corridors in Springfield Township. These soils are shown on Figure 19. Hydric soils are generally associated with wetland areas and as such should be considered critical areas that should be protected. Hydric soils are not suitable for on site septic use.

Prime agricultural soils should also be considered areas that require special protection and/or preservation. Dwindling farmland resources within southeast Pennsylvania highlight the need for consideration of the prime agricultural soil regimes.

Land Ownership

Land ownership is based upon the information supplied in the Bucks County Continuum (January, 1994). Land ownership and use, based upon the 1990 data, reflect that the majority of the land is privately owned. In the table below the three major municipalities within the watershed were again used for calculating watershed wide data.

	Acres	Private	Commercial	Institutional
Durham Township	5,882	4,457	26	212
Springfield Township	19,699	14,630	248	720
Riegelsville Borough	634	385	7	122

Critical Areas

Based upon the Cooks Creek Wetlands Management Plan desktop study (MJE et al. May, 2000) and field reconnaissance, it appears that the wetlands and streams are largely undisturbed and unstressed. There are, however, certain areas that are critical to water quality protection, the potable water supply, and the continued existence of rare and/or threatened species. These areas include:

- Wetlands and the streams located in karst-prone formations that may serve as groundwater recharge areas. Spatial analysis was performed for identifying critical areas related to karst issues within Cooks Creek Watershed. The following “Karst Overlay Zones” were outlined using GIS methods**:**
    - Durham Carbonate Valley and Tax Map Parcels, Figure 13
    - Sinkholes and Tax Map Parcels, Figure 14, and,
    - Karst-prone areas and Tax Map Parcels, Figure 15.
- Headwater segments of the tributaries, which are vulnerable to disturbance and development.

- Springs and seeps, especially along the base of the channel banks. These groundwater discharge areas contribute cool, high quality base flow water to Cooks Creek.

- Habitats that support or potentially could support threatened and endangered species (Wetland Areas: D, P, X, Y, AA, AC, and AD).

    - *Area D*: *Potential bog turtle habitat*. This includes a small tributary to Cooks Creek that drains from the north of the main channel along Haupts Bridge Road. A palustrine-forested wetland was identified in this area. Relatively steep slopes, springs/seeps, and potential habitat for the bog turtle characterize the area. Development has encroached within about 300 feet of the site. The wetlands and waters of the US in this area are located in a rock unit that is prone to karst formation.

    - *Area P* – This area includes several segments that are located near the headwaters of the main stem of Cooks Creek. It includes waters of the US, plus numerous fringe wetlands scattered along the channel. Wetland types included predominantly palustrine forested, with smaller areas of palustrine emergent and palustrine scrub/shrub. Many of these field-identified wetlands are not depicted on the National Wetland Inventory (NWI) maps. One potential wetland mitigation site was identified near the southern end of this wetland. Some recreational use, and disturbance of wetlands from mowing and livestock grazing were noted. Development ranged from 200 to 2,000 feet away from the site. Some potential bog turtle habitat was observed.

    - *Area X* – This area includes a 4,000-foot section of the main channel of Cooks Creek along Springhouse Lane. The area is predominantly waters of the US, although several fringe wetlands (palustrine scrub/shrub and palustrine emergent) were located along the length of the channel. Three wetlands were field identified that are not shown on the NWI maps. Some of the area was cleared and a power line crosses the area. No significant water quality problems were noted although algae blooms were observed. One area had potential bog turtle habitat.

    - *Area Y* – This area includes about a 2,000-foot segment of Cooks Creek near Sliffer Valley and Knechts Bridge Roads. Several field-identified wetlands were discovered along the length of two small intermittent tributaries to Cooks Creek. These areas had riverine, and palustrine emergent wetlands. The area had habitat that would support bog turtles.

    - *Area AA* – This area includes segments of two unnamed tributaries and their confluences. The area is located near Walnut Lane and Sliffer Valley Road. Drainage channels that would be considered waters of the U.S dissect it. One large palustrine-forested, one fairly large palustrine emergent, and one large palustrine open-water wetland were accurately depicted on the NWI map. The field reconnaissance identified a large palustrine forested wetland and several small palustrine forested fringe wetlands. Bog turtles have been reported in this area, but none were observed. The hydrology of the area has been modified by construction of an old dam.

- *Area AC* – This area is within the headwaters of an unnamed tributary to Cooks Creek near Bursonville Road. The area includes palustrine scrub/shrub, palustrine emergent and palustrine open-water wetlands. The area had potential habitat for bog turtles.

- *Area AD* – This area is within the headwaters of a *first order* tributary of Cooks Creek located near Harrow Road. A fairly extensive palustrine scrub/shrub and palustrine emergent wetlands were identified. Several small areas of palustrine open-waters were correctly mapped on the NWI map. A spring was identified in the headwaters of the tributary. The area had potential habitat for special status species.

❖ Segments near developed areas primarily Springtown, Pleasant Valley and the eastern portion of Durham Township. These areas are stressed by road crossings.

❖ Disturbed wetlands included in Area J, M, T, W, and X (Figure 20). These areas are described below:

- *Area J* - This area includes a small tributary of Cooks Creek that extends northward through Springtown. A spring was noted at the headwaters of this tributary, as were several seeps along the course of the stream. Some segments of this stream were located in close proximity to residences. The area appeared to be used for recreation and water supply. There was evidence of stream alteration through channelization, small check dams, culverts, and water withdrawal by pumping.

- *Area M* – This area includes the headwaters of a *first order* stream near Springtown Road. Several small ponds were identified in the headwaters along with a palustrine emergent wetland that was not depicted on the NWI maps. The ponds supported ducks, blue heron, and a wide variety of songbirds. Some areas of wetland areas were mowed and used for recreation.

- *Area T* – This area includes about a 3,000-foot segment of an unnamed tributary to Cooks Creek near Amity. The channel was determined to be waters of the US. The area includes several NWI mapped palustrine open-water and emergent wetlands scattered along the stream. Two additional fringe wetlands were identified in the field. In many places, wetlands and riparian areas were mowed to the edge of the channel. Development averaged about 200 feet away from the channel.

- *Area W* – This area includes the headwaters of two *first order* tributaries of Cooks Creek near Old Bethlehem Road and Sliffer Valley Road. Waters of the US (riverine wetlands) and small areas of palustrine emergent and palustrine open-water wetlands characterize the area. The area has several horse trails, a debris pile, and is mowed.

- *Area X* – This area includes about a 4,000-foot section of the main channel of Cooks Creek along Springhouse Lane. The area is predominantly waters of the US, although several fringe wetlands (palustrine scrub/shrub and palustrine emergent) were scattered along the length of the channel. Three wetlands were field identified that are not shown on the NWI maps. Some of the area was cleared where a power line crossed the area.

No significant water quality problems were noted although algae blooms were observed. One area has potential bog turtle habitat.

Hazard Areas

Hazard areas are shown on Figure 21.

Landfills

There are no landfills in Durham or Springfield Townships.

Waste Management Sites

There are two waste management sites in Springfield, the Delguerico Waste Transfer Station and the Gemstar Tires used tire storage facility. The Gemstar Facility has been closed and the tires removed, however there has been no evaluation of historical impacts (if any). Visual assessment conducted was not proximal to this facility (Figure 21) nor to the DelGuerico facility as part of this study However, given the nature of these activities, the proximity to the Cooks Creek, and the sensitivity of the Cooks Creek system to water quality impacts, additional survey work should be conducted in these areas to determine if any potential threat to water quality exists.

Abandoned Mines--Quarries

The information regarding the history, location, and use of mining resources within the watershed was gleaned from the Durham Resource Inventory Plan (June, 1995) and Place Names in Bucks County (MacReynolds, 1995. pages 144-145).

An iron ore mine was developed along a spur of South Mountain at Mine Hill in as early as 1698. Another mine was opened in 1851, which was considered the largest and best of the Durham Mines.

The abandoned Durham Mine, near Durham Furnace. has become an important bat hibernaculum, the second largest in Pennsylvania with 8,000 -10,000 bats recorded in a 1997 survey. A rare fresh water invertebrate, Prices' Cave Isopod, also has been found in the mine. In 1994, the Pennsylvania Game Commission and Heritage Conservancy collaborated to install specially designed gates to exclude humans but allows the bats to enter and leave freely. Problems involving vandalism of the gates have occurred, requiring continual monitoring and repairs.
A quarry is also located in the same general region as the mines within the watershed. There is also evidence of historic quarrying activity on the east side of Drifting Drive just north of Route 212/412 in Springfield Township and in the vicinity of the confluence of Cooks Creek with the Delaware River in Durham Township. There are currently no ongoing quarrying activities in the Watershed.

Sinkholes

Previous evaluations of Cooks Creek Watershed geological data (Conservation and Management Practices For Buckingham and Durham Carbonate Valleys, February 1985; Wetlands Management Plan, May, 2000; and, this report) presented specific areas in the Durham Carbonate Valley zone that are prone to sinkhole formation or disappearing streams.

The field delineation of karst-prone areas (MJE & Golder, April, 2000, Wetlands Management Plan, and MJE & Golder, June, 2000) was performed using industry standard methods (Figure 15). These methods include: correlation of topographic flat areas with stressed vegetation using topographic maps and aerial photographs.

The sinkholes shown on geologic maps were delineated in various phases of geologic field survey, performed by USGS (Drake, A. A., 1969), and during an environmental assessment for on-lot sewage system suitability in the carbonate valleys of Bucks County (Roy F. Weston, Inc. 1978).

The following "Karst Overlay Zones" were outlined using GIS tools (i.e. intersections and buffering):

- Durham Carbonate Valley zone – Figure 13;
- Known Sinkholes zone – Figure 14; and,
- Karst-prone areas zone – Figure 15.

Mismanagement practices in areas underlain by limestone can induce opening of older sinkholes or result in new sinkhole formations. No information about "Disappearing Streams" or "Blind Valleys" in Durham Carbonate Valley was available for the watershed. The limited information obtained was gathered during desktop studies including reviews of existing reports, aerial photographs, USGS Quadrangle maps, and similar information.

A thorough inventory of the stream system for the entire watershed was completed during field survey tasks for this project (*Seepage Runs and Creek Reconnaissance* and *Karst-Prone Areas Reconnaissance Completion*). When landowners limited access, the stream inventory was completed by visual observations from nearby public roads.

The "Karst-Prone Areas" that were delineated are considered to be at high risk for sinkhole development. The general lack of many active sinkholes, the presence of mostly mantled sinkholes (i.e. sinkholes formed by collapse of a mantle of soil above bedrock), and the general absence of exposed bedrock in the topographically lowest portions of the valley, suggest that the Cooks Creek karst is a mature system. Mature karst systems of limestone bedrock within the watershed are masked by extensive soil coverage (Figure 16).

Consequently, karst hydrologic definition and assessment is difficult for the following reasons:

- Many of the features of concern lie underground and are inaccessible or accessible only by drilling.

- Carbonate rock terrain in Cooks Creek drainage basin generally occur in lowlands. Outcrops of the underlying bedrock are masked by overlain soils including alluvium and other material washed in from the surrounding highlands.

- The discharge point or points of a drop of water falling in a karst watershed can only be assigned a probability.

- Discharge points in karst can change periodically as plugging and unplugging of conduits (caverns, voids, etc.) occur with varying storm intensities.

- Drainage in karst watersheds tends to be three dimensional, flowing laterally across the surface, as well as vertically underground.

Sinkholes provide direct recharge routes to groundwater; therefore, water quality in wells, caves, and springs may be affected by discharge of runoff from developed sinkhole areas. Consequently, any sinkhole evaluation must address potential impacts of proposed development on receiving groundwater, and must consider water quality management measures to mitigate any resulting impacts. The nature of site-specific karst conditions should be evaluated on a site-by-site basis within the identified karst-prone areas. These evaluations should be performed by a licensed geologist familiar with karst.

Sinkholes can also directly impact engineered structures in their proximity by causing instability or even collapse. Engineered structures include not only homes and businesses, but bridges and roadways as well. Care must be taken to guard against inappropriate development in areas where the expected land use will result in sinkhole formation near proposed or existing engineered structures.

These sinkhole evaluation reports performed for new developments shall identify whether the site lies within a critical area or a sensitive area based upon the following classifications.

- Areas within 100 feet of private water supply wells.

- Areas within 1,000 feet of public water supply wells.

- Areas within 500 feet of springs used for public or private water supply.

- Areas within 1,000 feet of caves, providing habitat to rare or endangered species.

The Durham and Springfield Township Engineers may at their discretion wish to change the distances listed above, where the recharge areas for a well, spring, or cave have been independently evaluated by site-specific studies conducted by a qualified engineer or geologist.

V. Water Resources

The aquifers underlying an area comprise its groundwater system. Hydraulically, the system serves two functions:

- It stores water (dictated by the porosity); and,

- It transmits water from recharge areas to discharge areas.

Thus, a groundwater system serves as both a reservoir and as a transmitting medium. Water enters the groundwater system in recharge areas and moves through the system to the discharge areas. The rate of movement of groundwater from recharge areas to discharge areas is dependent upon the hydraulic conductivity and hydraulic gradients.

A groundwater map is a graphical representation of the occurrence and distribution of groundwater within a geographical locale. Hydrogeological maps divide groundwater into four broad categories, depending on their basic content and/or principal purpose. These categeories are:

- *Geological Groundwater Map.* This type of map shows the extent to which the geology of an area may provide indications of the occurrence, distribution, and movement of groundwater. This type of map presents an essentially static picture of what in nature is a dynamic system. It implies a closer relationship between geological formations and groundwater occurrence than what actually exists (Figure 12, and Figures 12-1 through 12-7). These figures depict the geologic formations throughout the watershed.

- *Hydraulic Groundwater Map.* This type of map utilizes the classification of rocks and formations according to the conditions under which water normally occurs within them. The geological formations are defined by their hydraulic and closely related characteristics, such as porosity, permeability, degree of fracturing, and shape of the aquifer. Hydraulic groundwater maps show limits of artesian and watertable conditions, groundwater divides, distribution of hydraulic characteristics, and the elements of geological structure, which influence groundwater occurrence (Figures 22-1 through 22-7). These figures depict the hydrogeologic or water-bearing units within the watershed. Each geologic formation has common characteristics with respect to its water-bearing capacity. Information supplied by Pennsylvania Groundwater Information System Database (DCNR, July, 1998) was used to illustrate the formation and yield for individual wells.

- *Groundwater Resource Map.* This type of map is widely used to indicate groundwater yield and characteristics of water quality (i.e., domestic, municipal, agricultural and industrial use). Groundwater resource maps generally do not show groundwater hydraulics and dynamics. In this report the Hydraulic Groundwater and Groundwater Resource Maps are combined in Figure 23, and Figures 22-1 through 22-7.

- *Groundwater Contour Map.* This type of groundwater mapping and assessment, utilizes concepts based upon the mapping of hydrological properties and classical geological characteristics. The information presented on the map may include the ability of the subsurface rocks to transmit and store water, as well as their permeabilities, transmissivities, storage coefficients, hydrochemical characteristics and the characteristics of the water table (Figure 23).

- Hydrologic information of precipitation, evaporation, and water level measurements are used to estimate the general direction of groundwater flow, the location of recharge and discharge areas, and the connection between aquifers and surface water systems. Water chemistry data can be used to infer flow directions, identify sources and amounts of recharge, estimate groundwater flow rates, and define local, intermediate, and regional flow systems.

Major Tributaries

The Cooks Creek Watershed includes a total of 40 sub-watersheds that were delineated using the GIS technique to outline the drainage basin divides. Tributaries provide the essential quantity and quality of water for the larger stream systems, and are most vulnerable to the impacts of land disturbance and development. Land use issues are directly linked to the potential adverse impacts upon the watershed (Figures 12, and Figures 12-1 through 12-7).

It should be noted that two small tributaries CC20a and CC22a, located in Area 5 in the southwestern portion of the watershed, have not been classified as *second-order tributaries*. (Figure 5-5). These streams and their smaller tributaries are classified as *direct local drainage of the headwaters area*, thus showing the special importance of *first order* streams.

Watershed Water Quality Sampling

As part of the Water Quality Subtask, a Water Quality Survey of Cooks Creek and its tributaries were conducted. Twenty-seven (27) locations were surveyed within the Cooks Creek Watershed (Figure 24). Field parameters tested include: alkalinity, carbon dioxide, ambient air temperature, water temperature, pH, specific conductivity, turbidity, and dissolved oxygen. In addition, laboratory chemical analyses were conducted to supplement the field survey work. Twelve stream samples were analyzed for phosphates and nitrates, and 8 samples were analyzed for fecal coliform. These parameters and their importance to water quality are discussed below. This information was obtained from the Delaware River Basin Commission (DRBC) website.

Alkalinity: Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes (keeps the pH fairly constant) and makes water less vulnerable to acid rain. The main sources of natural alkalinity are rocks, which contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates may also contribute to alkalinity.

Limestone is rich in carbonates, so waters flowing through limestone regions generally have high alkalinity -- hence its good buffering capacity. Conversely, granite does not have minerals that contribute to alkalinity. Therefore, areas rich in granite have poor buffering capacity.

Water Temperature - Water temperature is an important environmental factor for fish and other aquatic life. Many species can only tolerate specific temperature variations. Of particular importance to Cooks Creek is maintaining temperature suitable for maintaining the wild and native trout populations.

pH pH is a measure of the acid/alkaline relationship in a water body. pH values range on a scale of 0 to 14, with 7 being neutral. Since pH is logarithmic, a one-notch change in pH (e.g., from 6 to 7) represents a 10-fold increase.

A pH of about 6 to 9 is generally favored by aquatic life, especially fish. Chemicals released from industry, mining, acid rain, and other man-made sources can adversely impact in-stream pH levels. Natural sources such as limestone deposits in bedrock and tannic acid (produced by certain vegetation) can also influence pH.

Conductivity - Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids, such as chloride, nitrate, sulfate and phosphate **anions** (i.e., ions that carry a negative charge) or sodium, magnesium, calcium, iron and aluminum **cations** (i.e., ions that carry a positive charge). Organic compounds like oil do not conduct electrical current very well therefore they have a low conductivity.

Conductivity is useful as a general measure of stream water quality. Each stream tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements. Significant changes in conductivity could then be used as an indicator that a discharge or some other source of pollution has entered a stream. For example, a failing wastewater plant would raise the conductivity because of the presence of chloride, phosphate and nitrate. On the other hand, an oil spill would lower conductivity.

Turbidity In simple terms, turbidity answers the question, "How cloudy is the water?" Light's ability to pass through water depends on how much suspended material is present. Turbidity may be caused when light is blocked by large amounts of silt, microorganisms, plant fibers, sawdust, wood ashes, chemicals, and coal dust. Any substance that makes water cloudy will cause turbidity. The most frequent causes of turbidity in lakes and rivers are plankton and soil erosion from stormwater runoff

Dissolved Oxygen Dissolved oxygen (DO) is oxygen that is dissolved in water. It is produced through diffusion from the surrounding air; aeration of water that has tumbled over falls and rapids or as a by-product of photosynthesis. The amount of dissolved oxygen present is affected by temperature. Cold water generally contains more DO than warm water.

Nitrate and Phosphate - Nitrate and phosphate are necessary for aquatic plant growth, which support the rest of the aquatic food chain. An appropriate level of nutrients is one of the driving forces of the aquatic ecosystem. Both of these nutrients are derived from a variety of natural and artificial sources, including decomposition of plant and animal materials, man-made fertilizers, and sewage. Rainfall also can be a significant source of nitrates. Excessive nutrients might cause undesirable plant growth, which negatively impacts water quality.

Determining the optimum levels of nitrates and phosphates in water is extremely complex. Their levels often fluctuate considerably because they are constantly being taken up and released by aquatic life, being exchanged with stream bed sediments, and undergoing various other transformations.

In natural unpolluted water, phosphate levels are generally very low. Phosphorus, which combines with oxygen to form phosphate, is most often the limiting factor for plant production in streams. Nitrogen uptake by algae is generally in the nitrate form if nitrate is available. However different types of fresh water algae can utilize either organic nitrogen or inorganic nitrogen in the form of ammonia, depending on which is available (Stumm and Stumm-Zollinger, 1972). Algae typically require phosphorus in an inorganic form, usually as orthophosphate ion (Kormondy, 1969).

Fecal Coliform - Fecal coliform is the measure of the amount of human or animal waste in the water. The amount of fecal coliform affects the health of the stream and determines the ability of the stream to support aquatic life.

Results of Water Quality Monitoring (Field Parameters)

Two (2) sediment samples were collected, one upgradient and one downgradient of the dam at Paper Mill Facility. One water sample was collected near downgradient of the dam. Sediment samples are designated with the letter ”S” and numbered sequentially. The sediments samples (S1 and S2) were analyzed in a laboratory for toxic metals, pesticides and herbicides. Stream water samples were designated with the letters “SW” and numbered sequentially. The stream water sample (SW1) was analyzed for toxic metals, pesticides, herbicides, phosphorus and nitrates. Twelve (12) samples were collected and analyzed for phosphate and nitrates. Fecal coliform was also analyzed from 8 field locations. These field survey results did not reveal any indication of chemical contamination. Sampling sites were established at locations within the watershed where appropriate base line stream characterization could be calculated. A summary of the results is shown on Table 1.

USEPA National Watershed Characterization, dated September 1999, indicates less than 5 % of water quality samples collected exceed maximum contaminant levels (MCLs) for groundwater and surface water within the watershed. MCLs are the highest amount of contaminant the USEPA permits in drinking water. MCLs were established to ensure drinking water posed no short or long-term health based risks to the general public. This particular finding is, therefore, an indication of relatively good drinking water quality throughout the watershed.

The watershed is not without water quality issues, however. A literature search and a field survey revealed that both suspended sediments and nutrient runoff have contributed to apparent stress in various locations throughout the watershed. Nutrient levels up to 1 mg/L and elevated phosphorous concentrations suggest a concern within the watershed. Evidence of blue-green algae in Silver Creek, near the firehouse on the south side of Route 412, reflects the results of such water quality issues. While the data collected to date do not indicate a definitive management action, they do indicate the need for a more detailed investigation into the reasons for their presence and to suggest appropriate management action.

Field parameter screening was conducted at the 27 stream quality assessment locations. These results are summarized in Table 2. The following list presents the range of results noted during this investigation:

- Water temperature 13.8˚C to 23.9˚C,
- pH 7.5 to 8.88 standard units,
- Conductivity 0.136 to 0.298 mS/m
- Turbidity 0.0 to 17.0 NTU
- Dissolved Oxygen 5.02 to 11.2 mg/L

These results indicate a varying degree of water quality within the watershed. Field parameter graphs are shown in Appendix B, Attachment B1.

Stream Visual Assessment

The Delaware River Basin Commission (DRBC) protocol was utilized to visually assess the stream conditions in the watershed. The same 27 water quality sample locations were visually assessed in conjunction with the water quality sampling. As part of the visual assessment the following factors were assessed: instream cover, fine particle sediments, flow patterns, stream bank conditions, disturbances to the riparian buffer, riparian zone vegetative width, litter, and overall assessment (Table 3).

The visual assessment revealed that several stream segments within the watershed would be classified with the qualifiers of *marginal* and *poor* conditions according to this assessment protocol. The majority of these *marginal* and *poor* sites are located at road crossings (SW8, SW11, SW14, SW15, SW16, SW17, SW21, SW22, SW23, and SW25).

No other areas showing specific mismanagement with respect to surface water were found during this study; however, Springfield Township may wish to consider periodic assessment of the downstream locations from the trash transfer station and the used tire yard. Similar areas are often a source of stream contamination, therefore, these areas may warrant close attention.

Stream Morphology Assessment (Rosgen Classification Technique)

Morphology is the study of the form and structure of a biological system. Stream classification is key in understanding and predicting natural stream response to restoration and predicting patterns and conditions of stream flow. Natural self-stabilizing tendencies have proven to be much more successful in channel restoration than engineering control practices. Understanding the natural morphologic features of an un-impacted stream can serve as a basis for achieving natural stability, rather than attempting to employ rigid engineering controls (i.e. gabion channels, etc.). Letting "nature take its course" can be beneficial when planning and implementing stream restoration or enhancement. Watershed management is enhanced through the proper classification and basic understanding of stream morphology.

Rosgen developed a *Field Guide For Stream Classification* (1998) that has become a widely accepted methodology to classify streams. The effective classification of a stream requires objective, quantifiable data or criteria that yields consistent results from varying individuals (e.g. two people in two separate evaluations yield the same results from the same method). A method like this can provide uniform, reproducible, reliable, and comparable classification of streams.

Rosgen effective classification of streams is shown in Appendix B, Attachment B2.

Rosgen's Method was used to classify seven (7) areas or transects within the watershed. Figure 25 depicts the location of these transects, while Table 4 shows the results of the classification. Attachment B2 includes the classification key for single thread natural rivers, established in Rosgen's *Field Guide For Stream Classification*, (1998).

Point Source Pollution

In order to maintain the watershed's EV status, protection against stream water quality degradation is crucial. *Point source* pollution is pollution that can be traced to a single source, such as a discharge pipe from an industry. Industrial plants and sewage treatment plants in the watershed are the main sources of *point source* pollution. Sewage treatment effluent discharges nutrients and phosphorous from human waste and household chemicals into the watershed. Industrial wastewater may have more pollutants related to manufacturing processes. A total of approximate 2,200 *point source* discharges exist as septic systems within the watershed (Figure 26).

Historically there was one known solvent spill, within the Cooks Creek Watershed on January 17, 1987. This area is known as the Durham Township Drum Site. Emergency response activities took place on February 4, 1987. The enforcement removal administrative record file is available at USEPA Region 3 –HSCD, Incident Notification Report, Case No. PA87251

Non-Point Sources

Non-point source pollutants are those pollutants that do not come from a pipe or single source, but rather from a wide area or diffuse source. Typically, nonpoint pollution results from chemicals carried in stormwater runoff. Nonpoint source pollution can also come from the atmosphere or move through groundwater. For the Cooks Creek Watershed, minimizing nonpoint source pollution is the single most important act that can be done by residents to maintain water quality.

Examples of sources of *non-point source* pollution are:

- Roads
- Parking lots,

- Lawns,
- Cultivated fields and livestock maintenance areas,
- Construction sites, and,
- Stormwater management control systems.

Examples of non-point source pollution are:

- Siltation
- Nitrates and Phosphates
- Petroleum Hydrocarbons
- Trace Metals (lead, cadmium, chromium)
- Pesticides and Herbicides
- Bacteria

Proper public education and information dissemination can greatly reduce the impact from *non-point source* pollution.
Impervious surfaces are relatively low within the watershed. Index of Watershed Indicators (IWI) data (EPA, 2001) indicates Cooks Creek watershed as a watershed with Less Serious Water Quality Problems. For Overall Watershed Characterization maps generated based on IWI data and DRBC maps are shown in Appendix B, Attachment B3.

Stormwater Management

New impervious surfaces (i.e. areas where water no longer penetrates the ground surface such as paved surfaces) result in significantly reduced groundwater infiltration and aquifer recharge since water or wastewater resources are exported from the watershed system. Reduced recharge results in lowering the water table with a corresponding reduction in stream base flow. As base flow decreases during dry periods, crucial first-order tributaries and existing shallow wells may dry up resulting in drastic ecological consequences.

Conversely, the impervious surfaces that reduce infiltration result in increased stormwater discharge. Even with careful design, the use of detention basins for stormwater management increases the total volume of stormwater discharged. This is due to the fact that such detention basins only control the peak rates of stormwater discharge.

As detention basins multiply throughout a watershed, adverse downstream impacts may result. These adverse impacts include: flooding, increased runoff volumes, stream bank and channel erosion, and altered stream morphology. Water pollutants resulting from increased stormwater runoff is also an important concern.

This water quality impact includes wet weather discharges or "mass loads" of *non-point source* pollution from these new impervious areas, containing hydrocarbons (petroleum product residuals), metals, biological/chemical oxygen demand (BOD/COD), and a host of other pollutants. Stormwater pollution also is generated from large areas of chemically maintained landscapes, such as lawns and gardens, as well as agricultural fields and livestock maintenance areas. These areas generate nutrients, sediment, COD, pesticides and herbicides. During dry weather, *non-point source* water quality impacts include malfunctioning on-site septic systems and other small but significant wastewater flows.

Efforts should be taken to minimize additional *non-point source* pollutant inputs into surface waters. Surface water *non-point source* pollution in particular, erosion and sedimentation, and lack of groundwater recharge are, perhaps, the greatest concern with respect to stormwater management. Stormwater management ordinances should be consistent with guidelines presented in *Pennsylvania Handbook of Best Management Practices for Developing Areas* (1998) or in the *PADEP Erosion and Sediment Pollution Control Program Manual* (2000). For instance, the 2-year storm or one that produces 3.2 inches of rain in a 24-hour period of time, is the most frequent storm resulting in erosion and flooding. Comprehensive ordinances should incorporate provisions to protect against the impacts from such events.

Wetlands

General Description

Possible wetland areas were first identified with the use of U.S. Fish and Wildlife Service NWI maps, aerial and color infrared photography followed by onsite reconnaissance. The Cooks Creek Watershed supports a great abundance and diversity of wetlands. Figure 27 shows the approximate location, classification, extent of wetlands, and waters of the U. S. that were field identified in June and July of 1999 by the EEE and classified on the NWI maps. As previously mentioned, a Wetlands Management Plan was developed from this study.

The NWI maps depict 337 acres of wetlands within the watershed. A total of 259 acres of wetlands were field investigated in 1999. Of the 259 acres, only 158 acres had been previously shown on the NWI maps. This suggests that there may be considerably more wetland areas within the watershed than previously interpreted. Based upon this information all developments along the Cooks Creek corridor should require a wetland evaluation prior to development to protect against the loss of these resources.

Springs and Seeps

Numerous springs or seeps were found in the watershed, particularly in the headwaters. Most springs and seeps are located within 500 feet of a first-order stream (Figure 28). The springs and seeps are critical to the continued existence of nearby wetlands, special status species and the trout populations. This is due to the fact that the discharge from springs and seeps provide year-round base flow and contribute cool, high quality water that is vital to the survival of these populations.

The numerous springs or seeps from the base of slopes found in the area, are most vulnerable to the impacts from land use, land disturbance, and development. Special consideration should be given to the protection recommendations in this study.

Wetland Threats

Wetlands within the watershed do not appear to be significantly stressed due to hydrological modification, development, or human activities. Groundwater discharge and stream flows provide the crucial water source for most wetlands. If these hydrologic sources are modified, the wetlands may be at risk. In addition, increased or intense development in close proximity to wetlands could adversely affect them.

Wetland Functions and Values

According to the Wetland Evaluation Techinque (WET II) analysis, wetlands in the Cooks Creek Watershed are highly effective in providing groundwater recharge, groundwater discharge, flood-flow alteration, wildlife migration and wintering, aquatic diversity, and recreation.

Riparian Buffer Areas

A riparian area is defined as the area within 75 to 100 feet from the edge of both banks of the stream. Simply defined, riparian buffers are streamside plant zones. These buffers have a variety of functions, including: absorption of excess nutrients; shading and cooling waters; reducing the speed and volume of runoff entering a stream; and providing stream bank stabilization. These buffer zones provide an important phase of protection against *non-point source* discharges such as sediment, nutrients, and pollutants. The roots of trees and vegetation secure soils and therefore, reduce flooding and stream bank erosion. Littoral waste or leaves, twigs, branches, and other organic debris that fall in streams and waterways, decay and become an important part of the food web for micro and macro organisms within the stream. Trees and herbaceous plants provide shade along tributaries and maintain cooler water temperatures necessary for natural aquatic organisms, including brook and brown trout.

A 75-foot wide cover on each side of a tributary is typically recommended in southeastern Pennsylvania's local zoning ordinances. This maximizes the benefits to a stream's health and sustains conservation of watershed resources. Reforestation efforts, although generally effective may not provide the best habitat for "native" flora and fauna. While vegetative cover is recommended along tributaries, it may be beneficial to have scrub/shrub or herbaceous plant species rather than woody plants and trees. "Riparian Buffer Easements" or a landowner's voluntary agreement to maintain the stream corridor, have been found to be one of the most efficient ways to maintain and/or restore stream riparian buffers.

It should be noted, that a common misconception is that the riparian buffer zone can be reduced in size as one nears the headwaters of a stream. This is due to the fact that the headwater channels are smaller in size. Headwater channels may include ephemeral channels including streams, ditches, or swales that flow only during storm events. These areas are the most vulnerable to adverse impacts from *non-point source* discharges and, therefore, should have *the same or greater* width of protection through riparian buffer zones.

GIS maps were used to evaluate these areas. A total of 1,607 acres of riparian buffer zones were found Figure 28. The majority of the buffer is deciduous forestland (45 %) and farmland (43 %). The remaining buffer consists of: herbaceous rangeland, scrub/shrub rangeland, mixed rangeland and coniferous forest each comprising 3 % or less of the riparian buffer. Further evaluation regarding riparian buffer zone quality should be conducted within the watershed, to ensure continued protection of watershed resources.

Lakes and Ponds

Most of the lakes and ponds currently within the watershed cannot be considered naturally occurring. The watershed area was not influenced by glacial activity from the most recent Wisconsin Ice Age. Thus, the lakes and ponds within the watershed were not created by glacial scouring, but were created by human activity. There are approximately 95 lakes and ponds within Cooks Creek Watershed. Seventy-eight (78) are associated with area wetlands. The high percentage of wetland-associated ponds and lakes, stresses the importance of wetland protection in the watershed (Figure 29). Some ponds were constructed for use in mill processes and farming purposes.

Floodplains

Flooding has not been a serious problem in the Cooks Creek Watershed even though significant amounts of stormwater runoff reach the streams. The 100-year floodplain is mapped on the hydrologic resource map (Figure 30). Adverse effects from impervious surfaces are relatively low within the watershed; therefore, floodplains are still somewhat undeveloped. Impacts from flood-related concerns experienced in heavily suburbanized areas have not been felt in this region. The cumulative effects from flooding impacts due to conventional stormwater management systems can be avoided through proper planning and zoning.

Recent flooding experienced in other areas of the state, such as in the Darby Creek Watershed reflect the need for appropriate protection of floodplains and flood-prone areas. Floodplains provide the storage capacity for storm water events that occur within any given watershed. The Federal Emergency Management Agency (FEMA) administers the National Flood Insurance Program. This program enables property owners to purchase insurance coverage against losses resulting from flooding. In areas not mapped by FEMA, PADEP has established jurisdiction over all activities occurring within 50 feet from the top of bank of a watercourse.

Critical Areas Related to Water Quality

Spatial analysis performed during the wetland management study that identified critical areas related to the surface water to groundwater interconnection issues within Cooks Creek Watershed produced the following *overlay zones* in need of special attention:

- First-Order Sub-basins,
- Wetlands Buffer,

- Riparian (Floodplain) Map, and,
- Lakes and Ponds.

Water Supply

Most of water supply is private residential potable water wells.

Public

The community of Springtown in Springfield Township is serviced by a public water supply. The water is collected from a spring located near the Cooks Creek Watershed divide near Springfield Township's boundary with Lower Saucon Township. This public water supply system also includes production wells. The area served by the public water supply is shown on Figure 31. This public water service covers approximate 750 acres with approximately 230 customers.

Private

The total number of private residential wells is approximately 500 in Durham Township and 1700 in Springfield Township

Water supply is typically groundwater-based, pumped from the aquifers with corresponding reductions in stream base flow. Water use can be considerable for different land uses and activities. Water consumption increases during the warmer weather months when stream flow is already at its lowest point.

The concept of Sustainable Watershed Management (*Sustainable Watershed Management at the Rapidly Growing Urban Fringe*, T. H. Cahill, et al., Watershed 96 Proceedings) utilizes fundamental resource management objectives to: 1) measure the tolerance limits of the natural system, and 2) balance the human use of land and water resources in order that the carrying capacity of these natural systems are not exceeded. The following management objectives have been established based on this concept, with modeling methodologies developed to achieve these objectives:

- Maintain stream base flow, and, in particular, during drought periods (Utilizing $Q_{7\text{-}10}$ methodology). In the Cooks Creek Watershed additional information is necessary to evaluate the $Q_{7\text{-}10}$; therefore, further data collection is required.
- Maintain groundwater levels in order to protect existing/future wells.
- Assure that stream flooding is not increased.
- Prevent groundwater contamination, particularly from nitrate.

Well Head Protection Areas

The depth to the water table is highly variable and ranges from zero to hundreds of feet below the ground surface. Usually, the depth to the water table is shallow near permanent bodies of surface water such as streams, lakes, and wetlands. An important characteristic of the water table is that its configuration varies seasonally and from year to year.

Although typically only wells that are screened near the water table are used for establishing a groundwater map, all accessible water wells were used in order to obtain a sufficient number of data points. The depth to the water table was determined by measuring it from the ground surface with a water level meter. Water levels are referenced to a common datum generally sea level. This allows one to configure the water table and provide an indication of the approximate direction of ground-water flow. Arrows drawn perpendicular to water table contours indicates the direction of ground-water flow along the upper surface of the ground-water system (Figure 23). The water table is continually adjusting to changes in the recharge and discharge patterns of the groundwater; therefore, water level measurements were made at approximately the same time, and the resulting map is representative only of that specific time (November 12-15, 1999).

VI. BIOLOGICAL RESOURCES

Wildlife

Overview

The wildlife habitat within Cooks Creek Watershed has been assessed several times since the Division of Water Quality (DWQ) has developed water quality standards designating Cooks Creek as “Exceptional Value”. These habitat evaluations targeted specific wildlife habitats (i.e. streams, lakes, wetlands, bogs), in various areas of the watershed. Appendix A presents findings and interpretations of various habitat evaluation reports completed from 1990 to present. Research relating to the wildlife resources of the watershed include: *Natural Areas Inventory of Bucks County, Pennsylvania* (June, 1999), *Bucks County Natural Resources Plan (*March*, 1999),* and *The Pennsylvania Department of Conservation and Natural Resource*s *Database.*

According to the U.S. Fish and Wildlife Service (USFWS), the Cooks Creek supports several populations of bog turtles (*Clemmys muhlenbergii*), which is listed as a federally threatened species. Bog turtles inhabit shallow, spring-fed fens (marshes), sphagnum bogs, swamps and pastures that have an open-canopy and are characterized by soft muddy bottoms and clear cool water that is usually ground-water fed. According to the USFWS, occasional transient species that are federally threatened or endangered may visit the Cooks Creek Watershed as well. A list of these species is included in Appendix C. The Pennsylvania Department of Conservation and Natural Resources database showed that the following state-threatened or endangered species have been recorded within or near the watershed:

Species	Status
Spreading Globeflower (*Trollius laxus Salisb.*)	State endangered
Red-bellied turtle (*Pseudemys rubriventris*)	State threatened
Least bittern (*Ixobrychus exilis*)	State threatened
Peregrine falcon (*Falco peregrinus)*	State endangered
Sedge wren (*Cistothorus platensis*)	State threatened
Bog turtle (*Clemmys muhlenbergii*)	State endangered

Information concerning the habitat, natural history, management practices, and identifying characteristics for each of these species is included in Appendix C. According to the Nature Conservancy, the bog-turtle and other special status species including the red-bellied turtle and the eastern mud salamander (*Pseudotriton montanus*) have been documented at one site within the watershed (Bureau of Water Quality Management, 1991).

The Bureau of Water Quality Management (1991) fish surveys within Cooks Creek Watershed reveal a diverse population of primarily cold-water fishes including:

Common Name	**Scientific Name**
Brown trout	*Salmo trutta*
Brook trout	*Salvelinus fontinalis*
Rainbow trout	*Oncorhynchus mykiss*
Rock bass	*Ambloplites repestris*
Redbreast sunfish	*Lepomis auritus*
Bluegill	*Lepomis macrochirus*
Green sunfish	*Lepomis cyanellus*
Pumpkinseed	*Lepomis gibbosus*
Largemouth bass	*Micropterus salmoides*
Smallmouth bass	*Micropterus dolomieui*
Longnose dace	*Rhinichthys cataractae*
White sucker	*Catostomus commersoni*
Blacknose dace	*Rhinichthys atratulus*
Common shiner	*Luxilus cornutus*
Swallowtail shiner	*Notropis procne*
Spotfin shiner	*Cyprinella spiloptera*
Silvery minnow	*Rhinichythys falactus*
Bluntnose minnow	*Pimephales notatus*
Cutlips minnow	*Exoglossum maxillingua*
Creek chub	*Semotilus atromaculatus*
Margined madtom	*Noturus insignis*
Tesselerated darter	*Etheostoma olmstedi*
Slimy sculpin	*Cottus cognatus*

Avian Species

The avian (bird) population within the county includes 135 nesting species and 117 transient or occasional visitors. Species, which have been lost or suffered the greatest declines are those associated with wetland habitats and grasslands. In recent years the Peregrine falcon (*Falco peregrinus*), a federal endangered species, has been noted nesting on bridges along the Delaware River corridor.

The Audubon Society utilizes a number of locations within the Cooks Creek Watershed during its Annual Christmas Bird Count, including sampling points located along stream corridors. At least 196 avian species have been recorded within the basin. Using a feeding guild classification system, 39 of these species are directly dependent upon water for survival. The Cooks Creek Watershed, because of its proximity to the Delaware River corridor, is utilized by a number of migratory avian species. Numerous resident species are dependent upon the continued excellent water quality. This is an example of how the benefits of the EV status extend far beyond the physical boundaries of the watershed.

Terrestrial Species

Ten species of turtles including at least one population of bog turtle have been observed in Bucks County. The Red-eared slider (C*hrysemys scripta*), an introduced species, is well established in many areas of the county. Fifteen (15) snake species are present in Bucks County, one of which is poisonous, the Copperhead. Eleven (11) amphibian species (frogs and toads) are present within Bucks County. Twelve (12) salamander and two (2) lizard species are also present.

Several mammal species such as raccoon (*Procyon lotor)*, opossum (*Didelphis virginiana)*, cottontail rabbit (*Sylvilagus floridanus)*, groundhog (*Marmota monax)*, striped skunk (*Mephitis mephitis*), chipmunk (*Tamias striatus*), and gray squirrel (*Sciurus carolinensis*) are common, abundant, and have adapted to humans. Red squirrels (*Tamiasciurus hudsonicus*) and flying squirrels (*Glaucomys volans)* are less common. The red fox (*Vulpes fulva*) has become increasing abundant, but the native gray fox (*Urocyon cinereoargenteus)* is rare. Beaver (*Castor Canadensis)* have become fairly common after being extirpated around the turn of the century and subsequently reintroduced from farther west. Muskrats (*Ondrata zihethicus)* are abundant throughout the region.

The Virginia white-tailed deer (*Odocoileus virginianus)* is the only large herbivore that thrives in this area. Small mammals include five shrews (*Cryptotis)*, three voles (*Microtus*), two native mice (*Pitymys*), and three mole (*Scalopus)* species. Although rarely seen, weasel (*Mustela frenata)*, ermine (*Mustela erminea)*, and mink (*Mustela vison)* are also present. The introduced Norway rat (*Rattus nervegicus*) and house mouse (*Mus musculus*) are common in areas adjacent to human activity but do not generally occur in natural habitats (*Natural Areas Inventory of Bucks County Pennsylvania*, 1999).

Large carnivorous mammals have declined in diversity throughout Pennsylvania due to the systematic early eradication of the Gray wolf (*Canis lupus)*, Wolverine (*Gulo luscus)*, Cougar (*Felis concolor)*, and Lynx (*Lynx Canadensis*). Coyotes (*Canis latrans)* are occasionally spotted in Bucks County. An occasional river otter (*Lutra Canadensis)* has been seen in Upper Bucks County and occasionally individual black bears (*Ursus americanus*) are spotted foraging in the region but none are known to frequent the area. Durham Mine in northern Bucks County is the second largest bat hibernaculum in Pennsylvania, housing 8,000-10,000 bats when last surveyed in 1997.

The interspersion of forest and agricultural lands, along with numerous wetlands located along stream channels, provides habitat for a variety of woodland, farmland, and wetland wildlife species. Game species include gray squirrel, raccoon, fox, ruffed grouse (*Bonasa umbellus)*, wild turkey (*Meleagris gallopavo)*, pheasant (*Phasianus colchicus)*, white-tailed deer, eastern cottontail rabbit, muskrat, weasel, and mink. Non-game species include numerous small mammals, reptiles, shore birds, raptors, and various songbirds. Many of these species are dependent on forested, agricultural, and wetland areas for food and cover.

Currently there has been no comprehensive evaluation of the wildlife fauna of the Cooks Creek Watershed, in spite of the recognition that the area has received from wildlife managers. In order to ensure that valuable habitat for wildlife is protected, this evaluation should be performed, focusing on those areas already identified as having the potential to support wildlife, particularly protected species.

Aquatic Species

Throughout the last century, fish diversity has declined in Southern Bucks County due to water pollution, habitat degradation, and the detrimental impact of introduced species. However, the Cooks Creek Watershed still maintains a diverse and natural complement of aquatic life.

Biological investigations of Cooks Creek by the Pennsylvania Fish Commission (PFC) and the Bureau of Water Quality Management (BWQM) reveal diverse, well-balanced, functional benthic macro-invertebrate communities. Sampling conducted by the BWQM in 1990 indicates a moderately high taxa count (ranging from 14 to 19 species). Samples were dominated by a number of mayfly, stonefly, and caddisfly genera. These are positive indicator species that reflect good to excellent water quality conditions within the sampling areas. An extensive evaluation of the benthic invertebrate communities in Cooks Creek was performed by the Durham Township EAC in 1997 and 1998 (Symbiosis, 1998). Overall, the invertebrate communities are typical of the high water quality present in the surface waters of the Cooks Creek Watershed, but are sensitive to low flow conditions. It is unknown if this is due to the reduced flow itself or from increased concentrations of low level nutrient pollution that comes with reduced flow.

Fish population studies confirm Cooks Creek and its tributaries are dominated by naturally reproducing brown trout and other fishes indigenous to a cold-water habitat. Fish species typical of warm/cool water habitats (e.g., green sunfish, bluegill, largemouth and smallmouth bass, and carp) have also been collected from Cooks Creek. These species were most likely transient individuals migrating from the Delaware River or introduced species from fish producing farm ponds. American eels (*Anguilla rostrata)* have also been noted in Cooks Creek Watershed.

Electro fishing by the PFC and the BWQM confirms natural population of brown and brook trout in Cooks Creek. Brook trout are established in a number of the unnamed tributaries. Brown trout biomass is highest in the tributary, which flows through Springtown and the main stem reach below their confluence. As described in the Surface Water section of this report, numerous limestone springs augment the main stem flow of Cooks Creek in this region. The naturally high fertility of these limestone springs in association with their effects on habitat stability (stable flows and temperature) supports a valuable cold-water fishery. BWQM personnel observed numerous brown trout between 12 and 18 inches during the March 13, 1990 survey.

Vegetation

General habitat types found in the Cooks Creek basin include old-field, pasture and cultivated lands (30 to 40 %), hardwood forest (30 to 40 %), wetlands, and riparian areas. Within woodlands, timber composition is primarily mixed oak, with American elm (*Ulmus Americana)* and red maple (*Acer rubrum)* present in the stream valleys.

Cooks Creek Watershed has a diversity of naturally occurring plants with 2,038 different species recorded. Prior to European settlement 1,393 native species were present. An additional 645 plant species were introduced.

Some introduced plants have become nuisance species such as: purple loosestrife (*Lythrum salicaria*), multiflora rose (*Rosa multiflora*), and lesser celandine (*Ranunculus ficaria*). These compete with native plant species. It is not known at this time the extent of infiltration of these species in the watershed or their impact on native flora. Another major threat to the native flora is the overpopulation of white tail deer, which over browse herbaceous species. This over browsing has resulted in the depletion of low-growing vegetation including native wild flowers, shrubs, tree seedlings, and saplings. Forest regeneration is threatened since there are no young tree seedlings and saplings to replace existing aging forest cover. Furthermore, erosion of steep slopes has resulted from loss of vegetative cover.

Natural Areas Inventory/PNDI Species

The Natural Areas Inventory is a program funded in part by PADCNR and sponsored by The Nature Conservancy. The purpose of these inventories is to provide the most complete compilation of data available regarding local flora and fauna. In addition the inventories include state or federally listed rare, threatened or endangered plant or wildlife species. The Pennsylvania Natural Diversity Inventory (PNDI) compiles inventories describing rare and significant natural resources within the Commonwealth of Pennsylvania.

Endangered and Protected Species were identified on the following sites. The numbering system of these sites is based upon *Natural Areas Inventory of Bucks County, Pennsylvania* (June, 1999) (Figure 32).

- **Durham Mine, Mine Hill and Rattlesnake Hill - "Site 6"--** The abandoned mine has become an important bat hibernacula, the second largest in Pennsylvania with 8,000 -10,000 bats recorded in a 1997 survey. Six species of bats have been identified at the mine, including two species of special concern in the state. The 150 to 175-acre forest that covers the northern and eastern slopes of Mine Hill and Rattlesnake Hill provides a link between the mine and the Cooks Creek and Delaware River corridors which is of significance for the bats and also provides habitat for 62 bird species including 10 rare breeders.

- **Buckwampum Mountain - " Site 55"** -- This site includes approximately 320 acres of forested slopes and hilltop; it straddles the boundary between Durham and Springfield Townships. Headwaters streams of Gallows Run and Cooks Creek originate in seeps and wetlands on the slopes of Buckwampum Hill. Fifty-eight species of birds have been recorded including 7 rare breeders.

Important Habitats

Several important habitats were assigned priority ranking. Six sites were ranked as priority 1, 2 or 3 as determined through information available at the time of this report (Figure 32).

Priority 1 Sites

Cooks Creek – Site No. 4 ***Springfield Township, Durham Township***

Cooks Creek (also known as Durham Creek) originates in the Triassic diabase and quartzite hills of western Springfield Township and flows in a northeasterly direction through Brunswick Formation shales into a limestone valley at Springtown. From there it follows a course through the Cambrian limestones of Springfield and Durham Townships to its confluence with the Delaware River below Riegelsville. The main stem of Cooks Creek is approximately 15 miles in length, the tributaries total an additional 37 miles. The creek has been designated an Exceptional Value (EV) stream by the PADEP. It supports a native brown trout population.

Headwaters of the main channel of Cooks Creek are on the lower slopes of The Lookout (see site # 35 below). Most of the land along the creek is agricultural, although extensive sedge meadows are present in several locations. Industry borders the creek near its mouth in the vicinity of Durham Furnace, the site of an early iron forge.

Cooks Creek is an outstanding aquatic resource. Protection efforts should extend from the headwaters downstream to the mouth at the Delaware River.

Notable features include:

- Tussock sedge marsh
- Red maple - scrub/shrub palustrine woodland
- Sugar maple - basswood forest
- Red oak - mixed hardwood forest
- Tulip tree - beech - maple forest
- Silver maple floodplain forest
- Red maple - scrub/shrub palustrine woodland

Durham Mine, Mine Hill, and Rattlesnake Hill – Site No. 6 ***Durham Township***

This site consists of extensive north-facing forested slopes extending for about two miles along Route 212 from Mine Hill Road to the intersection with Route 32 south of Riegelsville. The ridge represents a spur of the Reading Prong and is composed of Hardyston quartzite and Byram gneiss separated from the main mass of the Reading Prong by the limestone valley encompassing Cooks Creek. The early forge at Durham was supplied iron ore from Mine Hill. In 1851 a larger mine was opened to the east in Rattlesnake Hill, which supplied the nearby Durham Iron Works with ore.

The abandoned mine has become an important bat hibernacula, the second largest in Pennsylvania with 8,000 -10,000 bats recorded in a 1997 survey. Six species of bats have been identified at the mine, including two species of special concern in the State. Due to the importance of the hibernacula, in 1994 the Pennsylvania Game Commission and Heritage Conservancy collaborated to install specially designed gates to exclude humans, but allow bats to enter and leave freely. Problems involving vandalism of the gates have occurred, requiring continual monitoring and repairs. Increased monitoring of the gates is urgently needed to protect the bats, which are very vulnerable to disturbance, especially during hibernation. A rare fresh water invertebrate, Price's cave isopod, also, has been found in the mine.

The 150-175 acre forest on the northern and eastern slopes of Mine Hill and Rattlesnake Hill provides a link between the mine and the Cooks Creek and Delaware River corridors. This forest is important for the bats and also provides habitat for 62 bird species including 10 rare breeders.

Notable features:	Threatened and/or Endangered Status		
❖ Bat hibernacula housing 8,000-10,000 bats;			
❖ Red oak-mixed hardwood forest;			
❖ Eastern small-footed myotis Myotis leibii;	G3	S 1	PT
❖ Northern myotis-Myotis septentrionalis;	G4	S2S3	CR
❖ Price's cave isopod Caecidotea pricei;	G3	S2S3	
❖ 62 bird species, including 10 rare breeders.			

Priority 2 Sites

Cressman Hill – Site No. 27 ***Springfield Township***

This site consists of approximately 300-forested acres of slopes and flat uplands on diabase. It is contiguous with additional forested land comprising the Dimple Creek watershed, which extends into Haycock Township and includes Lake Towhee County Park. To the north Cressman Hill is part of the Cooks Creek Watershed. The forest is continuous except for utility right-of-ways and several roads that bisect it. It is a typical boulder-strewn diabase forest, ranging from moist to wet. Dominant canopy species include: tuliptree (*Liriodendron tulipifera*), red maple (*Acer rubrum*), red oak (*Quercus rubra*), white oak (*Q. alba*), swamp white oak (*Q. bicolor*), and shagbark hickory (*Carya ovata*). The herbaceous flora is rich and diverse.

Notable features:

- ❖ Tuliptree – beech – maple forest;
- ❖ Red maple terrestrial forest;

- Headwaters of tributaries of Cooks Creek, Three Mile Run and dimple (Kimbles) Creek; and,
- Large forested expanse.

The Lookout – Site No. 49 ***Springfield Township***

This site consists of a forested diabase hill (part of the Haycock diabase sheet) that rises more than 150 feet above the surrounding countryside to a maximum elevation of 911 feet. It is surrounded by approximately 300 acres of mixed deciduous forest with a rich herbaceous layer extending from Richlandtown Pike west to Salem Road. There is a large abandoned quarry on the southeast slope. An electrical power transmission right-of-way crosses The Lookout from north to south. The surrounding forests include old stonewalls, vernal ponds, and other varied habitat. Headwater streams of both Cooks Creek and the Tohickon Creek originate on The Lookout fed by springs on the lower slopes. The site is identified as an outstanding scenic geological feature of Pennsylvania (Geyer and Bolles 1979).

Notable features:

- Outstanding scenic geologic feature;
- Headwaters of Cooks Creek including springs on lower slopes of The Lookout;
- Red oak-mixed hardwood forest; and,
- Sugar maple-basswood forest.

Priority 3 Sites

Buckwampum Mountain – Site No. 55 ***Springfield Township, Durham Township***

This site includes approximately 320 acres of forested slopes and hilltop; it straddles the boundary between Durham and Springfield Townships. Headwater streams of Gallows Run and Cooks Creek originate in seeps and wetlands on the slopes of Buckwampum Hill. Fifty-eight species of birds have been recorded including 7 rare breeders. The county owns several parcels on the hill including a communications tower. Residences are scattered along the lower slopes on a dirt road, which leads to the top on the south side. Deer browsing is moderate to severe throughout the area. Geology is Triassic shale and quartzite and the site lies immediately adjacent to the Monroe Border Fault. A description of the forest composition approximately 100 years ago is provided by the journals of two local botanists, John and Harvey Ruth (White and Rhoads 1996).

Notable features:

- Headwaters of tributaries of Gallows Run and Cooks Creek;
- Red oak-mixed hardwood forest;
- Red maple-blackgum-palustrine forest; and,
- 58 bird species including 10 rare breeders.

Chestnut Hill – Site No. 57 ***Durham Township***

This site consists of extensive wooded slopes with scattered houses tucked into the woods. The entire area is heavily browsed by deer and consequently lacks shrub and under story canopy layers. Herbaceous species are also sparse. Chestnut Hill is composed of Triassic shale and quartzite and is adjacent to the Monroe Border Fault. Surveys by the Bucks County Audubon Society have identified 63 bird species on Chestnut Hill including 10 rare breeders.

Notable features:

- Immediately adjacent to the Monroe Border Fault;
- Red oak - mixed hardwood forest; and,
- 63 birds species including 10 rare breeders.

VII. CULTURAL RESOURCES

Durham Township

Durham Township has limited cultural resources. There is one small un-named municipal park located in the vicinity of Dogwood Lane. Local residents identify this park as the *Durham Township Park,* although no official name has been designated. This park consists of a baseball field, basketball court, and small playground for younger children. No privately owned athletic facilities are in existence within the Township. No hiking or biking trails are available at this park or in any other area of the Township. (Janet Davis, August 2001, personal communication)

In spite of Cooks Creek trout population, public fishing is difficult, as all the land adjacent to Cooks Creek is privately owned. Residents gain access to the Creek from areas adjacent to public roads or from bridges. No open space is currently designated by the Township; however, an application is being prepared for submission. An Open Space Plan has been approved and a parcel on Red Bridge Road is being pursued at this time. In addition, it should be noted that several farm land parcels are held under agricultural preservation and conservation easements.

Springfield Township

The following information was obtained via a telephone interview with Jeffery Mease, Springfield Township Zoning Officer, August 2001. Springfield Township has no municipally owned parks, hiking, or biking trails. There is discussion with officials pertaining to the construction of a hiking trail between Durham and Springfield Townships.

Fishing throughout the Township is similar to Durham, where all land adjacent to Cooks Creek is privately owned. Admittance to fishing areas is limited to public road or bridge access. Springtown Village is the home of a privately owned Athletic Association equipped with tennis courts, basketball courts and baseball fields primarily used for little league baseball. Playground areas are available for use under limited conditions at public school buildings.

No municipally held land is designated for open space. The Township is actively investigating the opportunities for the purchase of land or development rights for open space use. The Springfield Township Open Space and Farmland Preservation Plan identifies the following privately held properties within Springfield Township:

- The Heritage Conservancy owns 63.7 acres dedicated for open space,
- The Haycock Camping Ministries owns 160.78 acres, and
- The Silver Creek Recreation Area holds 31.83 acres for private recreation.

This plan further identifies the following conceptual recreational trails (Figure 33):

- Silver Creek Athletic Association to Durham Athletic Association;
- Walnut Street, Springtown to Springtown Rod and Gun Club;
- Springfield School to Silver Valley Conservation Area;
- Quarry Road to Ebert Road for access to Passer Community Association;
- Active/Passive Recreation Area on PP&L Property on Wrecsics Road; and,
- Route 212 Richlandtown Borough to Funks Mill Road/Old Bethlehem Road.

Cooks Creek Watershed

Cooks Creek Watershed Association

The Cooks Creek Watershed Association (CCWA) is a private not for profit corporation providing a forum for public education and advocacy for the Cooks Creek Watershed. The CCWA was founded in 1974 and has membership ranging from a few dozen to a few hundred concerned citizens. The Association adopted the following as its goal. "To protect, preserve and improve the quality of water, land and life in the Cooks Creek Watershed."

In the years since its founding CCWA has done much to further this lofty goal. Environmental camps have been conducted jointly CCWA and other nearby environmental education groups almost every year from 1975 to 1995. Camps have explored topics ranging from life in ponds and wetlands, forest ecology, Native Americans, and included night-time owlings. Recently, these outreach activities have been reinvigorated through the CCWA participation in the Rivers Conservation program.

In 1975, Cooks Creek was classified as a "warm water fishery" suitable for trout stocking. The CCWA recognized that the water quality was much higher than warm water fishery since Cooks Creek supported reproducing populations of brown and brook trout, had abundant macro invertebrates and had many other small fishes. In 1976 CCWA initiated the first stream reclassification effort and saw Cooks Creek's classification raised to "cold water fishery." In the late 1980's, after much work on the part of the members of CCWA the classification was again raised, this time to "exceptional value waters."

Stream Improvement was a very important part of CCWA during the 1980's. Starting in 1977 when its first gabion was placed to divert the storm flow away from an eroding bank until 1991 when the program was completed CCWA members worked with the Soil Conservation District, the Fish Commission and Trout Unlimited to reduce soil erosion and flooding.

Water Quality has been a driving force of CCWA since the first reclassification of the waters of Cooks Creek in 1976. CCWA has tested the stream at varying places and times. In 1975, testing for *E. coli* bacteria was started and continued until 1977. The Fish Commission has surveyed the stream with shock treatments and the Delaware River Keepers Network has tested the waters for dissolved oxygen, pH, temperature, nitrates and phosphates. CCWA has joined the River Keeper and is now testing for these five parameters at four sites in the watershed. CCWA was asked to assist the U.S. Geologic Survey in measuring the groundwater levels and flows in the Cooks Creek Watershed. CCWA members participated for two years, measuring rainfall and recording meteorological events. The 1990's saw CCWA help broker a deal that involved the donation of a 64-acre tract of land to the Heritage Conservancy.

In addition to the CCWA, the watershed also has two functioning Environmental Advisory Councils (Durham and Springfield Townships). There is also a movement underway to establish a private land conservancy.

Bucks County

Limited cultural and recreational resources are available within Durham and Springfield Townships; however, access to numerous resources within Bucks County is available. These facilities are in close proximity to Cooks Creek Watershed, and can be enjoyed by all watershed residents. A brief description of Bucks County's cultural and recreational resources follows.

The Bucks County Department of Parks and Recreation and Bucks County.com web sites identify the following park and recreation areas within the County:

- Seven (7) Parks: These parks offer: playgrounds, picnicking, hiking, ball fields, horseback riding trails, boating, fishing, camping, swimming, ice skating, nature areas, and rest rooms,
- Two (2) State Parks: These are: Delaware Canal State Park and Nockamixon State Park,
- Two (2) Nature Centers: These centers offer educational recreation,
- Two (2) Boat Rental Facilities, and
- One (1) Wildflower preserve.

Three environmental organizations are based in Bucks County. Each offers services for the protection, restoration, and enhancement of Bucks County's natural resources. These are: Delaware Riverkeeper Network in Washington Crossing, The Heritage Conservancy in Doylestown, and The Raymond Proffitt Foundation in Langhorne.

The area also boasts numerous Bed and Breakfast Inns throughout the region. Tourists are attracted to this region as it offers antique shopping, specialty stores, outdoor fun, and historic sites. These historic sites include: Washington Crossing Historic Park, The Pearl S. Buck House, The Fonthill Museum, The Moravian Pottery & Tile Works Museum, The Mercer Museum, and the Michener Art Museum.

VIII. WATER BUDGET

A water budget can be compared to financial budget. A financial budget is used to maintain a balance between a persons' income and their outgoing cash flow or debt. A water budget can be considered much the same way. In other words, to maintain a balance in the ecological system one must account for the *income* (sources of water) and *outgoing* (water losses in the system) water resources. A water budget is used to manage growth and development within a community, and to guarantee that a sustainable supply of water remains consistent over time. This is also called the carrying capacity of the groundwater system. The quality and quantity of surface and groundwater sources, would be limiting factors with respect to growth density and siting for development. Careful planning should prevent exceeding the carrying capacity of the watershed.

The water budget takes into account the water cycle, evapotranspiration, groundwater and surface water supplies, and interbasin (import and export) transfers of water. A water budget is important to understand since it provides crucial information regarding the carrying capacity of the land with regard to water resources.

Aspects of the Water Budget

The Hydrologic Cycle or Water Cycle is the complex naturally occurring cycle or movement of water through evaporation, wind transport, stream flow, percolation, and other related processes. This cycle links the relationship between:

1. *Surface water* including: streams, run-off, and discharges; and,
2. *Groundwater* including: recharge, geologic formation yield potential, soil storage capacity, and aquifers.

The cycle describes how water circulates through the natural process. This system begins with the sun evaporating ocean and surface water. The evaporated water vapor enters the earth's atmosphere and moves with the flowing winds. Some of the water condenses into water droplets and is precipitated as rainfall and snow. The precipitation runs off the land surface and eventually flows back to the ocean completing the cycle. The cycle is generally limited by the local climate and the amount of precipitation. The cycle can also be influenced, to some degree, by human activities.

The water budget is dependent upon this cycle and the influences upon it. Understanding the geology and hydrogeology of the underlying formation of the watershed helps assess the potential for groundwater yield. Soil matrix, topographic relief (i.e., slope), and vegetative cover are other factors that may affect stream base flow and thus water quality and quantity. All of these are factors that affect the *income* of the budget.

Development activities can affect the water budget since they can alter groundwater recharge and stream flow. Clear cutting forests, drilling residential wells, plowing or displacing soils, construction of impervious surfaces, and stormwater control systems all may adversely affect the natural hydrologic cycle through altered uptake and additional usage of water resources. These may result in *outgoing* losses to the budget.
The challenge is to understand how to sustain and maintain the water quality and quantity in light of current and future development trends. Current water demands should be compared with future water demand projections to evaluate the potential carrying capacity of the watershed.

Base flow analysis calculated from Cooks Creek stream gauge data indicate that the watershed basin has a large storage capacity sustaining up to 92.29 % of stream flow during dry seasons. Analysis of the stream flow data from 1990 through 1999 further indicates that groundwater attributed to an average of 68.24 % of the base flow to Cooks Creek (Appendix D).

It should be noted, data gaps exist in the data collected between 1992 and 1999. Ongoing stream flow monitoring is being conducted. Data pertaining to the ongoing work up to the date of this report is included in Appendix D. Currently there are four (4) types of data being collected that can be used to assess the water budget of the watershed including:

1) Cooks Creek flow monitoring collected at the former USGS gauging station. An additional monitoring point is planned at the confluence of Spring Creek and Silver Creek;

2) Monthly residential observation well water level monitoring (at four (4) locations);

3) Collection of water levels data from residential wells to upgrade the existing groundwater contour mapping; and,

4) Water quality analytical sampling events within various locations of the watershed.

The calculation of a hydrologic budget is relatively simple, involving the subtraction of total outflow from total inflow, plus or minus the change in storage within the region. Of all the variables affecting the water budget, evapotranspiration (or transpiration) estimates pose the greatest problem. Evaporation refers to water losses directly through the air, while transpiration is defined as the water given off from plants and trees directly into the air. These factors are extremley difficult to measure and predict.

Numerous empirical methods of calculating evapotranspiration have been developed. The most common is that of Thornthwaite and Mather (1957) where potential evapotranspiration (PET) is estimated solely from climatological measurements. PET is defined as the amount of water that would be removed from the land surface by evaporation and transpiration processes. Table 5 presents the results of the PET determination for the Cooks Creek Watershed. With this data the actual evapotranspirartion (AET) can be calculated to provide the basis for determining deficits or surpluses in the overall water budget equation.

Water Budget calculations are shown in greater detail in Appendix D.

IX. WATER BALANCE

The hydrologic equation, which is basically a statement of the law of conservation of matter, as it applies to the hydrologic cycle, defines the water balance. It states that in a specific period of time all water entering an area must either go into storage within its boundaries, be consumed therein, be exported from, or flow out either onto the surface or underground.

Groundwater is an integrated dynamic system based upon a combination of climatic, hydrologic, geologic, topographic, ecologic and soil-forming factors that collectively form a regime. These factors are interrelated in such a way that each provides some insight to the function of the system as a whole. Each factor can serve as an indicator of specific conditions present in the availabilty of groundwater. It is possible, therefore, to calculate the potential of an area for groundwater development by assessing as many of the factors listed above as possible. These factors are then compared or interpreted against known relationships among the factors and their effect on the groundwater regime.

A water balance input or *income* can be generated, in part, by calculating the potential groundwater yield from the geologic formations underlying the watershed. Varying geologic formations have been determined to yield specific quantities of groundwater. Geologic formations are comprised of hydrogeologic units. Data collected from these hydrogeologic units, have been used to determine the amount of groundwater each formation typically yields. For example, limestone formations are expected to yield a predictable quantity of groundwater, while crystalline formations yield an entirely different amount.

The area (size) of the 40 sub-watersheds was first determined using GIS based information. Next, the area of the geologic formations within each sub-watershed was calculated. The hydrogeologic units within each formation were then calculated to establish base flow contributions to the groundwater yield estimates (Table 6). The groundwater estimates were determined by taking the percentage of geologic units in each sub-watershed and multiplying the expected groundwater yield from each hydrogeologic unit. The expected groundwater yield was calculated for the following geologic categories, (1) Brunswick Group and Lockatong Formation, (2) the diabase, (3) carbonate rocks, and (4) crystaline rocks (Figure 22.1 through Figure22.7).

Each of the 40 sub-watersheds experience some amount of water use, primarily based upon residential use, which is expressed in "equivalent dwelling units" (EDUs). Based upon assumptions with respect to the number of dwelling units in each sub-watershed (estimated from the GIS database for population and households from the 1990 census) the consumptive use of water per dwelling unit was calculated at 300 gallons per day (GPD) (Table 7).

One statistic available to define the critical base flow condition is the Q7-10. The Q7-10 is the lowest consecutive 7-day average of stream flow, having the probability of occurring no more than once in a 10-year period. The recorded data for Cooks Creek flow-measurement station (12/12/1990 to 02/20/93, 05/11/1999 to 08/29/1999, and 12/18/1999 to present) indicates a critical base flow of 222 GPD/acre.

Due to the limited stream gauge data available for Cooks Creek, yield ratios for the various rock aquifers were estimated from annual base flow for the 2, 5, 10, 25, and 50 year recurrence intervals at stream flow-measurement stations on Brandywine and Neshaminy Creek Basins (USGS Water-Resources Investigations Report 96-4127).

Analyzing the current and future hydrologic balance for each of the 40 sub-watersheds required the application of the Water Balance Model (WBM). This conceptual model considers the dynamics of water movement from precipitation through the soil and then into the groundwater reservoir, with eventual discharge as stream base flow. The WBM can be thought of as a bookkeeping process that accounts for the dynamics of the water cycle by considering each sub-watershed under stress conditions. The stream base flow is used as the net result of all limiting factors, including evaporation, transpiration and human intervention, so that existing uses and conditions are taken into consideration. The WBM has been applied and compiled for the entire watershed to identify potential stress conditions in the system to protect the resource (Table 7).
The water balance equation is: The quantity of precipitation (P) is equal to the stream flow (SF) plus evapotranspiration (PET), plus groundwater pumpage (GP), plus increase in groundwater storage (IGWS). P = SF + PET + GP + IGWS

Examples of Water Use Based upon Existing Conditions within the Watershed

Sub-watershed **CC1** is 2,643 acres and should yield 222 GPD/acre in drought conditions. Establishing the consumptive loss limit at 50% for the base flow reflects that 305,852 GPD would be evaporated. The 409 existing dwelling units in the sub-watershed, all of which are assumed to use on-site wastewater systems, will cumulatively lose approximately 24,540 GPD. This is only 4% of the Q7-10 stream flow; therefore, base flow is not affected.

Nitrate loading resulting from residential on-site septic systems are of concern. These on-site septic systems may generate nitrate loading to the groundwater, which may eventually negatively impact the aquifer. The nitrate loading is estimated in the last column of Table 7. This estimate was evaluated assuming the background concentration is 2 mg/1 within groundwater. Calculations performed reflect concern since all drainage areas detected Nitrate limits in excess of the Nitrate load.

X. BEST MANAGEMENT PRACTICES

Best Management Practices (BMP) is considered to be the “best” guidelines and/or practices under current technology and understanding. BMPs can be initiated in the planning and design phases of projects in order to obtain the most benefit. BMPs have been prepared for numerous facets of development including: watershed management and protection; water quality protection; flora and fauna habitat protection; as well as residential well, septic system, and storm water control system design, construction and maintenance and/or monitoring.

Many publications have been prepared regarding BMPs. The primary sources widely used at the local or municipal level are:

- Pennsylvania Association of Conservation Districts, Inc. et.al. Pennsylvania Handbook of Best Management Practices for Developing Areas. Prepared by CH2MHill. Spring 1998.

- The National Farm *A* Syst / Home *A* Syst Program. Home *A* Syst – An Environmental Risk Assessment Guide for the Home. Natural, Resource, Agriculture, and Engineering Service (NRAES). April 1997.

- Commonwealth of Pennsylvania, Department of Environmental Protection. Erosion and Sediment Pollution Control Program Manual. DEP 363-2134-008, March 2000.

- Commonwealth of Pennsylvania, Department of Environmental Protection. Erosion and Sedimentation Control Plan Development Checkilists, Standard Worksheets, Details and Notes. A Companion to the Pennsylvania Erosion and Sediment Pollution Control Program Manual. January 1996.

- Commonwealth of Pennsylvania, Department of Environmental Protection. Summary Report of Urban Stormwater Nonpoint Source Pollution Controls and Practices. Prepared by Bureau of Watershed Conservation, 1998.

- Natural Resource Conservation Service. Pennsylvania Soil and Water Conservation Technical Guide, Part G, Section IV, Standards/Specifications. March 1983, revised October 1986.

- Pennsylvania State University. The Argonomy Guide. College of Agricultural Sciences. 1996 or most recent section.

- Commonwealth of Pennsylvania, Department of Transportation. Specifications. Publication 408M. 1996.

Appendix E provides copies of several BMP documents referencing wells, septic, and storm water systems. BMPs should be used when developing zoning ordinances or when passing local municipal codes with respect to the land use. Guiding Growth – Building Better Communities and Protecting Our Countryside, (Pennsylvania Environmental Council, September 1993), should be used as a planning guide to establish the framework for sound development and growth within Pennsylvania municipalities.

Utilizing GIS soil information from this report, detailed mapping was prepared showing the correlation between soil types and the "best" septic system design for the soil classification within a given parcel (Figures 36-41). This is an example of employing BMPs with the use of soil classifications when selecting various on-lot septic or conventional sewer systems available within the Cooks Creek Watershed.

XI. MANAGEMENT OPTIONS AND RECOMMENDATIONS

The overall goal of this Cooks Creek Watershed Conservation Plan is two fold: 1) to formulate a management program that truly sustains water resource through utilization of Best Management Practices (BMPs) and 2) to highlight those characteristics or critical issues in the watershed that require further study. This can be achieved through projects conducted in cooperation with watershed associations, agricultural organizations, various governmental agencies and others. Management options will include maintenance, enhancement and restoration activities. The following management options and recommendations should be considered for protecting, enhancing, and preserving the Cooks Creek Watershed resources:

1. Develop a Water Management Plan

Using data developed from ongoing and future studies, develop a Sustainable Watershed Management Plan that provides for wellhead and baseflow protection in the Cooks Creek Watershed.

2. Monitoring Cooks Creek Flow

The critical baseflow condition ($Q_{7\text{-}10}$) values are used in the Water Balance Model. The $Q_{7\text{-}10}$ has not been collected from the Cooks Creek Watershed using data from a ten-year period. Less than four years of data have been collected for this calculation. This equation requires the collection and use of 10 years of data, therefore, continued monitoring of the "Red Bridge Road" bridge location gauging station should be conducted to obtain the additional data required. The following maintenance actions should be conducted:

- *Maintenance of Red Bridge Gauge* – Continue to maintain and periodically download the computer at the Red Bridge Road monitoring station and upload into WAMOS;

- *Maintenance of the Rating Curve for the Red Bridge Road Gauging Station*. The Rating Curve requires annual riverbed profile measurements and periodic stream velocity measurements; and,

- *Install a Second Stream Gauging Station* – A second stream gauge station should be installed in the eastern edge of the watershed. Preferably this station should be upstream of the confluence of Silver Creek with the main stem of Cooks Creek, in the village of Springtown.

3. Monitoring Aquifer Levels

Water levels should be measured monthly at 4 to 6 residential wells. This data is used in groundwater storage and water budget calculations in WAMOS computer interface.

4. Generate an Upgraded Water Table Map.

In this study approximately 75 residential wells were utilized to establish the water table map. An additional 30 residential wells are suggested to measured for depth to water to upgrade the water table map.

5. Expand the GIS Database

As more watershed related data becomes available, expand and incorporate all data into GIS and computer applications. Train municipal officials in the use and maintenance of GIS databases. Develop and maintain current land use maps.

6. Continue to Develop the Hydrologic Database managed using the computer interface WAMOS

As more hydrologic data becomes available, continue to incorporate, expand, and enhance the hydrologic database and facilitate its use in planning activities.

7. Develop a Nutrient Management Plan

Low level, chronic nutrient pollution has been observed in the watershed and has been shown to impact water and habitat quality. Perform a comprehensive nutrient balance to determine the sources and causes of nutrient enrichment in the Cooks Creek Watershed. Use this information to pinpoint appropriate management actions.

8. Develop a Township Level Storm water Management Plan

Extremely local erosion problems have been observed contributing to siltation in the streambeds. Given the sensitivity of the wildlife and fisheries of the watershed these problems should be carefully examined and controlled, if possible. Although a county-wide storm water management plan exists a specific township level plan should be developed to determine the locations and magnitude of storm water runoff in the watershed. Monitor erosion throughout the watershed and determine its causes. Develop a plan to manage both storm water and erosion and determine appropriate management actions.

9. Develop a Comprehensive Biological Inventory

Considerable biological resources exist in the watershed. In order to monitor the success of this plan and to alert officials to any future problems, work with local watershed groups to establish and monitor the health of the biological resources of the watershed including but not limited to:

- Fish population surveys;

- Rare and endangered species (flora and fauna);
- Wetland plant inventory;
- Bats of Mine Hill; and,
- Benthic invertebrate diversity and health.

10. Expand and Maintain a Water Quality Monitoring Program

In order to expand water quality monitoring information and track improvement, the following community programs should be encouraged:

- Stream Watch Program (Philadelphia Academy of Sciences program or equivalent);
- Nutrient Survey and Management Plan; and,
- Visual assessment (Delaware River Basin Commission method or equivalent).

11. Educational Activities

Educational programs are necessary to change misconceptions regarding watershed resources and to encourage future protection and enhancement of Cooks Creek Watershed. The following educational programs or forums should be considered:

- Water Quality Seminars for Local Government Officials:
    - Maintaining current or limited ground water levels in order to protect against excessive groundwater draw down that would result in adverse effects to wellheads and stream baseflows;
    - Suitability of soils for on-site septic systems including:
        - Soils feasible for conventional systems;
        - Soils feasible for alternative systems;
        - Soils not feasible for any type of on-site system;
        - Carbonate derived soils, not feasible in Bucks County for any on-site system; and,
        - Soils subject to flooding, not feasible for any on-site systems.
    - Minimization practices for point and non-point source pollutants; and
    - Improving riparian buffer management along tributaries.
- Public Workshops
    - Public awareness of non-point source pollution;

- Implementation of animal nutrient management plans;
- Improving farming practices especially with respect to livestock stream crossings and stream corridor livestock fencing initiatives; and,
- School outreach..

12. Riparian Buffer Improvements

A complete assessment of current stream bank conditions should be conducted to determine priority sites within the watershed requiring riparian buffer enhancements. Riparian buffer improvement and management programs should be employed.

13. Ordinances and Planning Documents

Update the Comprehensive Plans for both Durham and Springfield Townships. Include the data in this plan, and referenced studies. Work to ensure that water quality and quantity are sufficient to support local vision for the future of the watershed.

The following critical areas should be considered for zoning ordinance and Comprehensive Plan preparation:

- Storm water management and erosion control;
- Wetlands protection;
- Baseflow protection;
- Conservation easements and open space;
- Endangered and/or threatened species habitat protection;
- Karst and sinkhole land development standards;
- Overlay districts of critical areas (first order sub-basins; wetland buffers; riparian (flood plain); and, lakes and ponds);
- Septic systems types based upon soil districts;
- Steep slopes;
- Stream or riparian buffers; and,
- Wellhead protection.

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