Conservation Plan
for the
Cooks Creek Watershed
Bucks County, Pennsylvania

A CASE FOR PROTECTION OF THE COOKS CREEK WATERSHED

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

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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 have been prepared to implement this plan consistent with the results of these studies.

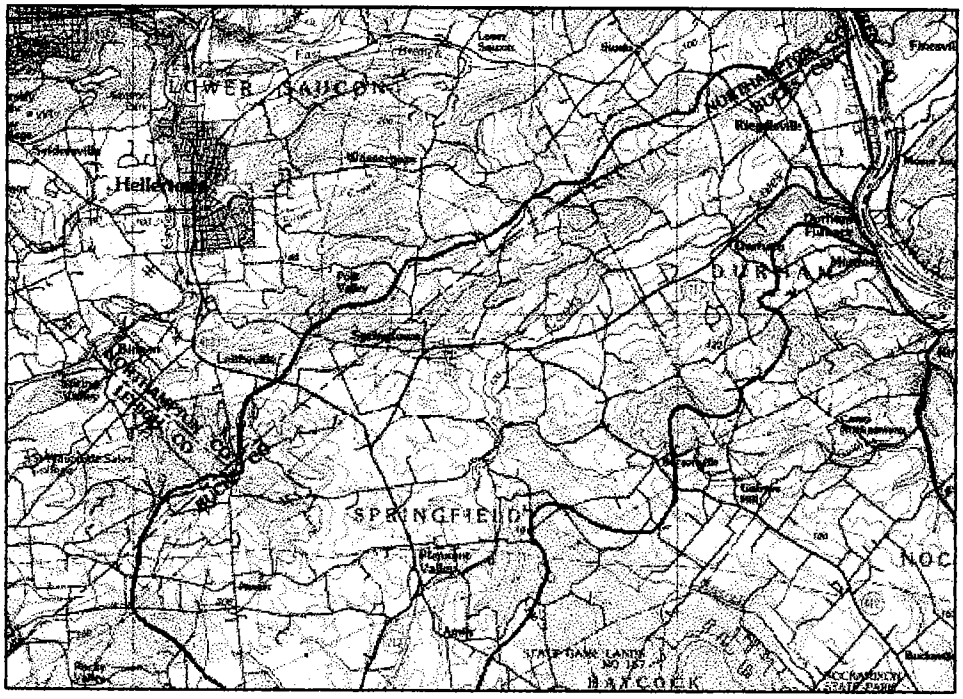

Figure ES1 - Cooks Creek watershed area.

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.

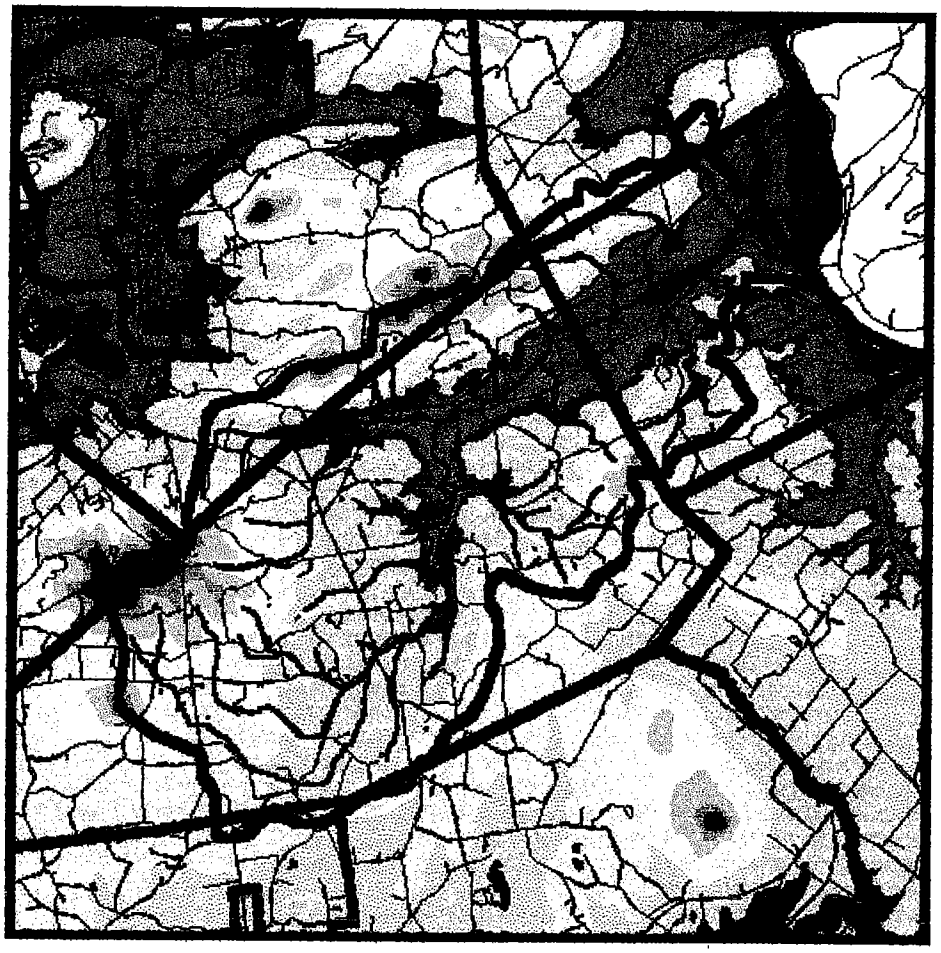

Figure ES2 – Watershed Topographic Map

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.

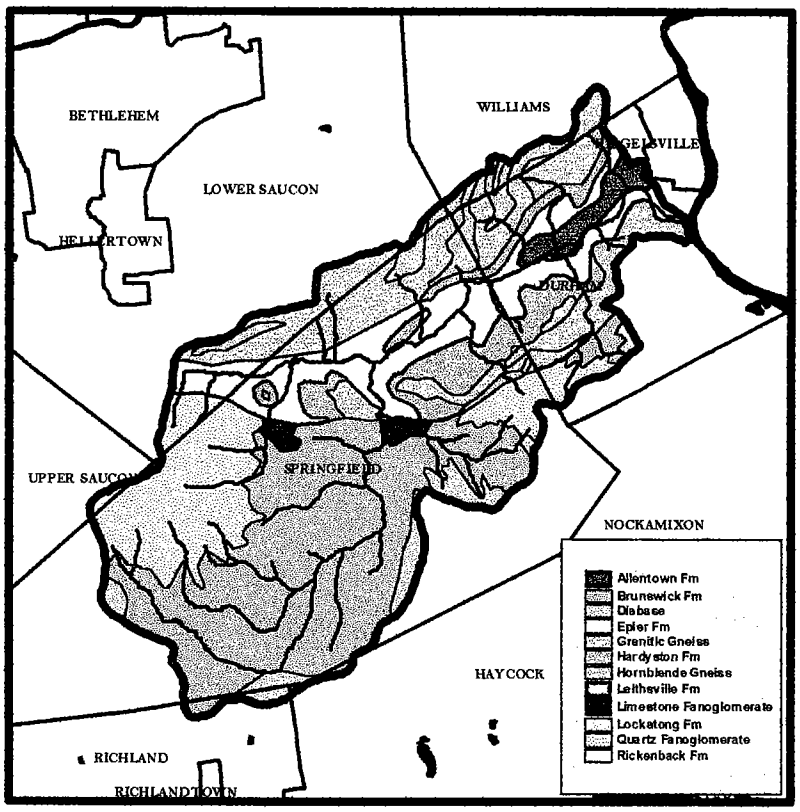

Figure ES3 – Geology Map.

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.

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: stormwater/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 7Q10 statistic. The 7Q10 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 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. Over 100 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.

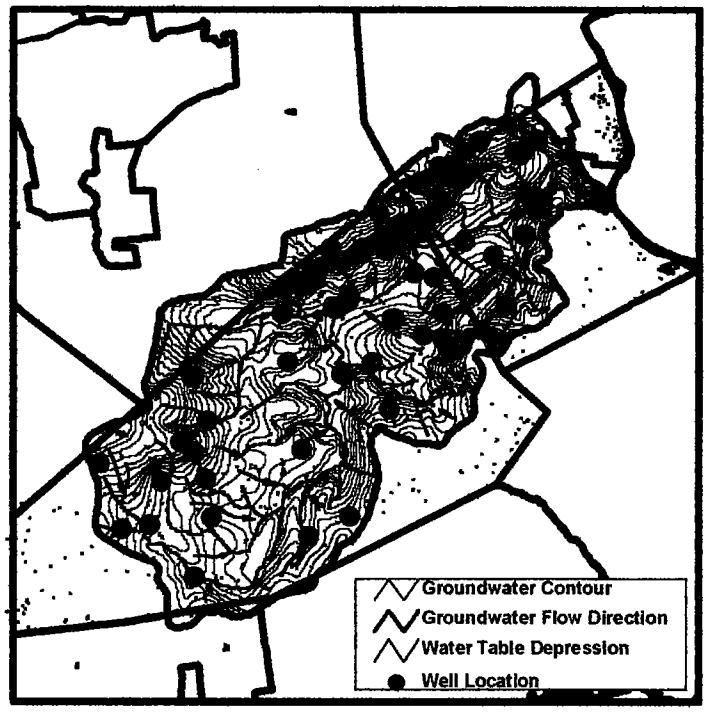

Figure ES4 – Groundwater Contour Map.

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

SEDIMENT AND WATER QUALITY ANALYTICAL RESULTS

SAMPLE ID	ANALYTE	METHOD	RESULT	UNITS	MDL	MCL mg/L
S1	**Chlorinated Herbicide**	EPA8151				
	2,4-D		0.014	mg/Kg	0.0077	0.07
	Mercury	EPA7471A	0.97	mg/Kg	0.16	0.002
	TAL Metals	EPA6010				
	Aluminum		12,000	mg/Kg	580	0.2
	Arsenic		7.50	mg/Kg	3.8	0.05
	Barium		120	mg/Kg	19	2.0
	Beryllium		1.30	mg/Kg	0.77	0.004
	Calcium		3,900	mg/Kg	960	NA
	Chromium		27	mg/Kg	7.7	0.1
	Cobalt		12	mg/Kg	3.2	NA
	Copper		31	mg/Kg	7.3	NA
	Iron		30,000	mg/Kg	520	0.3
	Lead		42	mg/Kg	7.7	NA
	Magnesium		5,100	mg/Kg	700	0.05
	Manganese		580	mg/Kg	31	0.05
	Nickel		20	mg/Kg	4.7	NA
	Potassium		1,200	mg/Kg	210	NA
	Vanadium		40	mg/Kg	9	NA
	Zinc		130	mg/Kg	19	5.0
SW1	Phosphorous, Total	EPA365.2	ND	mg/L	0.05	NA
	Nitrates	EPA300	1.7	mg/L	0.2	10
	TAL Metals	EPA 200.7				
	Barium		28	ug/L	23	2.0
	Calcium		25,000	ug/L	380	NA
	Magnesium		12,000	ug/L	260	0.05
	Potassium		1,700	ug/L	140	NA
	Sodium		6,700	ug/L	390	NA
S2	**Chlorinated Herbicide**	EPA8151				
	2,4_D		0.0071	mg/Kg	0.0058	0.07
	Mercury	EPA7471A	0.48	mg/Kg	0.12	0.002
	TAL Metals	EPA6010				
	Aluminum		6,700	mg/Kg	430	0.2
	Arsenic		6.2	mg/Kg	2.9	0.05
	Barium		100	mg/Kg	14	2.0
	Beryllium		0.96	mg/Kg	0.58	0.004
	Calcium		11,000	mg/Kg	720	NA
	Chromium		15	mg/Kg	5.8	0.1
	Cobalt		8.9	mg/Kg	2.4	NA
	Copper		26	mg/Kg	5.5	NA
	Iron		21,000	mg/Kg	390	0.3
	Lead		52	mg/Kg	5.8	NA
	Magnesium		6,900	mg/Kg	520	0.05
	Manganese		600	mg/Kg	23	0.05
	Nickel		14	mg/Kg	3.5	NA
	Potassium		760	mg/Kg	160	NA
	Vanadium		30	mg/Kg	6.8	NA
	Zinc		140	mg/Kg	14	5
SW2	Phosphorous, Total	EPA365.2	ND	mg/L	0.05	NA
	Nitrates	EPA300	1.60	mg/L	0.2	10

SEDIMENT AND WATER QUALITY ANALYTICAL RESULTS

SAMPLE ID	ANALYTE	METHOD	RESULT	UNITS	MDL	MCL mg/L
SW3	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	1.5	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	38	cfu/100ml	2	
SW5	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	1.40	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	38	cfu/100ml	2	
SW8	Phosphorous, Total	EPA365.2	ND	mg/L	0.05	NA
	Nitrate-N	EPA300	1.40	mg/L	0.2	10
SW9	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	1.90	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	4.0	cfu/100ml	2	
SW10	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	0.50	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	4.0	cfu/100ml	2	
SW11	Phosphorous, Total	EPA365.2/SM4500P-E	0.06	mg/L	0.05	NA
	Nitrates	EPA300	3.0	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	640	cfu/100ml	2	
SW13	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	1.30	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	30	cfu/100ml	2	
SW14	Phosphorous, Total	EPA365.2	ND	mg/L	0.05	NA
	Nitrates	EPA300	1.0	mg/L	0.2	10
SW18	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	2.8	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	110	cfu/100ml	2	
SW19	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	0.6	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	72	cfu/100ml	2	

Notes:

Laboratory results as presented in the Hampton Clarke, Inc. (Veritech Laboratories) report dated June 6, 2000.

MDL = Method Detection Limit or the lowest level at which the laboratory can detect the analyte.

MCL = Maximum Contaminant Levels or the levels established by the USEPA for safe drinking water.

NA = Not Applicable. No MCL established by USEPA

mg/L = parts per million (ppm), mg/Kg = ppm, ug/L = parts per billion (ppb)

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 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.

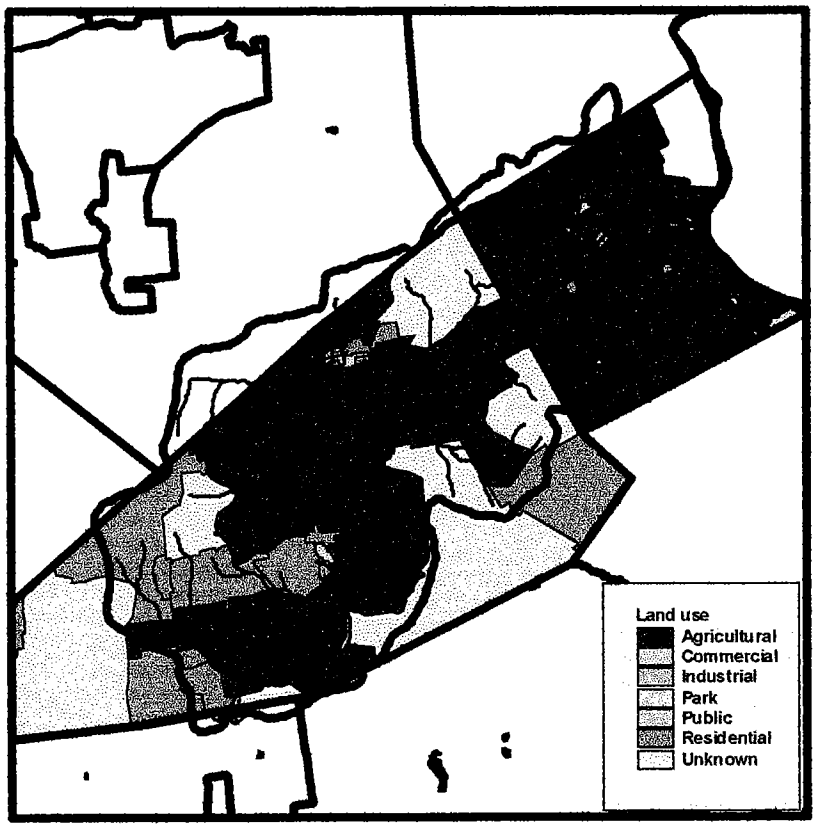

Figure ES5 – Existing Land Use Map.

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 make use the sub-watershed system to incorporate the results of this study in the most effective manner.

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.

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)).

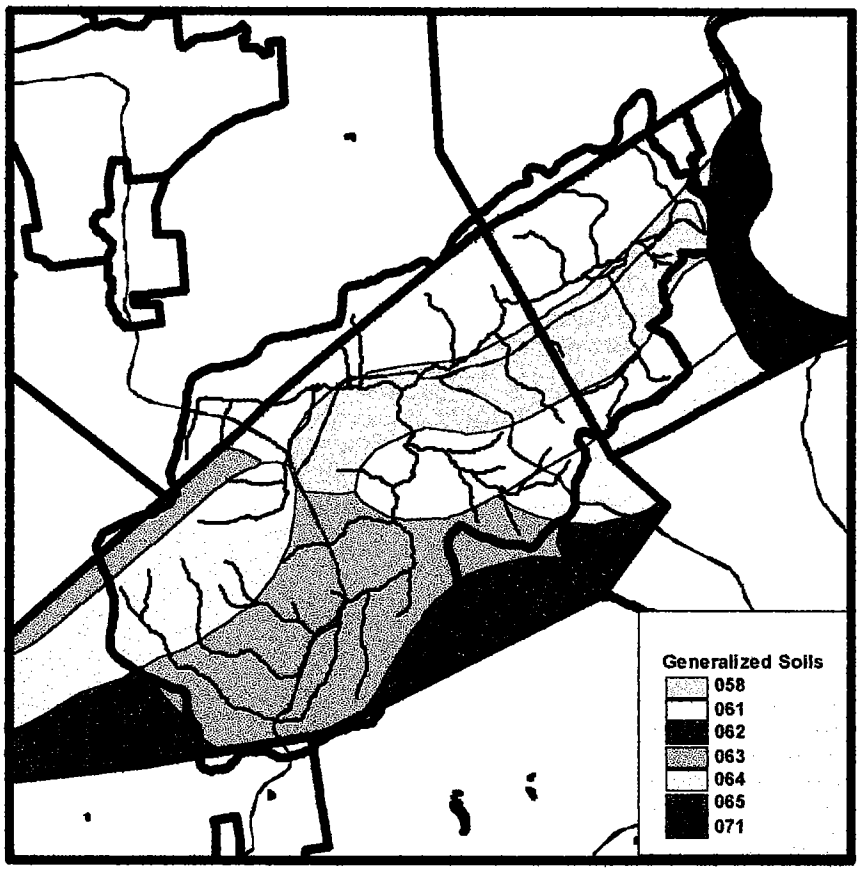

Figure C - Generalized Soils Map for the Watershed.

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 (Q7-10) values are used in the Water Balance Model. The Q7-10 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.

- *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.

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 and 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

Nutrient pollution has been determined to exist 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 Stormwater Management Plan

Perform a comprehensive study to determine the locations and magnitude of stormwater runoff in the watershed. Monitor erosion throughout the watershed and determine its causes. Develop a plan to manage both stormwater 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
- 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 or equiv.
- Nutrient Survey and Management Plan
- Visual assessment Snap- Shot, DRBC Program or equiv.

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;
  - 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;
  - 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.

- stormwater 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.

We, the undersigned, in the interests of the citizens of Springfield and Durham Townships, will utilize the findings of this study to the best of our ability to effectively manage the resources of the Cooks Creek Watershed for the maximum benefit of all citizens:

Signed and attested, this _____day of _____, 2001

_____

Bartley Millett
Chairman, Durham Board of Supervisors

_____

Richard Johnson
Durham Board of Supervisors

_____

Manfred Marshewski
Durham Board of Supervisors

_____

Peter Lamana
Springfield Board of Supervisors

_____

James Hopkins
Springfield Board of Supervisors

_____

Rodney Weider
Springfield Board of Supervisors

_____

Charles Halderman
Springfield Board of Supervisors

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, and designed the hot blast stoves and double bell and hopuer 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 most 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;

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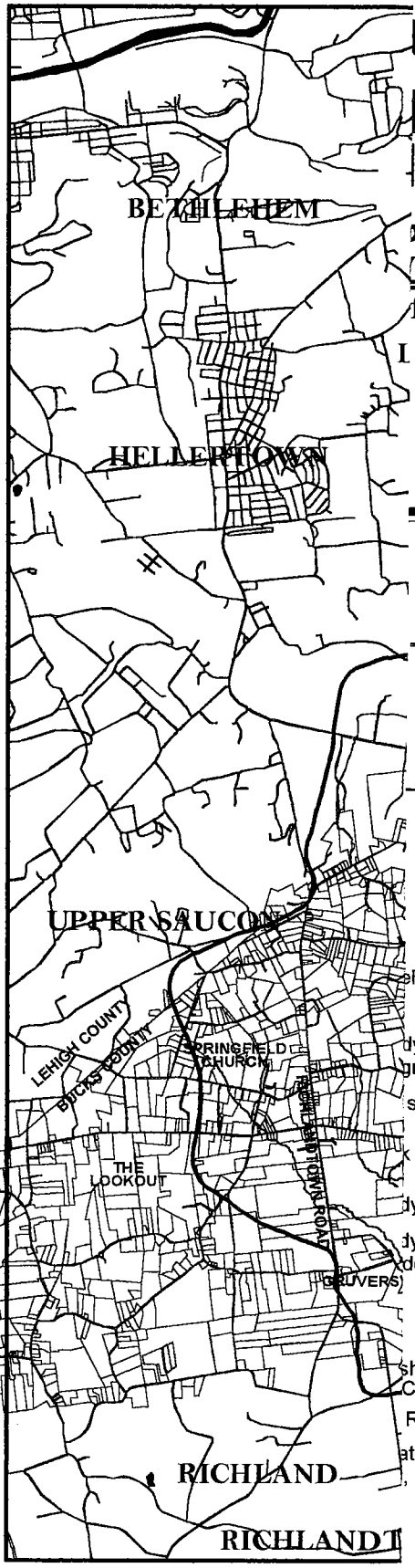

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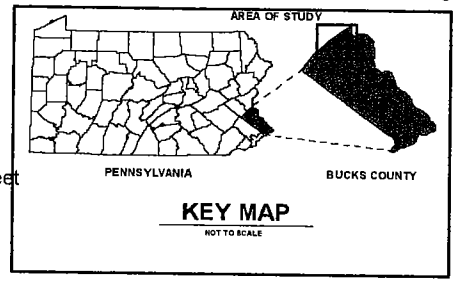

- Figure A -
Historic Resources Map

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sites

sites - Sites on National Register

dy - Individual

dy - may contribute to a multiple resource.
dustry

ship Open Space and Farmland Preservation Plan, Bucks
Commission, July 1999.

Resource Inventory Plan, 1994

ata Analysis, Durham Township, Bucks County Historic
, Bucks County Conservancy, October 1, 1992.

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- 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.

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COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis

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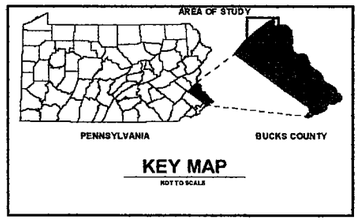

- Figure B -
Scenic Roadways Map

LEGEND

- Watershed Boundary
- Roads & Railroads
- Waterways
- Tax Map Parcels
- Scenic Roadways

SOURCES:1) Springfield Township Open Space and Farmland Preservation Plan, Bucks County Planning Commission, July 1999.
2) DTEAC, Durham Resource Inventory Plan, 1994
3) Final Report & Data Analysis, Durham Township, Bucks County Historic Resource Survey, Bucks County Conservancy, October 1, 1992.

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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). 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.

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%).

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.

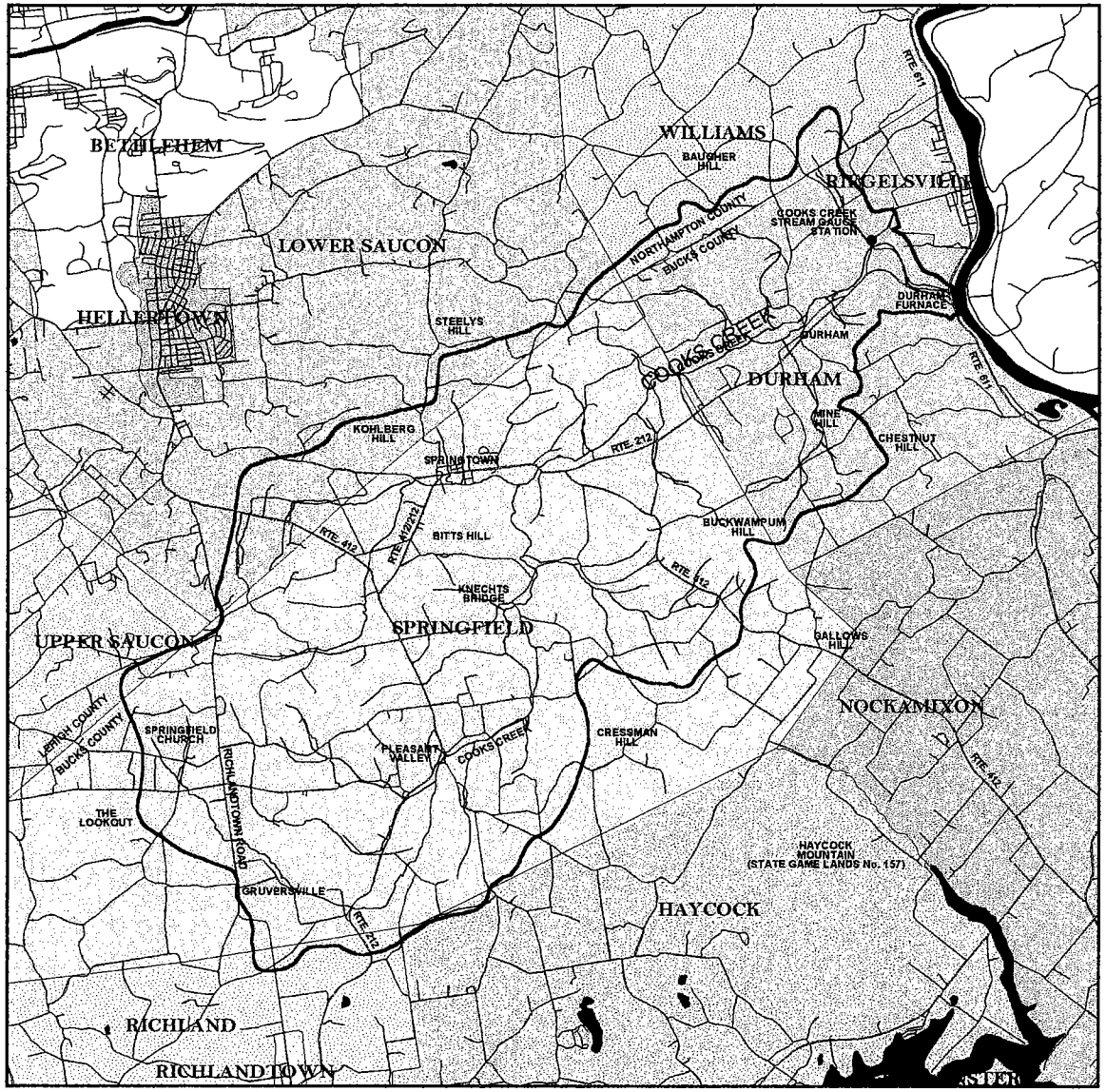
Topography

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 to steep 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



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DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis

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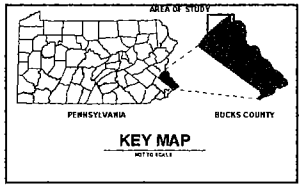

- Figure 1 -
The Base Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Municipal Boundaries

- BEDMINSTER
- BETHLEHEM
- DURHAM
- FREEMANSBURG
- HAYCOCK
- HELLERTOWN
- LOWER SAUCON
- NOCKAMIXON
- RICHLAND
- RICHLANDTOWN
- RIEGELSVILLE
- SPRINGFIELD
- TINICUM
- UPPER SAUCON
- WILLIAMS

SOURCES: 1) DTEAC , MJE , Wetlands Management Plan, Watershed digital map, 1999

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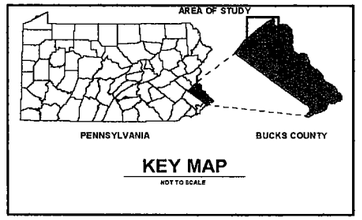

- Figure 2 - Topographic Map

LEGEND

- Watershed Boundary
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Ground Surface Contour

SOURCES: 1) United States Geologic Survey Topographic Quadrangle Map, Riegelsville, PA - NJ, 1973; Hellertown, PA 1992; Quakertown, PA 1994; Bedminster, PA 1992, Translation, attribution and analysis by MJE, August 2000.

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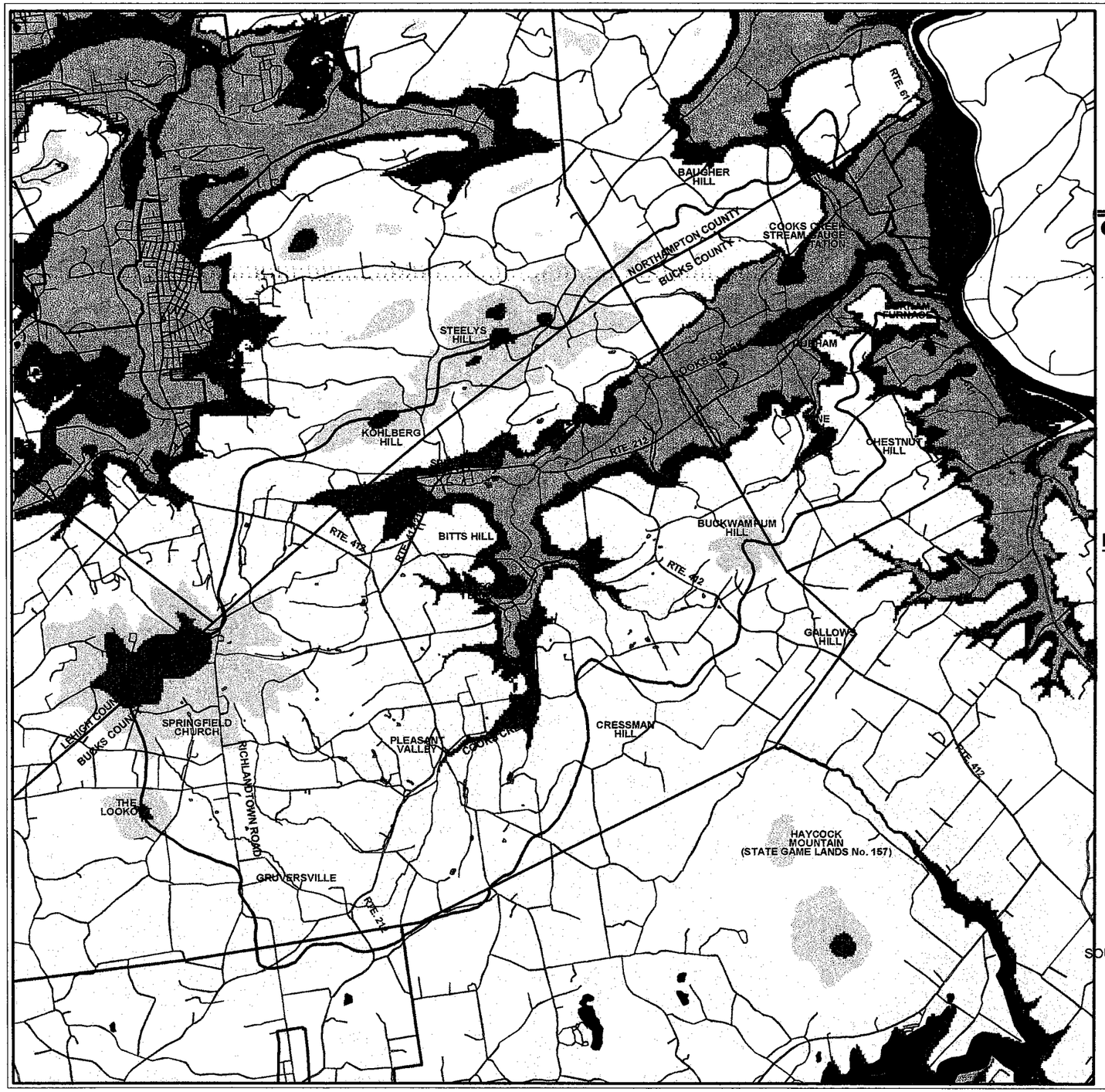

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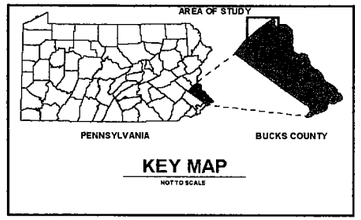

- Figure 3 -
Topographic Map - DEM

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds

Elevation MSL (feet)

- 98 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350
- 350 - 400
- 400 - 450
- 450 - 500
- 500 - 550
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- 750 - 800
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- 850 - 900
- 900 - 950
- 950 - 1100
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SOURCES: 1) United States Geologic Survey Topographic Quadrangle Map, Riegelsville, PA - NJ, 1973; Hellertown, PA 1992; Quakertown, PA 1994; Bedminster, PA 1992, Translation, attribution and analysis by MJE, August 2000.

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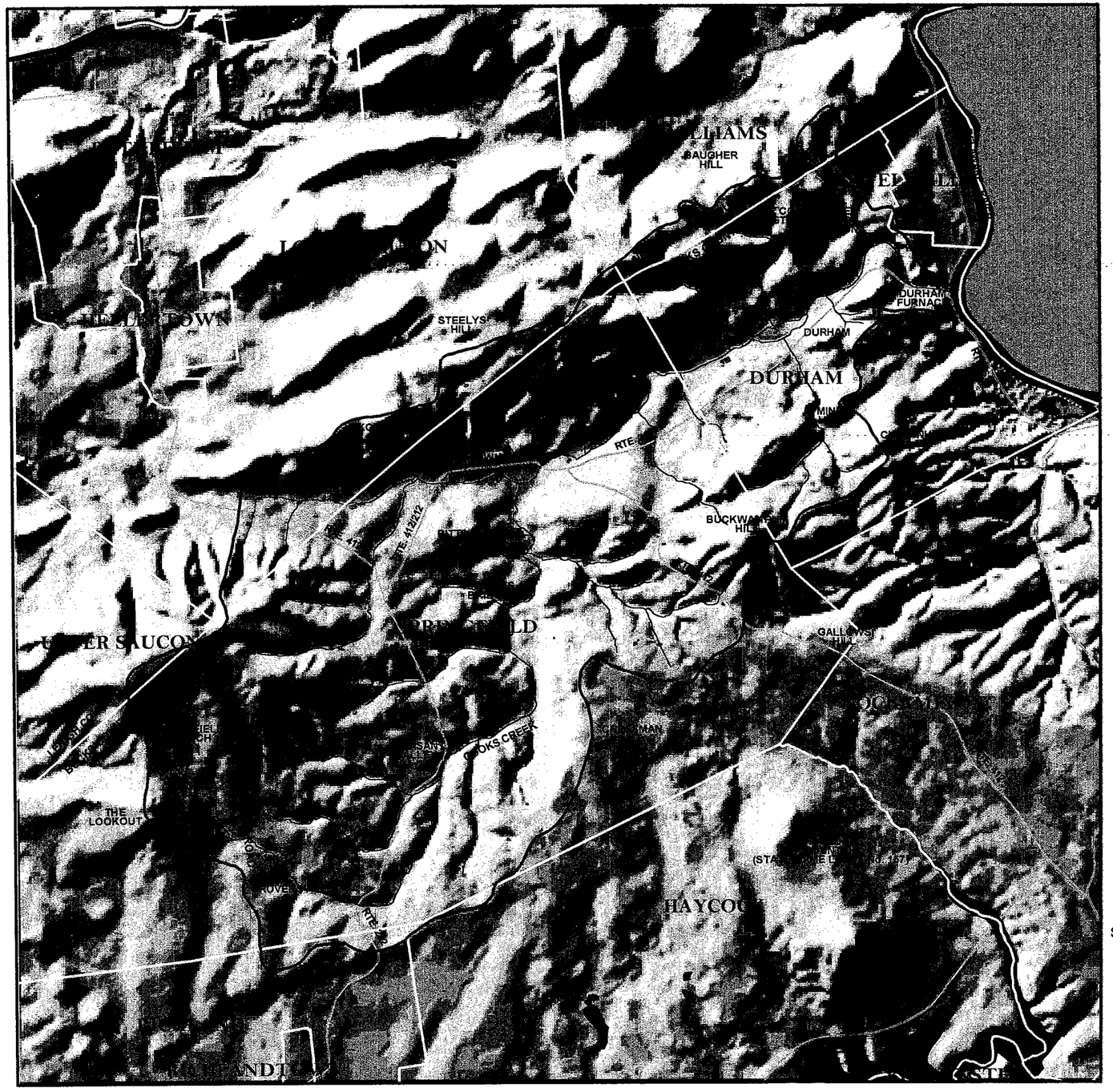

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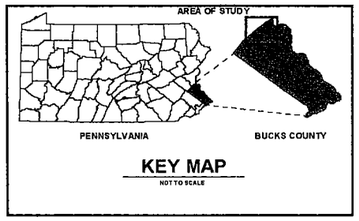

- Figure 4 - Hillshade View of the Cooks Creek Watershed

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds

SOURCES: 1) United States Geologic Survey Topographic Quadrangle Map, Riegelsville, PA - NJ, 1973; Hellertown, PA 1992; Quakertown, PA 1994; Bedminster, PA 1992, digitize, translation, attribution and analysis by MJE, August 2000.

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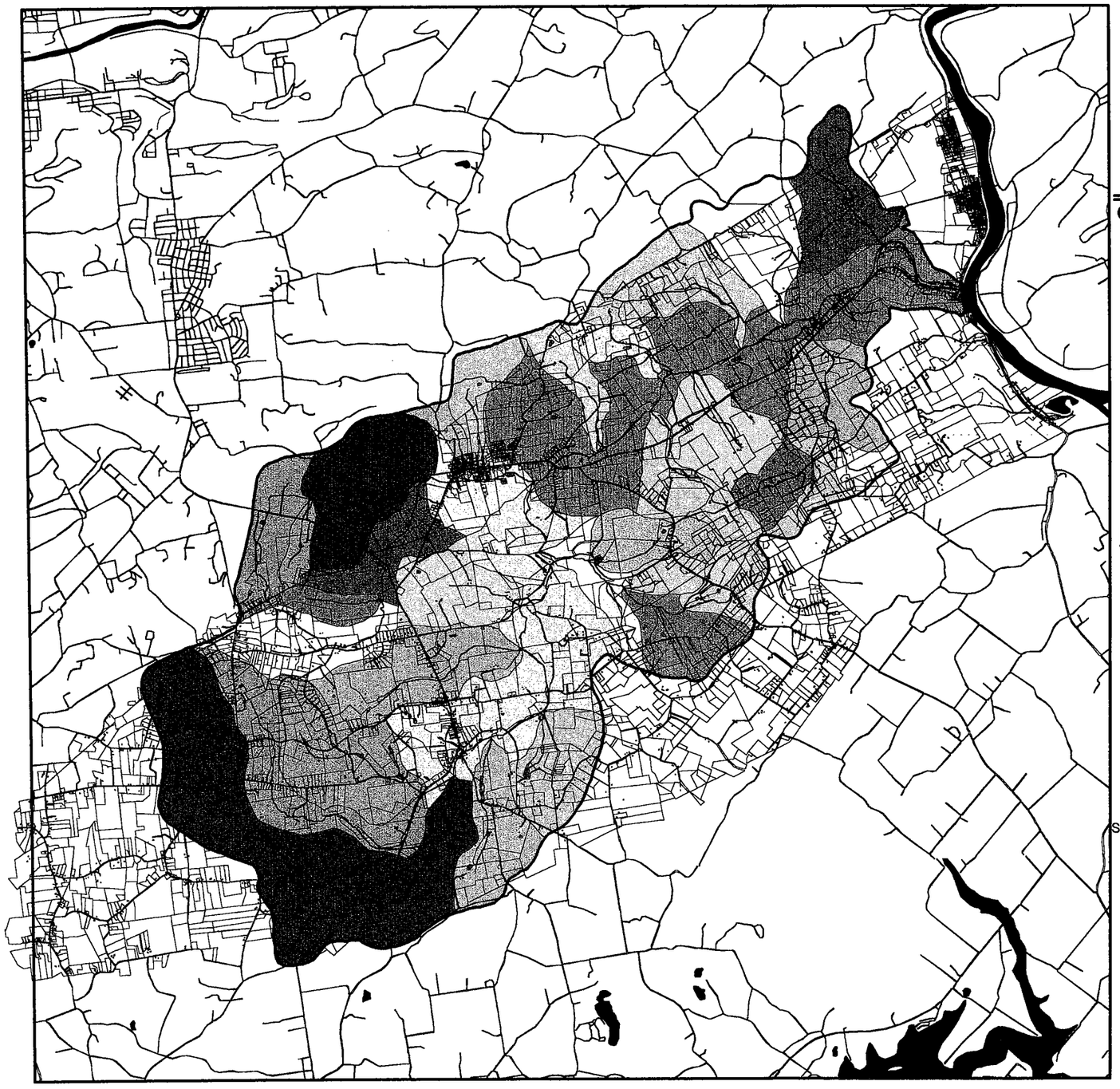

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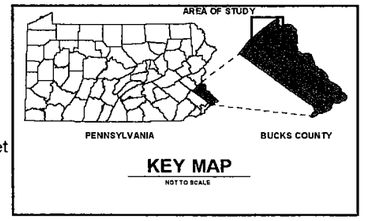

- Figure 5 -
Cooks Creek Watershed Sub-basins Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- Sub-basins
- Tax Map Parcels

SOURCES: 1) GIS Data Depot (GIS Web Sites located on the Internet). Translation, attribution and analysis by MJE.

2) DTEAC, MJE, Wetlands Management Plan, digital Tax Map, digital buildings, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.

3) MJE, digital Sub-basins Map of the Cooks Creek Watershed, October 2000.

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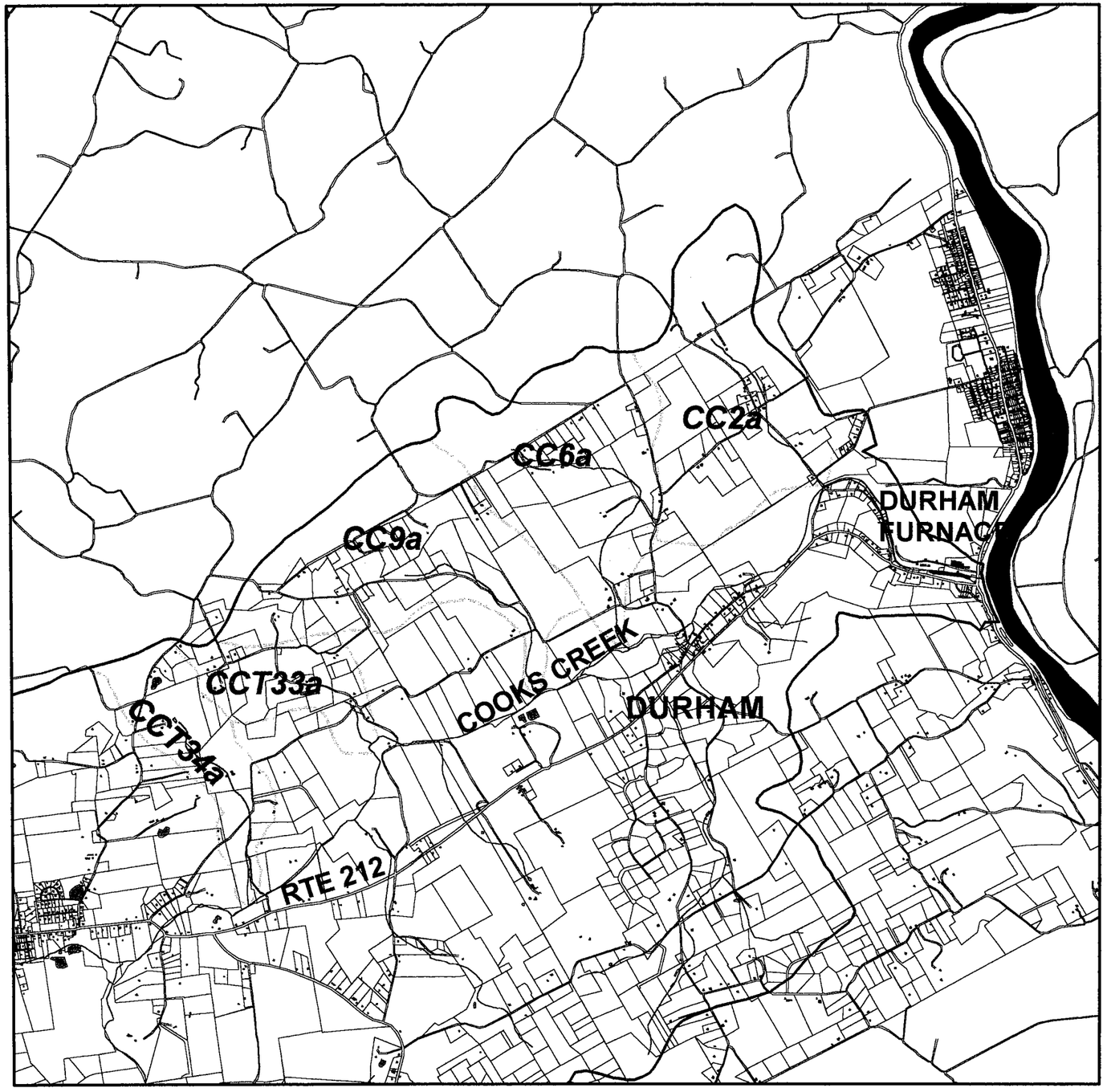

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BUCKS COUNTY, PENNSYLVANIA

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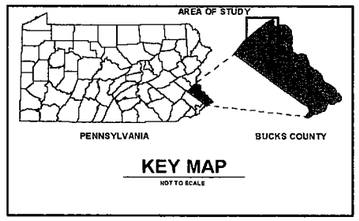

- Figure 5.1-
Area 1 Sub-basins Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- First Order Sub-basins
- Tax Map Parcels

SOURCES: 1) GIS Data Depot (GIS Web Sites located on the Internet). Translation, attribution and analysis by MJE.

2) DTEAC, MJE, Wetlands Management Plan, digital Tax Map, digital buildings, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.

3) MJE, digital Sub-basins Map of the Cooks Creek Watershed, October 2000.

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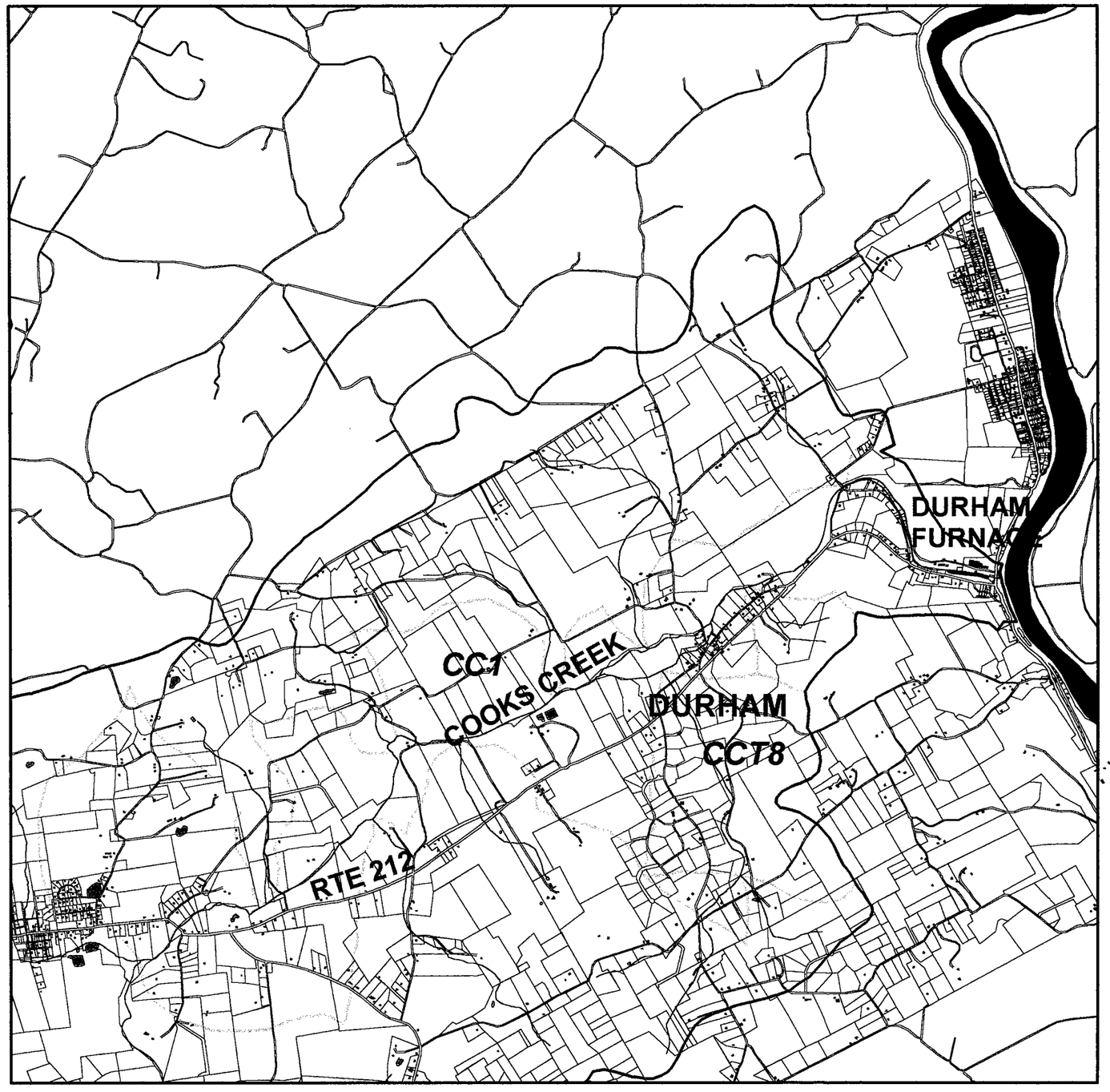

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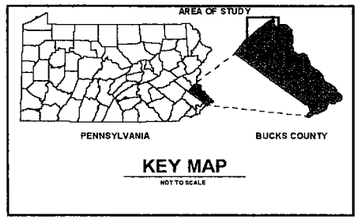

- Figure 5.2-
Area 2 Sub-basins Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- Second Order Sub-basins
- Tax Map Parcels

SOURCES: 1) GIS Data Depot (GIS Web Sites located on the Internet). Translation, attribution and analysis by MJE.

2) DTEAC, MJE, Wetlands Management Plan, digital Tax Map, digital buildings, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.

3) MJE, digital Sub-basins Map of the Cooks Creek Watershed, October 2000.

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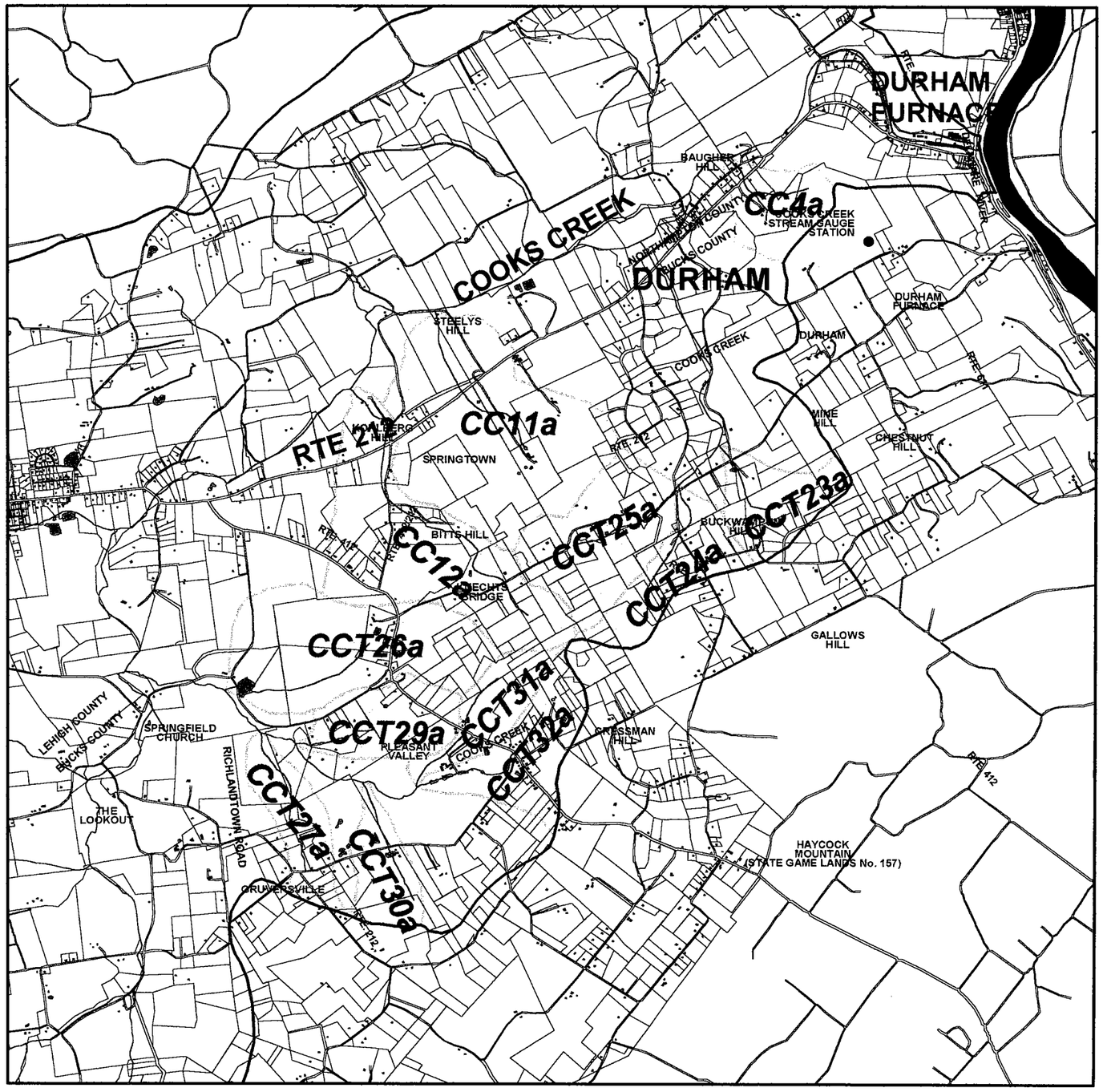
COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis



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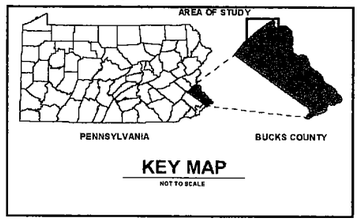

- Figure 5.3-
Area 3 Sub-basins Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- First Order Sub-basins
- Tax Map Parcels

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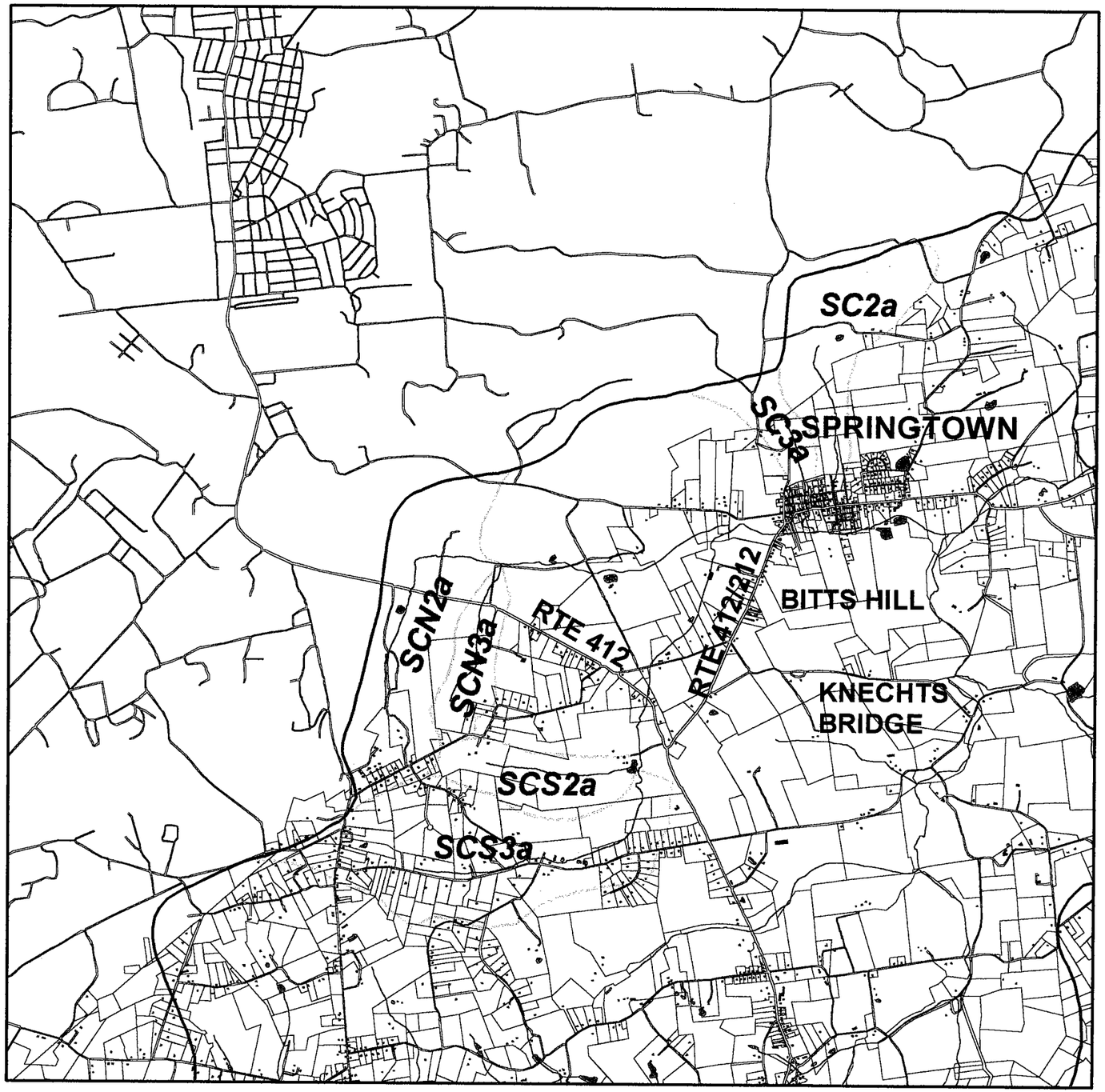

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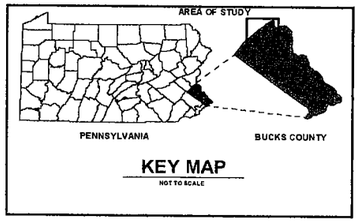

- Figure 5.4-
Area 4 Sub-basins Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- First Order Sub-basins
- Tax Map Parcels

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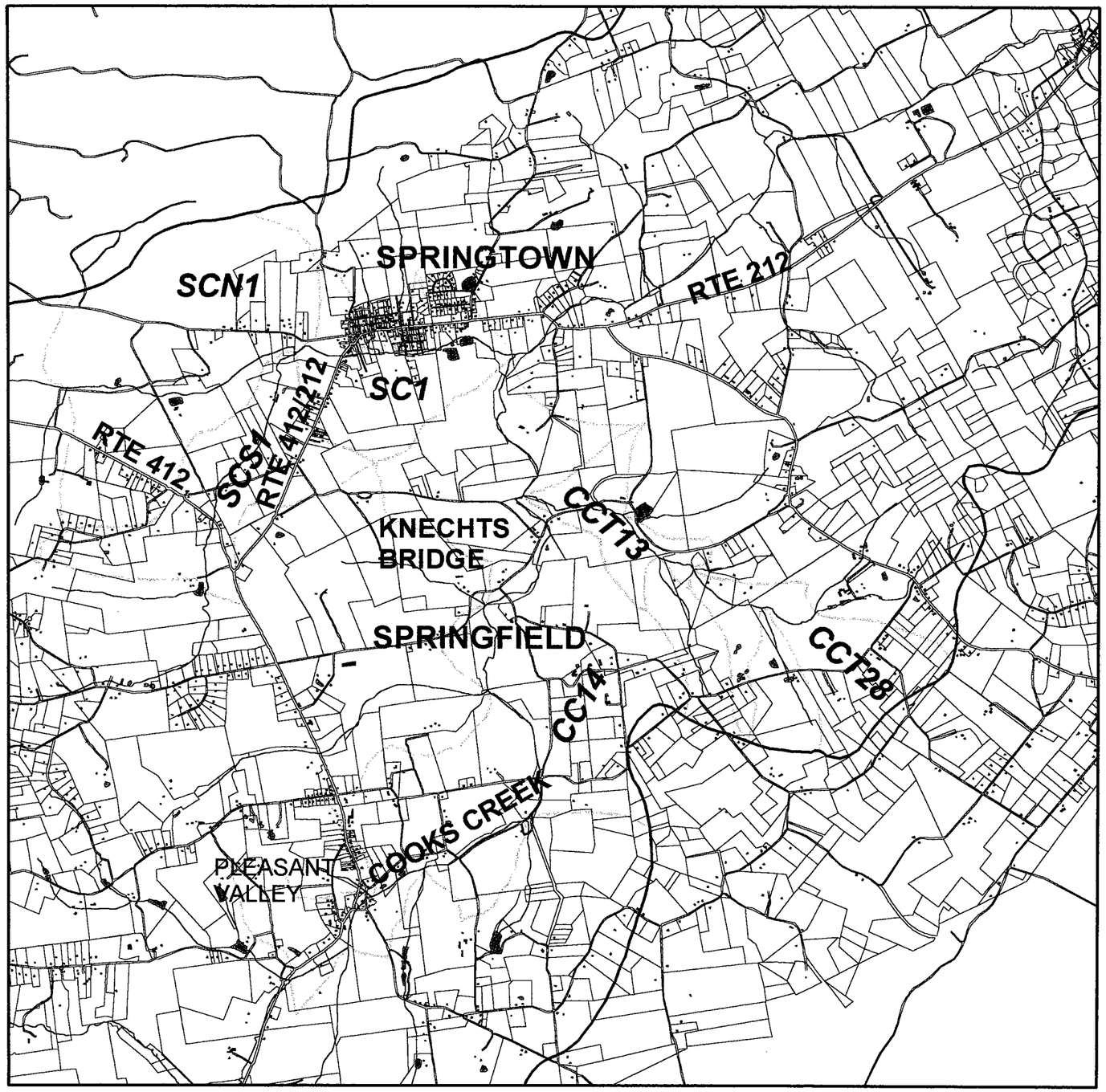

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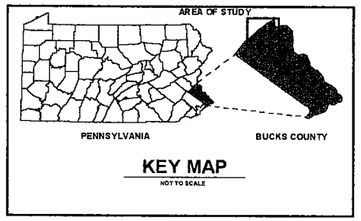

- Figure 5.5-
Area 5 Sub-basins Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- Second Order Sub-basins
- Tax Map Parcels

SOURCES: 1) GIS Data Depot (GIS Web Sites located on the Internet). Translation, attribution and analysis by MJE.

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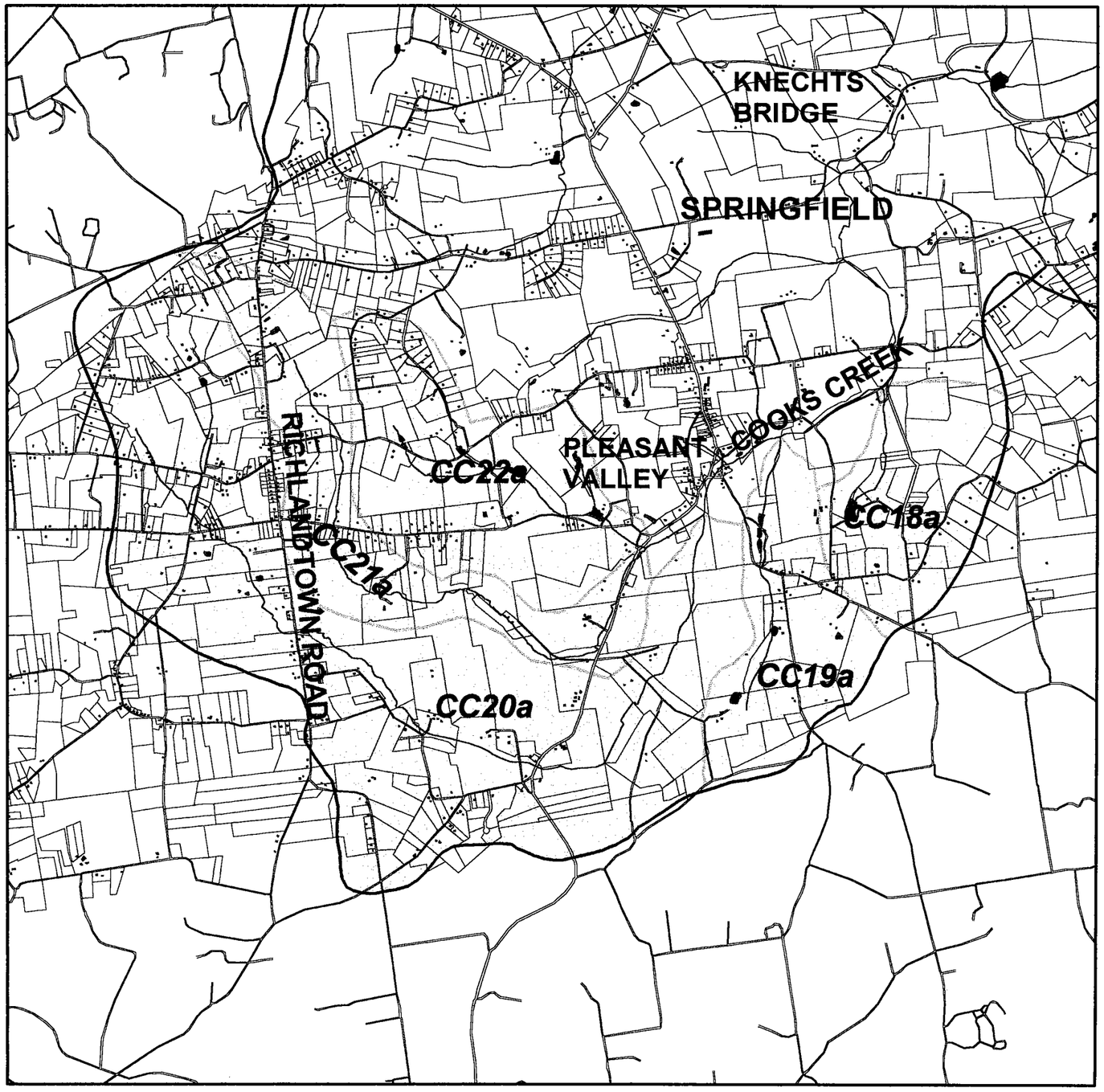

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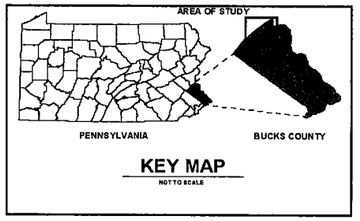

- Figure 5.6-
Area 6 Sub-basins Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- First Order Sub-basins
- Tax Map Parcels

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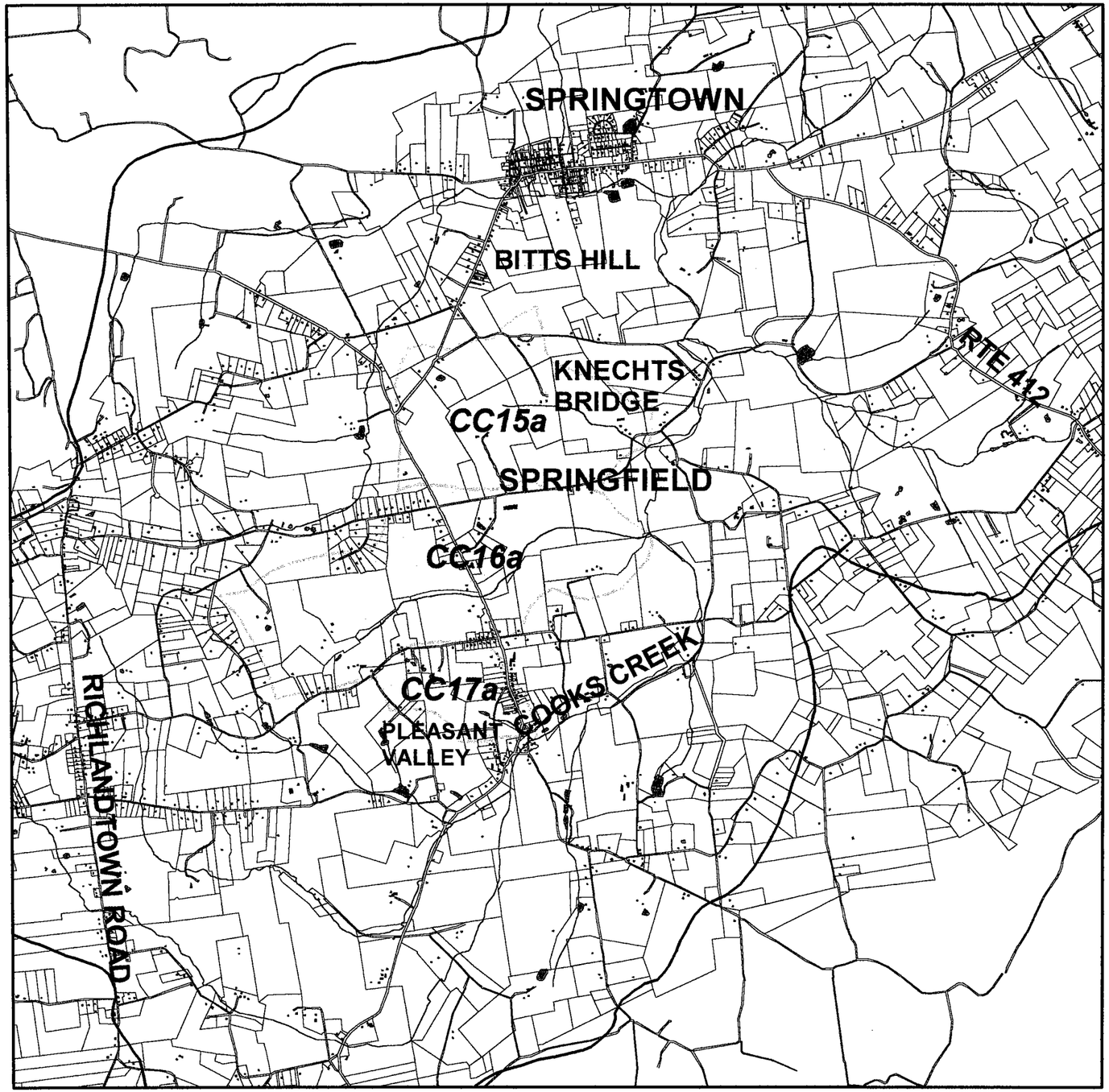

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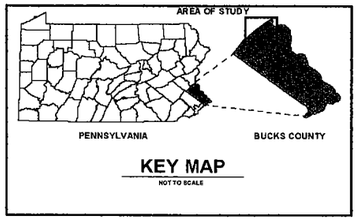

- Figure 5.7-
Area 7 Sub-basins Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- First Order Sub-basins
- Tax Map Parcels

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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.

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COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

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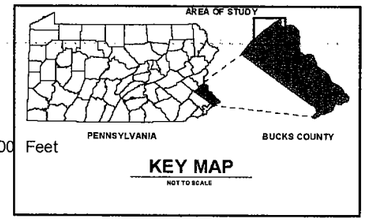

- Figure 6.1 -
First Order Sub-basin Geology Map

LEGEND

- Watershed Boundaries
- Waterways
- Lakes and Ponds
- Areas Susceptible to Karst Dissolution Features
- Sinkholes
- First Order Sub-basin
- Second Order Sub-basin
- Diabase
- Brunswick Formation
- Lockatong Formation
- Quartz Fanoglomerate
- Limestone Fanoglomerate *

  (Brunswick, Lockatong, Quartz Fanoglomerate, Limestone Fanoglomerate: Passaic Formation (Undifferentiated))
- Allentown Formation *
- Leithsville Formation *
- Hardyston Formation
- Hornblende Gneiss
- Granitic Gneiss

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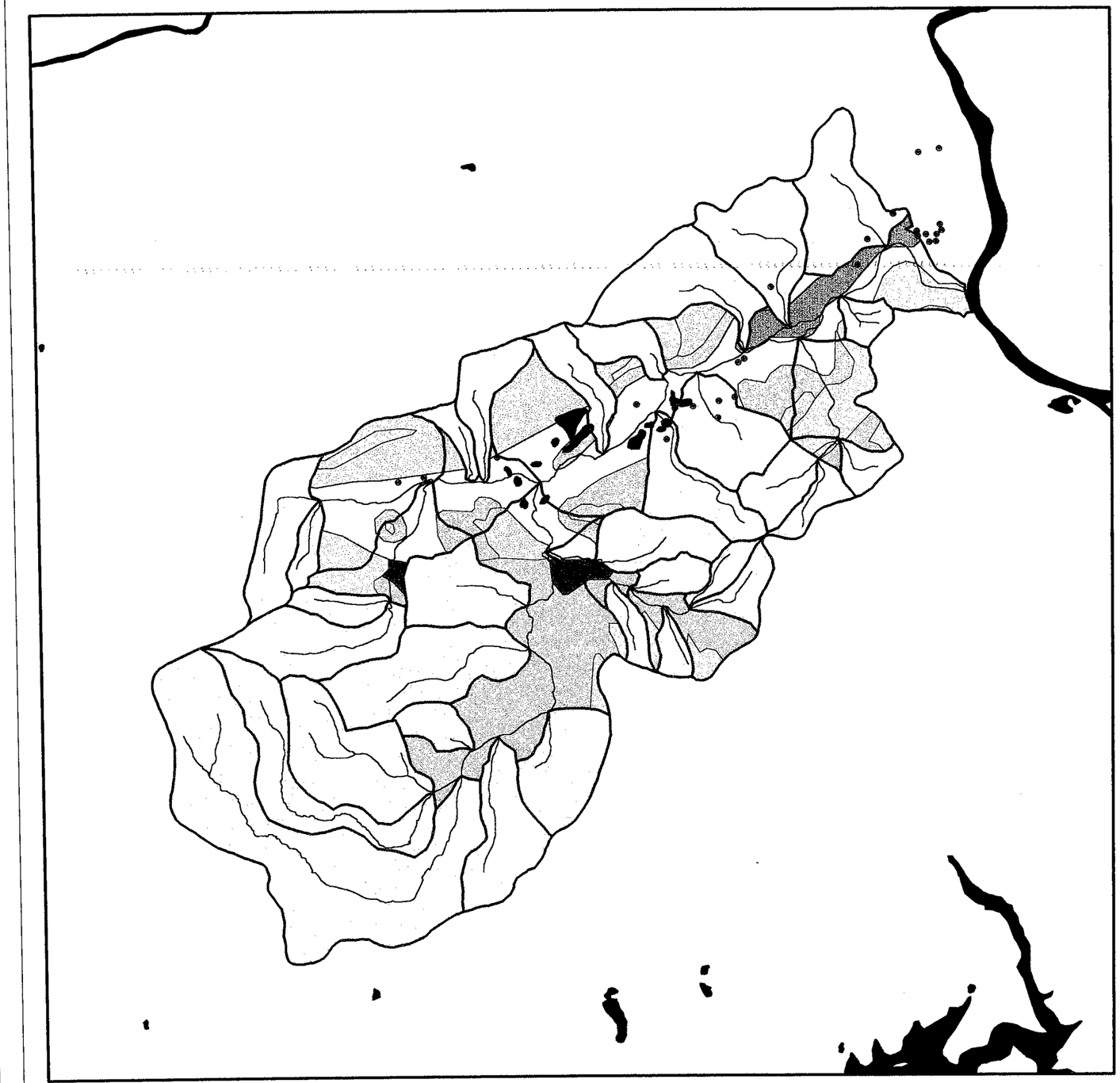

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BUCKS COUNTY, PENNSYLVANIA

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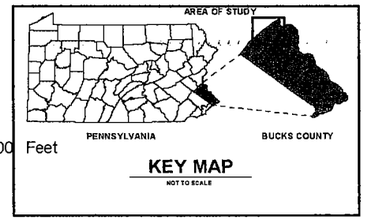

- Figure 6.2 -
Second Order Sub-basin Geology Map

LEGEND

- Watershed Boundaries
- Waterways
- Lakes and Ponds
- Areas Susceptible to Karst Dissolution Features
- Sinkholes
- First Order Sub-basin
- Second Order Sub-basin
- Diabase
- Brunswick Formation
- Lockatong Formation
- Quartz Fanoglomerate
- Limestone Fanoglomerate *

  (Brunswick, Lockatong, Quartz Fanoglomerate, Limestone Fanoglomerate: Passaic Formation (Undifferentiated))
- Allentown Formation *
- Leithsville Formation *
- Hardyston Formation
- Hornblende Gneiss
- Granitic Gneiss

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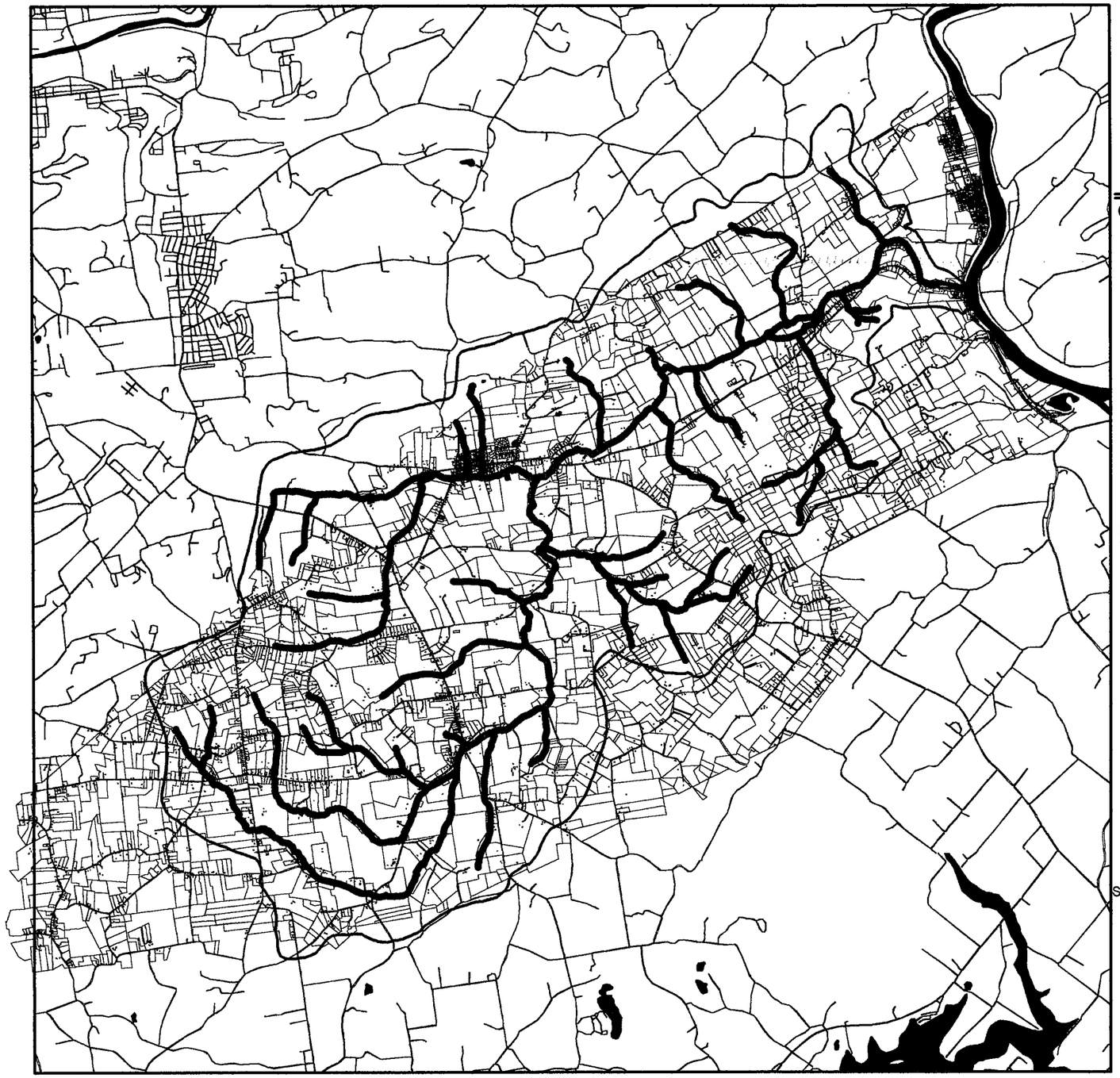

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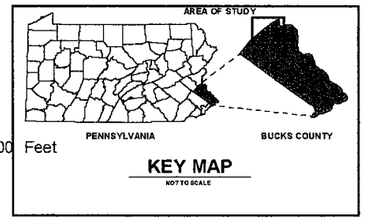

- Figure 7 -
Current Water Quality Classifications

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- Tax Map Parcels
- Water Quality Designation: Cold Water Fishes (CWF)
- Special Protection Waters under Chapter 93: High Quality Waters (HQ)

Stream Order Delineation

- First Order Stream
- Second Order or Higher

SOURCES: 1) GIS Data Depot (GIS Web Sites located on the Internet). Translation, attribution and analysis by MJE.

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- 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 Cooks Creek Watershed corridor is comprised of the 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. 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".

Agricultural areas may result in somewhat stressed conditions in the corridor and contribute to warming of the base temperature of the water. Warming typically occurs as a result of de-forestation along the tributaries. Additional monitoring of the watershed should provide data to evaluate present conditions. The stream morphology or the characteristics, patterns, and profiles of the stream are typical of eastern Pennsylvania waterways. The overall condition of the watershed corridor is good with the need for riparian buffer zones and stabilization in limited areas.

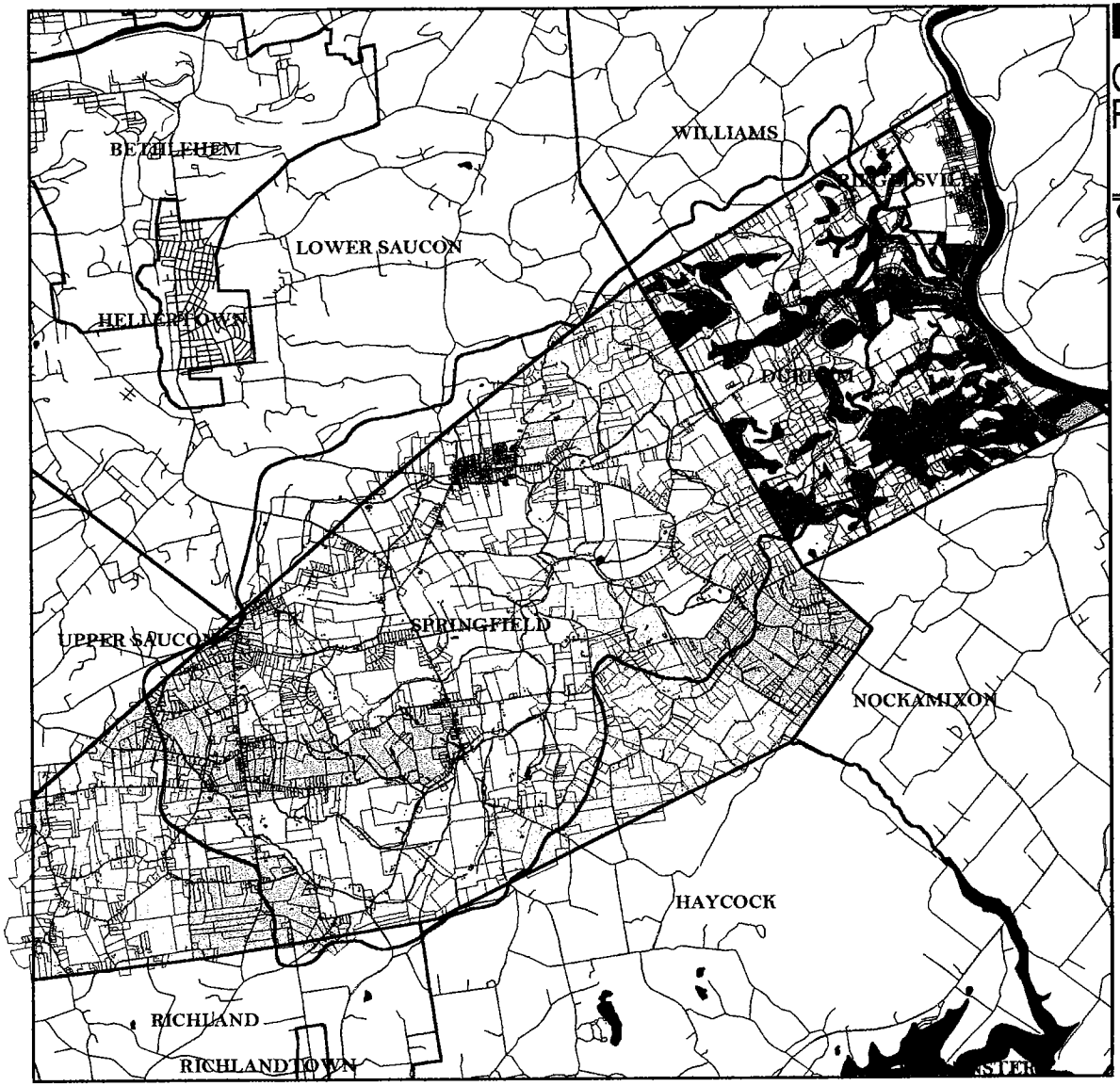
Climate

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)



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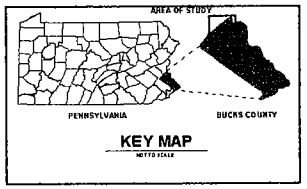

- Figure 8 - Land Use

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- Tax Map Parcels

Land Use

- Agricultural
- Commercial
- Industrial
- Park
- Public
- Residential
- Unknown
- Prime Agricultural

SOURCES: 1) Durham Township Amendments to Comprehensive Plan, Adopted February 1, 1977

2) Springfield Township Comprehensive Plan, 1988

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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, including Durham and Springfield Townships are serviced by

on-lot sewage treatment systems. Finally, the region is served by the Quakertown, Palisades, and Pennridge School Districts.

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):

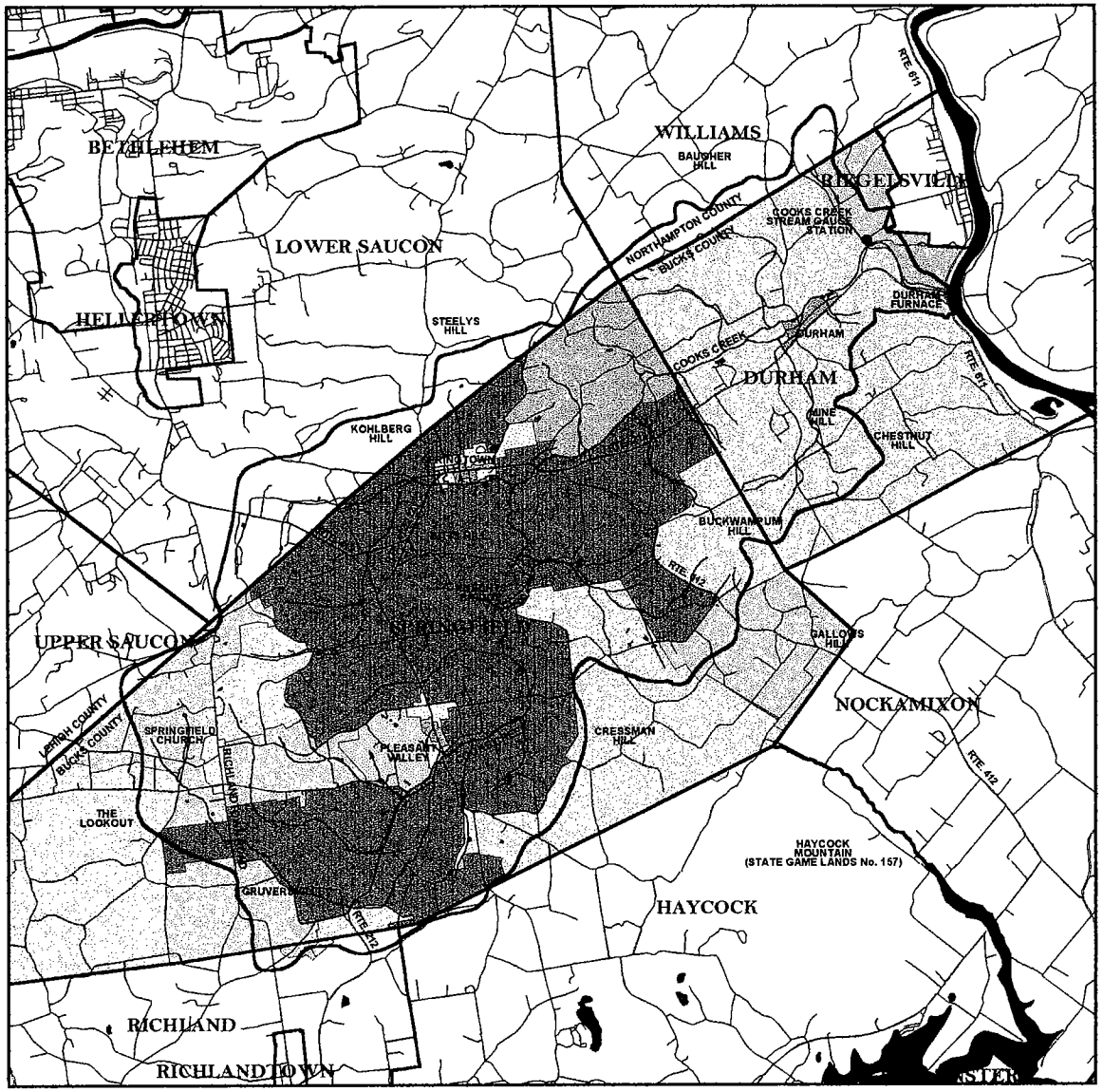
- *Resource Protection (RP).* The land in this district is identified in the Durham Township and Bucks County Comprehensive Plans. These lands contain important resource features and historic areas. The two-fold purpose of this ordinance is to: 1) maintain the agricultural industry and preservation of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



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COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis

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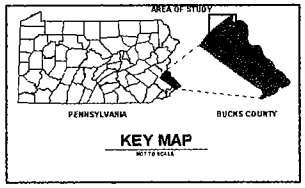

- Figure 9 - Existing Zoning Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds

Zones

- AD - Agricultural District
- DD - Development District
- PC-I - Planned Industrial-Commercial
- RP - Resource Protection
- RR - Rural Residential
- VC - Village Commercial
- VR- Village Residential
- WS - Watershed District

SOURCES: 1) Durham Township Zoning Ordinance, December 9, 1992.
2) Springfield Township Open Space and Farmland Preservation Plan, July 1999.

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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 following is a list of primary zoning districts within Springfield Township (Zoning Ordinance, August 1990):

- *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.

- *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%

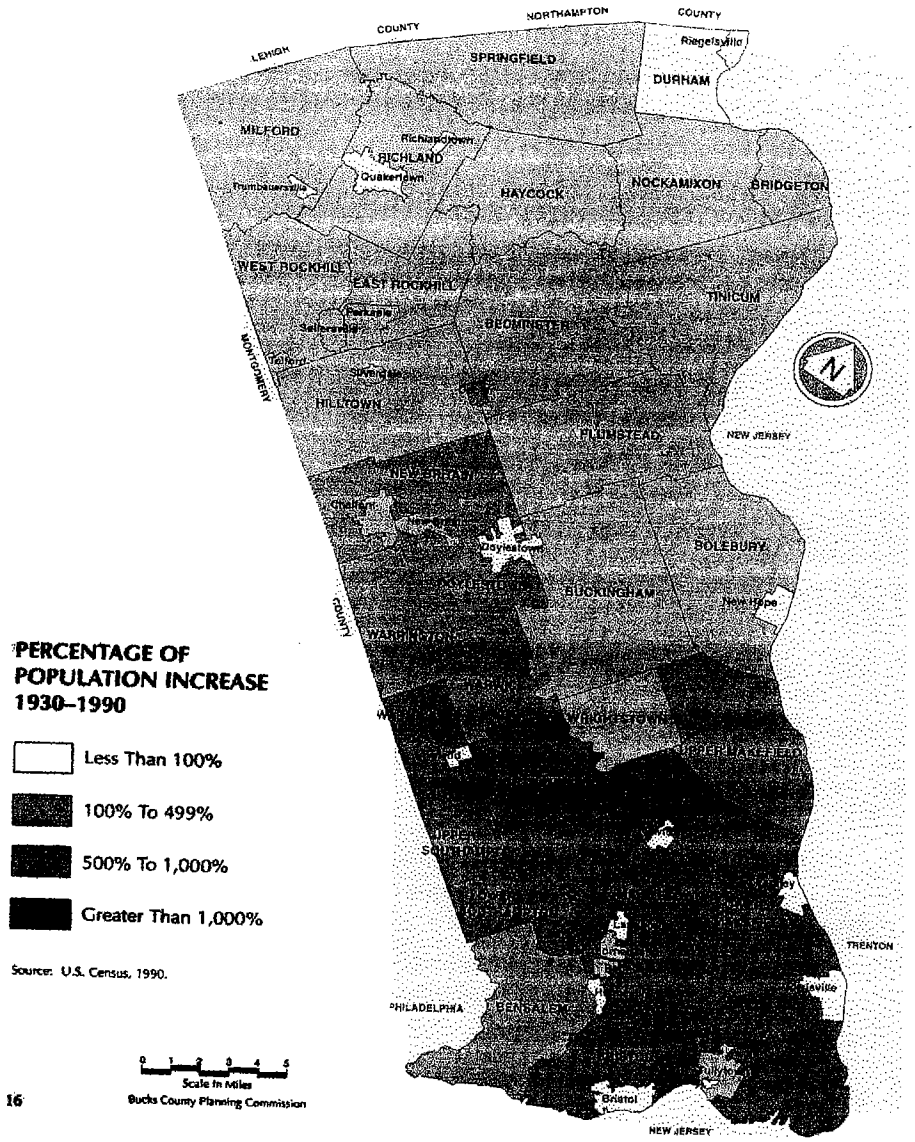


Figure 10. Percentage of population increase 1930 – 1990.

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 is gained from Routes 212, 611, and 412. Three airports are located in the region.

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.

Outstanding or Unique Features

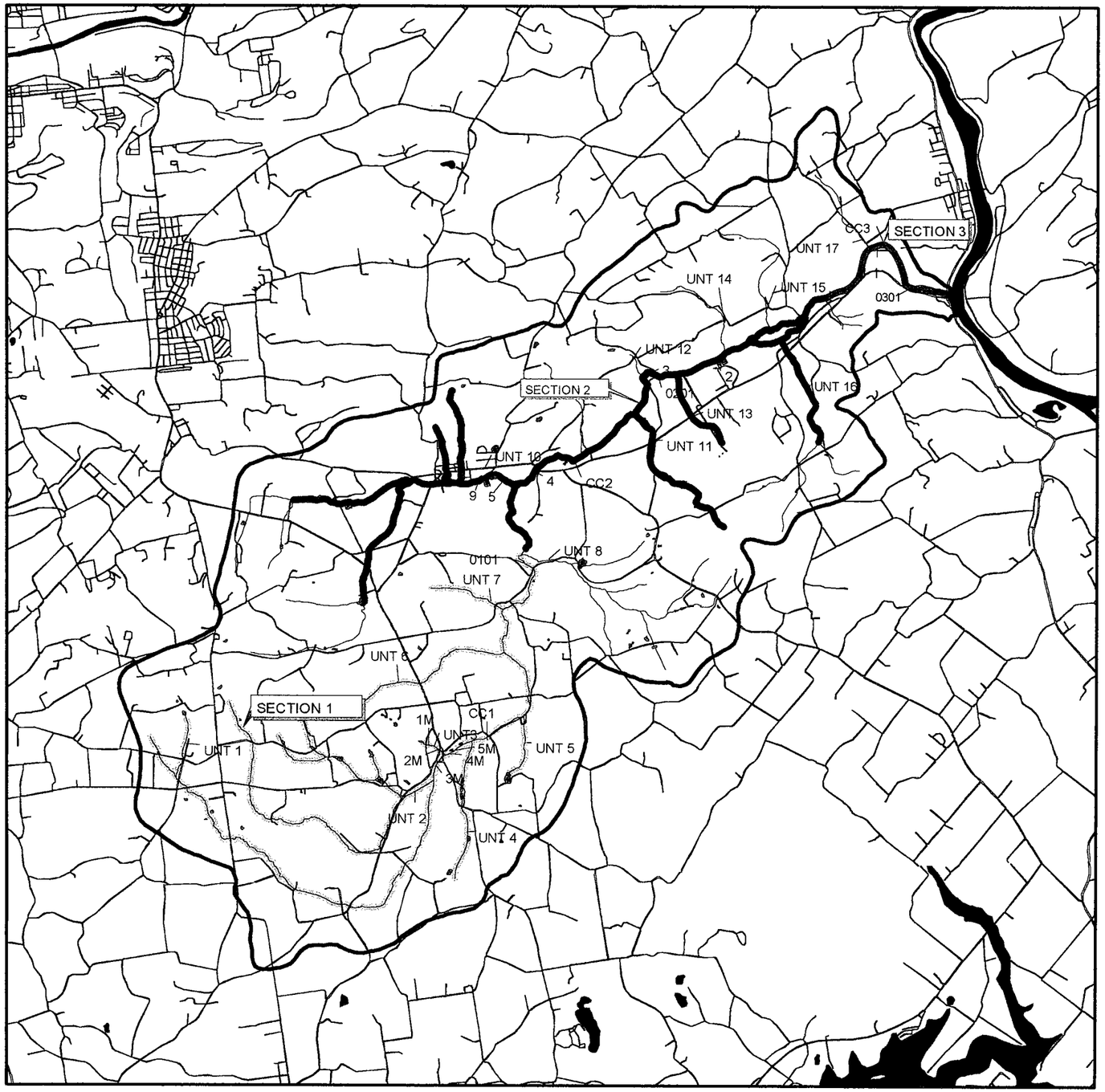
Cooks Creek boasts good to excellent water quality, a diverse macro-invertebrate benthic community, and a Class A wild brown trout (*Salmo trutta*) population. In addition, tributaries to Cooks Creek support both Class A wild brown trout populations and Class A wild brook trout (*Salvelinus fontinalis*) 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 limestone nature of the underlying 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. In addition the poor physical habitat contributes to warming of the water, which is not conducive to 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.



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COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis

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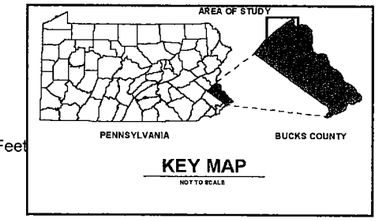

- Figure 11-
Sections Map for Wild Trout Population

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings

Stream Characteristics for Wild Trout Population:

- Section 1 - Poor physical habitat contributes to warming of the water.
- Section 2 - Somewhat restricted physical habitat for adult trout supports a Class A biomass.
- Section 3 - Supports less biomass than section 2 due to less physical habitat.

Sample Locations:

1 - PFC Stream Survey Report Station (AUG 1973)

0101 - PFC Stream Inventory Station (AUG 1976)

1M - PFC Macroinvertebrate Evaluation Station (Feb 1986)

UNT 1 - DER BWQM Water Quality Station on Unnamed Tributary (Nov 1989)

CC1 - DER BWQM Special Protection Evaluation Station (March 1990)

SOURCES: 1) Cooks Creek - Special Protection Evaluation Report Water Quality Standards Review. Quality Assessment Unit Division of Water Quality Bureau of Water Quality Management Departament of Environmental Resources. July, 1990.

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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 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; and,
- 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 WAMOS 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

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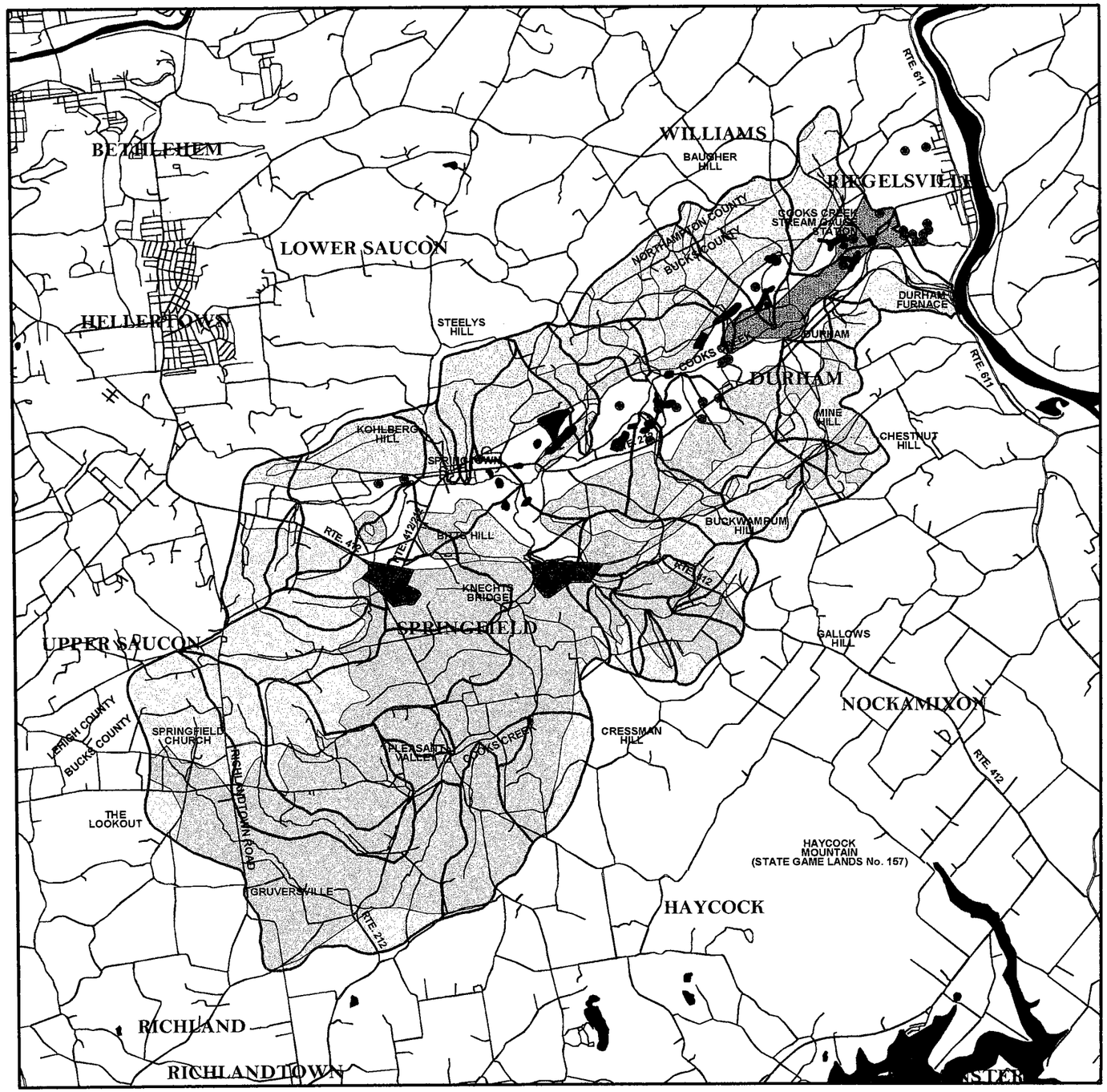

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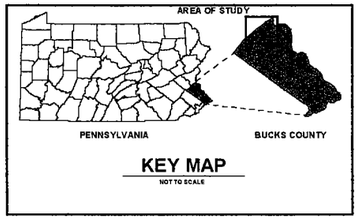

- Figure 12 -
Geologc Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Areas Susceptible to Karst Dissolution Features
- Sinkholes
- Sub-basin
- Diabase
- Brunswick Formation
- Lockatong Formation
- Quartz Fanoglomerate
- Limestone Fanoglomerate *

Passaic Formation (Undifferentiated)

- Allentown Formation *
- Leithsville Formation *
- Hardyston Formation
- Hornblende Gneiss
- Granitic Gneiss

NOTE: * denote karst-prone formations

SOURCES: 1) Pennsylvania Spatial Data Access system (PASDA), Surface Geology, Translation, attribution and analysis by MJE and Golder, 1999.
2) Conservation and Management Practices for Buckingham & Durham Carbonate Valleys, Bucks County Planning Commission, February 1985
3) Spruance Lybrary of The Mercer Museum, Doylestown, Aerial Photos, 1950, 1958.
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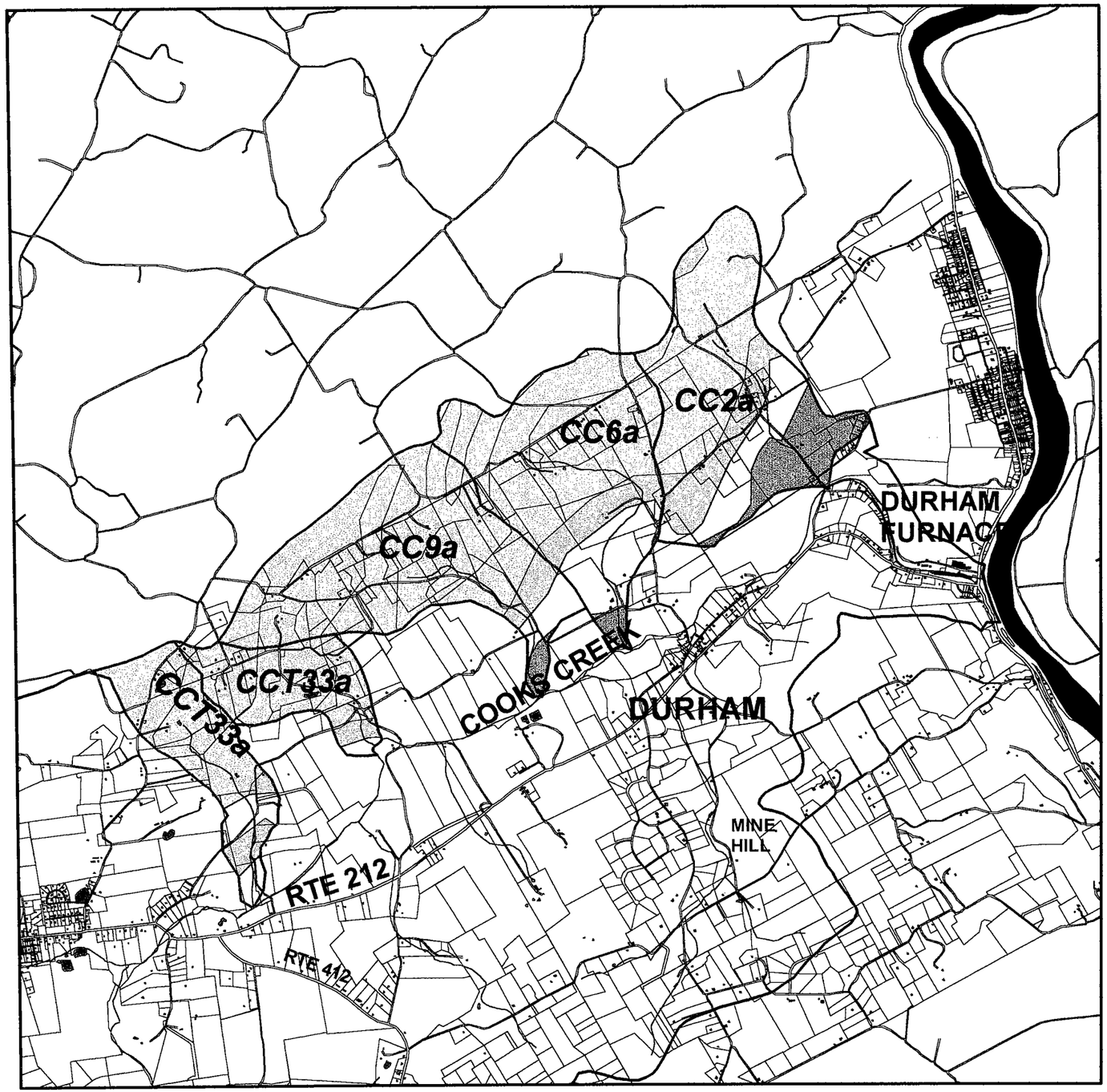

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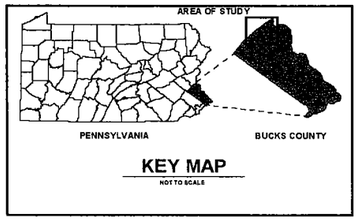

- Figure 12.1-
Area 1 Sub-basin Geology
- First Order Sub-basins -

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- Tax Map Parcels
- First Order Sub-basins
- Diabase
- Brunswick Formation
- Lockatong Formation
- Quartz Fanoglomerate
- Limestone Fanoglomerate *

Passaic Formation (Undifferentiated)

- Allentown Formation *
- Leithsville Formation *
- Hardyston Formation
- Hornblende Gneiss
- Granitic Gneiss

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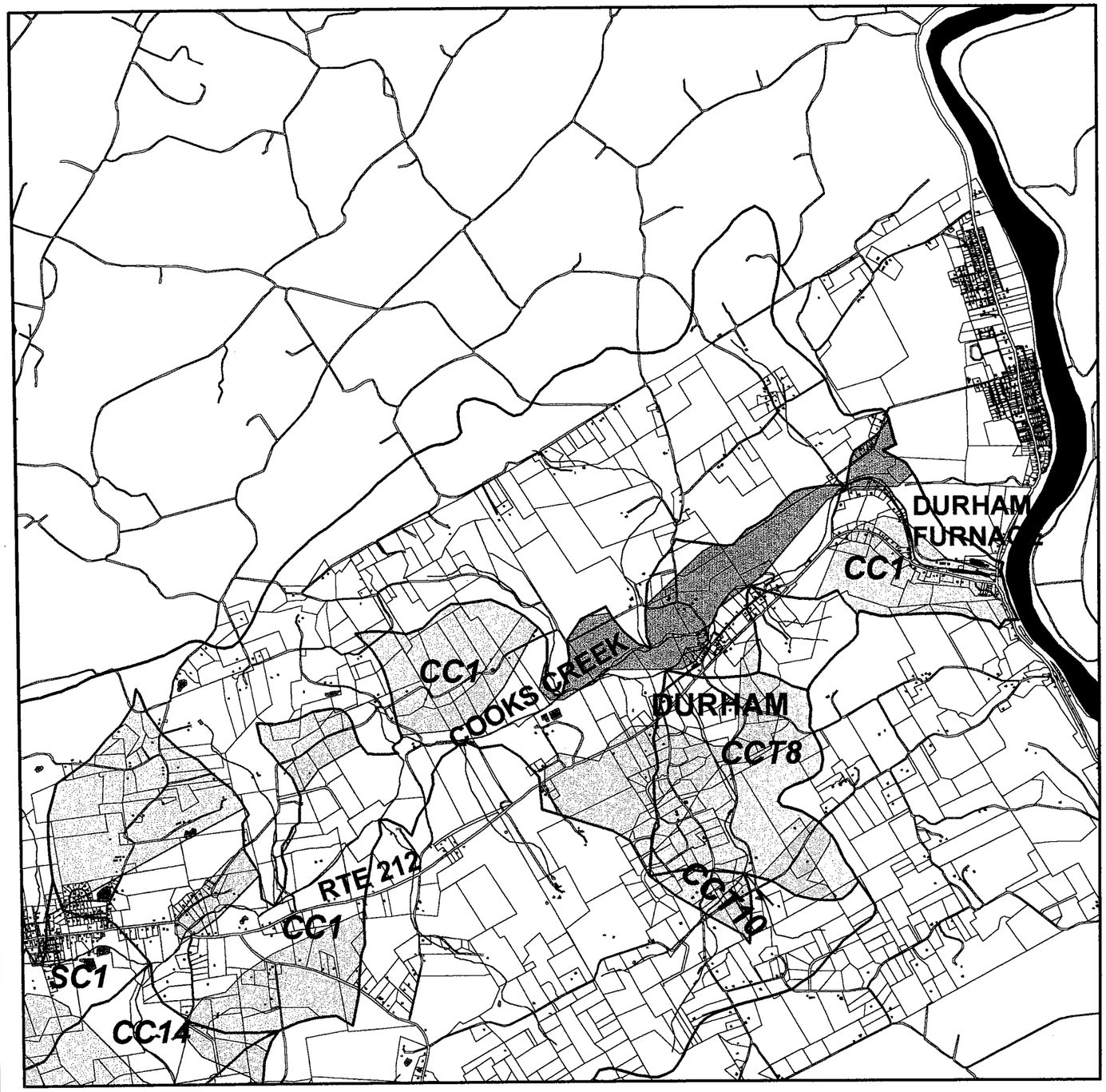

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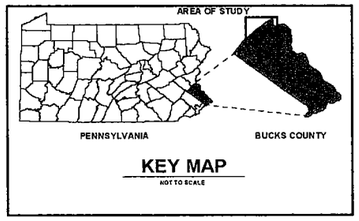

- Figure 12.2- Area 2 Sub-basin Geology - Second Order Sub-basins -

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- Tax Map Parcels
- Second Order Sub-basins

- Diabase
- Brunswick Formation
- Lockatong Formation
- Quartz Fanoglomerate
- Limestone Fanoglomerate *

Passaic Formation (Undifferentiated)

- Allentown Formation *
- Leithsville Formation *
- Hardyston Formation
- Hornblende Gneiss
- Granitic Gneiss

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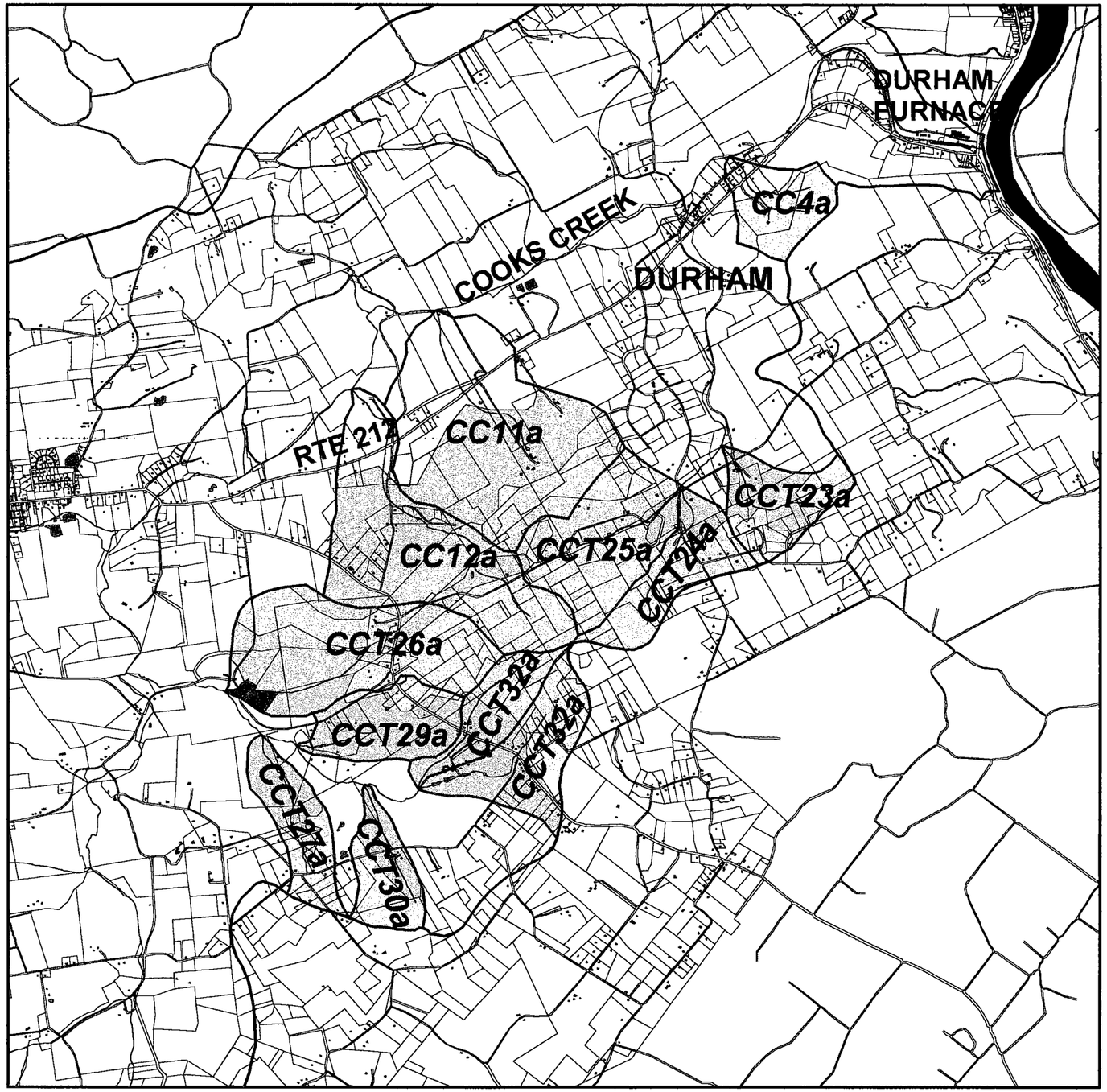

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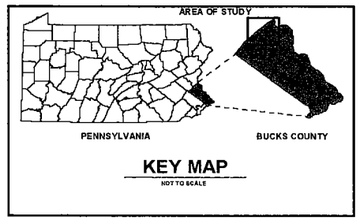

- Figure 12.3-
Area 3 Sub-basin Geology
- First Order Sub-basins -

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- Tax Map Parcels
- First Order Sub-basins
- Diabase
- Brunswick Formation
- Lockatong Formation
- Quartz Fanoglomerate
- Limestone Fanoglomerate *

Passaic Formation (Undifferentiated)

- Allentown Formation *
- Leithsville Formation *
- Hardyston Formation
- Hornblende Gneiss
- Granitic Gneiss

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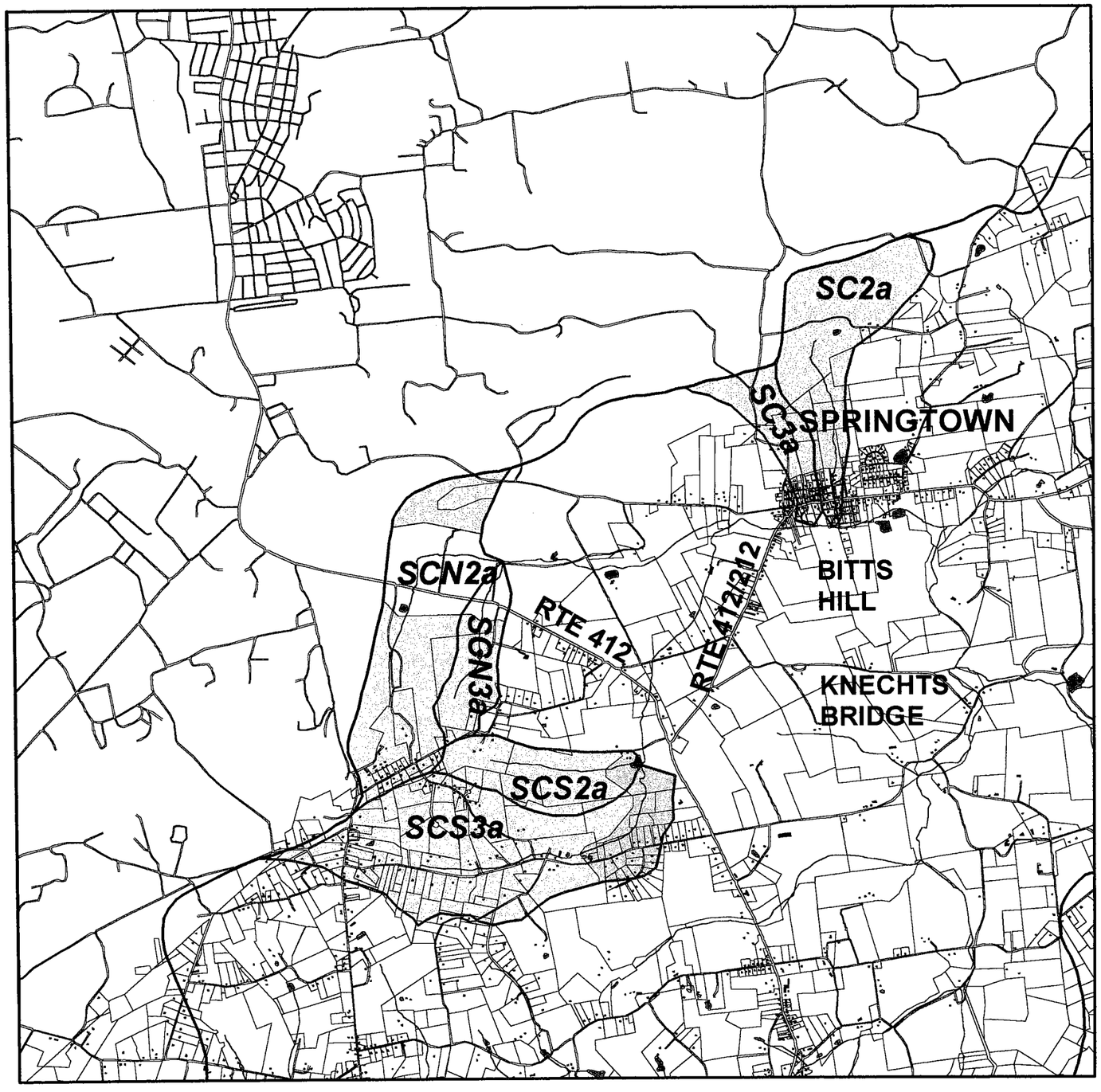

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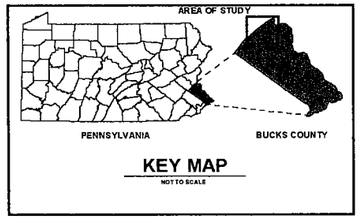

- Figure 12.4-
Area 4 Sub-basin Geology
- First Order Sub-basins -

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- Tax Map Parcels
- First Order Sub-basins
- Diabase
- Brunswick Formation
- Lockatong Formation
- Quartz Fanoglomerate
- Limestone Fanoglomerate *

Passaic Formation (Undifferentiated)

- Allentown Formation *
- Leithsville Formation *
- Hardyston Formation
- Hornblende Gneiss
- Granitic Gneiss

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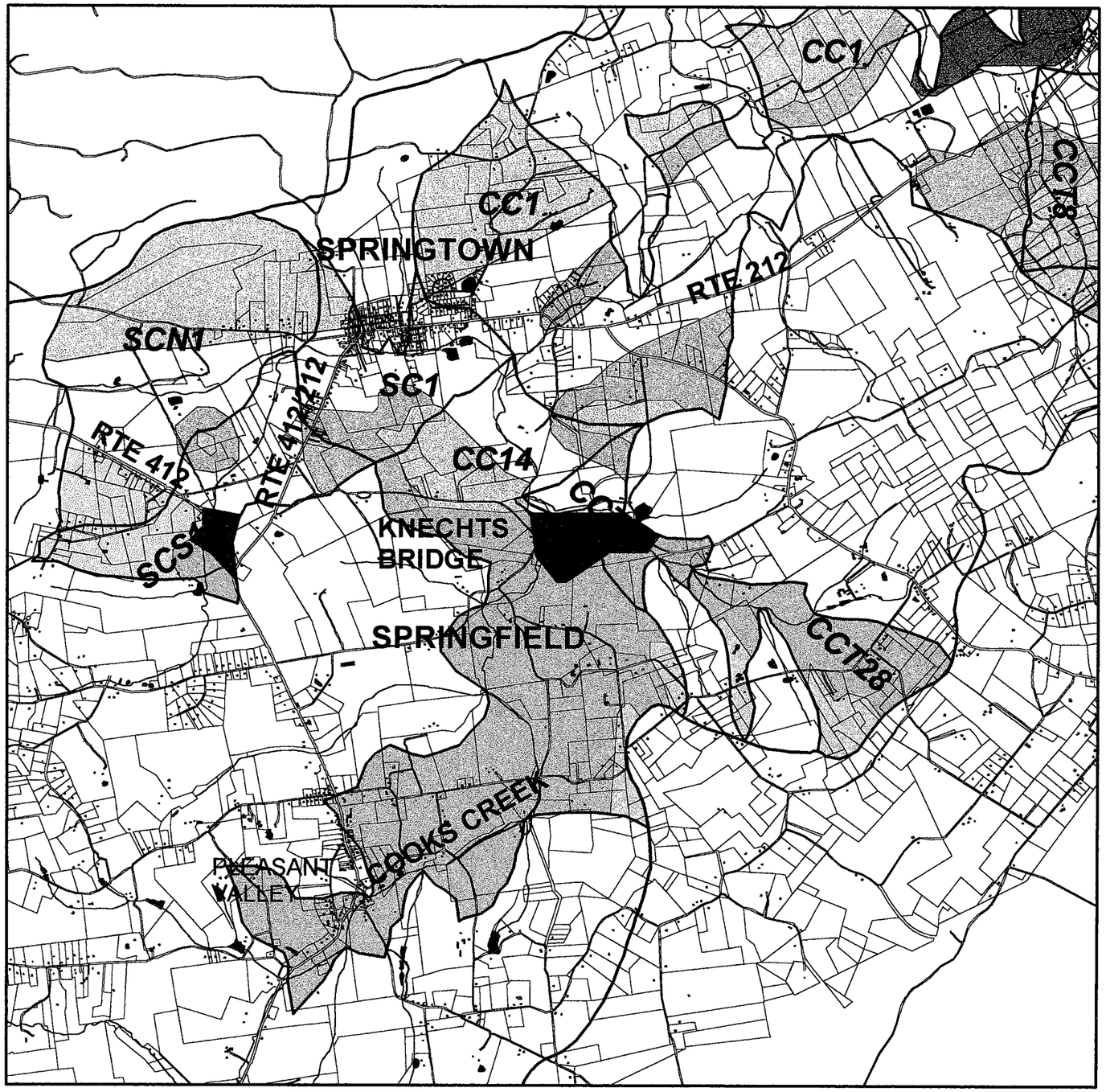

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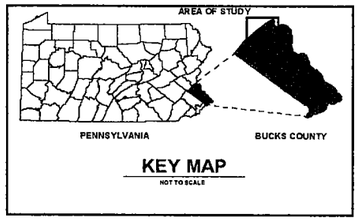

- Figure 12.5-
Area 5 Sub-basin Geology
- Second Order Sub-basins -

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- Tax Map Parcels
- Second Order Sub-basins
- Diabase
- Brunswick Formation
- Lockatong Formation
- Quartz Fanoglomerate
- Limestone Fanoglomerate *

Passaic Formation (Undifferentiated)

- Allentown Formation *
- Leithsville Formation *
- Hardyston Formation
- Hornblende Gneiss
- Granitic Gneiss

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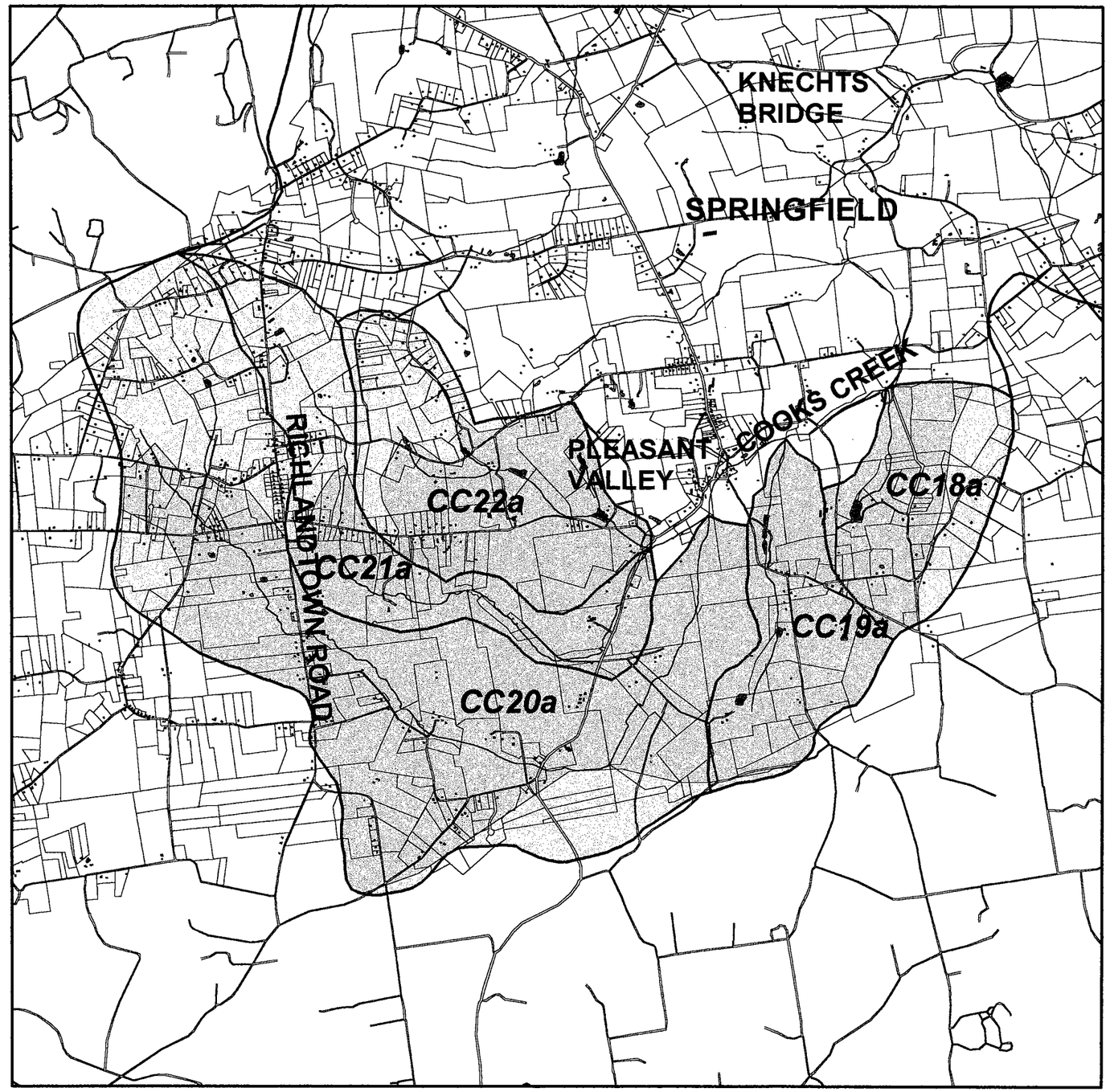

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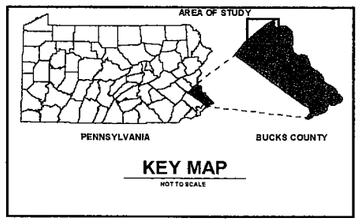

- Figure 12.6-
Area 6 Sub-basin Geology
- First Order Sub-basins -

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- Tax Map Parcels
- First Order Sub-basins
- Diabase
- Brunswick Formation
- Lockatong Formation
- Quartz Fanoglomerate
- Limestone Fanoglomerate *

Passaic Formation (Undifferentiated)

- Allentown Formation *
- Leithsville Formation *
- Hardyston Formation
- Hornblende Gneiss
- Granitic Gneiss

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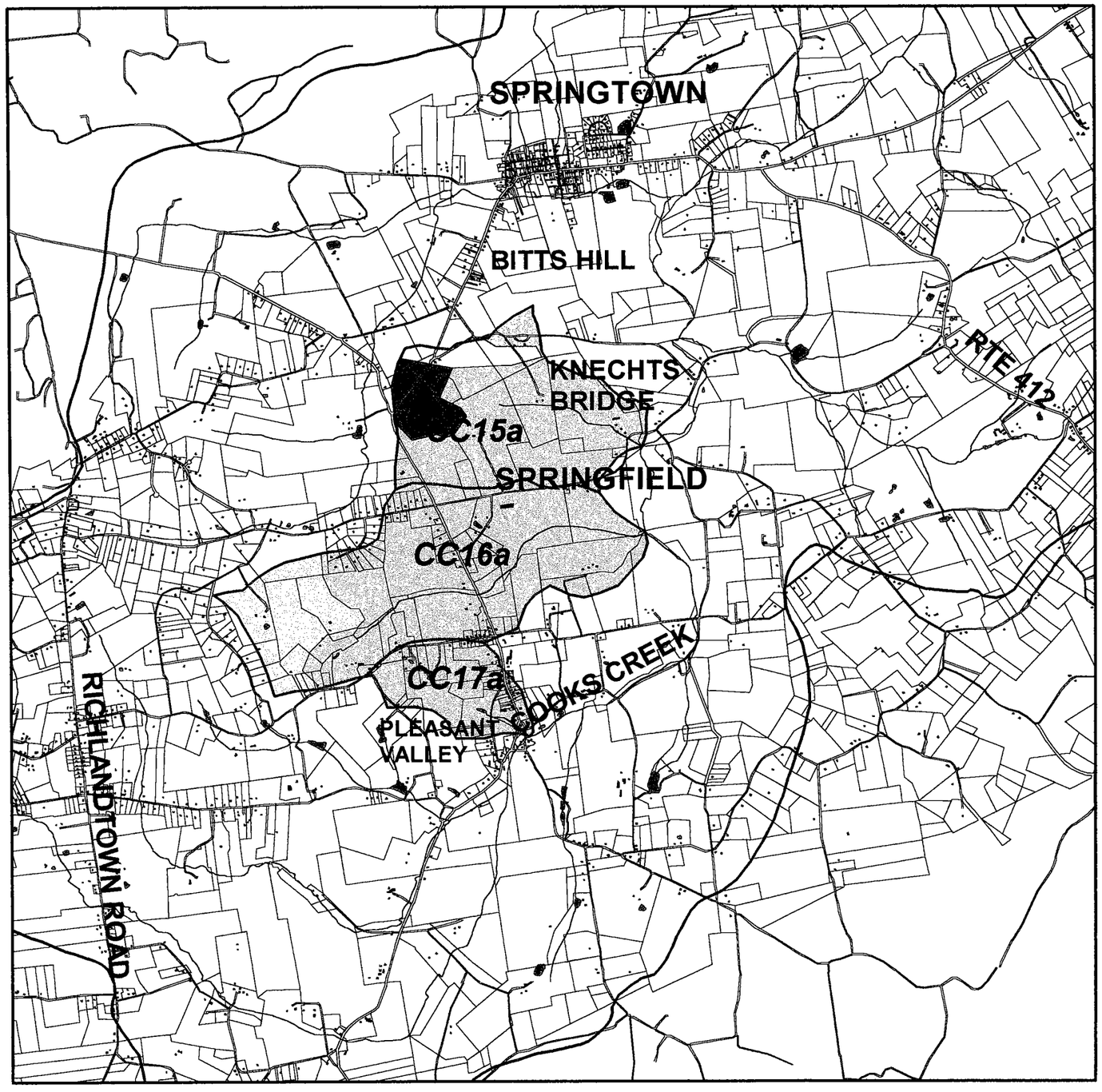

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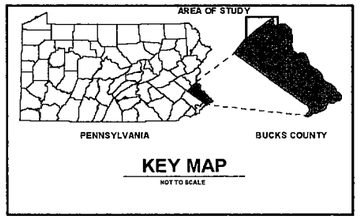

- Figure 12.7-
Area 7 Sub-basin Geology

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Buildings
- Tax Map Parcels
- Sub-basins
- Diabase
- Brunswick Formation
- Lockatong Formation
- Quartz Fanoglomerate
- Limestone Fanoglomerate *

Passaic Formation (Undifferentiated)

- Allentown Formation *
- Leithsville Formation *
- Hardyston Formation
- Hornblende Gneiss
- Granitic Gneiss

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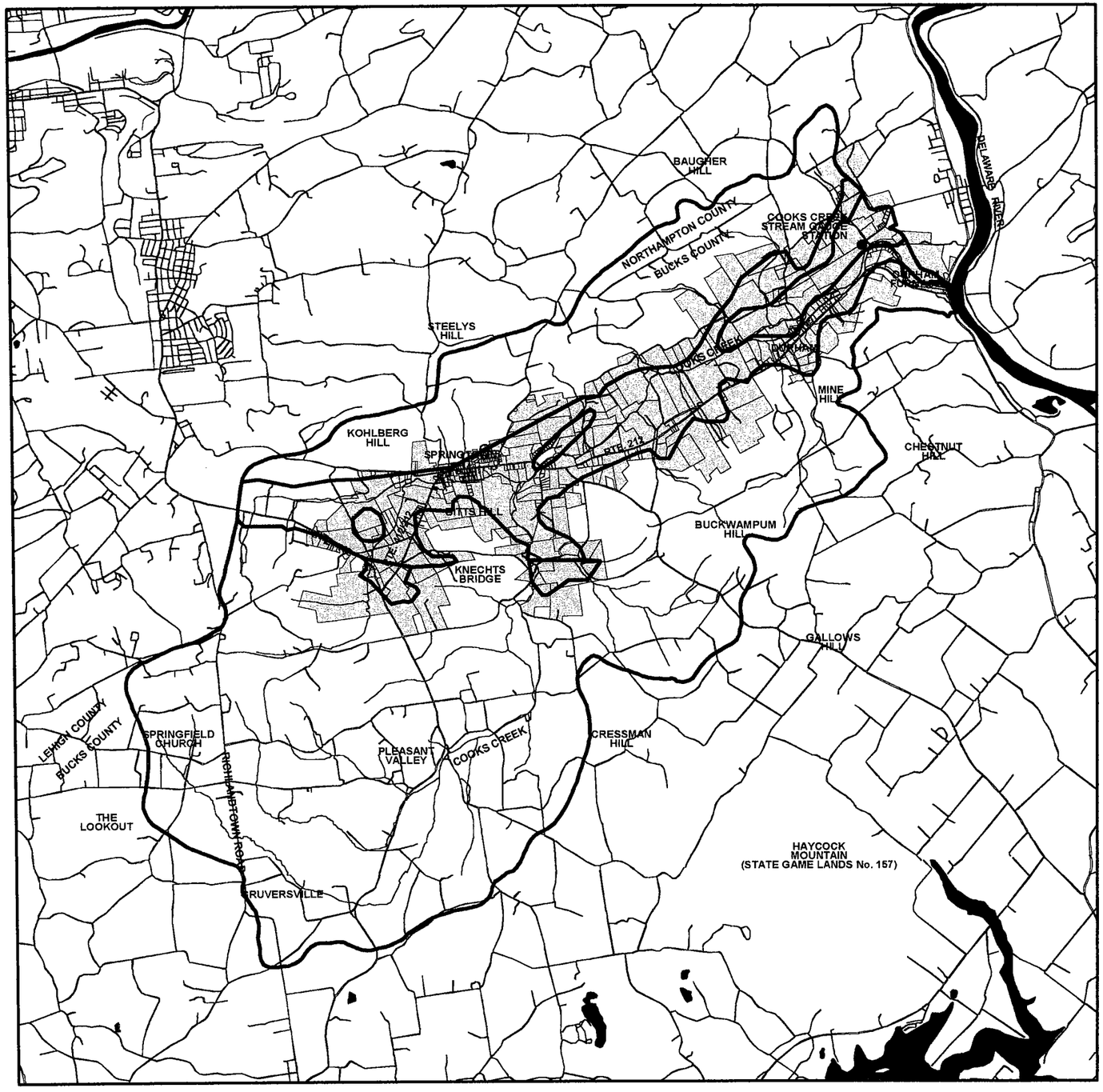

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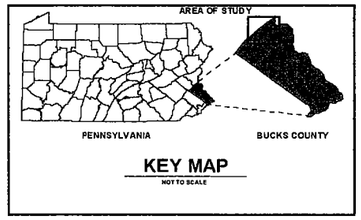

- Figure 13- Durham Carbonate Valley Parcels

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Durham Carbonate Valley - Geologic Contact
- Durham Carbonate Valley - Parcels

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3) Spruance Lybrary of The Mercer Museum, Doylestown, Aerial Photos, 1950, 1958.

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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.

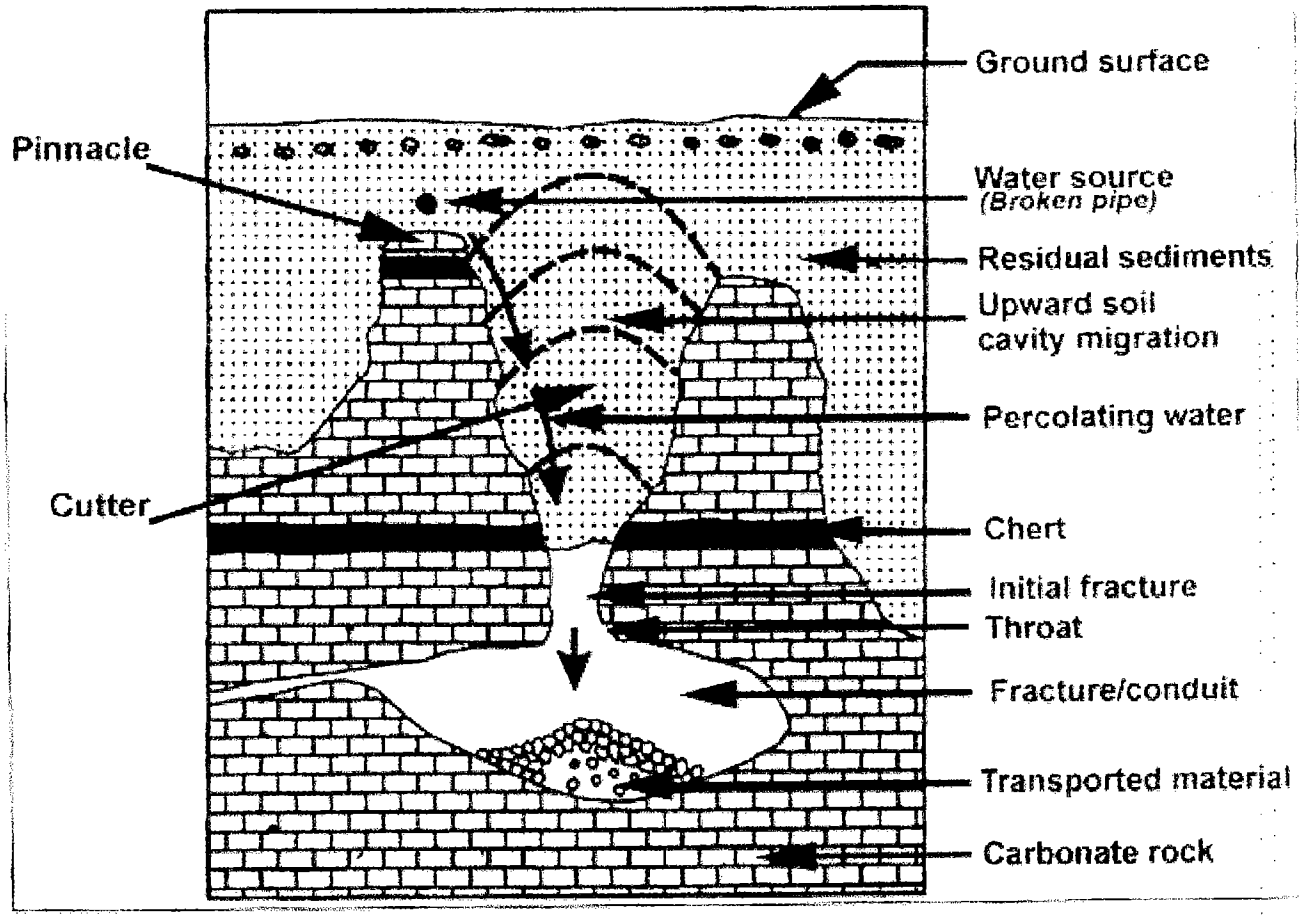

Figure 16. Conceptualization of Sinkhole Formation (Foundation Engineering Problems and Hazards in Karst Terranes, Fact Sheet 11, Maryland, Geologic Survey, Figure 4)

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.

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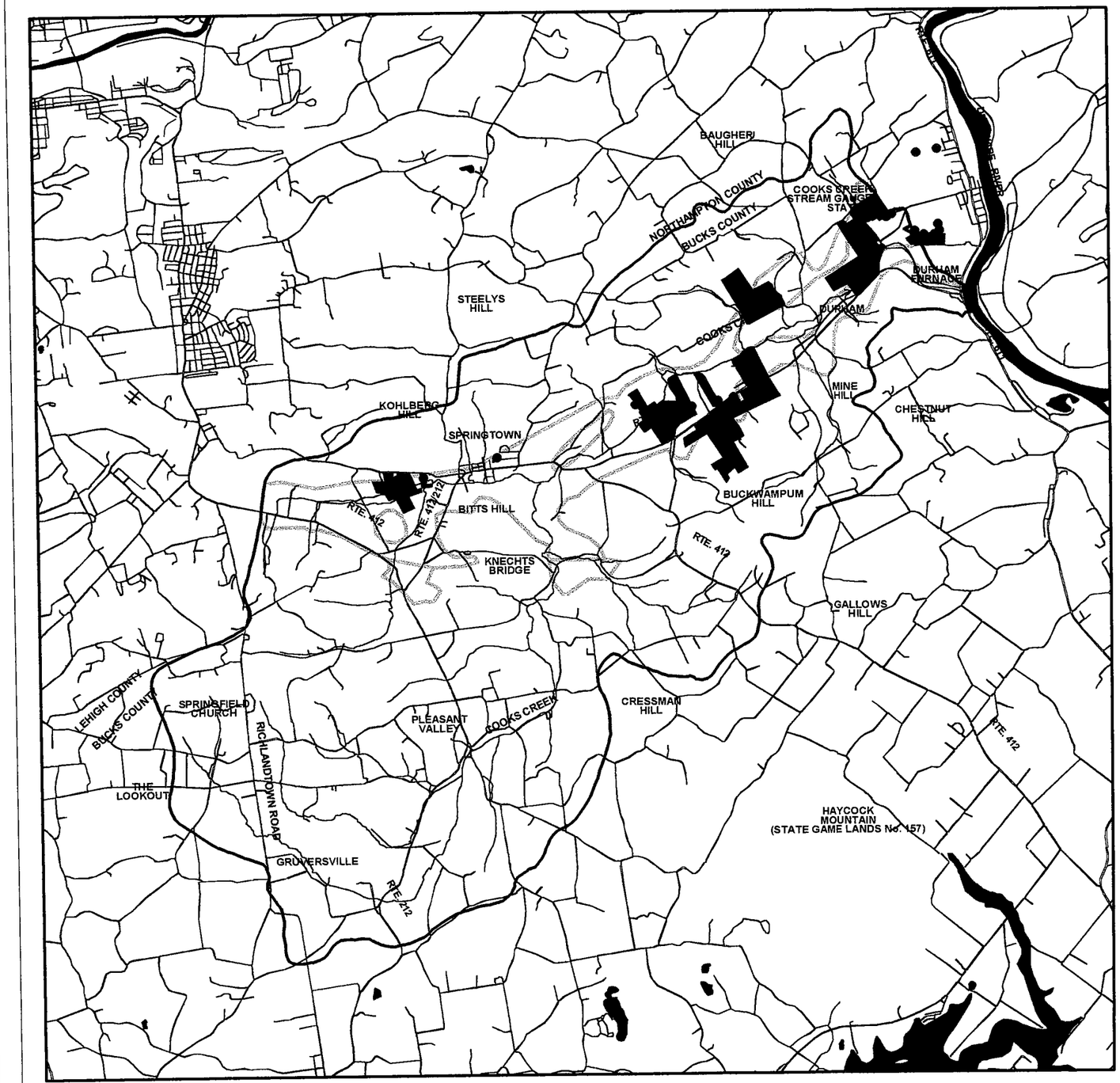

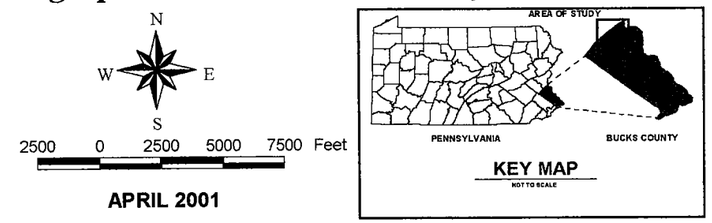

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- Figure 14 - Parcels with Sinkholes

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Parcels with Sinkholes
- Durham Carbonate Valley - Geologic Contact
- Sinkholes

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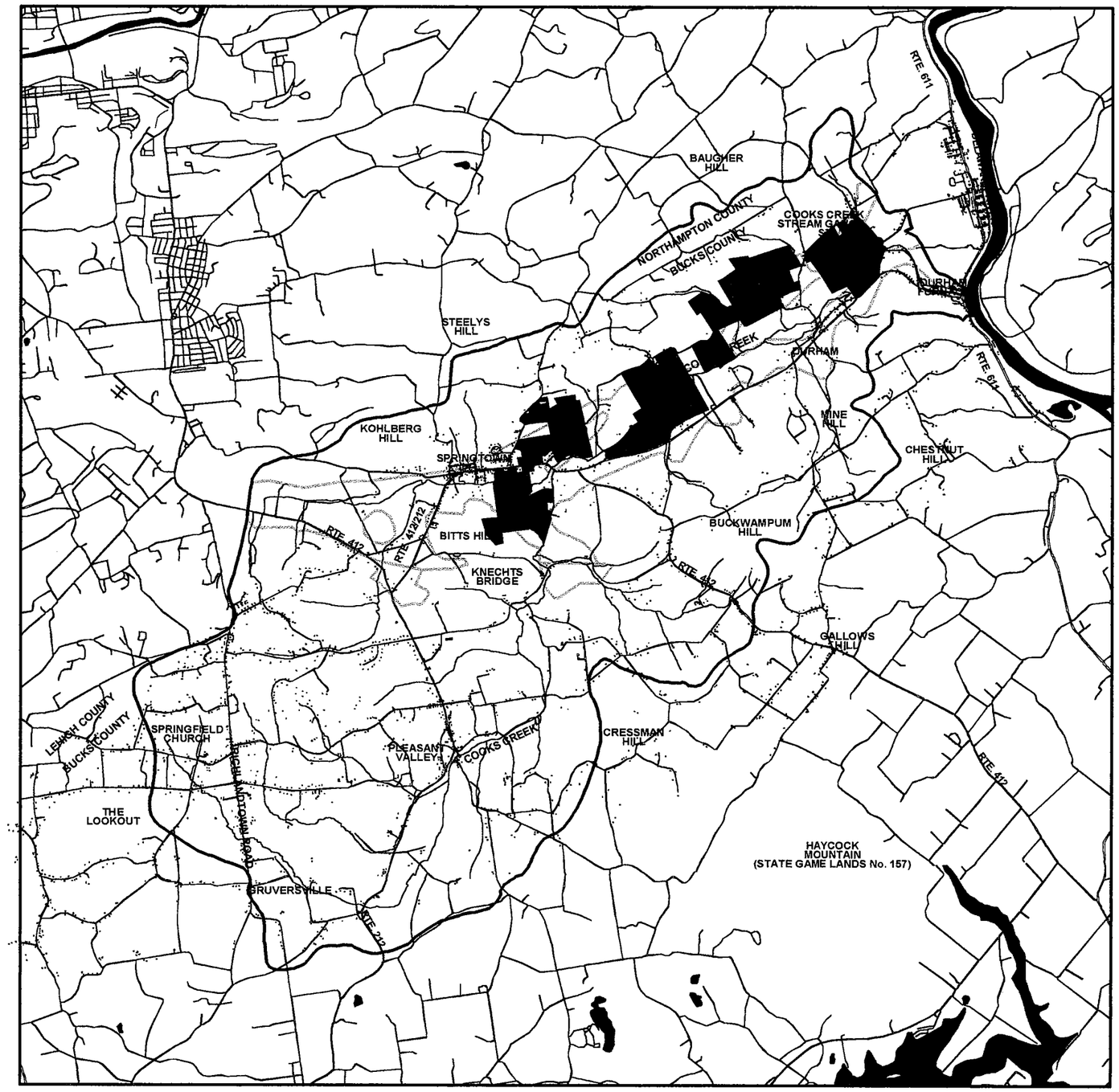
COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis



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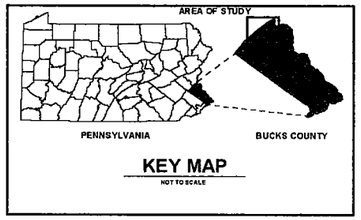

- Figure 15 -
Karst-Prone Areas Parcels

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Buildings
- Karst-Prone Areas Parcels
- Durham Carbonate Valley - Geologic Contact
- Areas Susceptible to Karst Dissolution Features

SOURCES: 1) Pennsylvania Spatial Data Access system (PASDA) , Surface Geology, Translation, attribution and analysis by MJE and Golder, 1999.

2) Conservation and Management Practices for Buckingham & Durham Carbonate Valleys, Bucks County Planning Commission, February 1985

3) Spruance Lybrary of The Mercer Museum, Doylestown, Aerial Photos, 1950, 1958.

4) DTEAC , MJE , Wetlands Management Plan, Areas susceptible to karst, 1999

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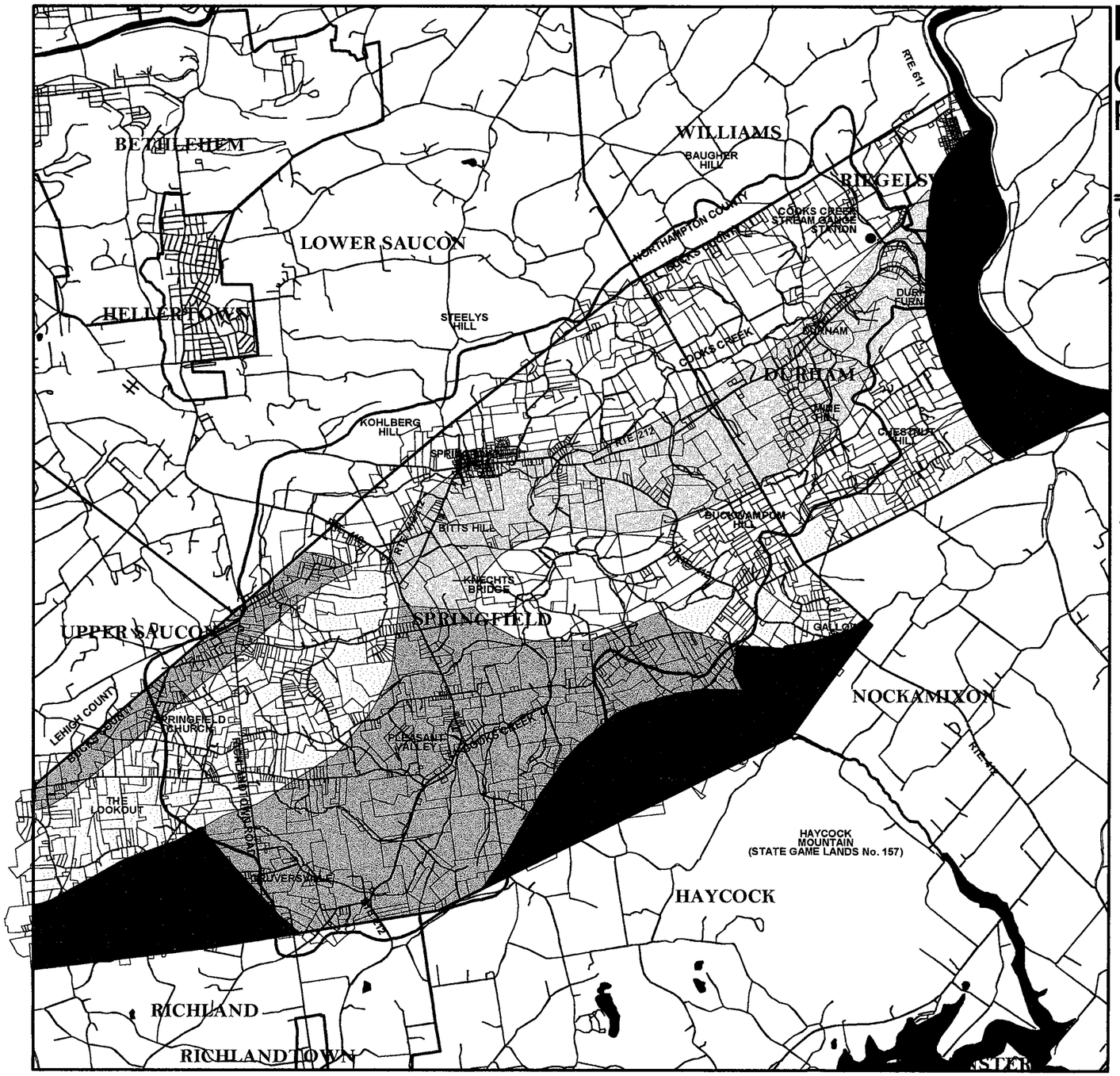

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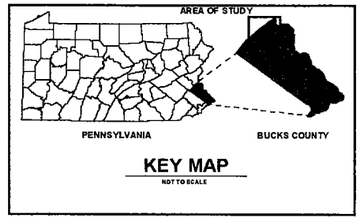

- Figure 17 - Generalized Soils Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Generalized Soils

DEEP SOILS THAT HAVE A MEDIUM TEXTURED SURFACE LAYER AND A MEDIUM TEXTURED OR MODERATELY FINE TEXTURED SUBSOIL:

- 061 - Chester association: Nearly level to moderately steep, well drained soils on uplands.
- 064 - Allenwood association: Gently sloping to moderately steep, well-drained soils on glacially influenced uplands.
- 062 - Towhee-Neshaminy-Mount Lucas association: Nearly level to moderately steep, poorly drained to well drained soils on uplands
- 058 - Duffield-Washington association: Gently sloping and sloping, well drained soils in upland valleys

SOILS THAT HAVE A MEDIUM-TEXTURED SURFACE LAYER AND A FIRM TO FRIABLE, BUT MAINLY FIRM AND COMPACT, SUBSOIL; SHALLOW TO DEEP OVER SHALE OR SANDSTONE:

- 065 - Abbottstown-Doylestown-Reaville association: Nearly level and gently sloping, moderately deep and deep, poorly drained to moderately well drained soils on uolands
- 063 - Penn-Klinesville association: Nearly level to moderately steep, shallow and moderately deep, well drained soils on upland.

DEEP SOILS THAT HAVE A MEDIUM TEXTURED SURFACE LAYER AND A MEDIUM TEXTURED OR MODERATELY COARSE TEXTURED SUBSOIL:

- 071 - Alton-Pope association: Nearly level and gently sloping, well-drained soils on terraces and flood plains.

SOURCES: 1) Pennsylvania Spatial Data Access system (PASDA is Pennsylvania's official geospatial information clearinghouse and the Commonwealth's node on the National Spatial Data Infrastructure (NSDI)), Translation, attribution and analysis by MJE, 1999.
2) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

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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)
- 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.

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BUCKS COUNTY, PENNSYLVANIA

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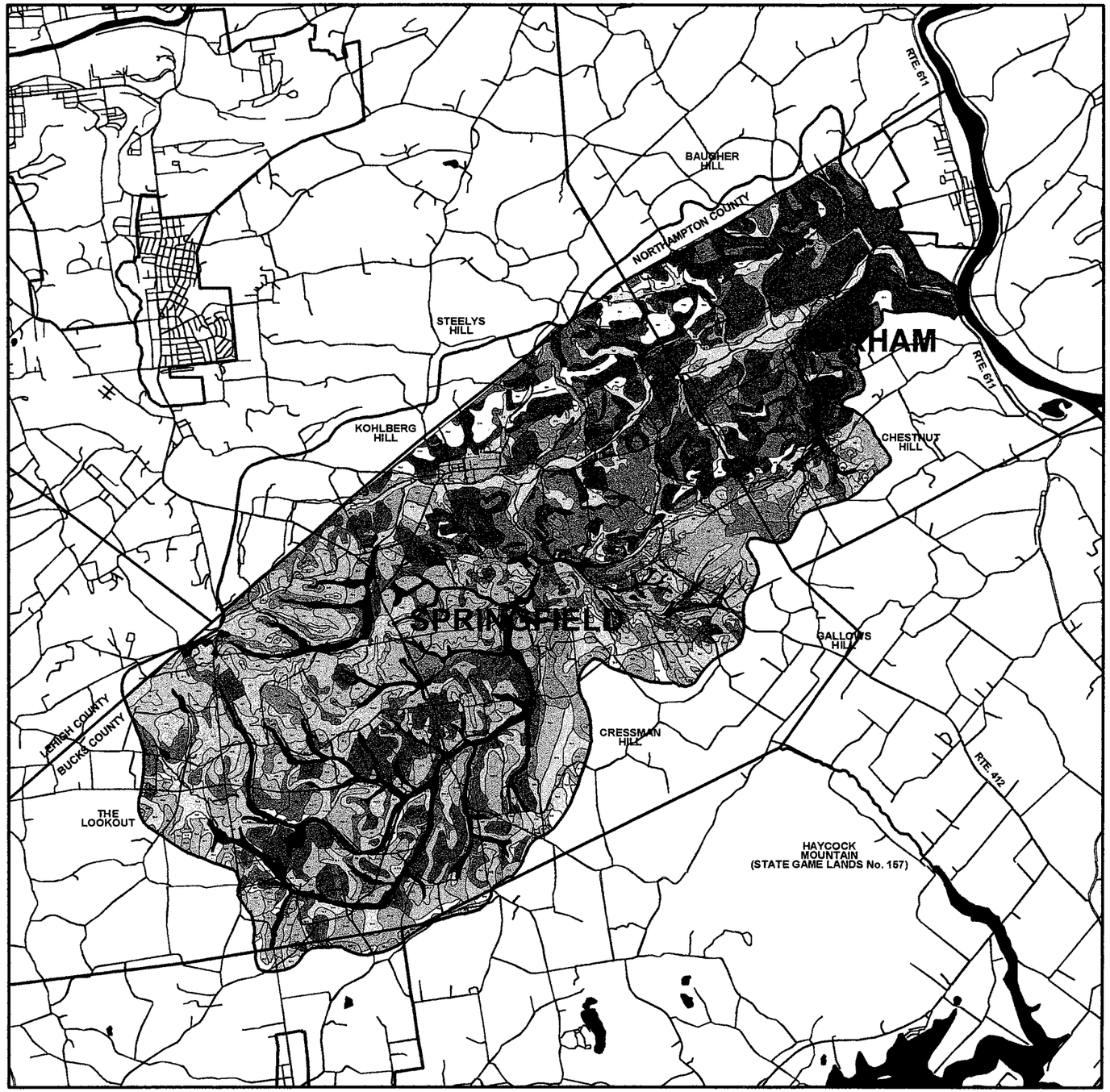

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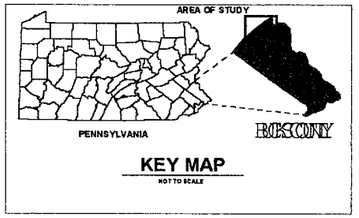

- Figure 18 - Soil Series Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Soil Series and Map Symbols

AbA	DoB	MIA	PpA
AbB	[illegible]	MIB	Quarry
AbC	[illegible]	MoB	RdA
AdB	[illegible]	MoD	RdB
AdC	[illegible]	NeB	RdC
AdD	[illegible]	NeC	ReA
Ae	[illegible]	NhB	ReB
AgB	[illegible]	NhC	ReC
AlA	[illegible]	NhD	Ro
Bo	[illegible]	NhE	ToA
CeA	[illegible]	PeA	ToB
CeB	[illegible]	PeB	TwB
CeC	[illegible]	PeC	UdB
CeD	[illegible]	PeD	UtC
ChD	MaB	PhB3	UrA
ClB	MaC	PkC3	UrB
CwB	MaD	PtD	WaB
CwC	MbD	PtE	WcD
DoA	McE	PoA	

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

2) Bucks County Natural Resources Plan, Bucks County Planning Commission, March 1999

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Figure 18.A- Soil Series Maps Legend

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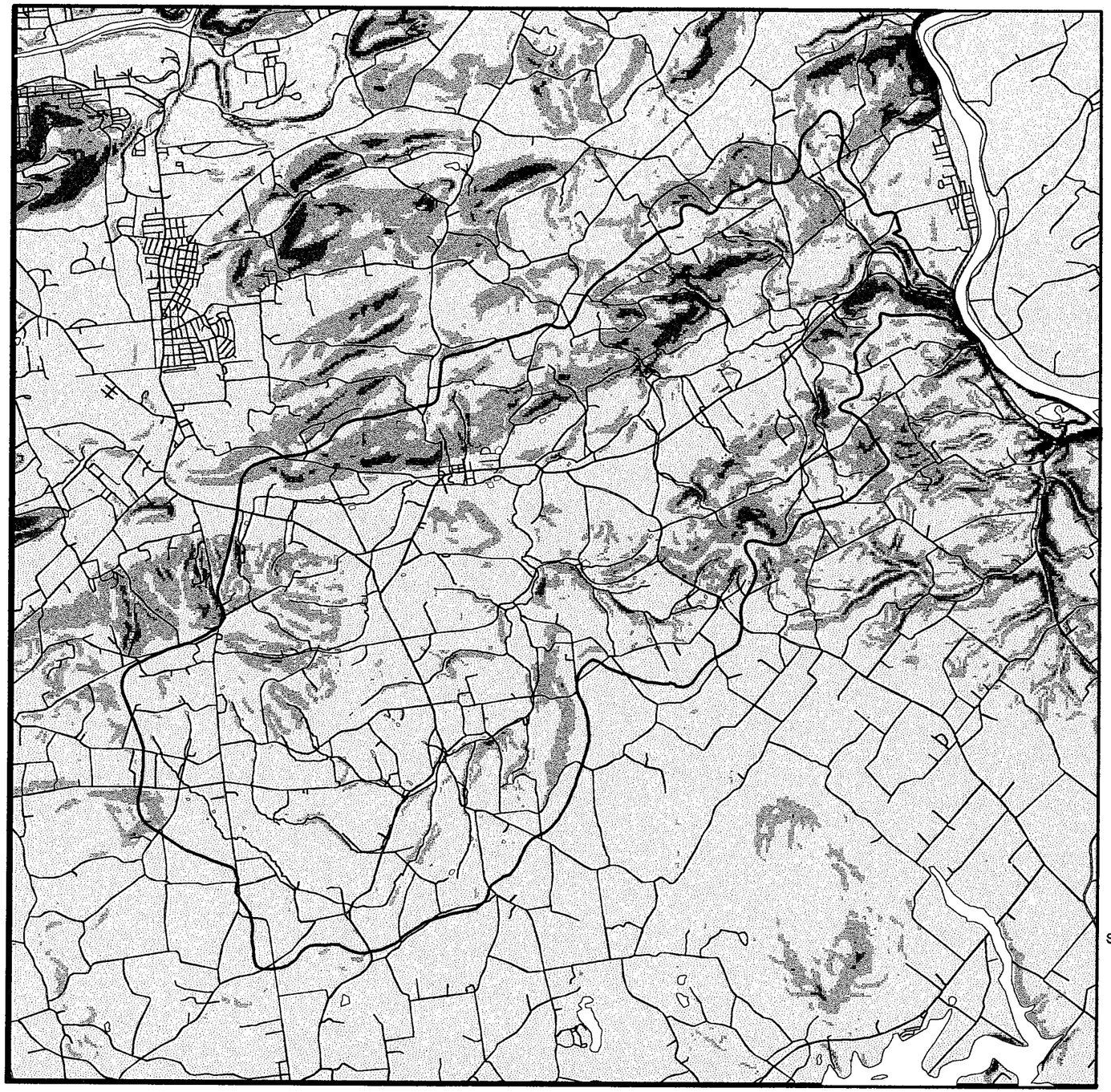
Geographic Information Systems Analysis

- AbA - Abbottstown silt loam 0 to 3 percent slopes
- AbB - Abbottstown silt loam 3 to 8 percent slopes
- AbC - Abbottstown silt loam 8 t0 15 percent slopes
- AdB - Allenwood gravelly silt loam, 3 to 8 percent slopes
- AdC - Allenwood gravelly silt loam, 8 to 15 percent slopes
- AdD - Allenwood gravelly silt loam, 15 to 25 percent slopes
- Ae - Alluvial land
- AgB - Alton gravelly loam, 3 to 8 percent slopes
- AlA - Alton gravelly loam, flooded, 0 to 5 percent slopes
- Bo - Bowmansville silt loam
- CeA - Chester silt loam, 0 to 3 percent slopes
- CeB - Chester silt loam, 3 to 8 percent slopes
- CeC - Chester silt loam, 8 to 15 percent slopes
- CeD - Chester silt loam, 15 to 25 percent slopes
- ChD - Chester extremely stony loam, 8 to 25 percent slopes
- ClB - Clarksburg silt loam, 2 to 6 percent slopes
- CwB - Culleoka - Weikert shaly silt loams, 3 to 8 percent slopes
- CwC - Culleoka - Weikert shaly silt loams, 8 to 15 percent slopes
- DoA - Doylestown silt loam, 0 to 3 percent slopes
- DoB - Doylestown silt loam, 3 to 8 8 percent slopes
- DtC - Duffield and Washington soils, 8 to 20 percent slopes
- Gravel Pit
- Ha - Hatboro silt loam
- KlB - Klinesville very shaly silt loam, 3 to 8 percent slopes
- KlC - Klinesville very shaly silt loam, 8 to 15 percent slopes
- KlD - Klinesville very shaly silt loam, 15 to 25 percent slopes
- LdB - Lansdale extremely stony loam, 0 to 8 percent slopes
- LdD - Lansdale extremely stony loam, 8 to 25 percent slopes
- LdE - Lansdale extremely stony loam, 25 to 50 percent slopes
- LhB - Lehigh channery silt loam, 0 to 8percent slopes
- LhC - Lehigh channery silt loam, 8 to 18 percent slopes
- LhD - Lehigh channery silt loam, 18 to 25 percent slopes
- LlD - Lehigh estremely stony silt loam, 8 to 25 percent slopes
- MaB - Manor loam, 3 to 8percent slopes
- MaC - Manor loam, 8 to 15 percent slopes
- MaD - Manor loam, 15 to 25 percent slopes
- MbD - Manor extremely stony loam, 8 to 25 percent slopes
- McE - Manor and Chester extremely stony loams, 25 to 50 percent slopes
- MlA - Mount Lucxas silt loam, 0 to 3 percent slopes
- MlB - Mount Lucas silt loam, 3 to 8 percent slopes
- MoB - Mount Lucas extremely stony silt loam, 0 to 8 percent slopes
- MoD - Mount Lucas extremely stony silt loam, 8 to 25 percent slopes
- NeB - Neshaminy channery silt loam, 3 to 8 percent slopes
- NeC - Neshaminy channery silt loam 8 to 15 percent slopes
- NhB - Neshaminy extremely stony silt loam, 0 to 8 percent slopes
- NhC - Neshaminy extremely silt loam, 8 to 15 percent slopes
- NhD - Neshaminy extremely stony silt loam, 8 to 25 percent slopes
- NhE - Neshaminy extremely stony silt loam, 25 to 50 percent slopes
- PeA - Penn silt loam, 0 to 3 percent slopes
- PeB - Penn silt loam, 3 to 8 percent slopes
- PeC - Penn silt loam, 8 to 15 percent slopes
- PeD - Penn silt loam, 15 to 25 percent slopes
- PhB3 - Penn - Klinesville shaly silt loams, 3 to 8 percent slopes, eroded
- PkC3 - Penn - Klinesville complex, 8 to 15 percent slopes, eroded
- PlD - Penn - Klinesville extremely stony silt loams, 8 to 25 percent slopes
- PlE - Penn - Klinesville extremely stony silt loams 25 to 50 percent slopes
- PoA - Pope loam, 0 to 5 percent slopes
- PpA - Pope loam, terrace, 0 to 3 percent slopes
- Quarry
- RdA - Readington silt loam, 0 to 3 percent slopes
- RdB - Readington silt loam, 3 to 8 percent slopes
- RdC - Readington silt loam, 8 to 15 percent slopes
- ReA - Reaville shaly silt loam, 0 to 3 percent slopes
- ReB - Reaville shaly silt loam, 3 to 8 percent slopes
- ReC - Reaville shaly silt loam, 8 to 15 percent slopes
- Ro - Rowland silt loam
- ToA - Towhee silt loam, 0 to 3 percent slopes
- ToB - Towhee silt loam, 3 to 8 percent slopes
- TwB - Towhee extremely stony silt loam, 0 to 8 percent slopes
- UdB - Urban land - Chester complex 0 to 8 percent slopes
- UlC - Urban land - Lansdale complex, 8 to 15 percent slopes
- UrA - Urbana silt loam, 0 to 3 percent slopes
- UrB - Urbana silt loam, 3 to 8 percent slopes
- WaB - Washington gravelly silt loam, 3 to 8 percent slopes
- WcD - Weikert - Culleoka shaly silt loams, 15 to 25 percent slopes



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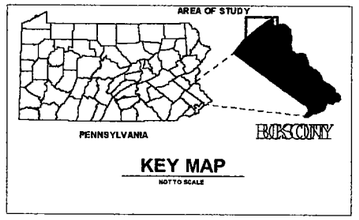

- Figure 18B - Slope Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds

Slope Range

- 0 - 7
- 7 - 14
- 14 - 24
- 24 - 100

SOURCES: 1) United States Geologic Survey Topographic Quadrangle Map, Riegelsville, PA - NJ, 1973; Hellertown, PA 1992; Quakertown, PA 1994; Bedminster, PA 1992, digitize, translation, attribution and analysis by MJE, August 2000.

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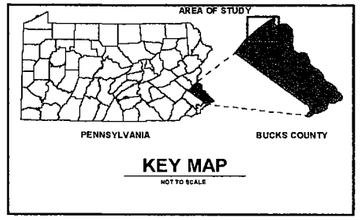

- Figure 18.1-
Soil Series Map
(Area 1)

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Soils Series and Map Symbols

AbA	DoB	MlA	PpA
AbB	DtC	MlB	Quarry
AbC	Gravel Pit	MoB	RdA
AdB	Ha	MoD	RdB
AdC	KlB	NeB	RdC
AdD	KlC	NeC	ReA
Ae	KlD	NhB	ReB
AgB	LdB	NhC	ReC
AlA	LdD	NhD	Ro
Bo	LdE	NhE	ToA
CeA	LhB	PeA	ToB
CeB	LhC	PeB	TwB
CeC	LhD	PeC	UdB
CeD	LlD	PeD	UlC
ChD	MaB	PhB3	UrA
ClB	MaC	PkC3	UrB
CwB	MaD	PlD	WaB
CwC	MbD	PlE	WcD
DoA	McE	PoA	

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

2) Bucks County Natural Resources Plan, Bucks County Planning Commission, March 1999

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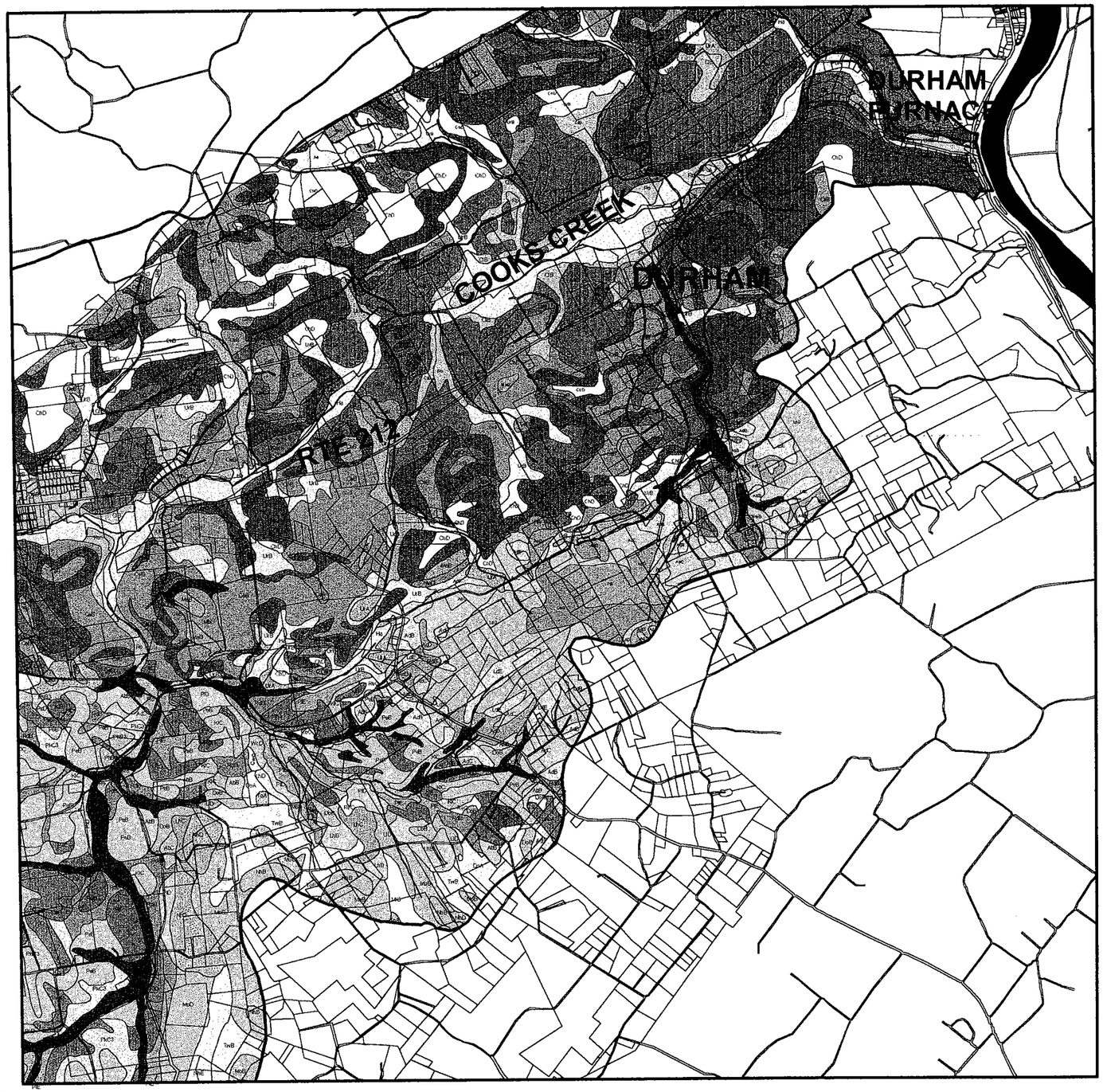

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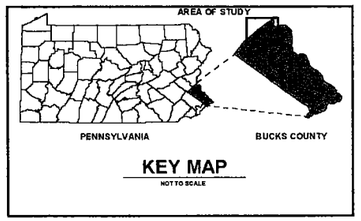

- Figure 18.3- Soil Series Map (Area 3)

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Soils Series and Map Symbols

AbA	DoB	MIA	PpA
AbB	DtC	MIB	Quarry
AbC	Gravel Pit	MoB	RdA
AdB	Ha	MoD	RdB
AdC	KlB	NeB	RdC
AdD	KlC	NeC	ReA
Ae	KlD	NhB	ReB
AgB	LdB	NhC	ReC
AlA	LdD	NhD	Ro
Bo	LdE	NhE	ToA
CeA	LhB	PeA	ToB
CeB	LhC	PeB	TwB
CeC	LhD	PeC	UdB
CeD	LlD	PeD	UlC
ChD	MaB	PhB3	UrA
ClB	MaC	PkC3	UrB
CwB	MaD	PlD	WaB
CwC	MbD	PlE	WcD
DoA	McE	PoA	

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

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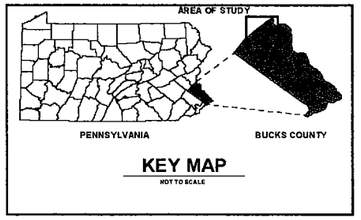

- Figure 18.4 - Soil Series Map (Area 4)

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Soils Series and Map Symbols

AbA	DoB	MIA	PpA
AbB	DtC	MIB	Quarry
AbC	Gravel Pit	MoB	RdA
AdB	Ha	MoD	RdB
AdC	KlB	NeB	RdC
AdD	KlC	NeC	ReA
Ae	KlD	NhB	ReB
AgB	LdB	NhC	ReC
AlA	LdD	NhD	Ro
Bo	LdE	NhE	ToA
CeA	LhB	PeA	ToB
CeB	LhC	PeB	TwB
CeC	LhD	PeC	UdB
CeD	LlD	PeD	UlC
ChD	MaB	PhB3	UrA
ClB	MaC	PkC3	UrB
CwB	MaD	PlD	WaB
CwC	MbD	PlE	WcD
DoA	McE	PoA	

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

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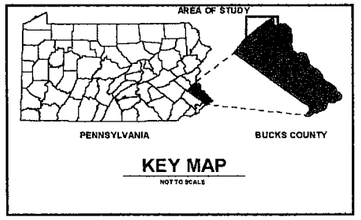

- Figure 18.5 - Soil Series Map (Area 5)

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Soils Series and Map Symbols

AbA	DoB	MIA	PpA
AbB	DtC	MIB	Quarry
AbC	Gravel Pit	MoB	RdA
AdB	Ha	MoD	RdB
AdC	KlB	NeB	RdC
AdD	KlC	NeC	ReA
Ae	KlD	NhB	ReB
AgB	LdB	NhC	ReC
AlA	LdD	NhD	Ro
Bo	LdE	NhE	ToA
CeA	LhB	PeA	ToB
CeB	LhC	PeB	TwB
CeC	LhD	PeC	UdB
CeD	LlD	PeD	UlC
ChD	MaB	PhB3	UrA
ClB	MaC	PkC3	UrB
CwB	MaD	PlD	WaB
CwC	MbD	PlE	WcD
DoA	McE	PoA	

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

2) Bucks County Natural Resources Plan, Bucks County Planning Commission, March 1999

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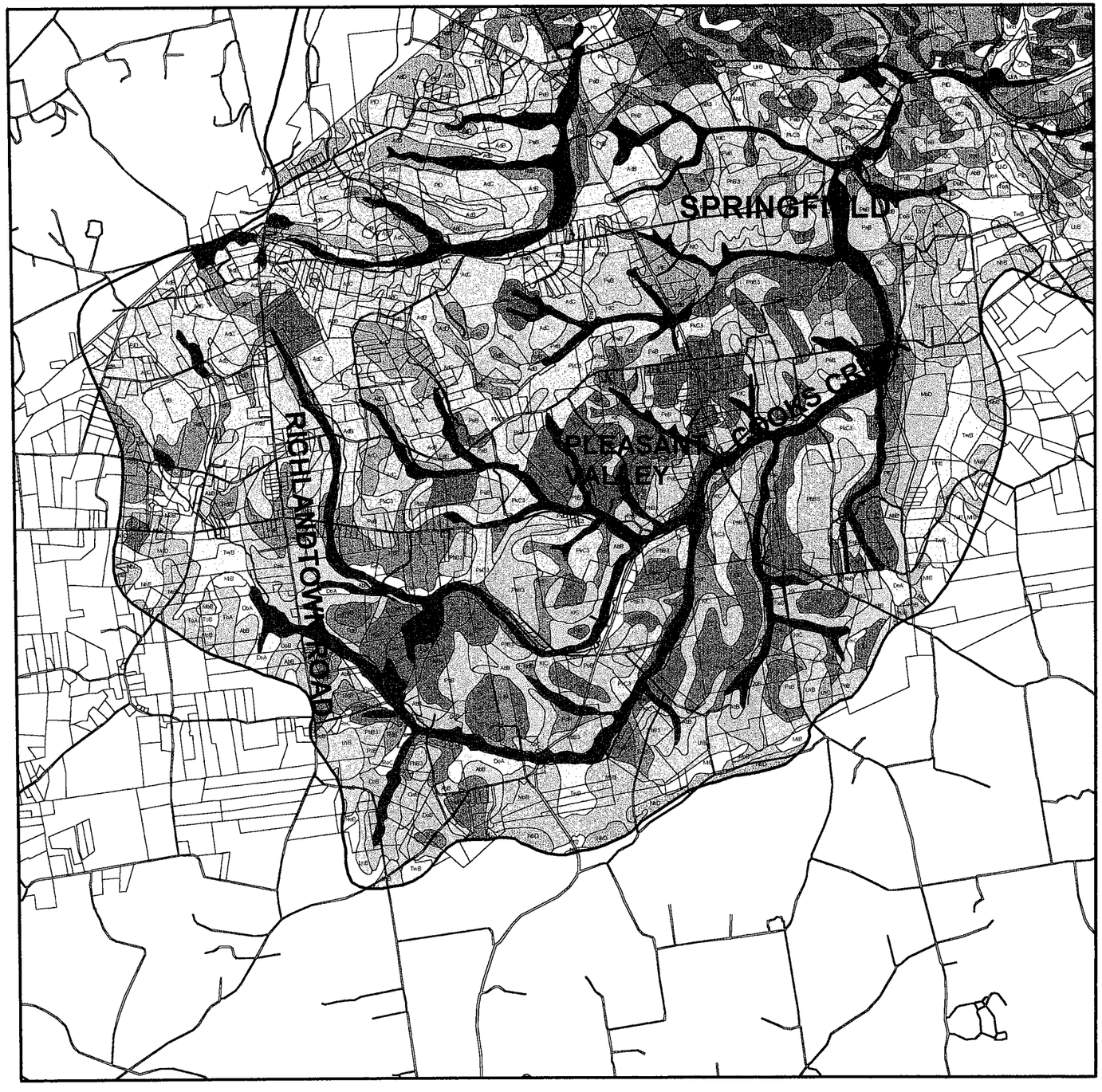

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COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis

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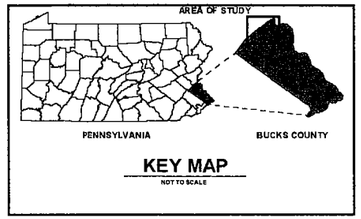

- Figure 18.6 - Soil Series Map (Area 6)

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Soils Series and Map Symbols

AbA	DoB	MA	PpA
AbB	DtC	MB	Quarry
AbC	Gravel Pit	MoB	RdA
AdB	Ha	MoD	RdB
AdC	KlB	NeB	RdC
AdD	KlC	NeC	ReA
Ae	KlD	NhB	ReB
AgB	LdB	NhC	ReC
AlA	LdD	NhD	Ro
Bo	LdE	NhE	ToA
CeA	LhB	PeA	ToB
CeB	LhC	PeB	TwB
CeC	LhD	PeC	UdB
CeD	UD	PeD	UlC
ChD	MaB	PhB3	UrA
ClB	MaC	PkC3	UrB
CwB	MaD	PtD	WaB
CwC	MbD	PtE	WcD
DoA	McE	PoA	

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

2) Bucks County Natural Resources Plan, Bucks County Planning Commission, March 1999

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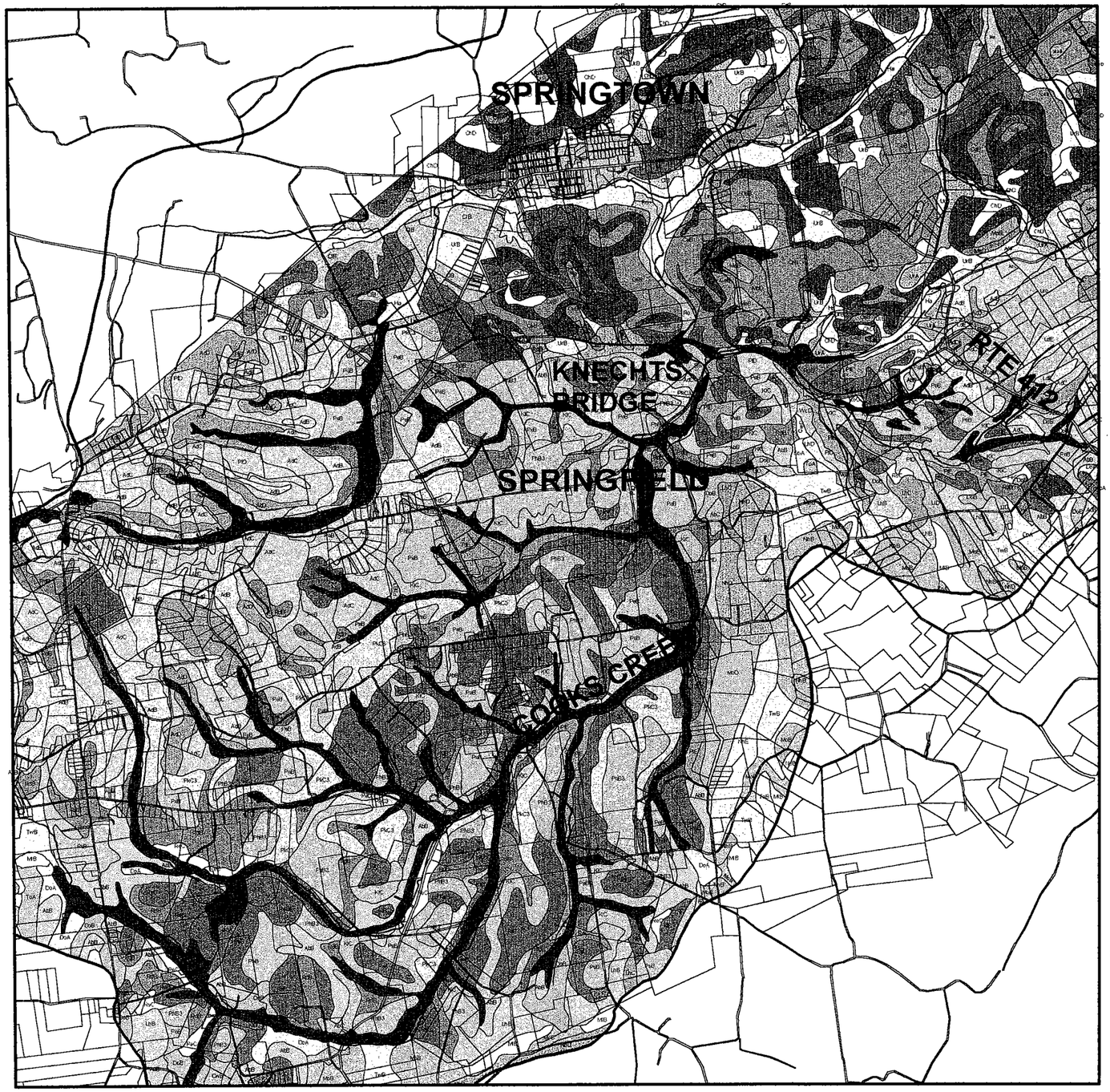

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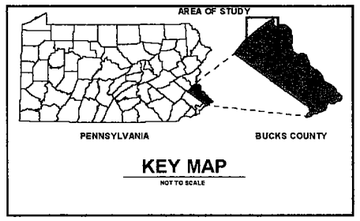

- Figure 18.7 - Soil Series Map (Area 7)

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Soils Series and Map Symbols

AbA	DoB	MIA	PpA
AbB	DtC	MIB	Quarry
AbC	Gravel Pit	MoB	RdA
AdB	Ha	MoD	RdB
AdC	KlB	NeB	RdC
AdD	KlC	NeC	ReA
Ae	KlD	NhB	ReB
AgB	LdB	NhC	ReC
AlA	LdD	NhD	Ro
Bo	LdE	NhE	ToA
CeA	LhB	PeA	ToB
CeB	LhC	PeB	TwB
CeC	LhD	PeC	UdB
CeD	LlD	PeD	UlC
ChD	MaB	PhB3	UrA
ClB	MaC	PkC3	UrB
CwB	MaD	PlD	WaB
CwC	MbD	PlE	WcD
DoA	MeE	PoA	

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

2) Bucks County Natural Resources Plan, Bucks County Planning Commission, March 1999

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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.

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COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

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BUCKS COUNTY, PENNSYLVANIA

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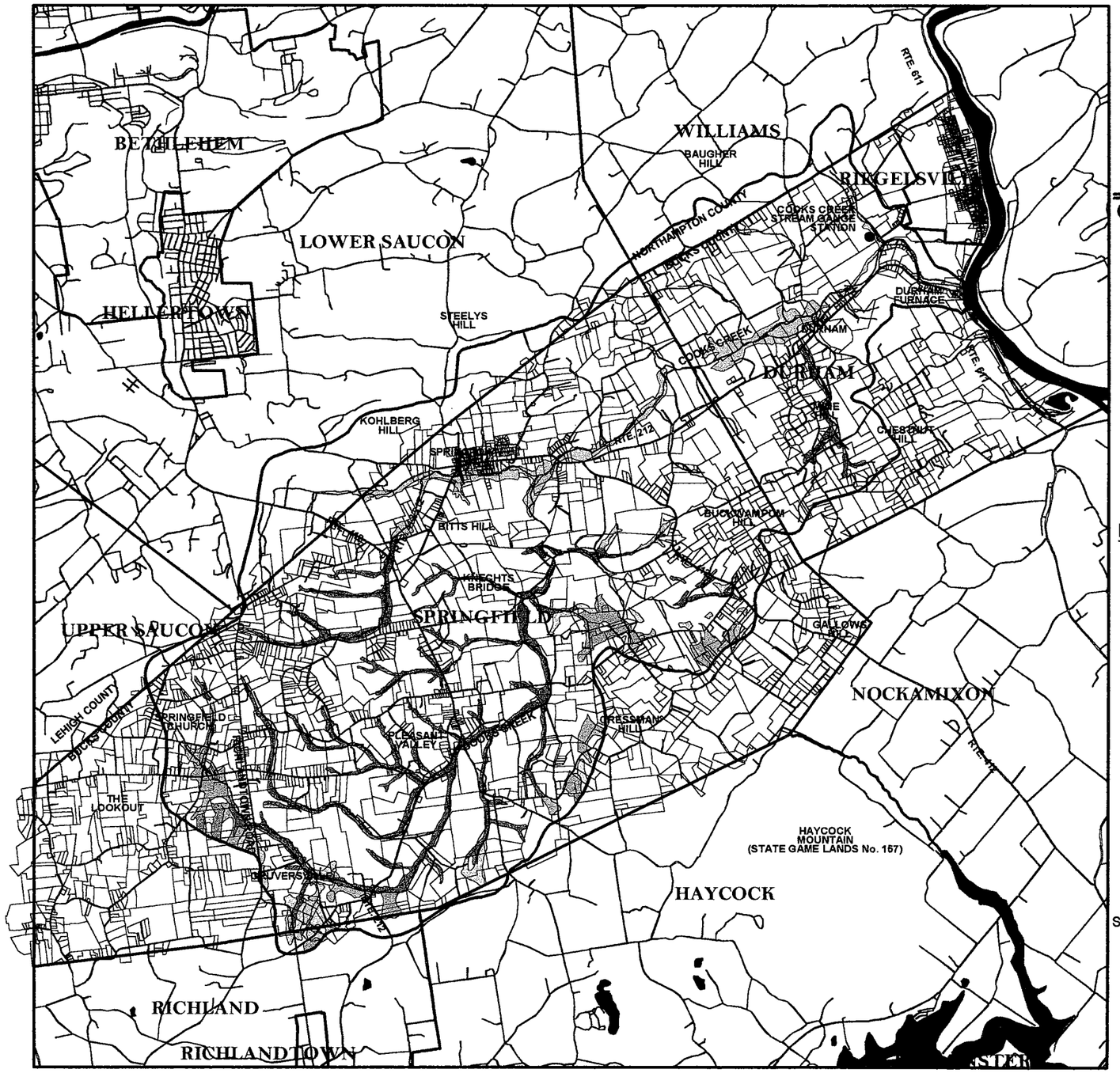

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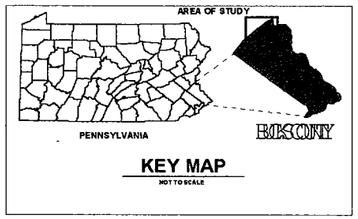

- Figure 19 -
Hydric Soils Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Hydric Soils

- Bo (Bowmansville silt loam)
- CwB (Culloka-Weikert shaly silt loam, 3 to 8 percent slopes)
- CwC (Culloka-Weikert shaly silt loam)
- DoA (Doylestown silt loam, 0 to 3 percent slopes)
- DoB (Doylestown silt loam, 3 to 8 percent slopes)
- Ha (Hatboro silt loam)
- ToA (Towhee silt loam, 0 to 3 percent slopes)
- ToB (Towhee silt loam, 3 to 8 percent slopes)
- TwB (Towhee extremely stony silt loam, 3 to 8 percent slopes)

Note: The first capital letter is the initial one of the soil name. A second capital letter, A, B, C, D, or E, shows the slope. Most symbols without a slope letter are those of nearly level soils, but some are for soils and land types that have a considerable range of slope.

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

2) Bucks County Natural Resources Plan, Bucks County Planning Commission, March 1999

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- 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 development.
  - *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.

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COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

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BUCKS COUNTY, PENNSYLVANIA

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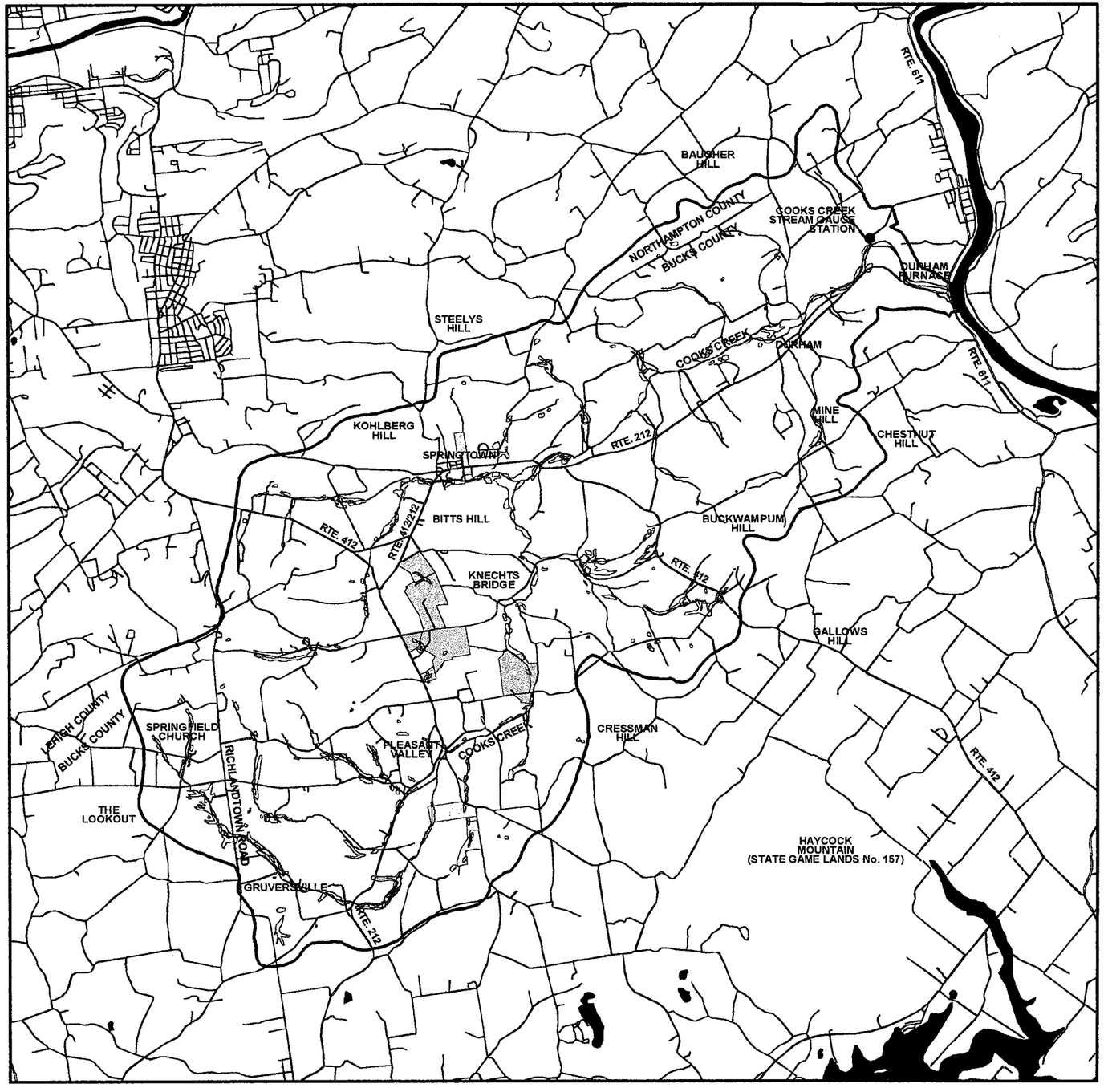

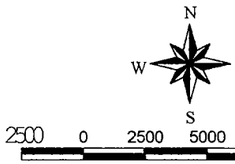

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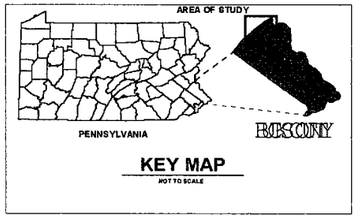

- Figure 20 - The Parcels Map with Disturbed Wetlands

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Wetlands
- Disturbed Wetland J
- Disturbed Wetland M
- Disturbed Wetland T
- Disturbed Wetland X
- Disturbed Wetland W

SOURCES: 1) Wetlands Management Plan, DTEAC, MJE et al., May 2000.

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Hazard Areas

Hazard areas are shown on Figure 21.

Landfills

There are no landfills in Durham or Springfield Townships.

Waste Sites

There are two waste sites in Springfield, the Delguerico Waste Transit Station and the Gemstar Tires used tire deposit.

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 early settlement of the Durham Township was spurred by the development of an iron ore forge in 1698. A blast furnace was erected at the forge in 1727. This blast furnace was powered by water from the Durham Creek, now called Cooks Creek. The furnace operations ceased and the property remained dormant from 1789 through 1848 at which time two furnaces, adapted for anthracite coal, were built. One furnace was near the Delaware River and the other was near the mouth of Durham Creek.
In 1876 new furnaces were constructed which remained in operation until about 1912. Boats built by Robert Durham transported the Durham Furnace goods down river to Philadelphia and points south. Pig iron, stoves, and iron bar were manufactured at these sites.

During the Revolutionary War, weapon shot and shell were produced at the Durham Furnace. At the time Durham Furnace Company was organized, it owned the entire land area of Durham Township (6,410 acres 123 perches), as well as portions of Springfield and Williams Townships.

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. 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 rare fresh water invertebrate, Prices' Cave Isopod, also has been found in the mine.

A quarry is also located in the same general region as the mines within 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.

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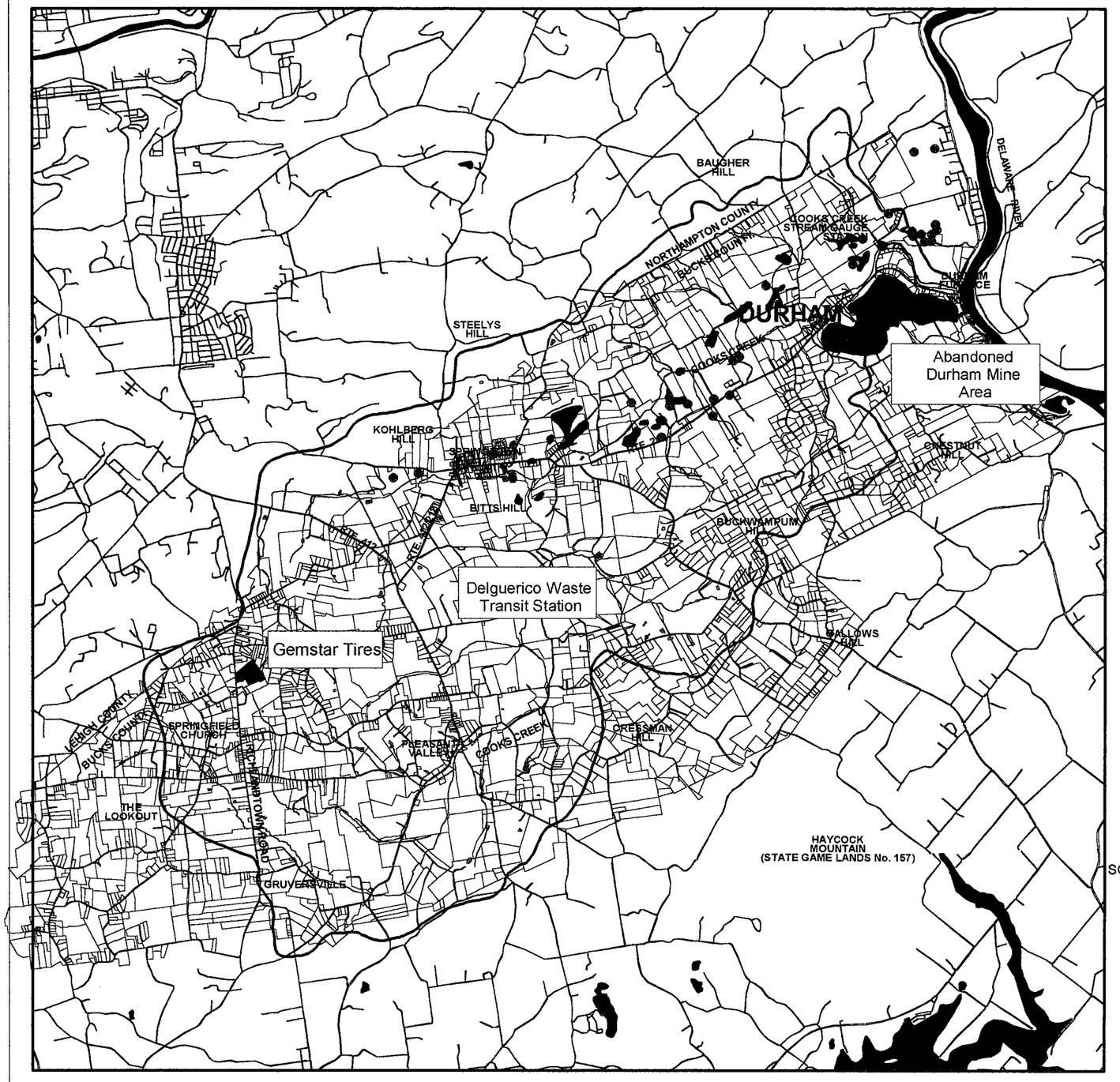

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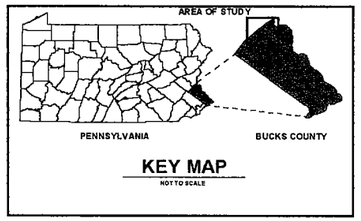

- Figure 21- Hazard Areas Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Stream
- Waterways
- Lakes and Ponds
- Karst-Prone Area
- Delguerico Waste Transit Station
- Gemstar Tires
- Abandoned Durham Mine Area
- Sinkholes

SOURCES: 1) Pennsylvania Spatial Data Access system (PASDA), Surface Geology, Translation, attribution and analysis by MJE and Golder, 1999.

2) Conservation and Management Practices for Buckingham & Durham Carbonate Valleys, Bucks County Planning Commission, February 1985

3) Spruance Lybrary of The Mercer Museum, Doylestown, Aerial Photos, 1950, 1958.

4) DTEAC, MJE, Wetlands Management Plan, Areas susceptible to karst, 1999

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- 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 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 22, 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

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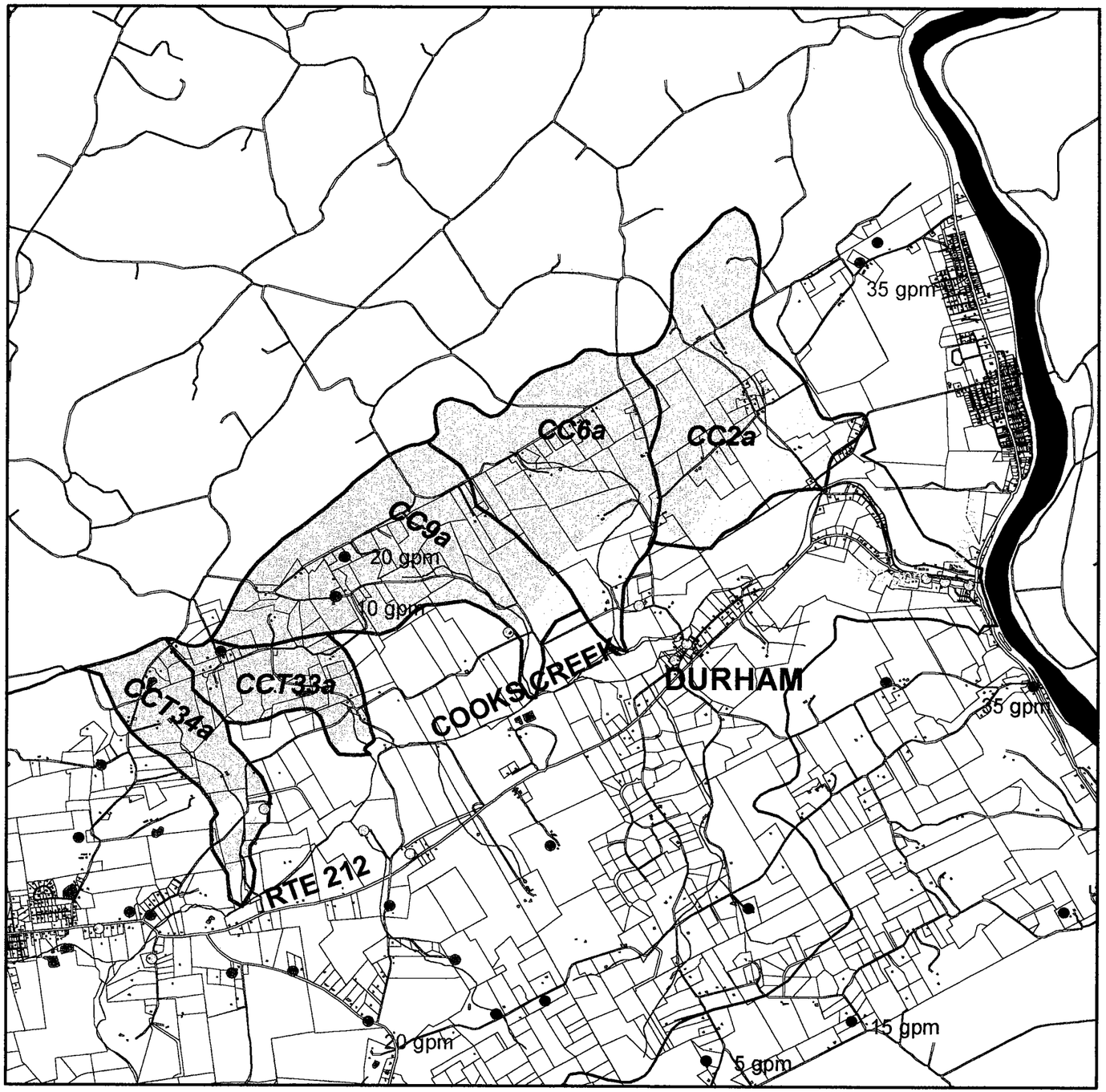

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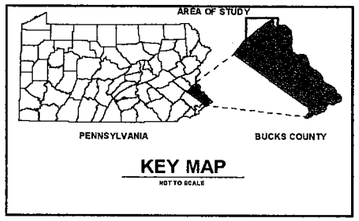

- Figure 22.1 -
Sub-basin Hydrogeologic Units Map (Area 1)

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Sub-basins
- Buildings
- Tax Map Parcels
- Lakes and Ponds

HYDROGEOLOGIC UNITS:
- Limestone
- Crystalline

FIRST ORDER SUB-BASINS ID:
- ***CC2a***
- ***CC6a***
- ***CC9a***
- ***CCT33a***
- ***CCT34a***

TAPED HYDROGEOLOGIC UNIT FOR PaGWIS DATABASE WELLS:
- Limestone
- Brunswick
- Crystalline
- Diabase
- 35 gpm Maximum Recorded Yield

SOURCES:
1) Pennsylvania Spatial Data Access system (PASDA) , Surface Geology, Translation, attribution and analysis by MJE and Golder, 1999.
2) DTEAC , MJE , Wetlands Management Plan, digital Tax Map, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.
3) DCNR, Pennsylvania Ground Water Information System, Water Well Data, July 1998.
4) United States Geologic Survey Topographic Quadrangle Map, Riegelsville, PA - NJ, 1973; Hellertown, PA 1992; Quakertown, PA 1994; Bedminster, PA 1992, Translation, attribution and analysis by MJE, August 2000.

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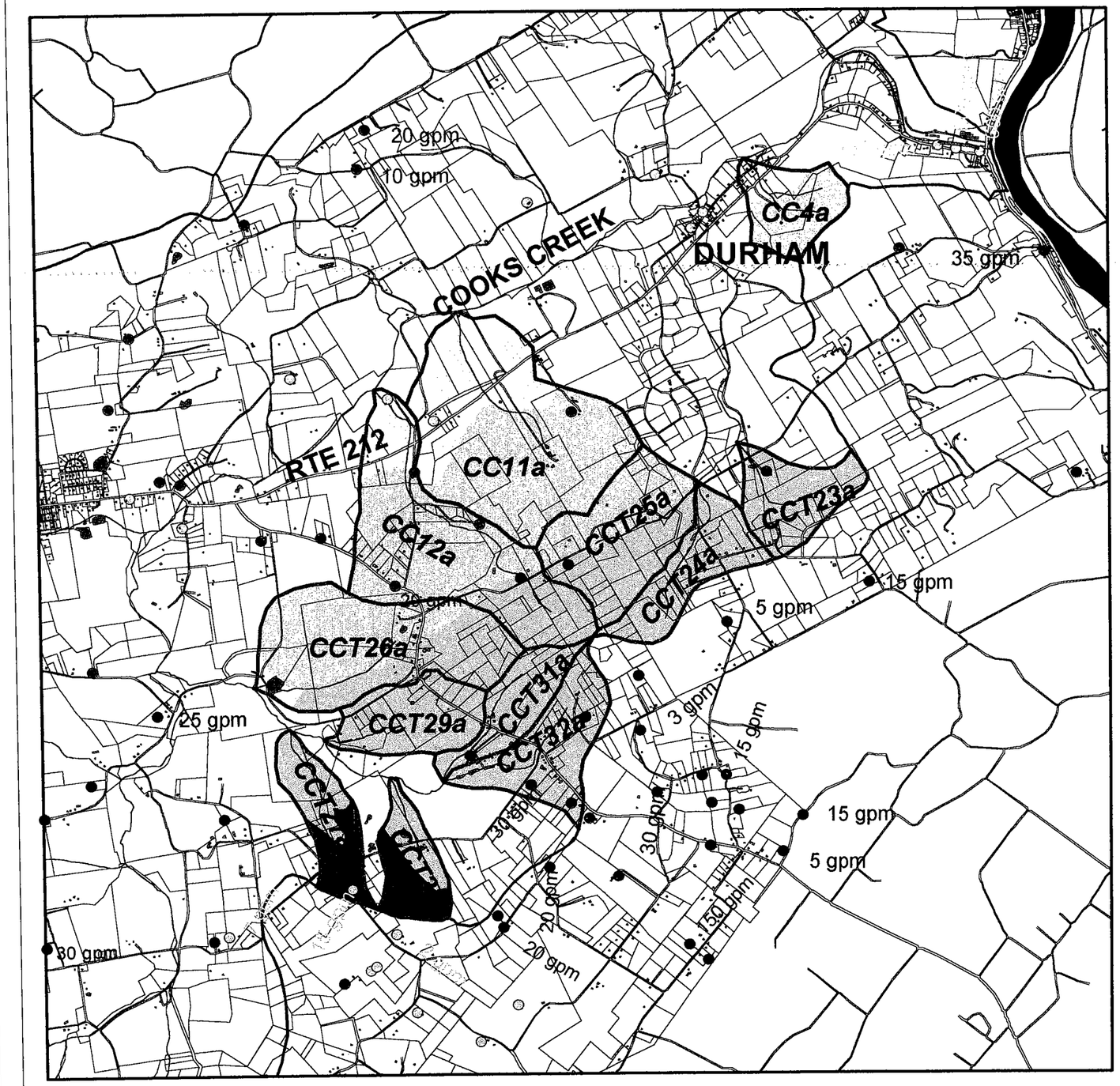

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COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis

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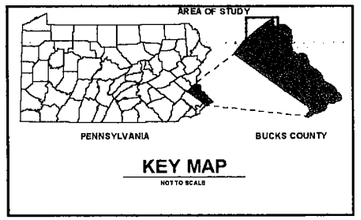
JANUARY 2001



- Figure 22.3 - Sub-basin Hydrogeologic Units Map (Area 3)

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Sub-basins
- Buildings
- Tax Map Parcels
- Lakes and Ponds

HYDROGEOLOGIC UNITS:

- Limestone
- Brunswick
- Crystalline
- Diabase

TAPED HYDROGEOLOGIC UNIT FOR PaGWIS DATABASE WELLS:

- Limestone
- Brunswick
- Crystalline
- Diabase
- 35 gpm Maximum Recorded Yield

FIRST ORDER SUB-BASINS ID:

CC4a	*CCT23a*	*CCT29a*
CC11a	*CCT24a*	*CCT30a*
CC12a	*CCT25a*	*CCT31a*
CCT21a	*CCT26a*	*CCT32a*

SOURCES:
1) Pennsylvania Spatial Data Access system (PASDA) , Surface Geology, Translation, attribution and analysis by MJE and Golder, 1999.
2) DTEAC , MJE , Wetlands Management Plan, digital Tax Map, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.
3) DCNR, Pennsylvania Ground Water Information System, Water Well Data, July 1998.
4) United States Geologic Survey Topographic Quadrangle Map, Riegelsville, PA - NJ, 1973; Hellertown, PA 1992; Quakertown, PA 1994; Bedminster, PA 1992, Translation, attribution and analysis by MJE, August 2000.

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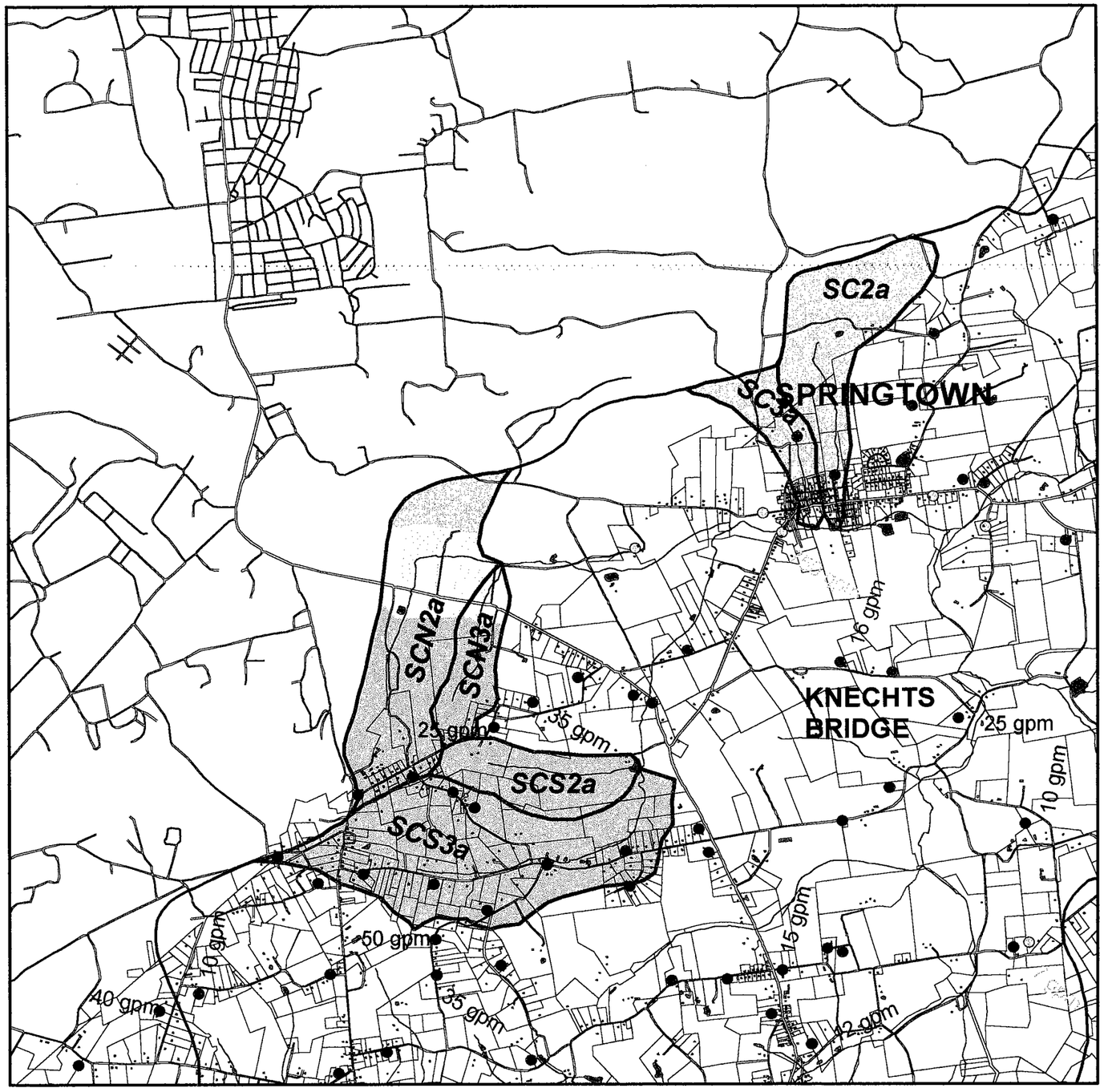
COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis



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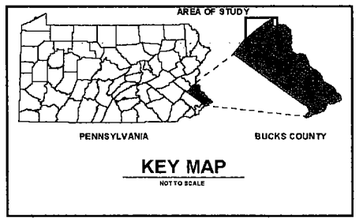

- Figure 22.4 -
Sub-basin Hydrogeologic Units Map (Area 4)

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Sub-basins
- Buildings
- Tax Map Parcels
- Lakes and Ponds

HYDROGEOLOGIC UNITS
- Limestone
- Brunswick
- Crystalline

FIRST ORDER SUB-BASIN ID:

SC2a	*SCN3a*
SC3a	*SCS2a*
SCN2a	*SCS3a*

TAPED HYDROGEOLOGIC UNIT FOR PaGWIS DATABASE WELLS:
- Limestone
- Brunswick
- Crystalline
- Diabase

35 gpm Maximum Recorded Yield

SOURCES:
1) Pennsylvania Spatial Data Access system (PASDA) , Surface Geology, Translation, attribution and analysis by MJE and Golder, 1999.
2) DTEAC , MJE , Wetlands Management Plan, digital Tax Map, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.
3) DCNR, Pennsylvania Ground Water Information System, Water Well Data, July 1998.
4) United States Geologic Survey Topographic Quadrangle Map, Riegelsville, PA - NJ, 1973; Hellertown, PA 1992; Quakertown, PA 1994; Bedminster, PA 1992, Translation, attribution and analysis by MJE, August 2000.

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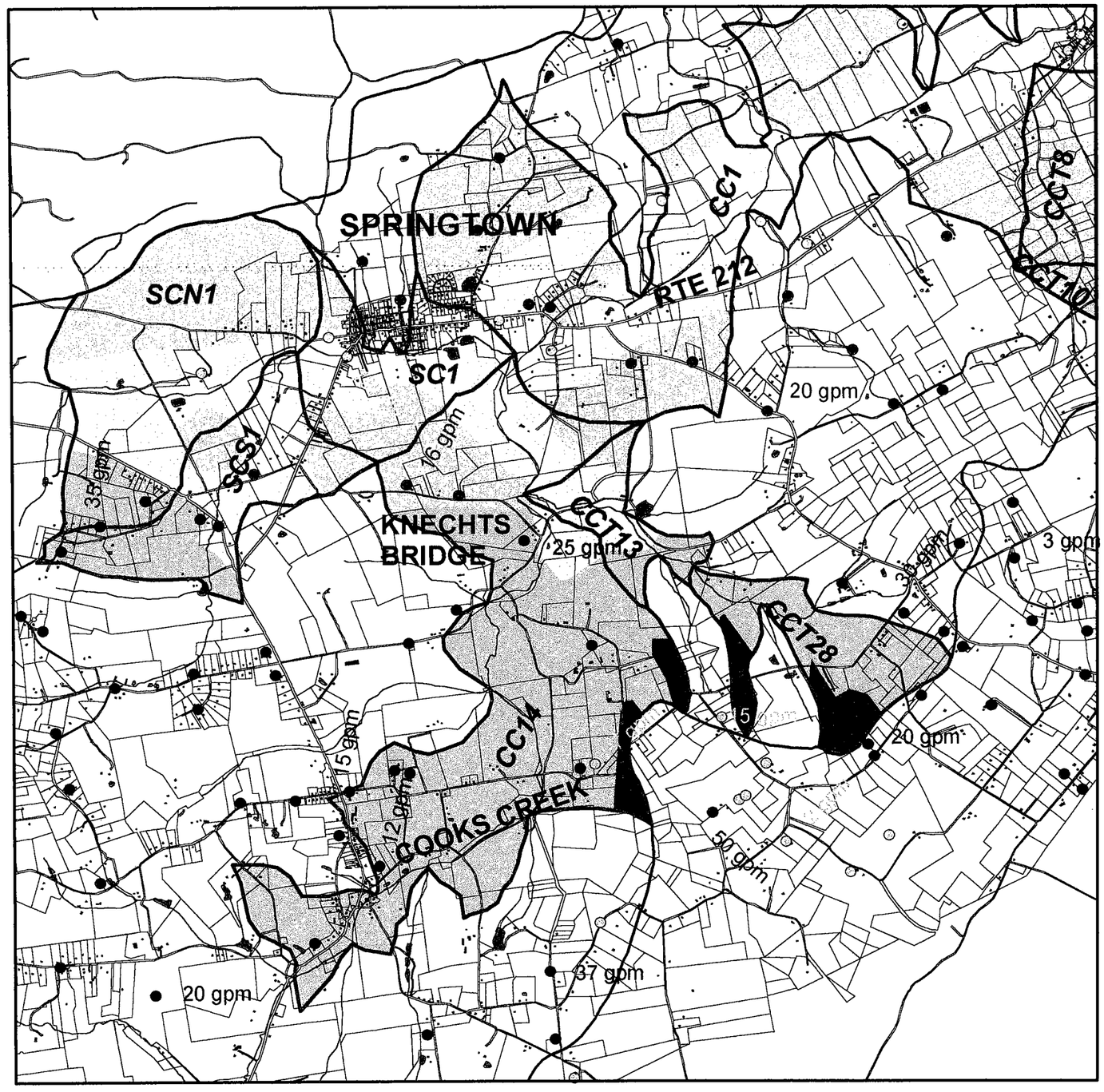
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis



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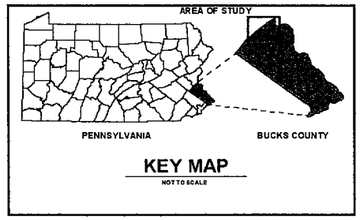

- Figure 22.5 -
Sub-basin Hydrogeologic Units Map (Area 5)

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Sub-basins
- Buildings
- Tax Map Parcels
- Lakes and Ponds

HYDROGEOLOGIC UNITS

- Limestone
- Crystalline
- Brunswick
- Diabase

- Limestone
- Brunswick
- Crystalline
- Diabase

35 gpm Maximum Recorded Yield

SECOND ORDER SUB-BASIN ID:

CC1 SCN1 CCT10
CC14 SCS1 CCT28
SC1 CCT8

SOURCES:1) Pennsylvania Spatial Data Access system (PASDA) , Surface Geology, Translation, attribution and analysis by MJE and Golder, 1999.

2) DTEAC , MJE , Wetlands Management Plan, digital Tax Map, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.

3) DCNR, Pennsylvania Ground Water Information System, Water Well Data, July 1998.

4) United States Geologic Survey Topographic Quadrangle Map, Riegelsville, PA - NJ, 1973; Hellertown, PA 1992; Quakertown, PA 1994; Bedminster, PA 1992, Translation, attribution and analysis by MJE, August 2000.

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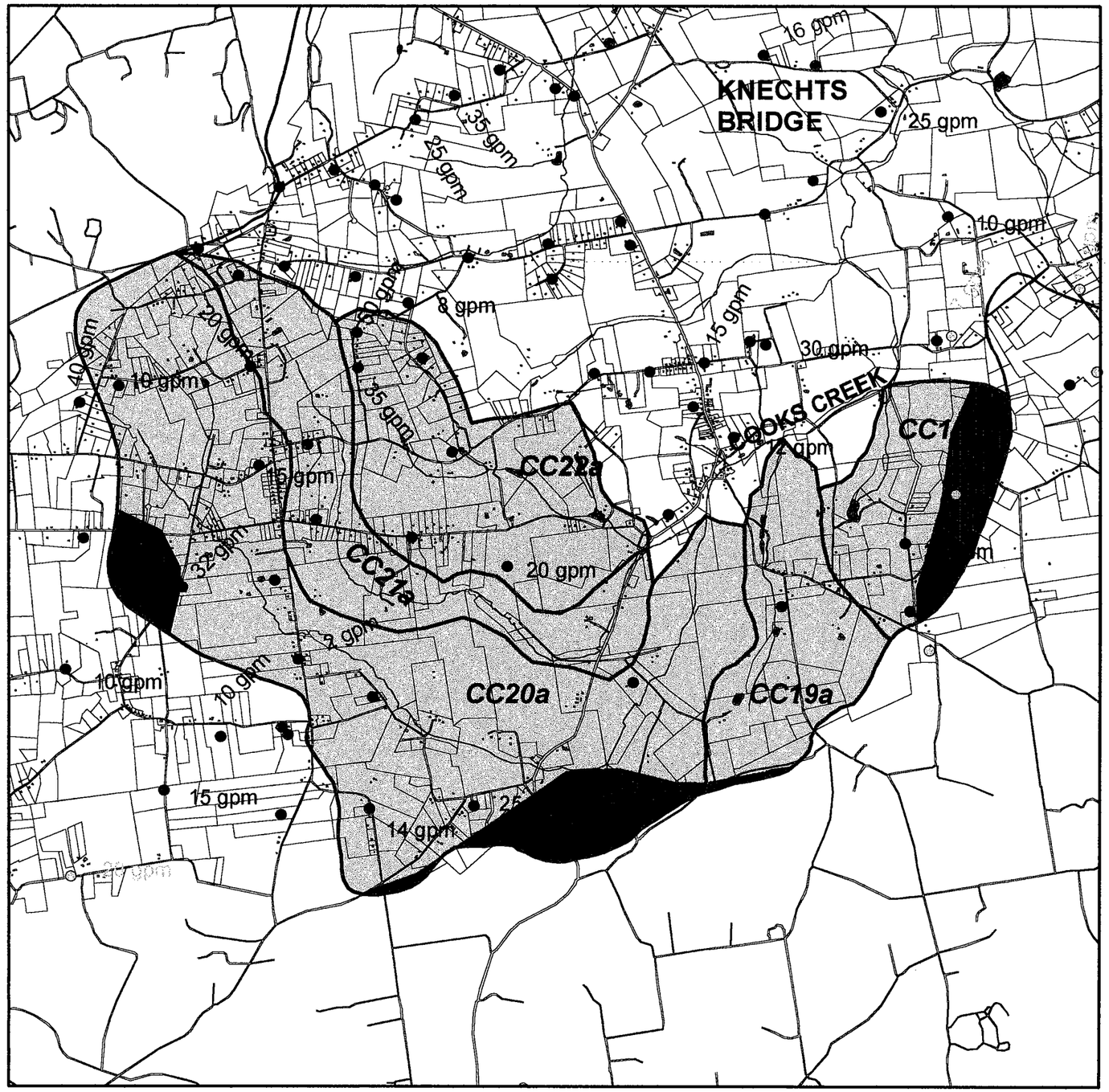
DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis



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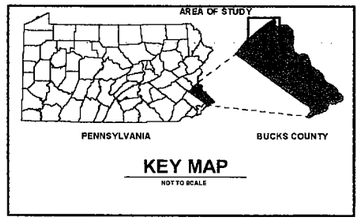

- Figure 22.6 - Sub-basin Hydrogeologic Units Map (Area 6)

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Sub-basin

HYDROGEOLOGIC UNITS

- Brunswick
- Diabase

FIRST ORDER SUB-BASIN ID:

CC18a ***CC21a***
CC19a ***CC22a***
CC20a

- Buildings
- Tax Map Parcels
- Lakes and Ponds

TAPED HYDROGEOLOGIC UNIT FOR PaGWIS DATABASE WELLS:

- Limestone
- Brunswick
- Crystalline
- Diabase

35 gpm Maximum Recorded Yield

SOURCES:
1) Pennsylvania Spatial Data Access system (PASDA) , Surface Geology, Translation, attribution and analysis by MJE and Golder, 1999.
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3) DCNR, Pennsylvania Ground Water Information System, Water Well Data, July 1998.
4) United States Geologic Survey Topographic Quadrangle Map, Riegelsville, PA - NJ, 1973; Hellertown, PA 1992; Quakertown, PA 1994; Bedminster, PA 1992, Translation, attribution and analysis by MJE, August 2000.

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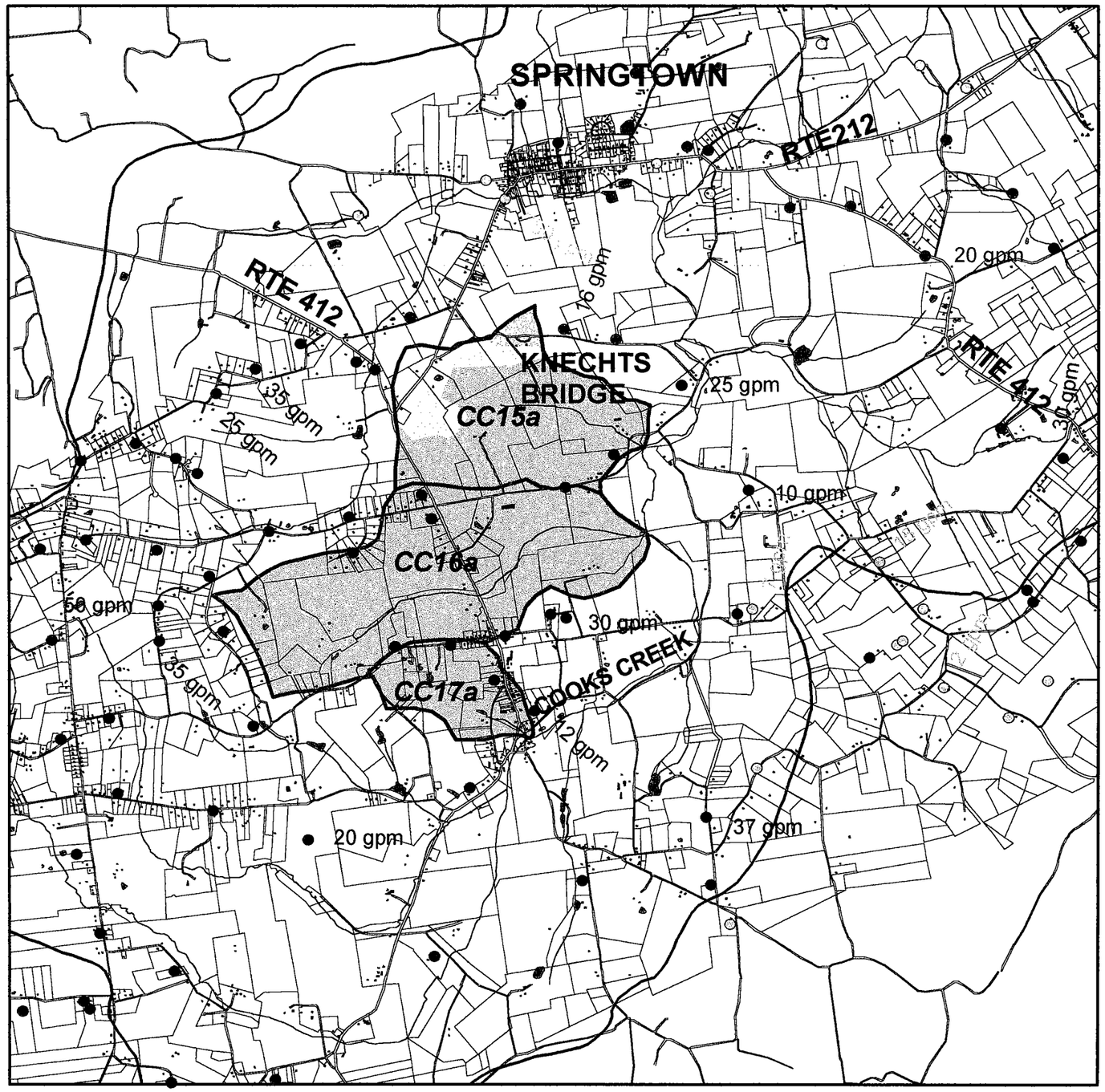

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COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis

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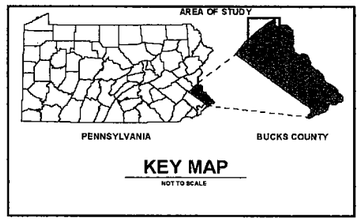

- Figure 22.7 - Sub-basin Hydrogeologic Units Map (Area 7)

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Sub-basin
- Buildings
- Tax Map Parcels
- Lakes and Ponds

HYDROGEOLOGIC UNITS

- Limestone
- Brunswick

FIRST ORDER SUB-BASIN ID:

CC15a
CC16a
CC17a

TAPED HYDROGEOLOGIC UNIT FOR PaGWIS DATABASE WELLS:

- Limestone
- Brunswick
- Crystalline
- Diabase

35 gpm Maximum Recorded Yield

SOURCES:
1) Pennsylvania Spatial Data Access system (PASDA) , Surface Geology, Translation, attribution and analysis by MJE and Golder, 1999.
2) DTEAC , MJE , Wetlands Management Plan, digital Tax Map, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.
3) DCNR, Pennsylvania Ground Water Information System, Water Well Data, July 1998.
4) United States Geologic Survey Topographic Quadrangle Map, Riegelsville, PA - NJ, 1973; Hellertown, PA 1992; Quakertown, PA 1994; Bedminster, PA 1992, Translation, attribution and analysis by MJE, August 2000.

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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.

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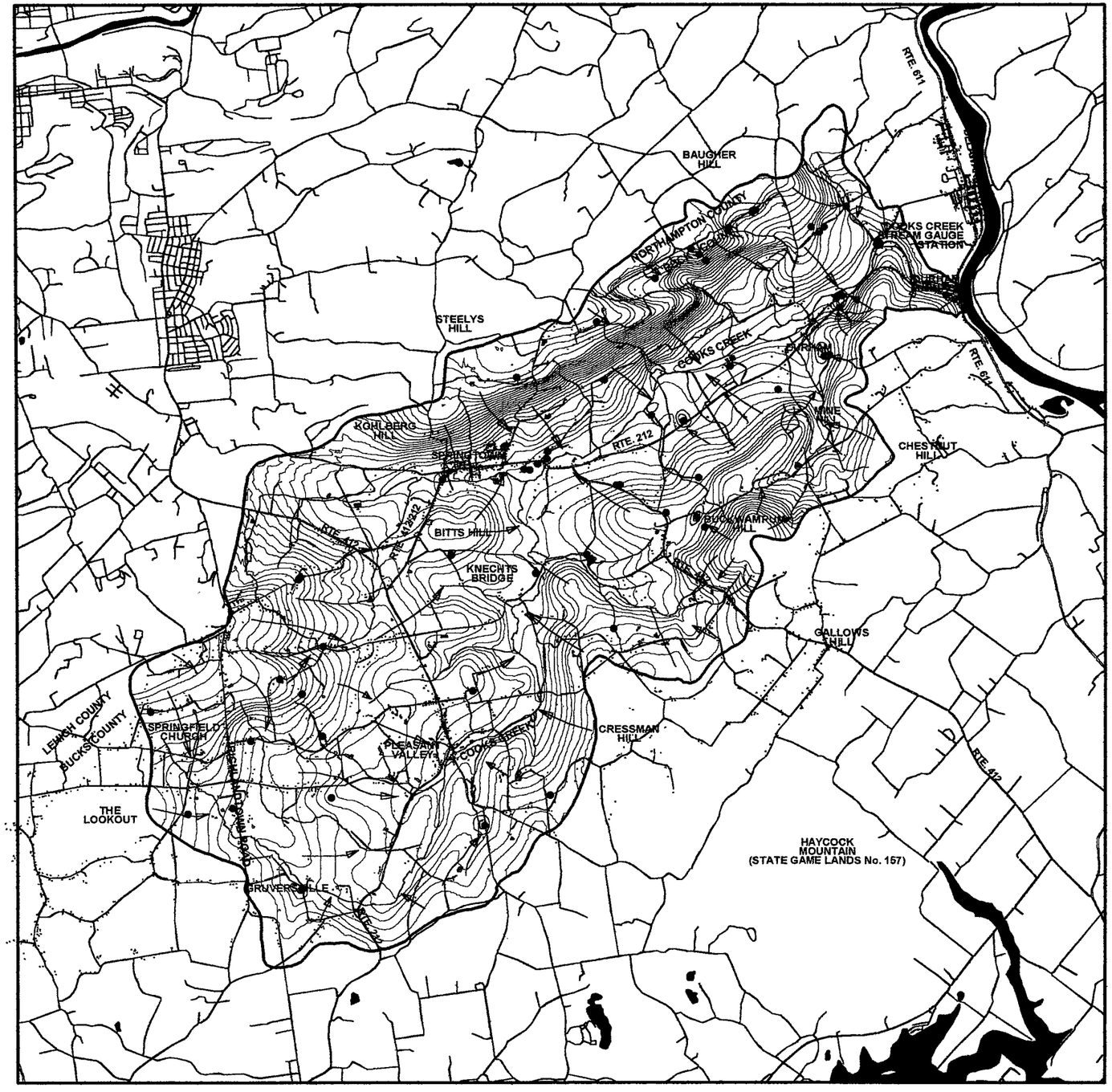
DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis



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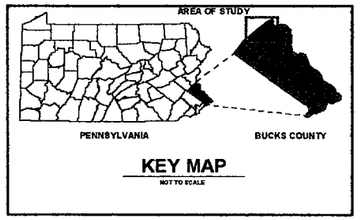

- Figure 23 - Groundwater Contour Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Buildings
- Groundwater Contour
- Groundwater Flow Direction
- Water Well

SOURCES:
1) Pennsylvania Spatial Data Access system (PASDA) , Surface Geology, Translation, attribution and analysis by MJE and Golder, 1999.
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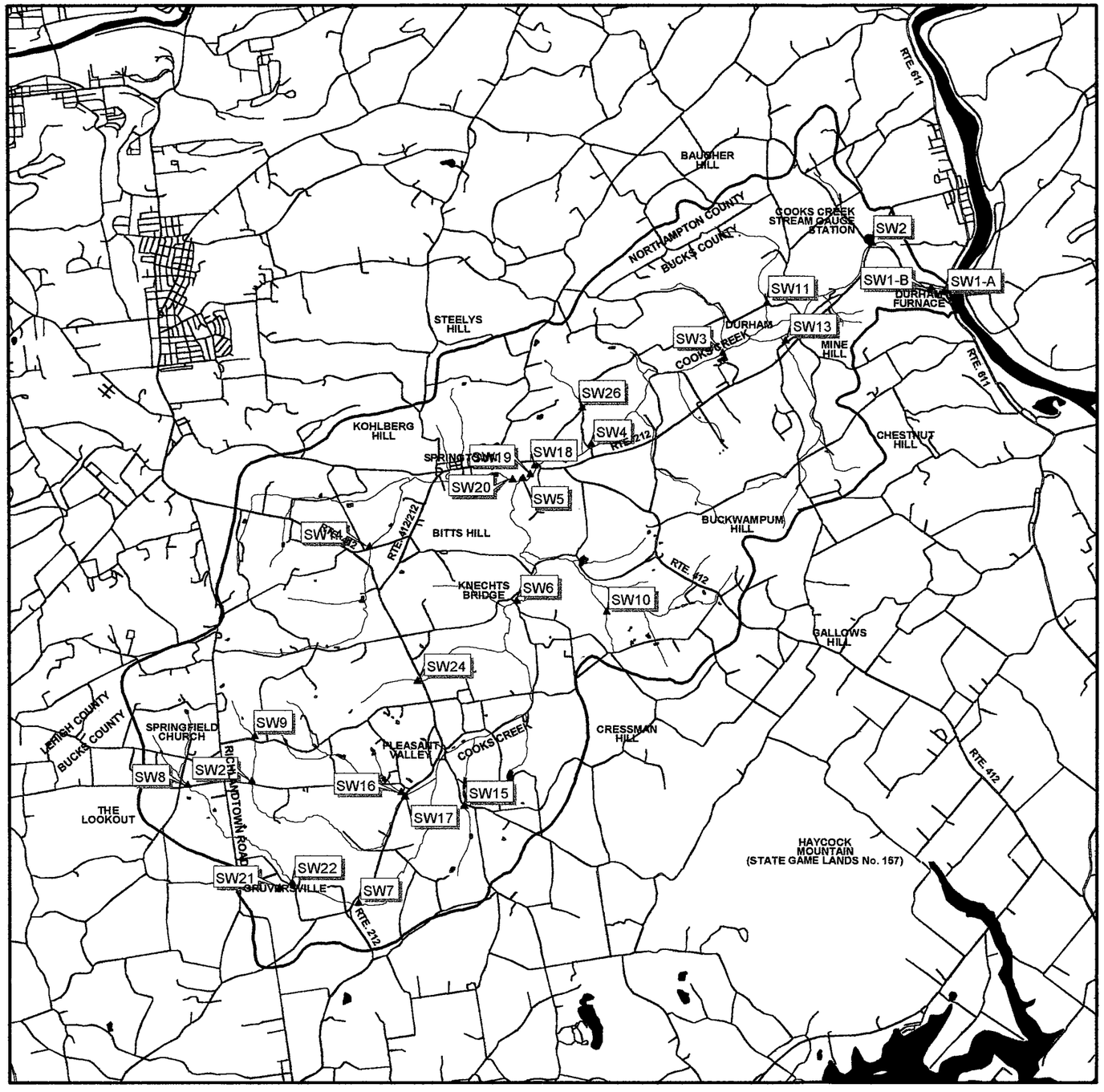
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis



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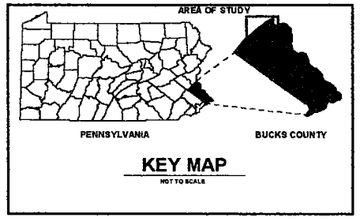

- Figure 24 -
Stream Properties and Stream Conditions Sampling

LEGEND

- Stream Sampling Location
- Watershed Boundaries
- Lakes and Ponds
- Stream
- Waterways
- Minor Roads
- Major Roads
- First Order Stream
- Second Order Stream

SOURCES: 1) Pennsylvania Spatial Data Access system (PASDA), Surface Geology, Translation, attribution and analysis by MJE and Golder, 1999.

2) DTEAC, MJE, Wetlands Management Plan, digital Tax Map, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.

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- Carbon Dioxide - Carbon dioxide is an odorless, colorless gas produced during the respiration cycle of animals, plants and bacteria, and through the burning of materials that contain carbon. When carbon dioxide levels are high and oxygen levels are low, fish have trouble respiring, and their problems become worse as water temperatures rise. Also, as carbon dioxide levels increase, pH decreases.

- Water Temperature - Water temperature is an important environmental factor for fish and other aquatic life. Many species can only tolerate specific temperature variations.

- 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.

- 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.

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.

- 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.

- 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

Water Quality
Table 1
Chemistry Summary of Results

SEDIMENT AND WATER QUALITY ANALYTICAL RESULTS

SAMPLE ID	ANALYTE	METHOD	RESULT	UNITS	MDL	PQL
S1	**Chlorinated Herbicide**	EPA8151				
	2,4-D		0.014	mg/Kg	0.0077	0.07
	Mercury	EPA7471A	0.97	mg/Kg	0.16	0.002
	TAL Metals	EPA6010				
	Aluminum		12,000	mg/Kg	580	0.2
	Arsenic		7.50	mg/Kg	3.8	0.05
	Barium		120	mg/Kg	19	2.0
	Beryllium		1.30	mg/Kg	0.77	0.004
	Calcium		3,900	mg/Kg	960	NA
	Chromium		27	mg/Kg	7.7	0.1
	Cobalt		12	mg/Kg	3.2	NA
	Copper		31	mg/Kg	7.3	NA
	Iron		30,000	mg/Kg	520	0.3
	Lead		42	mg/Kg	7.7	NA
	Magnesium		5,100	mg/Kg	700	0.05
	Manganese		580	mg/Kg	31	0.05
	Nickel		20	mg/Kg	4.7	NA
	Potassium		1,200	mg/Kg	210	NA
	Vanadium		40	mg/Kg	9	NA
	Zinc		130	mg/Kg	19	5.0
SW1	Phosphorous, Total	EPA365.2	ND	mg/L	0.05	NA
	Nitrates	EPA300	1.7	mg/L	0.2	10
	TAL Metals	EPA 200.7				
	Barium		28	ug/L	23	2.0
	Calcium		25,000	ug/L	380	NA
	Magnesium		12,000	ug/L	260	0.05
	Potassium		1,700	ug/L	140	NA
	Sodium		6,700	ug/L	390	NA
S2	**Chlorinated Herbicide**	EPA8151				
	2,4_D		0.0071	mg/Kg	0.0058	0.07
	Mercury	EPA7471A	0.48	mg/Kg	0.12	0.002
	TAL Metals	EPA6010				
	Aluminum		6,700	mg/Kg	430	0.2
	Arsenic		6.2	mg/Kg	2.9	0.05
	Barium		100	mg/Kg	14	2.0
	Beryllium		0.96	mg/Kg	0.58	0.004
	Calcium		11,000	mg/Kg	720	NA
	Chromium		15	mg/Kg	5.8	0.1
	Cobalt		8.9	mg/Kg	2.4	NA
	Copper		26	mg/Kg	5.5	NA

Water Quality
Table 1
Chemistry Summary of Results

	Iron		21,000	mg/Kg	390	0.3
	Lead		52	mg/Kg	5.8	NA
	Magnesium		6,900	mg/Kg	520	0.05
	Manganese		600	mg/Kg	23	0.05
	Nickel		14	mg/Kg	3.5	NA
	Potassium		760	mg/Kg	160	NA
	Vanadium		30	mg/Kg	6.8	NA
	Zinc		140	mg/Kg	14	5
SW2	Phosphorous, Total	EPA365.2	ND	mg/L	0.05	NA
	Nitrates	EPA300	1.60	mg/L	0.2	10
SW3	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	1.5	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	38	cfu/100ml	2	
SW5	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	1.40	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	38	cfu/100ml	2	
SW6	Phosphorous, Total	EPA365.2	ND	mg/L	0.05	NA
	Nitrate-N	EPA300	1.40	mg/L	0.2	10
SW8	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	1.90	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	4.0	cfu/100ml	2	
SW9	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	0.50	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	4.0	cfu/100ml	2	
SW11	Phosphorous, Total	EPA365.2/SM4500P-E	0.06	mg/L	0.05	NA
	Nitrates	EPA300	3.0	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	640	cfu/100ml	2	
SW13	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	1.30	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	30	cfu/100ml	2	
SW14	Phosphorous, Total	EPA365.2	ND	mg/L	0.05	NA
	Nitrates	EPA300	1.0	mg/L	0.2	10
SW15	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	2.8	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	110	cfu/100ml	2	
SW16	Phosphorous, Total	EPA365.2/SM4500P-E	<0.05	mg/L	0.05	NA
	Nitrates	EPA300	0.6	mg/L	0.2	10
	Fecal Coliform	SM 9222 D	72	cfu/100ml	2	

Notes:

Laboratory results as presented in the Hampton Clarke, Inc. (Veritech Laboratories) report dated June 6, 2000.

MDL = Method Detection Limit or the lowest level at which the laboratory can detect the analyte.

MCL = Maximum Contaminant Levels or the levels established by the USEPA for safe drinking water.

NA = Not Applicable. No MCL established by USEPA

mg/L = parts per million (ppm), mg/Kg = ppm, ug/L = parts per billion (ppb)

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.

Table 2
Cooks Creek
Field Parameter
Results

No.	Sample ID	Sampling Point Description	Location	Parameters					
				Air Temp (C)	H2O Temp (C)	pH (units)	Conductivity (mS/m)	Turbidity (NTU)	Dissolved Oxygen (mg/L)
1	SW1-A	Down-Stream Paper Mill Dam	Durham Twp., Cooks Creek at Down-Stream Paper Mill Dam near Rt. 611 bridge.	23.8	20.9	8.77	0.259	0	8.9
2	SW1-B	Up-Stream Paper Mill Dam	Durham Twp., Cooks Creek at Up-Stream Paper Mill dam.	25.9	21.9	8.82	0.251	1	10.1
3	SW2	Transect Reach 1	Durham Twp., Cooks Creek, down-stream of Red (Stouts) (Valley) T440 Bridge Road, Parcels: 11-007-001 and 11-008-110	23.1	22.7	8.86	0.241	0	9.82
4	SW3	Transect Reach 2	Durham Twp., Cooks Creek, Parcel 11-004-001 (Bart Millett, 4395 Rt. 212, Riegelsville, Pa) and 11-002-033.	25	22.1	8.88	0.246	0	10.32
5	SW4	Transect Reach 3	Springfield Twp., Cooks Creek, Haupts Bridge Rd., Parcels 42-017-111 and 42-017-112.	25.4	21.7	8.74	0.238	0	10.46
6	SW5	Transect Reach 4	Springtown Village, Cooks Creek, Parcels 42-017-025-007 (Scott Douglas, 3450 Rt. 212)and 42-017-025-008	24.5	20.8	8.4	0.234	1	10.27
7	SW6	Transect Reach 5	Springfield Twp., Cooks Creek at Knechts Bridge, Knechts Bridge Rd., Parcels 42-012-92 and 42-012-154-1.	25.7	20.5	8.81	0.202	0	9.83
8	SW7	Transect Reach 6	Springfield Twp., Cooks Creek, Parcels 42-020-005 (xxx Quakertown Rd.) and 42-020-006-001 (xxx Quakertown Rd.).	24.8	20.3	7.89	0.17	2	9.67
9	SW8	Transect Reach 7	Springfield Twp., Cooks Creek, Parcels 42-010-018 (xxx State Rd.) and 42-010-019 (xxx State Rd.).	22.2	16.4	7.64	0.151	5	9.71
10	SW9	Down-hill and down-stream of Gemstar/Tires facility.	Springfield Twp., Cooks Creek tributary 612 at Pleasant View Rd. Crossing.	22.1	19.1	8.16	0.196	4	9.49

Table 2
Cooks Creek
Field Parameter
Results

No.	Sample ID	Sampling Point Description	Location	Parameters					
				Air Temp (C)	H2O Temp (C)	pH (units)	Conductivity (mS/m)	Turbidity (NTU)	Dissolved Oxygen (mg/L)
11	SW10	Down-hill and down-stream of Delguaricor/Transfer Station.	Springfield Twp., Cooks Creek tributary 513	25.5	21.6	7.81	0.202	2	7.7
12	SW11	Reach 21	Durham Twp., CC Tributary at ??? Farm, Funks Mill Lane to Philadelphia Rd. (Durham Rd.).	23.7	19	7.68	0.168	3	8.67
13	SW12 DRY	Reach 23	Durham Twp., CC Tributary at Funks Mill Rd. Crossing	NA	NA	NA	NA	NA	NA
14	SW13	Reach 22	Durham Twp., CC Tributary 22 (Hollow Coon Run), between Durham Rd. Crossing and Cooks Creek.	23.8	21.2	8.29	0.213	1	8.58
15	SW14	Reach 412	Springfield Twp., CC Tributary, Hellertown Rd. (Rt. 412) Crossing, between Springtown Rd. and Bethlehem Rd.	23.7	21.2	8.12	0.233	1	8.55
16	SW15	Reach 55	Springfield Twp., CC Tributary at Old Bethlehem Rd. Crossing, between Rt. 212. and Roundhouse Rd.	23.3	21.4	7.7	0.16	3	9.61
17	SW16	Reach 611	Springfield Twp., CC Tributary at State Rd. Crossing, near Hottle Rd. and Rt. 212 intersection.	23.5	23.9	8.43	0.229	17	8.85
18	SW17	Reach 612	Springfield Twp., CC Tributary, the segment along Rt.212, between California Rd. and State Rd. at intersection with Hottle Rd.	23.5	20.3	7.65	0.161	3	7.76
19	SW18	Springtown Public Water Outlet	Springtown Public Water Outlet to Cooks Creek near Rt 212/412 Crossing.	24.1	13.8	7.89	0.382	0	10.5
20	SW19	Cooks Creek 600 feet up-gradient of 212/412	Cooks Creek 600 feet up-gradient of Rt. 212/412 bridge	23.7	22.3	8.64	0.227	1	11.2
21	SW20	Silver Run, Tributary 41 of Cooks Creek	Springtown, Silver Run, Tributary 41 of Cooks Creek near confluence	25.6	19.6	8.24	0.241	1	9.19
22	SW21	Reach 62	Springfield Twp., Reach 62 Tributary at Gruversville Rd.	20.1	16.4	7.85	0.18	6	5.52

Table 2
Cooks Creek
Field Parameter
Results

No.	Sample ID	Sampling Point Description	Location	Parameters					
				Air Temp (C)	H2O Temp (C)	pH (units)	Conductivity (mS/m)	Turbidity (NTU)	Dissolved Oxygen (mg/L)
23	SW22	Cooks Creek Reach 6-B	Cooks Creek Reach6-B near Gruversville Rd.	20.1	17.5	7.6	0.176	1	10.51
24	SW23	Reach 612	CC Tributary Reach 612 at State Rd Crossing	21.5	19.5	7.72	0.197	3	8.26
25	SW24	Reach 532	CC Tributary Reach 532 at Rt. 212 Crossing	23.4	19.1	7.74	0.183	4	8.28
26	SW25	Reach 531	CC Tributary Reach 531 at Pleasant Hollow Rd. Crossing	23.8	21.4	7.5	0.298	2	5.02
27	SW26	Reach 32	CC Tributary Reach 32 at Funks Mill Rd. Crossing near Adams Way.	24.1	21.1	7.77	0.136	1	10.54

TABLE 3

STREAM VISUAL ASSESSMENT RESULTS

No.	ID	Sampling Point	Location	Parameters						Visual Assessment (E=Excellent, G=Good, M=Marginal, P=Poor)							
				Air Temp (C)	H2O Temp (C)	pH (units)	Conductivity (mS/m)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Cover Instream	Fine Sediment	Flow Patterns	Bank Condition	Pressures (Ripar.)	Width of Ripar. Zone.	Litter	Overall Assessment
1	SW1-A	Down-Stream Paper Mill Dam	Durham Twp., Cooks Creek at Down-Stream Paper Mill Dam near Rt. 611 bridge.	23.8	20.9	8.77	0.259	0	8.9	P	P	P	P	P	P	M	P
2	SW1-B	Up-Stream Paper Mill Dam	Durham Twp., Cooks Creek at Up-Stream Paper Mill dam.	25.9	21.9	8.82	0.251	1	10.1	M	M	P	P	P	P	M	P
3	SW2	Transect Reach 1	Durham Twp., Cooks Creek, down-stream of Red (Stouts) (Valley) T440 Bridge Road, Parcels: 11-007-001 and 11-008-110	23.1	22.7	8.86	0.241	0	9.82	G	G	G	G	M	M	G	G
4	SW3	Transect Reach 2	Durham Twp., Cooks Creek, Parcel 11-004-001 (Bart Millett, 4395 Rt. 212, Riegelsville, Pa) and 11-002-033.	25	22.1	8.88	0.246	0	10.32	G	E	E	G	G	G	E	G
5	SW4	Transect Reach 3	Springfield Twp., Cooks Creek, Haupts Bridge Rd., Parcels 42-017-111 and 42-017-112.	25.4	21.7	8.74	0.238	0	10.46	E	E	E	G	E	G	E	E
6	SW5	Transect Reach 4	Springtown Village, Cooks Creek, Parcels 42-017-025-007 (Scott Douglas, 3450 Rt. 212)and 42-017-025-008	24.5	20.8	8.4	0.234	1	10.27	E	E	G	G	E	E	G	E

TABLE 3

STREAM VISUAL ASSESSMENT RESULTS

No.	ID	Sampling Point	Location	Parameters						Visual Assessment (E=Excellent, G=Good, M=Marginal, P=Poor)							
				Air Temp (C)	H2O Temp (C)	pH (units)	Conductivity (mS/m)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Cover Instream	Fine Sediment	Flow Patterns	Bank Condition	Pressures (Ripar.)	Width of Ripar. Zone.	Litter	Overall Assessment
7	**SW6**	Transect Reach 5	Springfield Twp., Cooks Creek at Knechts Bridge, Knechts Bridge Rd., Parcels 42-012-92 and 42-012-154-1.	25.7	20.5	8.81	0.202	0	9.83	M	M	M	G	G	M	E	G
8	**SW7**	Transect Reach 6	Springfield Twp., Cooks Creek, Parcels 42-020-005 (xxx Quakertown Rd.) and 42-020-006-001 (xxx Quakertown Rd.).	24.8	20.3	7.89	0.17	2	9.67	E	M	E	G	E	E	E	E
9	**SW8**	Transect Reach 7	Springfield Twp., Cooks Creek, Parcels 42-010-018 (xxx State Rd.) and 42-010-019 (xxx State Rd.).	22.2	16.4	7.64	0.151	5	9.71	M	M	G	G	M	M	G	M
10	**SW9**	Down-hill and down-stream of Gemstar/Tires facility.	Springfield Twp., Cooks Creek tributary 612 at Pleasant View Rd. Crossing.	22.1	19.1	8.16	0.196	4	9.49	E	P	G	E	G	E	E	E
11	**SW10**	Down-hill and down-stream of Delguaricor/Transfer Station.	Springfield Twp., Cooks Creek tributery 513	25.5	21.6	7.81	0.202	2	7.7	E	G	G	E	E	E	E	E
12	**SW11**	Reach 21	Durham Twp., CC Tributary at ??? Farm, Funks Mill Lane to Philadelphia Rd. (Durham Rd.).	23.7	19	7.68	0.168	3	8.67	P	G	G	M	P	P	E	M

TABLE 3

STREAM VISUAL ASSESSMENT RESULTS

No.	ID	Sampling Point	Location	Parameters						Visual Assessment (E=Excellent, G=Good, M=Marginal, P=Poor)							
				Air Temp (C)	H2O Temp (C)	pH (units)	Conductivity (mS/m)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Cover Instream	Fine Sediment	Flow Patterns	Bank Condition	Pressures (Ripar.)	Width of Ripar. Zone.	Litter	Overall Assessment
13	SW12 DRY	Reach 23	Durham Twp., CC Tributary at Funks Mill Rd. Crossing	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
14	SW13	Reach 22	Durham Twp., CC Tributary 22 (Hollow Coon Run), between Durham Rd. Crossing and Cooks Creek.	23.8	21.2	8.29	0.213	1	8.58	E	G	E	G	G	E	E	E
15	SW14	Reach 412	Springfield Twp., CC Tributary, Hellertown Rd. (Rt. 412) Crossing, between Springtown Rd. and Bethlehem Rd.	23.7	21.2	8.12	0.233	1	8.55	P	G	G	M	M	M	M	M
16	SW15	Reach 55	Springfield Twp., CC Tributary at Old Bethlehem Rd. Crossing, between Rt. 212. and Roundhouse Rd.	23.3	21.4	7.7	0.16	3	9.61	M	G	M	G	M	M	G	M
17	SW16	Reach 611	Springfield Twp., CC Tributary at State Rd. Crossing, near Hottle Rd. and Rt. 212 intersection.	23.5	23.9	8.43	0.229	17	8.85	P	G	G	M	P	P	E	M
18	SW17	Reach 612	Springfield Twp., CC Tributary, the segment along Rt.212, between California Rd. and State Rd. at intersection with Hottle Rd.	23.5	20.3	7.65	0.161	3	7.76	G	M	M	G	M	M	M	M

TABLE 3

STREAM VISUAL ASSESSMENT RESULTS

No.	ID	Sampling Point	Location	Parameters						Visual Assessment (E=Excellent, G=Good, M=Marginal, P=Poor)							
				Air Temp (C)	H2O Temp (C)	pH (units)	Conductivity (mS/m)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Cover Instream	Fine Sediment	Flow Patterns	Bank Condition	Pressures (Ripar.)	Width of Ripar. Zone.	Litter	Overall Assessment
19	**SW18**	Springtown Public Water Outlet	Springtown Public Water Outlet to Cooks Creek near Rt 212/412 Crossing.	24.1	13.8	7.89	0.382	0	10.5	G	MM	M	G	M	M	G	M
20	**SW19**	Cooks Creek 600 feet up-gradient of 212/412	Cooks Creek 600 feet up-gradient of Rt. 212/412 bridge	23.7	22.3	8.64	0.227	1	11.2	E	E	G	G	E	E	G	E
21	**SW20**	Silver Run, Tributary 41 of Cooks Creek	Springtown, Silver Run, Tributary 41 of Cooks Creek near confluence	25.6	19.6	8.24	0.241	1	9.19	E	E	E	E	G	G	E	E
22	**SW21**	Reach 62	Springfield Twp., Reach 62 Tributary at Gruversville Rd.	20.1	16.4	7.85	0.18	6	5.52	G	P	G	G	G	M	M	M
23	**SW22**	Cooks Creek Reach 6-B	Cooks Creek Reach6-B near Gruversville Rd.	20.1	17.5	7.6	0.176	1	10.51	M	G	G	G	P	P	M	M
24	**SW23**	Reach 612	CC Tributary Reach 612 at State Rd Crossing	21.5	19.5	7.72	0.197	3	8.26	M	P	G	G	P	P	G	M

TABLE 3

STREAM VISUAL ASSESSMENT RESULTS

No.	ID	Sampling Point	Location	Parameters						Visual Assessment (E=Excellent, G=Good, M=Marginal, P=Poor)							
				Air Temp (C)	H2O Temp (C)	pH (units)	Conductivity (mS/m)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Cover Instream	Fine Sediment	Flow Patterns	Bank Condition	Pressures (Ripar.)	Width of Ripar. Zone.	Litter	Overall Assessment
25	**SW24**	Reach 532	CC Tributary Reach 532 at Rt. 212 Crossing	23.4	19.1	7.74	0.183	4	8.28	G	G	G	P	M	G	G	G
26	**SW25**	Reach 531	CC Tributary Reach 531 at Pleasant Hollow Rd. Crossing	23.8	21.4	7.5	0.298	2	5.02	P	P	M	P	M	M	G	M
27	**SW26**	Reach 32	CC Tributary Reach 32 at Funks Mill Rd. Crossing near Adams Way.	24.1	21.1	7.77	0.136	1	10.54	E	E	E	E	E	E	E	E

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

The National Pollution Discharge Elimination System (NPDES) permitting system was created as part of the Clean Water Act of 1972. Initially, this program concentrated on *point source* pollution. Consequently, significant pollutant reduction was achieved and this program then focused on the *non-point source* pollutants. *Non-point source* pollutants are those pollutants that result from stormwater runoff. Examples of *non-point source* pollutants are:

- Roads
- Parking lots,
- Lawns,
- Cultivated fields,
- Construction sites, and,
- Stormwater management control systems.

TABLE 4
Stream Morfology Assessment (Rosgen Classification Technique)
(Continued)

Sampling Point	Location	Stream Type	Mean DEPTH D_{bkf} (Feet)	Maximum DEPTH D_{mbkf} (Feet)	WIDTH of Flood-Prone Area W_{fpa} (Feet)	Channel SINUOSITY (*) K	Base Flow X-Section Area A_{bsf} (SqFt)	Estimate Mean Velocity Basseflow Feet/sec	Estimate Discharge Basseflow cfs
Transect 1 Reach 1 4/5/00	Durham Twp., Cooks Creek, down-stream of Red (Stouts) (Valley) T440 Bridge Road, Parcels: 11-007-001 and 11-008-110	C3	2.12	2.7	118	1.006	20	2.49	50
Transect 2 Reach 2 4/13/00	Durham Twp., Cooks Creek, Parcel 11-004-001 (Bart Millett, 4395 Rt.212, Riegelsville, Pa) and 11-002-033	F3	4.3	1.08	78	1.06	27	1.29	35
Transect 3 Reach 3 4/6/00	Springfield Twp., Cooks Creek, Haupts Bridge Rd., Parcels: 42-017-111and 42-017-112	F3	2.28	2.29	158	1.11	37	0.84	31
Transect 4 Reach 4 4/5/00	Springtown Village,Cooks Creek, Parcels 42-017-025-007 (Scott Douglas, 3450 Rt. 212) and 42-017-025-008	B4c	2.49	3.22	124	1.07	15	1.94	29
Transect 5 Reach 5 4/14/00	Springfield Twp., Cooks Creek, at Knechts Bridge, Knechts Bridge Rd., Parcels 42-012-92 and 42-012-154-1	B3c	2.68	3.09	96	1.077	18	0.78	14
Transect 6 Reach 6 4/14/00	Springfield Twp., Cooks Creek, Parcels 42-020-005 (xxx Quakertown Rd) and 42-020-006-001 (xxx Quakertown Rd.).	B4c	1.28	1.91	51	1.03	12	1.1	13
Transect 7 Reach 7 4/16/00	Springfield Twp., Cooks Creek, Parcels 42-010-018 (xxx State Rd.) and 42-010-019 (xxx State Rd.)	B4c	1.33	1.78	28	1.01	2.48	0.75	2

TABLE 4
Stream Morfology Assessment (Rosgen Classification Technique)

Sampling Point	Location	Stream Type	Water Surface Slope (%)	Channel Materials D50 (mm)	Bankfull WIDTH (W_{bkf}) - Ft.	Bnkfl. X-Section Area Abkf (SqFt)	Entrenchment Ratio $ER = W_{fpa} / W_{bkf}$	Width / Depth Ratio W_{bkf} / d_{bkf} (Feet)	Sinuosity (*) (K)
Transect Reach 1	Durham Twp., Cooks Creek, down-stream of Red (Stouts) (Valley) T440 Bridge Road, Parcels: 11-007-001 and 11-008-110	C3	0.30	77 (57% cobble)	48	101	2.48	22.4	1.006
Transect Reach 2	Durham Twp., Cooks Creek, Parcel 11-004-001 (Bart Millett, 4395 Rt.212, Riegelsville, Pa) and 11-002-033	F3	0.60	50 (96% cobble)	72	309.6	1.08	16.74	1.06
Transect Reach 3	Springfield Twp., Cooks Creek, Haupts Bridge Rd., Parcels: 42-017-111and 42-017-112	F3 - F4	0.70	40 (46% cobble, 46% gravell)	72	160	0.45	31.58	1.11
Transect Reach 4	Springtown Village,Cooks Creek, Parcels 42-017-025-007 (Scott Douglas, 3450 Rt. 212) and 42-017-025-008	B4c	1.40	52 (53% gravell)	90	224	1.38	36.14	1.07
Transect Reach 5	Springfield Twp., Cooks Creek, at Knechts Bridge, Knechts Bridge Rd., Parcels 42-012-92 and 42-012-154-1	B3c	0.44	65 (33% cobble)	46	121	2.08	16.79	1.077
Transect Reach 6	Springfield Twp., Cooks Creek, Parcels 42-020-005 (xxx Quakertown Rd) and 42-020-006-001 (xxx Quakertown Rd.).	B4c	1	68 (44% gravell)	28	36	1.82	21.87	1.03
Transect Reach 7	Springfield Twp., Cooks Creek, Parcels 42-010-018 (xxx State Rd.) and 42-010-019 (xxx State Rd.)	B4c	0.80	50 (46% gravell)	16	21	1.8	11.65	1.01

Note: As a function of the "continuum of physycal variables" within stream reaches, values of **Entrenchment** and **Sinuosity** ratios can vary by +/- 0.2 units; while values for **Width / Depth** ratio can vary by +/- 2.0 units.

Non-Point Source pollution has the most significant impact on stream water quality in Cooks Creek Watershed. This type of pollution is linked to behavioral patterns of residents throughout the watershed. 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

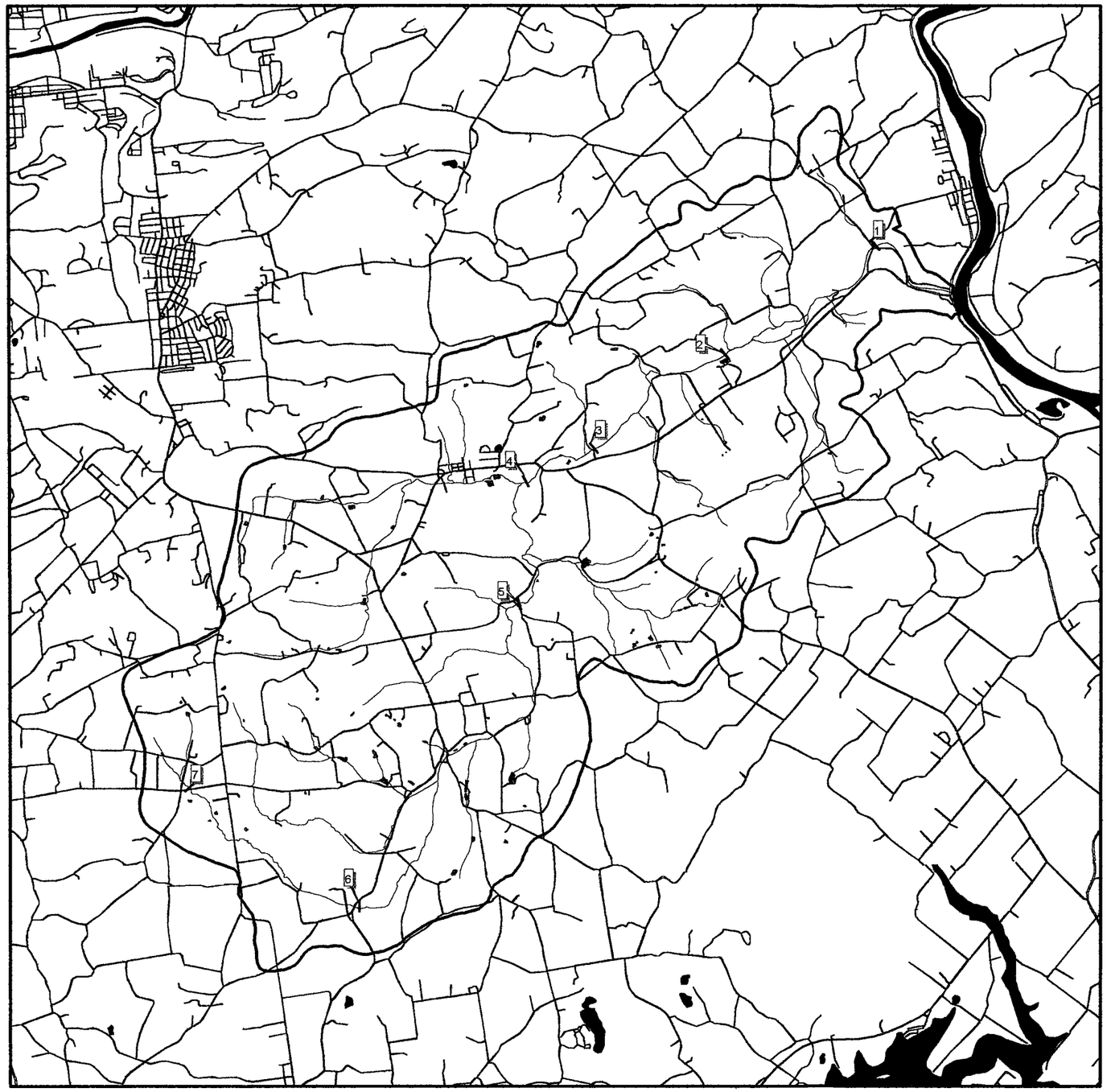
New impervious surfaces (i.e. areas where water no longer penetrates the ground surface such as paved surfaces) result in significantly reduced groundwater infiltration and aquifer recharge since water or wastewater resources are exported from the watershed system. Reduced recharge results in lowering 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. 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 such events.



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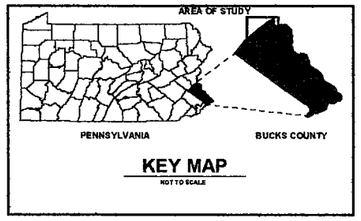

- Figure 25 -
Rosgen Transects Map

LEGEND

- Survey Transect Location, Rosgen Method
- Watershed
- Lakes and Ponds
- Stream
- Waterways
- Minor Road
- Major Road
- First Order Stream
- Second Order Stream

SOURCES: 1) Pennsylvania Spatial Data Access system (PASDA), Surface Geology, Translation, attribution and analysis by MJE and Golder, 1999.

2) DTEAC, MJE, Wetlands Management Plan, digital Tax Map, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.

3) United States Geologic Survey Topographic Quadrangle Map, Riegelsville, PA - NJ, 1973; Hellertown, PA 1992; Quakertown, PA 1994; Bedminster, PA 1992, Translation, attribution and analysis by MJE, August 2000.

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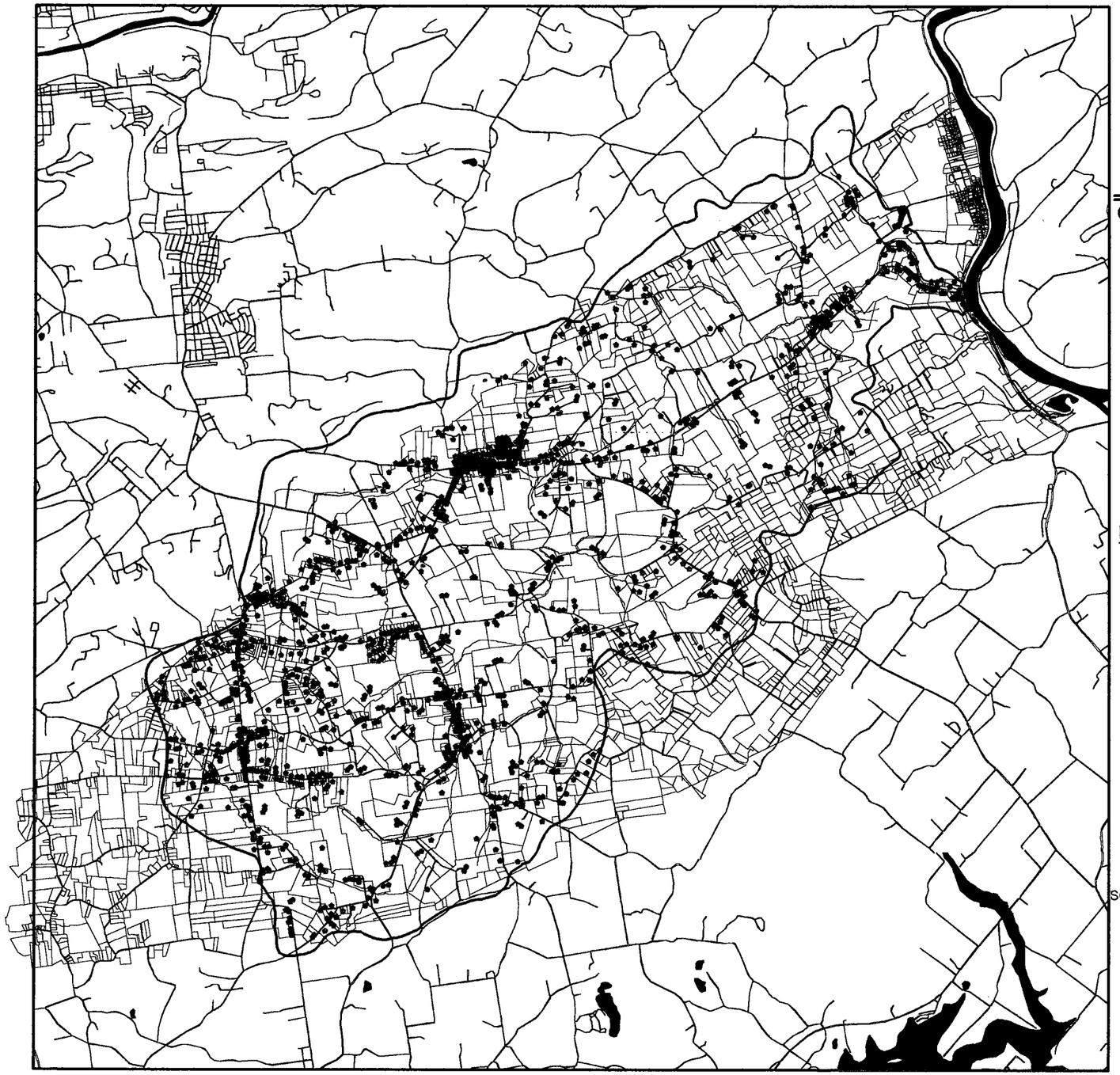

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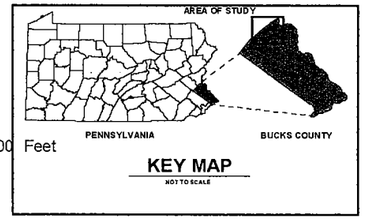

- Figure 26 -
Septic Systems Location Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds
- Tax Map Parcels
- Septic System Location

SOURCES: 1) GIS Data Depot (GIS Web Sites located on the Internet). Translation, attribution and analysis by MJE.

2) DTEAC, MJE, Wetlands Management Plan, digital Tax Map, digital buildings, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.

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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.

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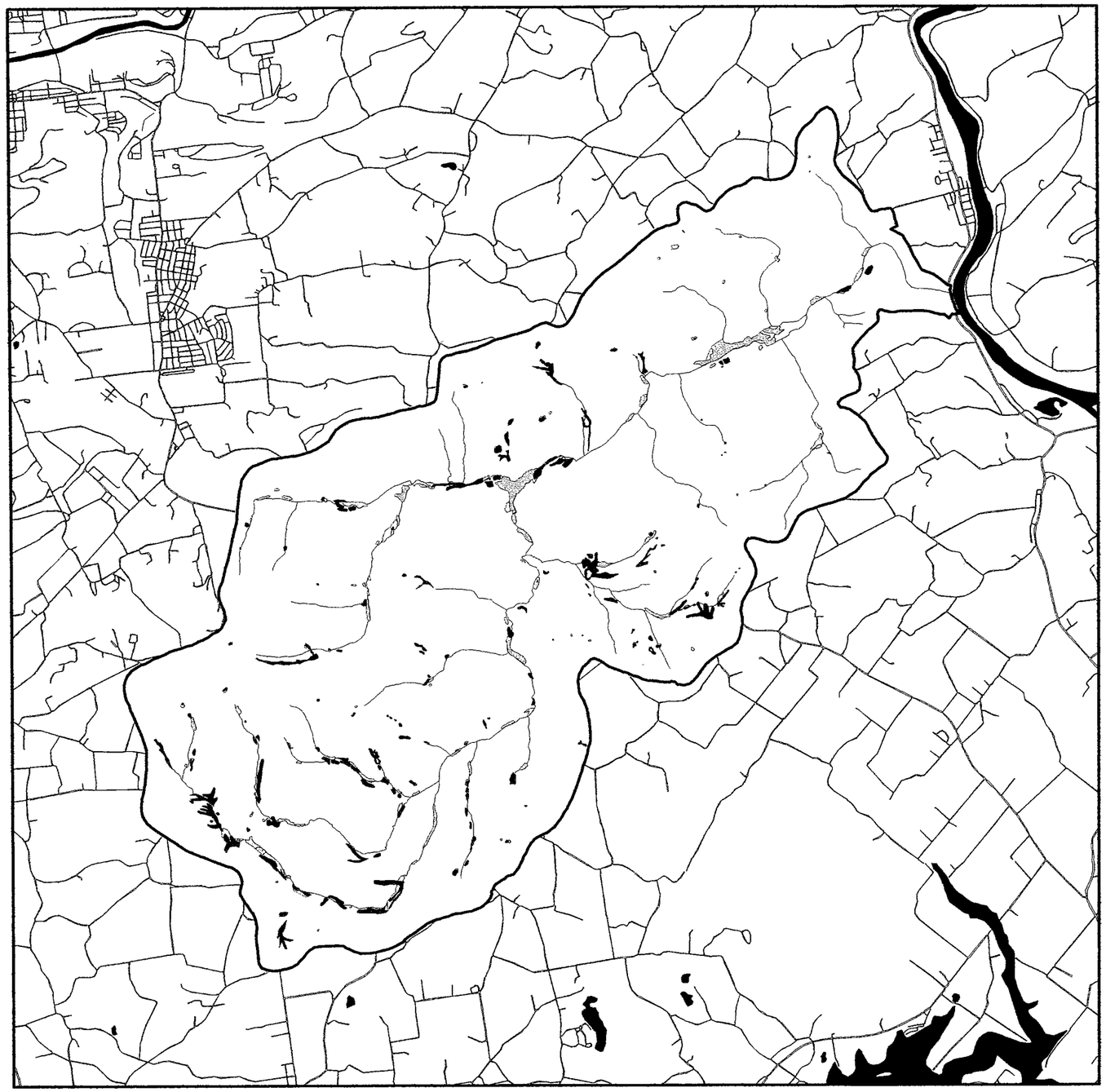

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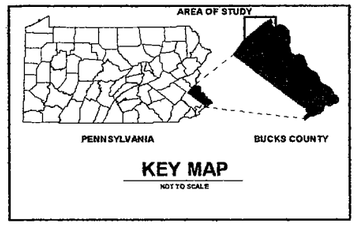

- Figure 27 -
Wetlands Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Stream
- Waterways
- Lakes and Ponds

Wetlands Overlay District

Field Identified Wetlands, EEE, June, 1999:

National Wetlands Inventory:

- PEM5A
- PEM5C
- PEM5CH
- PFO/SS1A
- PFO1/EM5
- PFO1A
- PFO1C
- PFO1E
- POWZH
- POWZX
- PSS1/EM5
- PSS1A
- PSS1C

SOURCES:1) GIS Data Depot (GIS Web Sites located on the Internet). Translation, attribution and analysis by MJE.

2) DTEAC, MJE, Wetlands Management Plan, digital Tax Map, digital buildings, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.

3) EEE, wetlands field survey of the Cooks Creek Watershed, June 1999.

4) MJE, digital Sub-basins Map of the Cooks Creek Watershed, October 2000.

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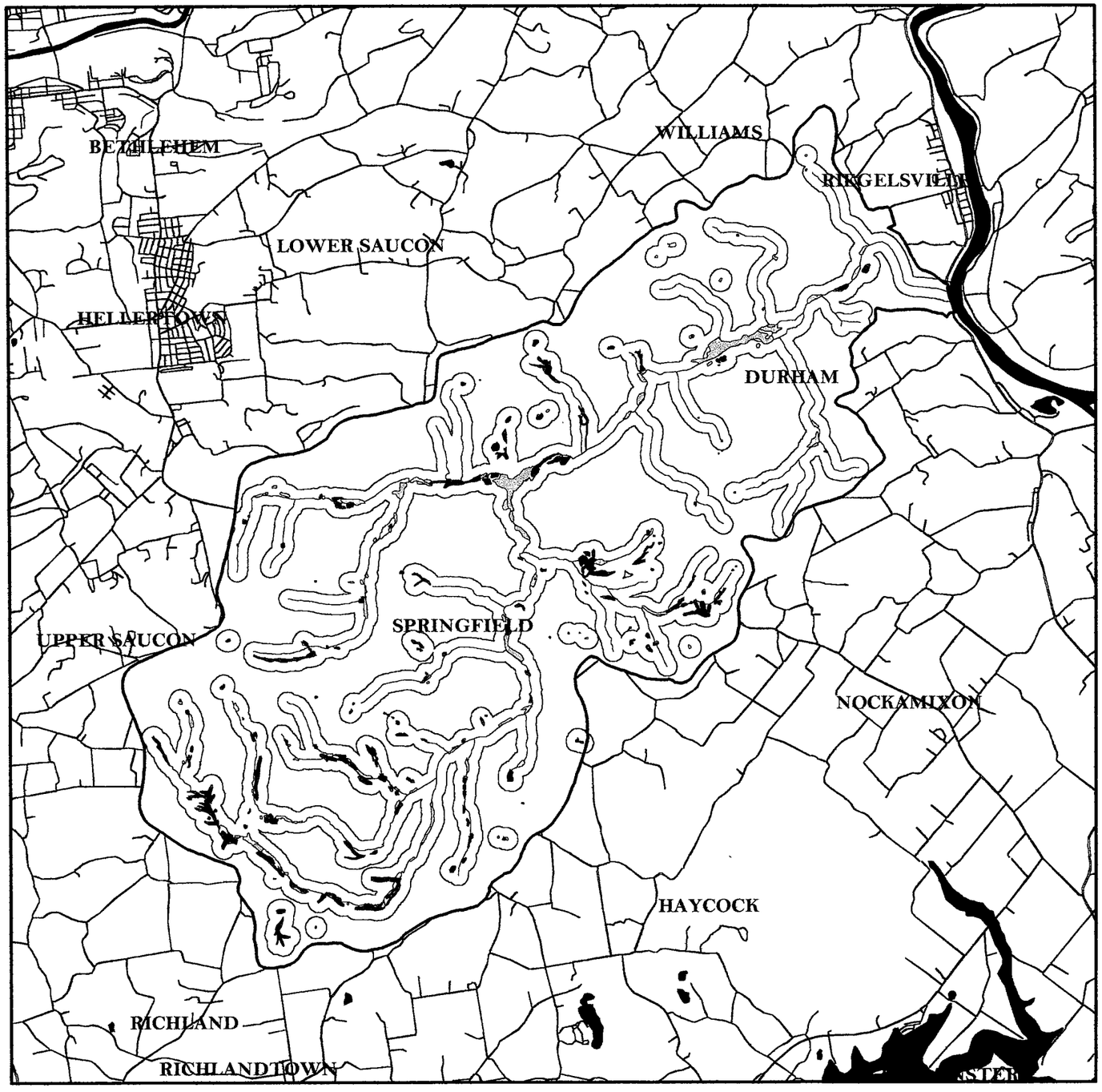

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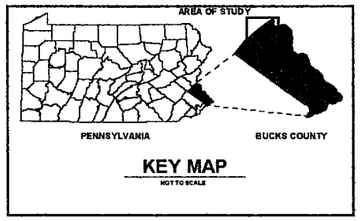

- Figure 28 -
500 feet All Waters Buffer

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Stream
- Waterways
- Lakes and Ponds
- 500 feet All Waters Buffer

Wetlands Overlay District

Field Identified Wetlands, EEE, June, 1999:

National Wetlands Inventory:

PEM5A	PFO1E
PEM5C	POWZH
PEM5CH	POWZX
PFO/SS1A	PSS1/EM5
PFO1/EM5	PSS1A
PFO1A	PSS1C
PFO1C	

SOURCES:1) GIS Data Depot (GIS Web Sites located on the Internet). Translation, attribution and analysis by MJE.

2) DTEAC, MJE, Wetlands Management Plan, digital Tax Map, digital buildings, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.

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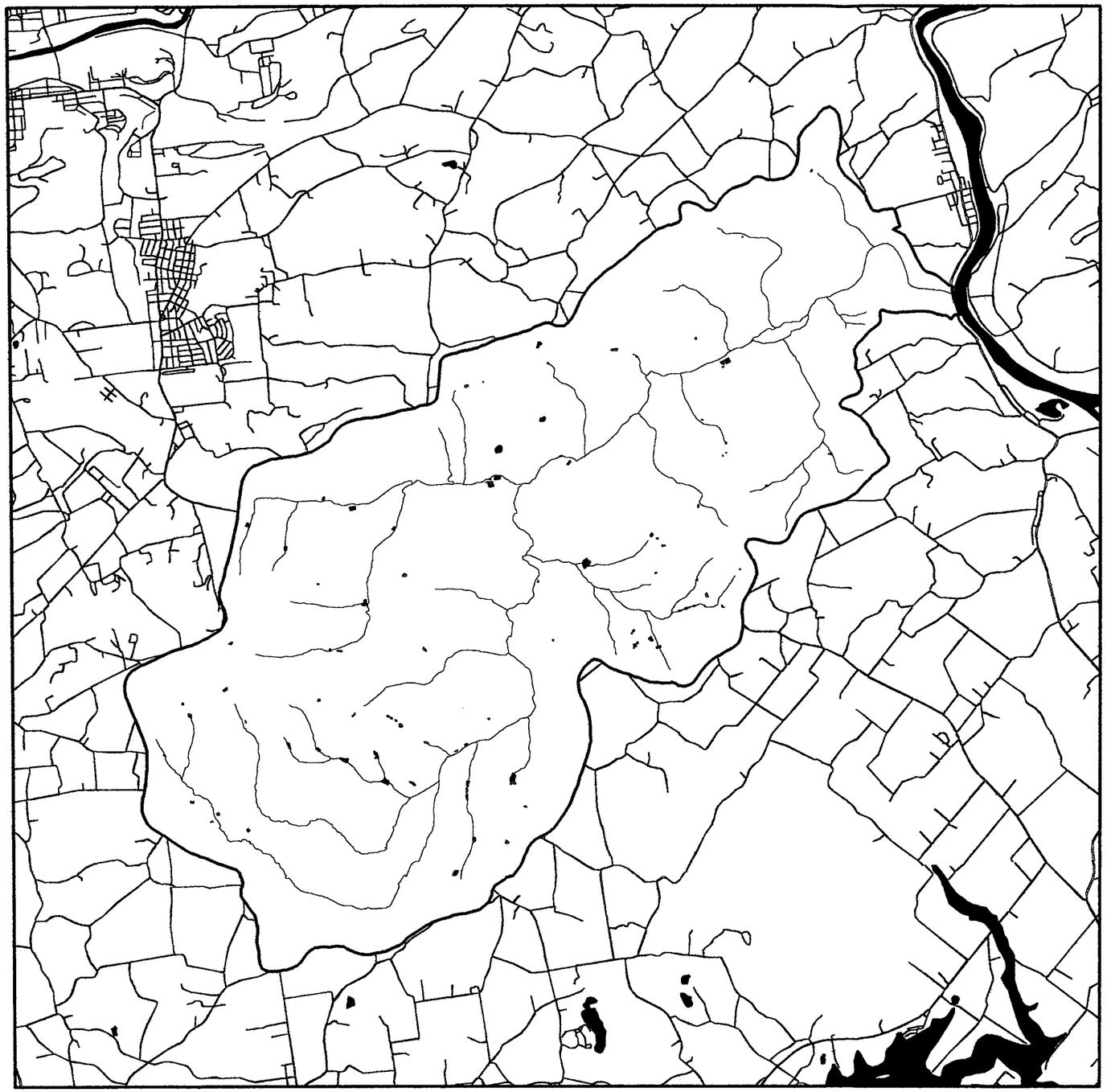

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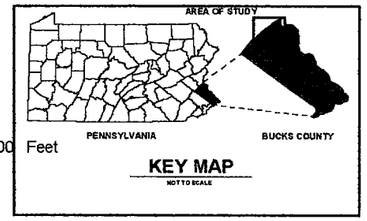

- Figure 29 -
Lakes and Ponds Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways
- Lakes and Ponds

SOURCES: 1) GIS Data Depot (GIS Web Sites located on the Internet). Translation, attribution and analysis by MJE.

2) DTEAC, MJE, Wetlands Management Plan, digital Tax Map, digital buildings, digital Watershed Map, digital Cooks Creek Map, digital Lakes and Ponds Map, May 2000.

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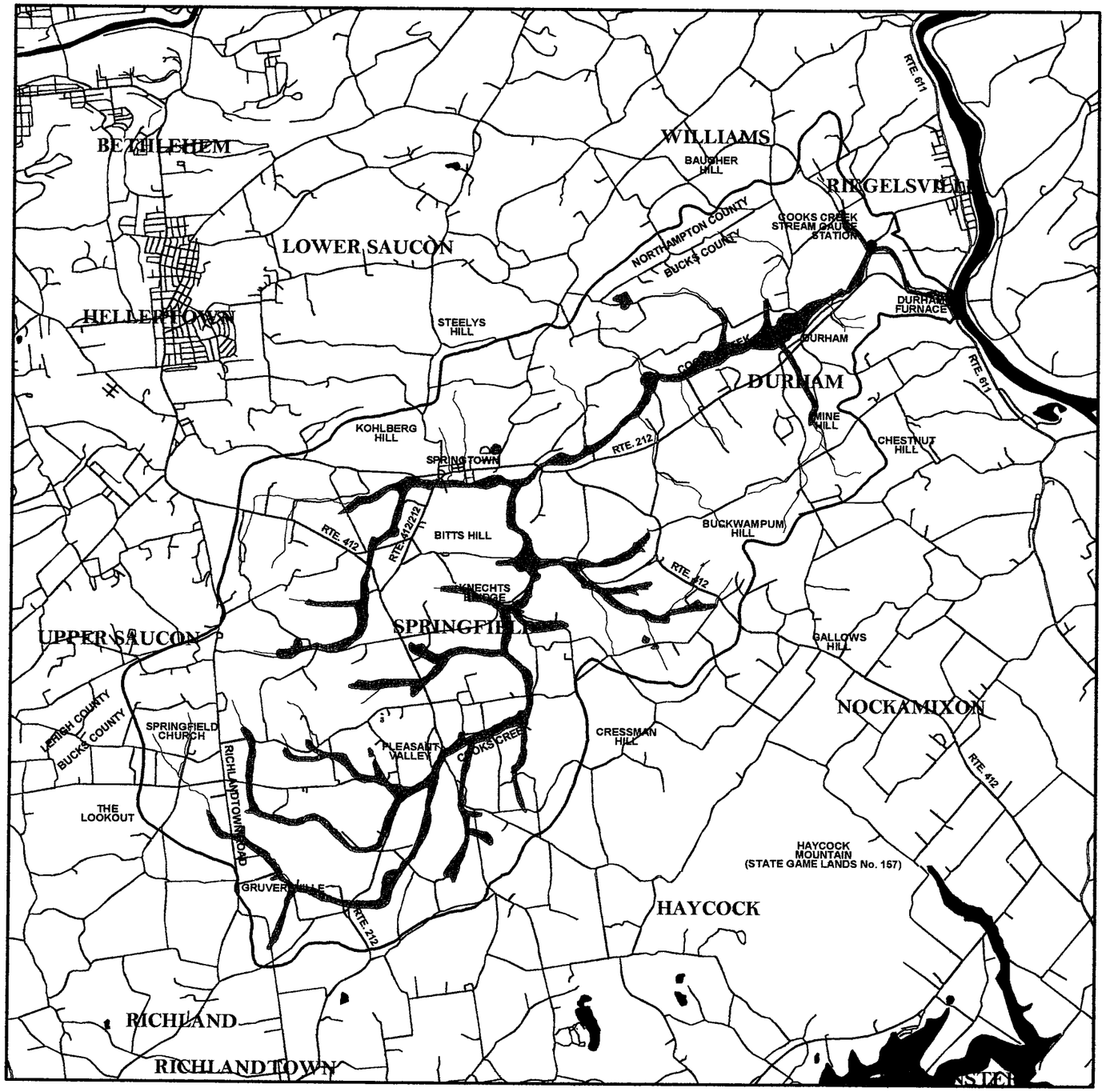

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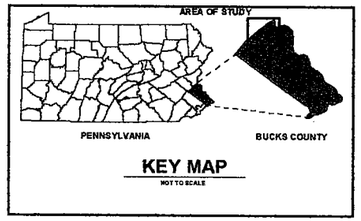

- Figure 30 - 100-year Floodplain Map

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Streams
- Waterways
- 100-year Floodplain Area

SOURCES: 1) PASDA , Digital data of the floodplains of Bucks, Lehigh and Northampton Counties, Translation, attribution and analysis by MJE, 2000.

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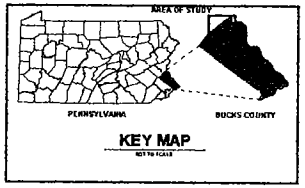

- Figure 31-
Centralized Water Area

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Streams
- Buildings
- Lakes and Ponds
- Public Water Supply Area

SOURCES: 1) Bucks County Water Suply System, Bucks County Planning Commission, 1994

2) Water System Plan, Springfield Township Municipal Authority, Bucks County, August 17, 1987

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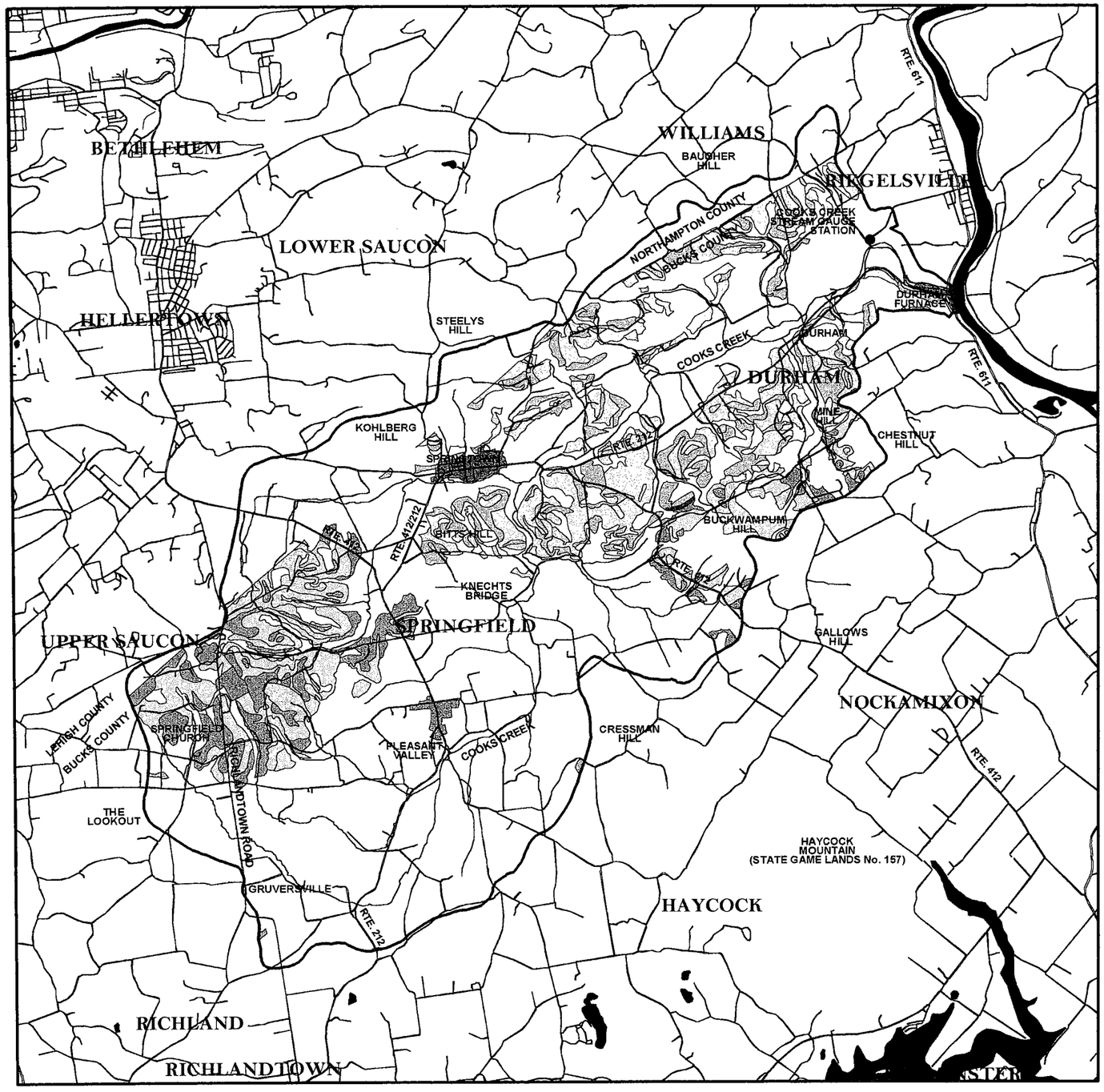

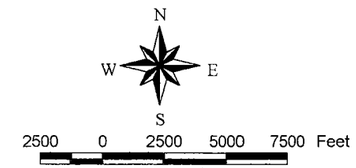

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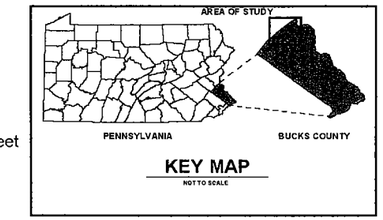

- Figure 34 -
Soil Series Feasible For Conventional Sewage Disposal Systems

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Soils Feasible for Conventional On-Site Sewage Disposal Systems

	AdB		MaB
	AdC		MaC
	AdD		MaD
	CeA		NeB
	CeB		NeC
	CeC		UdB
	CeD		UlC

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

2) Bucks County Natural Resources Plan, Bucks County Planning Commission, March 1999

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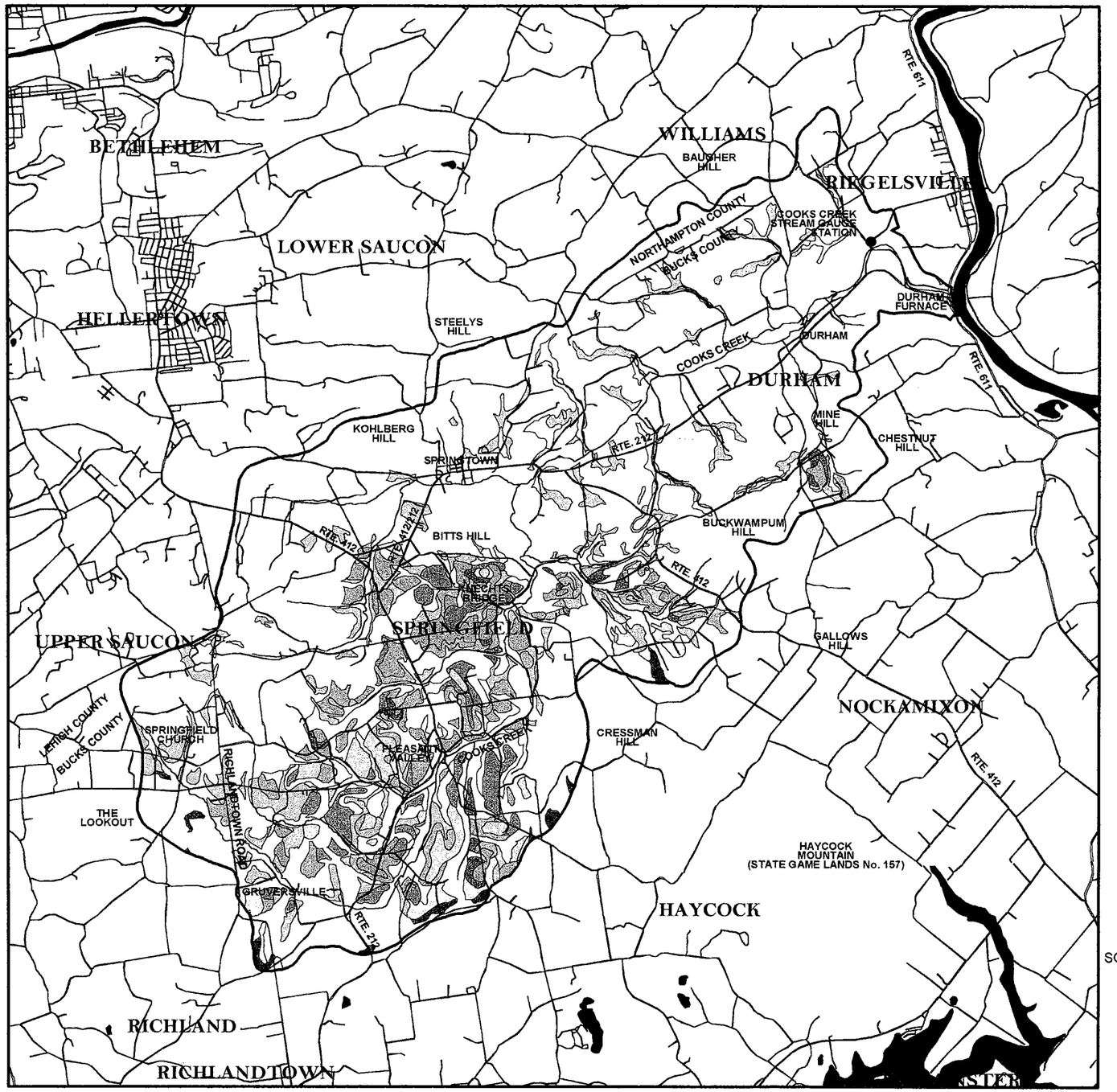

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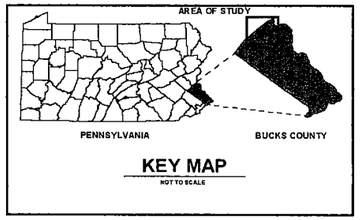

- Figure 35 -
Soil Series Feasible For Alternate Sewage Disposal Systems

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Soils Feasible for Alternate On-Site Sewage Disposal Systems

	AgB		PeA
	AlA		PeB
	CwB		PeC
	CwC		PhB3
	KlB		PkC3
	KlC		RdA
	LhB		RdB
	LhC		RdC
	MlA		UrA
	MlB		UrB

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

2) Bucks County Natural Resources Plan, Bucks County Planning Commission, March 1999

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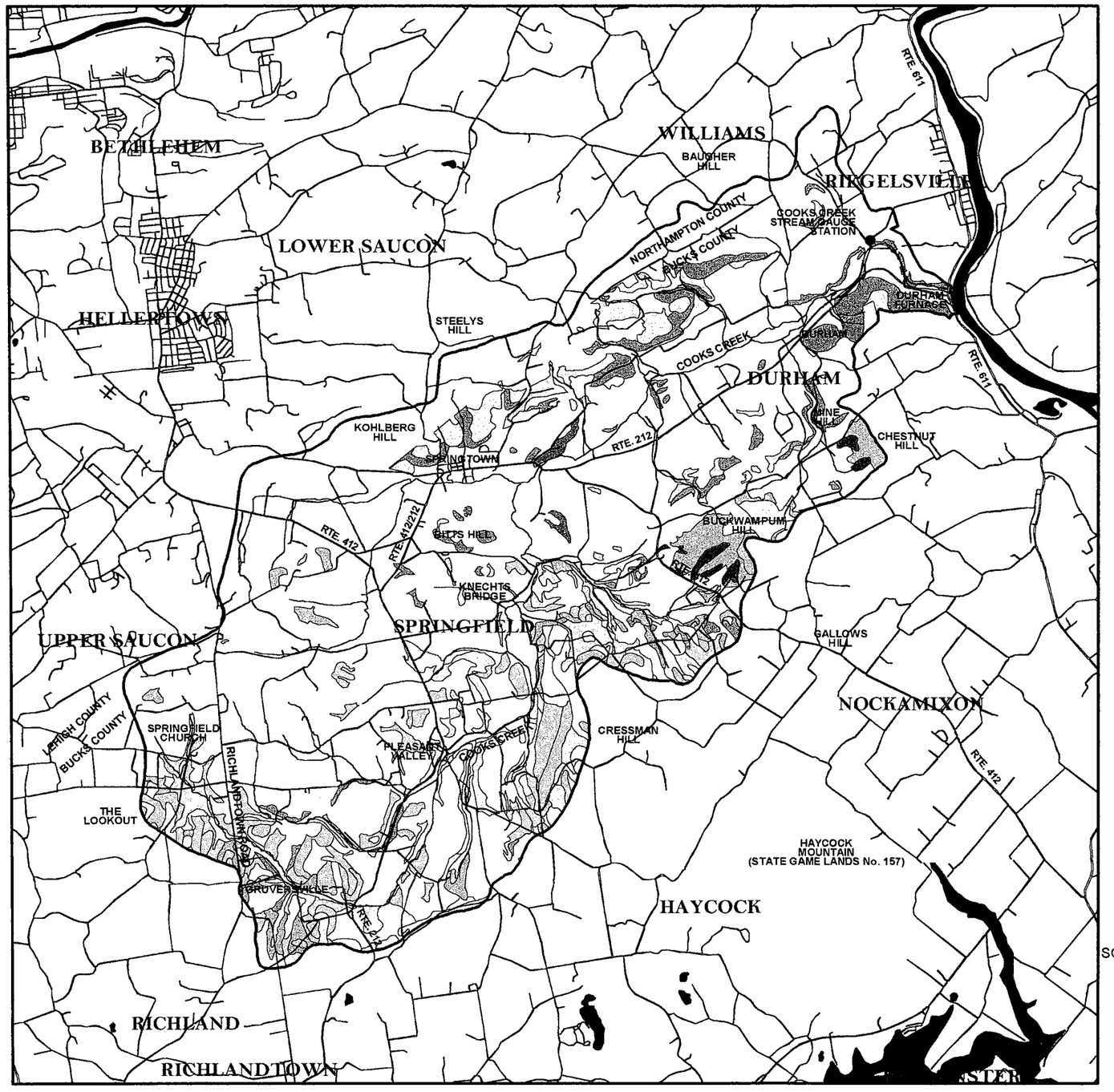

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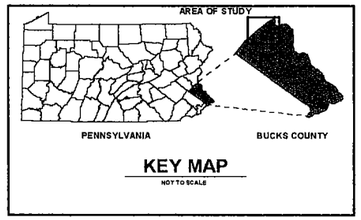

- Figure 36 -
Soil Series Not Feasible For Any Type of Sewage Disposal Systems

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Soils Not Feasible for Any On-Site Sewage Disposal Systems

AbA	LhD	PeD
AbB	LlD	PlD
AbC	MbD	PlE
ChD	McE	ReA
DoA	MoB	ReB
DoB	MoD	ReC
KlD	NhB	ToA
LdB	NhC	ToB
LdD	NhD	TwB
LdE	NhE	WcD

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

2) Bucks County Natural Resources Plan, Bucks County Planning Commission, March 1999

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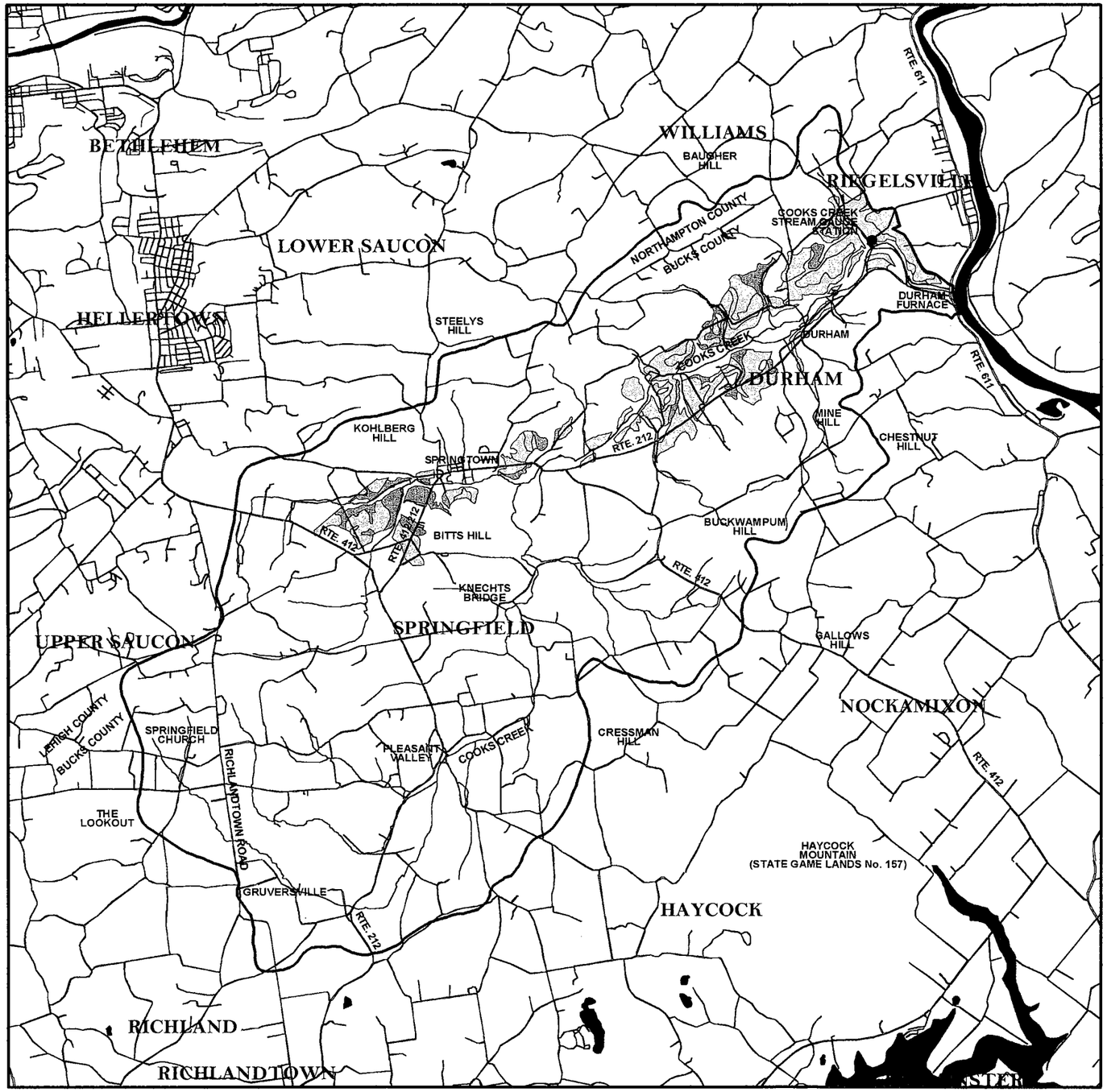

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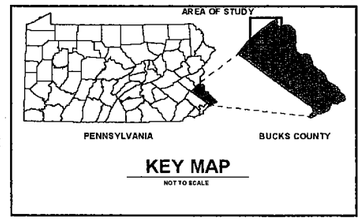

- Figure 37 -
Carbonate Derived Soils Not Feasible For Any Type of Sewage Disposal Systems

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Carbonate Derived Soils Not Feasible for Any On-Site Sewage Disposal Systems

- CIB
- DtC
- WaB

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

2) Bucks County Natural Resources Plan, Bucks County Planning Commission, March 1999

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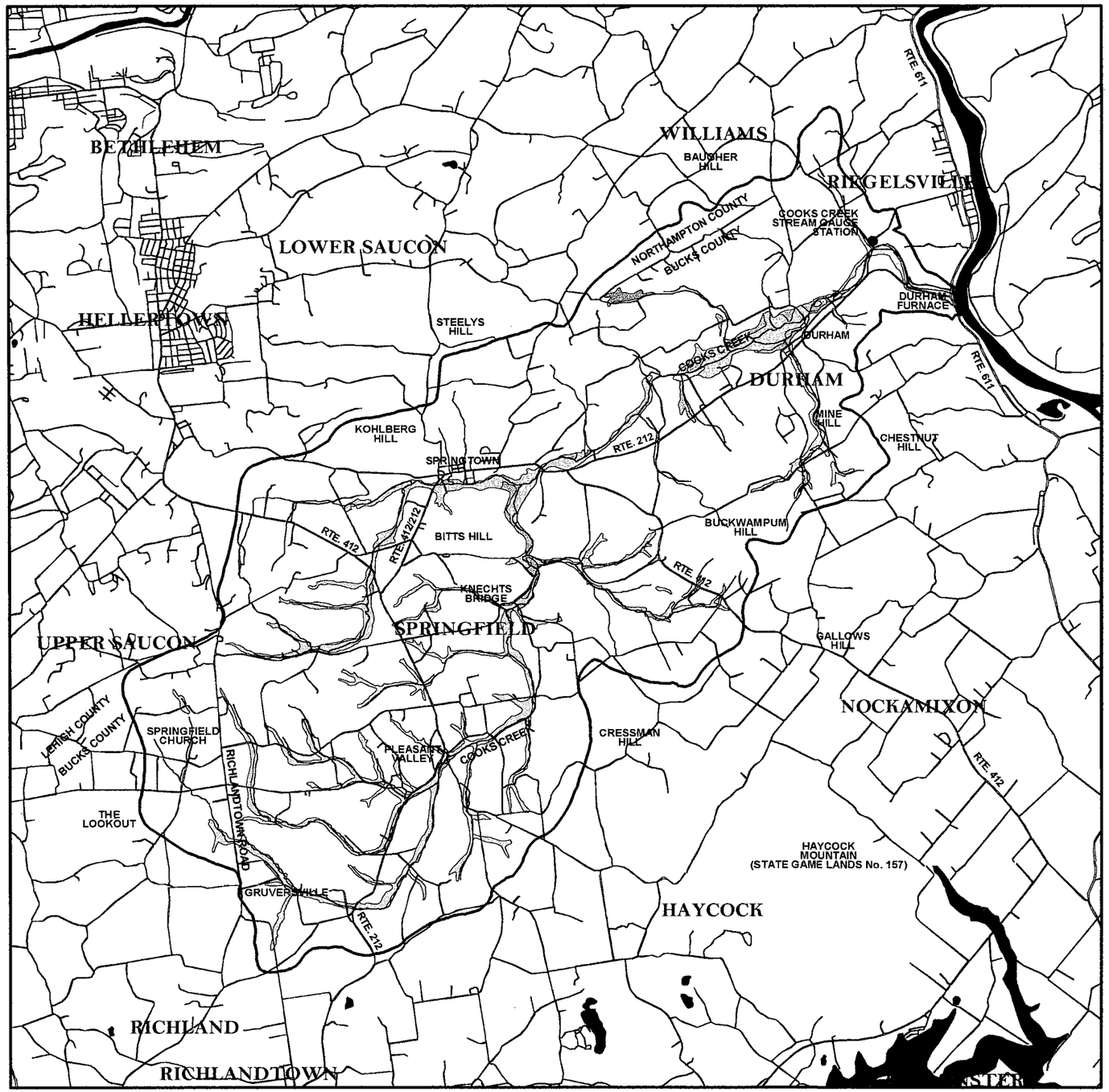
COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRIENGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis



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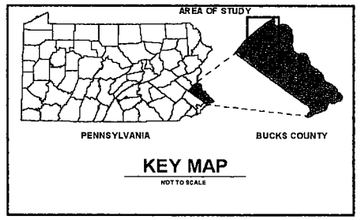

- Figure 38 -
Soils Subject to Flooding Not Feasible For Any Type of Sewage Disposal Systems

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Soils Subject to Flooding Not Feasible for Any On-Site Sewage Disposal Systems

- Ae
- Bo
- Ha
- PoA
- PpA
- Ro

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

2) Bucks County Natural Resources Plan, Bucks County Planning Commission, March 1999

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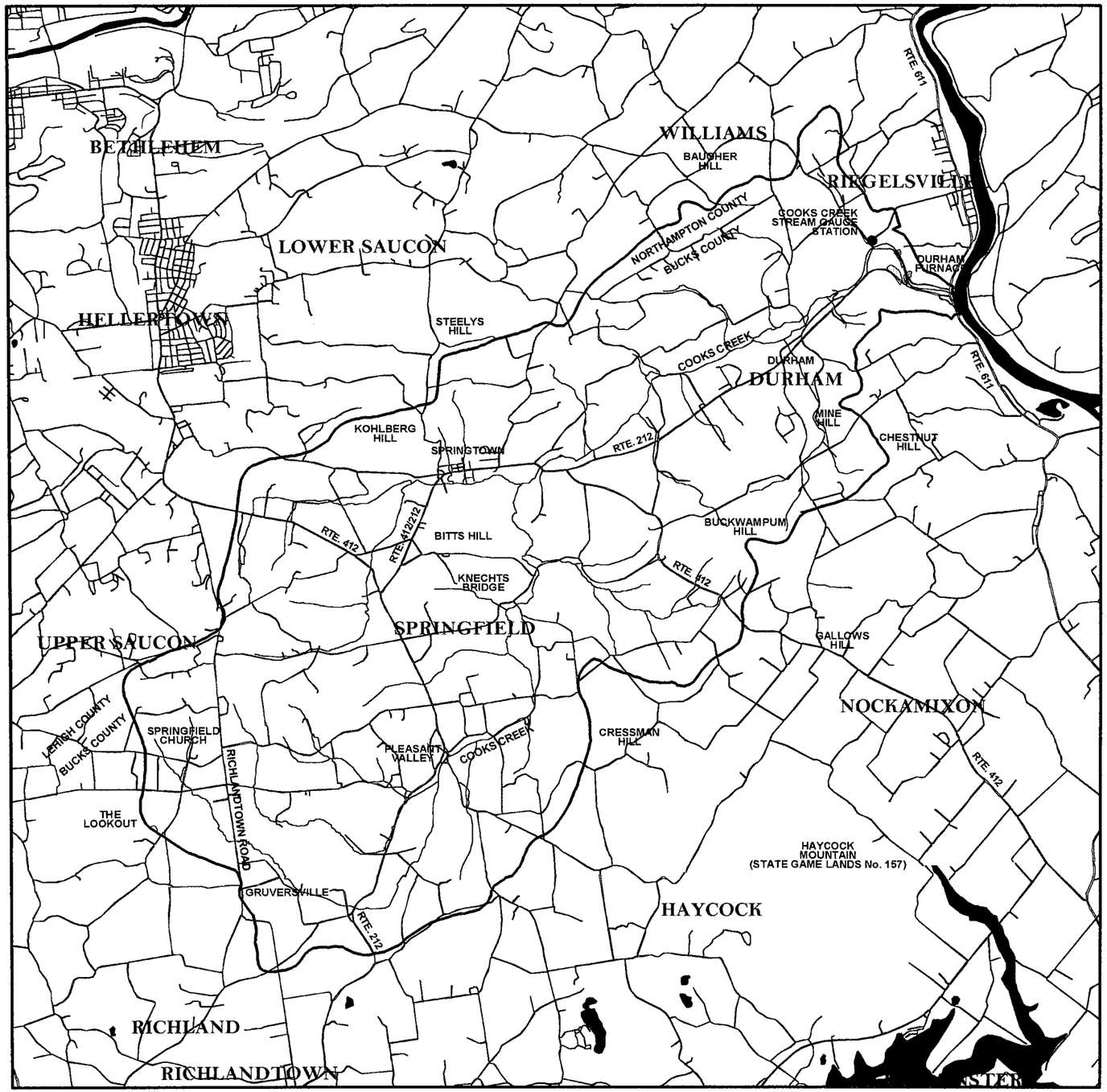
COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRIENGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis



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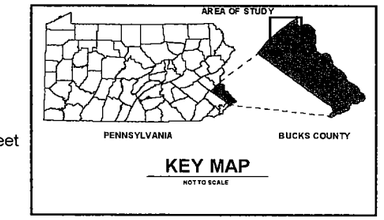

- Figure 39 -
Fill and/or Former Sand Pit or Quarry Not Feasible For Any Type of Sewage Disposal Systems

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Fill and/or Former Sand Pit or Quarry Not Feasible For Any Type of Sewage Disposal Systems

- Gravel Pit
- Quarry

SOURCES: 1) Soil Survey of Bucks and Philadelphia Counties, Pennsylvania, United States Department of Agriculture Soil Conservation Service, Pennsylvania Department of Environmental Resources State Conservation Commission, July 1975.

2) Bucks County Natural Resources Plan, Bucks County Planning Commission, March 1999

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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 Q7-10 methodology). In the Cooks Creek Watershed additional information is necessary to evaluate the Q7-10, 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 Resources 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 (*Chrysemys 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.

Aquatic Species

Fish diversity has declined, especially in Southern Bucks County due to water pollution, habitat degradation, and the detrimental impact of introduced species.

Most invertebrate groups are not well known. Several freshwater mussels have been studied four species have been found. The introduced Asian clam (*Corbicula fluminea*) has become well established in the county. Zebra mussel *(Dreissena polymorpha*) has not been found in Bucks County.

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.

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. 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

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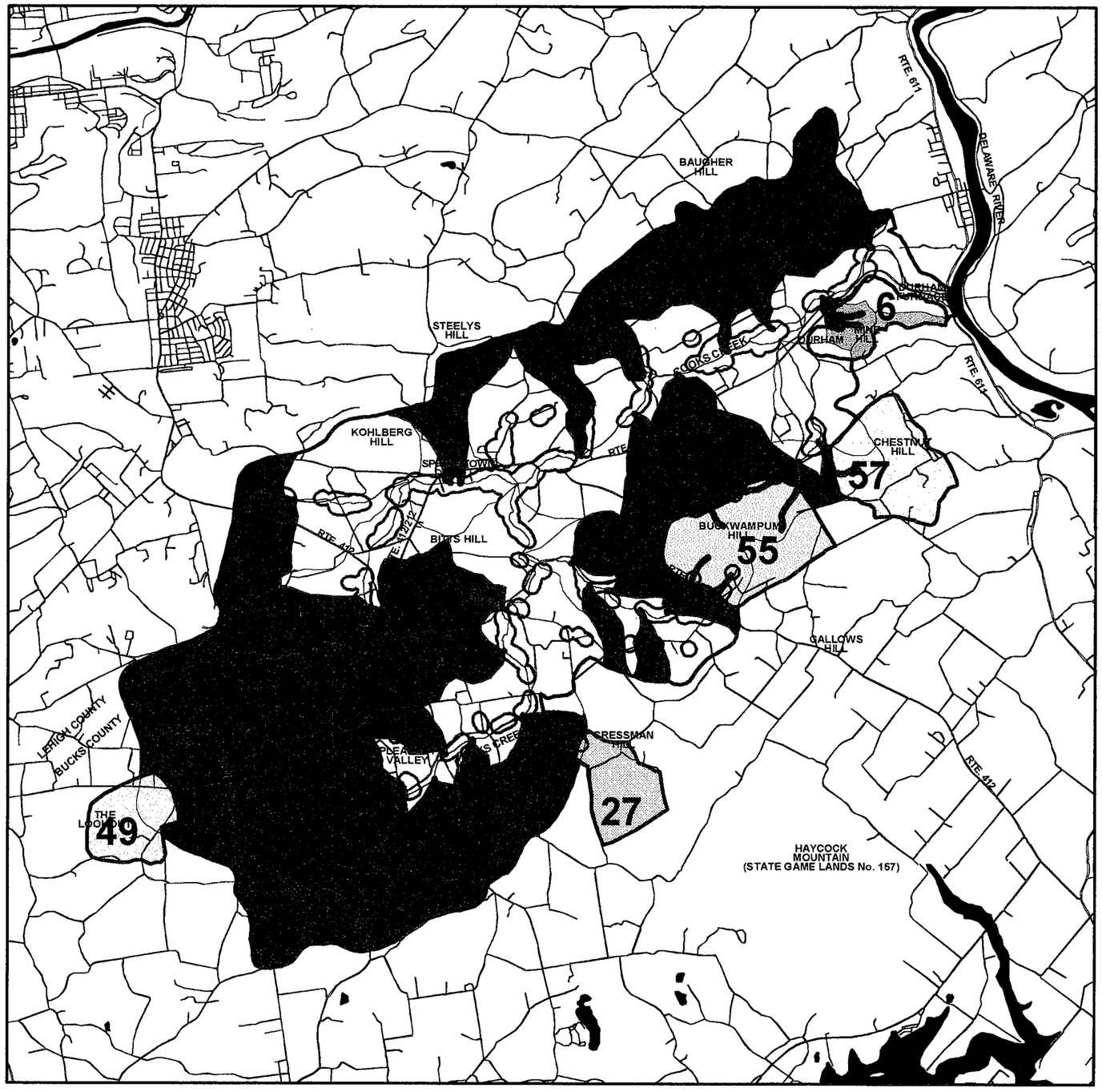
COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis



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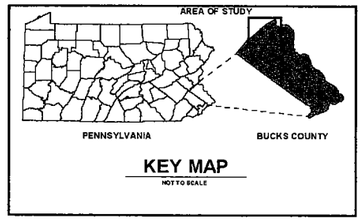

- Figure 32 - Priority Inventory Sites.

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Priority Areas

- First Order Stream
- First Order Sub-basin
- Wetland Buffer

Inventory Sites

- 4 - Cooks Creek (Priority 1 Site)
- 6 - Durham Mine, Mine Hill, and Rattlesnake Hill (Priority 1 Site)
- 27 - Cressman Hill and contiguous forested areas (Priority 2 Site)
- 49 - The Lookout (Priority 2 Site)
- 55 - Buckwampum Mountain (Priority 3 Site)
- 57 - Chestnut Hill (Priority 3 Sites)

SOURCES: 1) Natural Areas Inventory of Bucks County, Pennsylvania, Ann F. Rhoads & Timothy A. Block, Submitted to the Bucks County Commissioners. June, 1999.

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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):

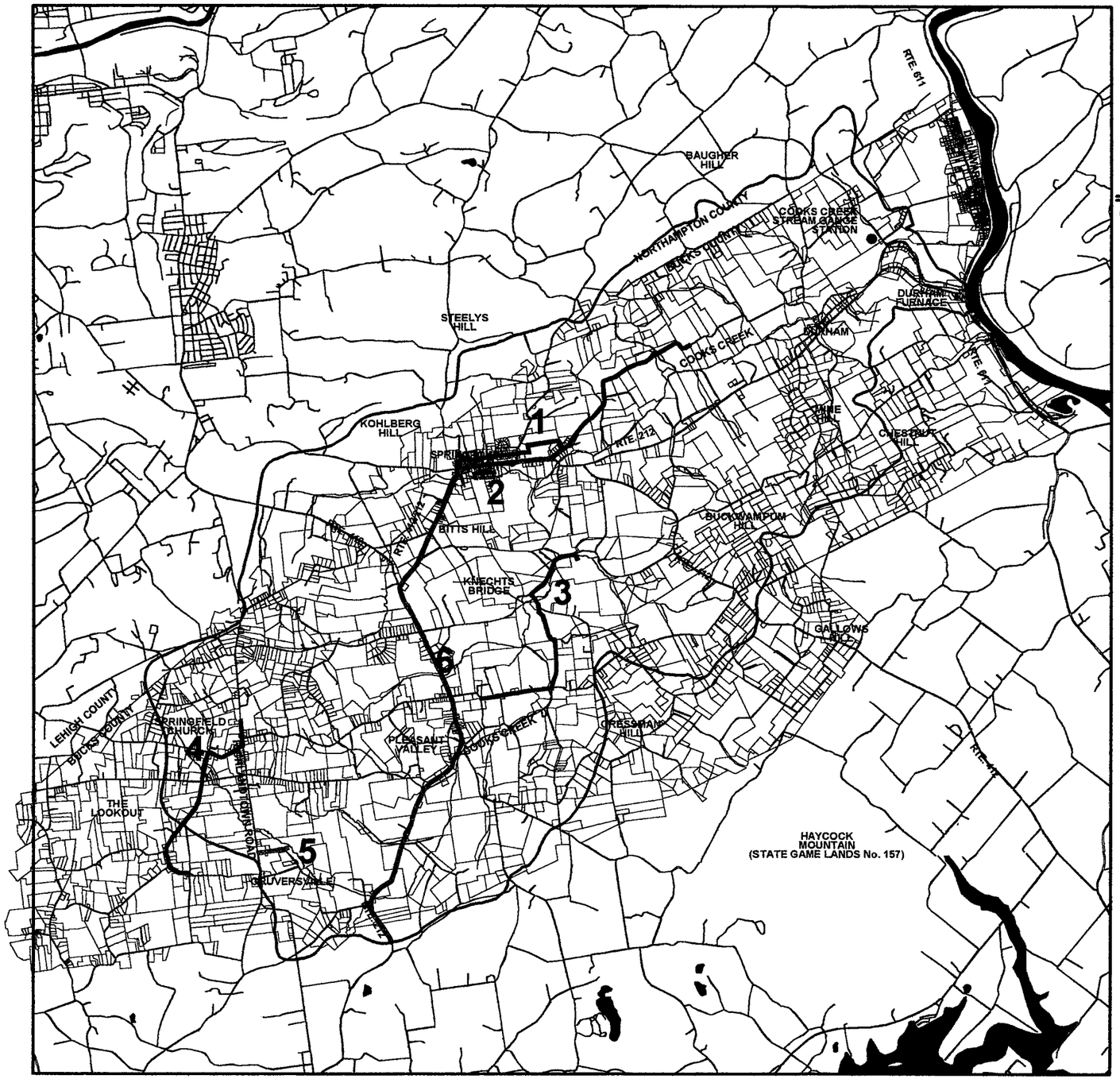
- Silver Creek Athletic Association to Durham Athletic Association;
- Walnut Street, Springtown to Springtown Rod and Gun Club;
- Springfield School to Silver Valley Conservation Area;
- Quarry Road to Ebert Road for access to Passer Community Association;

DTEAC - PaDCNR

COOKS CREEK WATERSHED RIVERS CONSERVATION PLAN

DURHAM AND SPRINGFIELD
BUCKS COUNTY, PENNSYLVANIA

Geographic Information Systems Analysis



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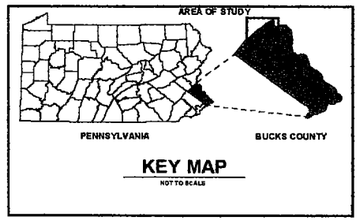
JULY 2000



- Figure 33 -
Proposed Recreational Trails

LEGEND

- Watershed Boundaries
- Roads & Railroads
- Waterways

Linkage Map

1. Silver Creek Athletic Association to Durham Athletic Association
2. Walnut Street, Springtown to Springtown Rod and Gun Club
3. Springfield School to Silver Valley Conservation Area
4. Quarry Road to Ebert Road for Access to Passer Community Assoc.
5. Active/Passive Recreation Area on PP&L Property on Wrecsics Rd.
6. Rt. 212 Richlandtown Borough to Funks Mill Rd./Old Bethleem Road

SOURCES: 1) Springfield Township Open Space and Farmland Preservation Plan, Bucks County Planning Commission, July 1999.

2) DTEAC, Durham Resource Inventory Plan, 1994

DTEAC
Durham Township
Environmental Advisory Council
Durham Township - 215 Old Furnace Road - Durham - Pennsylvania 1839

MJE
MJ Environmental Associates, Ltd.
132 Eaton Way - Cherry Hill - New Jersey - 08003
(856)-857-0660 eFax: (509) 692-6085
email: mjenviro@home.com

- Active/Passive Recreation Area on PP&L Property on Wrecsics Road; and,
- Route 212 Richlandtown Borough to Funks Mill Road/Old Bethlehem Road.

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.

Tabel 5
Potential evapotranspiration (PET) Calculation - Thorthwaite and Mather Method
1999

Thornthwaite Calculation

Doylestown

ppt(in.) = Precipitation, Inches
T(F) = Temperature, Faranheid
T(C) = Temperature, Celsius
T© = ((T(F)-32)/1.8)
Tm = Average Monthly Temperature (oC)
c coef = Daylight Coefficients at 40 o N latitude
Pot.ET = Potential Evapoptranspiration
ppt(mm) = Precipitation, Millimeters
av.moist(mm) = Available Moisture, Millimeters

month	ppt(in.)	T(F)	T©	(Tm/5)1.51	c coef	Pot.ET(mm)	ppt(mm)	av.moist(mm)	Pot.ET(in)	av.moist(in)
January	NA	NA	NA	NA	0.84	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	0.83	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	1.03	NA	NA	NA	NA	NA
April	NA	NA	NA	NA	1.11	NA	NA	NA	NA	NA
May	NA	NA	NA	NA	1.24	NA	NA	NA	NA	NA
June	NA	NA	NA	NA	1.25	NA	NA	NA	NA	NA
July	NA	NA	NA	NA	1.27	NA	NA	NA	NA	NA
August	5.20	73.40	23.00	10.02	1.18	199.94	132.08	-67.86	7.87	-2.67
September	11.36	66.30	19.06	7.54	1.04	150.23	288.54	138.31	5.91	5.45
October	3.31	51.30	10.72	3.16	0.96	85.16	84.07	-1.09	3.35	-0.04
November	0.00	37.00	2.78	0.41	0.83	23.43	0.00	-23.43	0.92	-0.92
December	3.25	36.60	2.56	0.36	0.81	21.30	82.55	61.25	0.84	2.41

I equals 21.50

a equals 0.85

Tabel 5
Potential evapotranspiration (PET) Calculation - Thorthwaite and Mather Method
2000

Thornthwaite Calculation

Doylestown

ppt(in.) = Precipitation, Inches
T(F) = Temperature, Faranheid
T(C) = Temperature, Celsius
T© = ((T(F)-32)/1.8)
Tm = Average Monthly Temperature (oC)
c coef = Daylight Coefficients at 40 o N latitude
Pot.ET = Potential Evapoptranspiration
ppt(mm) = Precipitation, Millimeters
av.moist(mm) = Available Moisture, Millimeters

month	ppt(in.)	T(F)	T©	(Tm/5)1.51	c coef	Pot.ET(mm)	ppt(mm)	av.moist(mm)	Pot.ET(in)	av.moist(in)
January	1.63	28.86	-1.74	NA	0.84	NA	41.40	NA	NA	NA
February	2.76	34.30	1.28	0.13	0.83	1.01	70.10	69.09	0.04	2.72
March	4.08	45.79	7.66	1.91	1.03	13.22	103.63	90.41	0.52	3.56
April	2.84	50.75	10.42	3.03	1.11	21.33	72.14	50.81	0.84	2.00
May	4.52	62.31	16.84	6.26	1.24	44.78	114.81	70.03	1.76	2.76
June	1.23	70.22	21.23	8.88	1.25	61.22	31.24	-29.98	2.41	-1.18
July	4.43	71.79	22.11	9.44	1.27	65.58	112.52	46.94	2.58	1.85
August	5.55	71.21	21.78	9.23	1.18	59.75	140.97	81.22	2.35	3.20
September	4.29	63.89	17.72	6.76	1.04	40.15	108.97	68.81	1.58	2.71
October	1.52	55.34	12.97	4.22	0.96	24.60	38.61	14.01	0.97	0.55
November	0.79	43.54	6.41	1.46	0.83	8.43	20.07	11.64	0.33	0.46
December	4.01	41.00	5.00	1.00	0.81	5.93	101.85	95.92	0.23	3.78

I equals 52.29

a equals 1.31

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.

Table 6
Area 1

SUBBASIN ID	SUBBASIN AREA_	SUBBASIN PERIMETER_	GEOLOGIC FORMATION	HYDROGEOLOGIC UNITS	AREA sq-feet
CC2a	25,376,041.98	24637.77	Leithsville Fm	Limestone	4,120,395.52
CC2a	25,376,041.98	24637.77	Allentown Fm	Limestone	4,555,786.12
				Total (sq-ft):	**8,676,181.64**
				Total (acres):	**216.90**
				Percentage	**34.19%**
CC2a	25,376,041.98	24637.77	Hardyston Fm	Crystalline	408,229.27
CC2a	25,376,041.98	24637.77	Hornblende Gneiss	Crystalline	11,754,892.65
CC2a	25,376,041.98	24637.77	Hardyston Fm	Crystalline	4,023,001.62
CC2a	25,376,041.98	24637.77	Granitic Gneiss	Crystalline	513,736.80
				Total (sq-ft):	**16,699,860.34**
Area CC2a:	**634.40**	**acres**		**Total (acres):**	**417.50**
				Percentage	**65.81%**
CC6a	24,490,315.07	22505.85	Leithsville Fm	Limestone	4,227,500.14
CC6a	24,490,315.07	22505.85	Allentown Fm	Limestone	595,593.75
				Total (sq-ft):	**4,823,093.89**
				Total (acres):	**120.58**
				Percentage	**19.69%**
CC6a	24,490,315.07	22505.85	Hornblende Gneiss	Crystalline	7,730,984.69
CC6a	24,490,315.07	22505.85	Hardyston Fm	Crystalline	2,432,331.73
CC6a	24,490,315.07	22505.85	Granitic Gneiss	Crystalline	6,748,225.49
CC6a	24,490,315.07	22505.85	Granitic Gneiss	Crystalline	661,328.48
CC6a	24,490,315.07	22505.85	Granitic Gneiss	Crystalline	79,424.76
CC6a	24,490,315.07	22505.85	Hornblende Gneiss	Crystalline	23,208.45
CC6a	24,490,315.07	22505.85	Hornblende Gneiss	Crystalline	1,991,717.57
				Total (sq-ft):	**19,667,221.17**
				Total (acres):	**491.68**
Area CC6a:	**612.26**	**acres**		**Percentage**	**80.31%**
CC9a	26,488,883.19	26615.98	Leithsville Fm	Limestone	1,422,848.46
CC9a	26,488,883.19	26615.98	Allentown Fm	Limestone	652,289.71
				Total (sq-ft):	**2,075,138.17**
				Total (acres):	**51.88**
				Percentage	**7.83%**
CC9a	26,488,883.19	26615.98	Hardyston Fm	Crystalline	1,185,082.60
CC9a	26,488,883.19	26615.98	Granitic Gneiss	Crystalline	14,219,264.38
CC9a	26,488,883.19	26615.98	Granitic Gneiss	Crystalline	415,011.80
CC9a	26,488,883.19	26615.98	Hornblende Gneiss	Crystalline	3,667,019.50
CC9a	26,488,883.19	26615.98	Hornblende Gneiss	Crystalline	3,666,268.78
CC9a	26,488,883.19	26615.98	Hornblende Gneiss	Crystalline	1,261,097.96

				Total (sq-ft):	**24,413,745.02**
				Total (acres):	**610.34**
Area CC9a:	**662.22**	**acres**		**Percentage**	**92.17%**
CCT33a	8,825,954.40	14812.85	Leithsville Fm	Limestone	327,691.73
	220.65			**Total (sq-ft):**	**327,691.73**
				Total (acres):	**8.19**
				Percentage	**3.71%**
CCT33a	8,825,954.40	14812.85	Hardyston Fm	Crystalline	544,862.38
CCT33a	8,825,954.40	14812.85	Granitic Gneiss	Crystalline	3,699,032.81
CCT33a	8,825,954.40	14812.85	Hornblende Gneiss	Crystalline	1,941,053.13
CCT33a	8,825,954.40	14812.85	Hornblende Gneiss	Crystalline	2,313,314.34
				Total (sq-ft):	**8,498,262.66**
				Total (acres):	**212.46**
Area CCT33a:	**220.65**	**acres**		**Percentage**	**96.29%**
CCT34a	10,761,744.62	18319.80	Leithsville Fm	Limestone	1,826,521.19
	269.04			**Total (sq-ft):**	**1,826,521.19**
				Total (acres):	**45.66**
				Percentage	**16.97%**
CCT34a	10,761,744.62	18319.80	Hardyston Fm	Crystalline	246,177.09
CCT34a	10,761,744.62	18319.80	Granitic Gneiss	Crystalline	6,073,595.21
CCT34a	10,761,744.62	18319.80	Hornblende Gneiss	Crystalline	1,770,749.73
CCT34a	10,761,744.62	18319.80	Hardyston Fm	Crystalline	844,701.39
				Total (sq-ft):	**8,935,223.42**
				Total (acres):	**223.38**
				Percentage	**83.03%**
Area CCT34a:	**269.04**	**acres**			

Table 6 (Continued)
Area 2

SUBBASIN ID	SUBBASIN AREA	SUBBASIN PERIMETER	GEOLOGIC FORMATION	HYDROGEOLOGIC UNITS	AREA
CC1	105,710,096.94	97,925.06	Leithsville Fm	Limestone	43,269,196.00
CC1	105,710,096.94	97,925.06	Allentown Fm	Limestone	11,862,652.00
				Total (sq-ft)	**55,131,848.00**
				Total (acres)	**1,378.30**
				Percentage	**52.15%**
CC1	105,710,096.94	97,925.06	Hardyston Fm	Crystalline	3,955,274.00
CC1	105,710,096.94	97,925.06	Granitic Gneiss	Crystalline	19,011,499.00
CC1	105,710,096.94	97,925.06	Hornblende Gneiss	Crystalline	3,088,219.00
CC1	105,710,096.94	97,925.06	Hornblende Gneiss	Crystalline	8,456,640.00
CC1	105,710,096.94	97,925.06	Hardyston Fm	Crystalline	307,117.00
CC1	105,710,096.94	97,925.06	Hardyston Fm	Crystalline	11,758,400.00
CC1	105,710,096.94	97,925.06	Granitic Gneiss	Crystalline	612,512.00
CC1	105,710,096.94	97,925.06	Hardyston Fm	Crystalline	2,071,251.00
CC1	105,710,096.94	97,925.06	Granitic Gneiss	Crystalline	1,317,336.00
				Total (sq-ft)	**50,578,248.00**
				Total (acres)	**1,264.46**
Area CC1:	**2,642.75**	**acres**		**Percentage**	**47.85%**
CCT10	2,435,679.89	7,352.41	Hornblende Gneiss	Crystalline	1,153,973.00
CCT10	2,435,679.89	7,352.41	Granitic Gneiss	Crystalline	497,257.00
				Total (sq-ft)	**1,651,230.00**
				Total (acres)	**41.28**
				Percentage	**67.80%**
CCT10	2,435,679.89	7,352.41	Brunswick Fm	Brunswick	784,450.00

					Total (sq-ft)	**784,450.00**
					Total (acres)	**19.61**
Area CCT10:	**60.89**	**acres**			**Percentage**	**32.21%**
CCT8	21,572,375.14		21,406.52	Leithsville Fm	Limestone	3,126,779.00
	539.31				**Total (sq-ft)**	**3,126,779.00**
					Total (acres)	**78.17**
					Percentage	**14.49%**
CCT8	21,572,375.14		21,406.52	Hornblende Gneiss	Crystalline	10,394,592.00
CCT8	21,572,375.14		21,406.52	Hardyston Fm	Crystalline	4,014,901.00
CCT8	21,572,375.14		21,406.52	Granitic Gneiss	Crystalline	1,070,075.00
					Total (sq-ft)	**15,479,568.00**
					Total (acres)	**386.99**
					Percentage	**71.76%**
CCT8	21,572,375.14		21,406.52	Quartz Fanoglomerat	Brunswick	999,237.00
CCT8	21,572,375.14		21,406.52	Brunswick Fm	Brunswick	1,966,791.00
					Total (sq-ft)	**2,966,028.00**
					Total (acres)	**74.15**
Area CCT8:	**539.31**	**acres**			**Percentage**	**13.75%**

Table 6 (Continued)
Area 3

SUBBASIN ID	SUBBASIN AREA_	SUBBASIN PERIMETER_	GEOLOGIC FORMATION	HYDROGEOLOGIC UNITS	AREA
CC11a	22,091,306.83	19,258.44	Leithsville Fm	Limestone	8,768,562.00
				Total (sq-ft)	**8,768,562.00**
				Total (acres)	**219.21**
				Percentage	**39.69%**
CC11a	22,091,306.83	19,258.44	Hornblende Gneiss	Crystalline	2,713,953.00
CC11a	22,091,306.83	19,258.44	Hardyston Fm	Crystalline	8,922,216.00
CC11a	22,091,306.83	19,258.44	Granitic Gneiss	Crystalline	518,551.00
CC11a	22,091,306.83	19,258.44	Granitic Gneiss	Crystalline	1,003,749.00
CC11a	22,091,306.83	19,258.44	Granitic Gneiss	Crystalline	164,275.00
				Total (sq-ft)	**13,322,744.00**
				Total (acres)	**333.07**
Area CC11a:	**552.28**	**acres**		**Percentage**	**60.31%**
CC12a	17,870,381.40	22,023.29	Leithsville Fm	Limestone	2,502,474.00
				Total (sq-ft)	**2,502,474.00**
				Total (acres)	**62.56**
				Percentage	**14.00%**
CC12a	17,870,381.40	22,023.29	Hornblende Gneiss	Crystalline	12,535.00
CC12a	17,870,381.40	22,023.29	Hardyston Fm	Crystalline	8,725,963.00
CC12a	17,870,381.40	22,023.29	Granitic Gneiss	Crystalline	2,434,375.00
				Total (sq-ft)	**11,172,873.00**
				Total (acres)	**279.32**
				Percentage	**62.52%**
CC12a	17,870,381.40	22,023.29	Quartz Fanoglomerate	Brunswick	4,195,035.00
				Total (sq-ft)	**4,195,035.00**
				Total (acres)	**104.88**
Area CC12a:	**446.76**	**acres**		**Percentage**	**23.48%**
CC4a	4,965,003.03	9,168.44	Leithsville Fm	Limestone	1,225,122.00
				Total (sq-ft)	**1,225,122.00**
				Total (acres)	**30.63**
				Percentage	**24.67%**
CC4a	4,965,003.03	9,168.44	Hornblende Gneiss	Crystalline	3,739,881.00

				Total (sq-ft)	**3,739,881.00**
				Total (acres)	**93.50**
Area CC4a:	**124.13**	**acres**		**Percentage**	**75.33%**
CCT23a	5,631,663.82	10,726.10	Hornblende Gneiss	Crystalline	49,486.00
				Total (sq-ft)	**49,486.00**
				Total (acres)	**1.24**
				Percentage	**0.88%**
CCT23a	5,631,663.82	10,726.10	Brunswick Fm	Brunswick	3,166,065.00
CCT23a	5,631,663.82	10,726.10	Quartz Fanoglomerate	Brunswick	1,168,454.00
CCT23a	5,631,663.82	10,726.10	Quartz Fanoglomerate	Brunswick	1,247,660.00
				Total (sq-ft)	**5,582,179.00**
				Total (acres)	**139.55**
Areas CCT23a:	**140.79**	**acres**		**Percentage**	**99.12%**
CCT24a	6,196,518.42	13,630.14	Granitic Gneiss	Crystalline	3,133.00
				Total (sq-ft)	**3,133.00**
				Total (acres)	**0.08**
				Percentage	**0.05%**
CCT24a	6,196,518.42	13,630.14	Brunswick Fm	Brunswick	1,090,176.00
CCT24a	6,196,518.42	13,630.14	Quartz Fanoglomerate	Brunswick	5,103,210.00
				Total (sq-ft)	**6,193,386.00**
				Total (acres)	**154.83**
Areas CCT24a:	**154.91**	**acres**		**Percentage**	**99.95%**
CCT25a	10,471,143.28	13,658.40	Hornblende Gneiss	Crystalline	1,528,292.00
CCT25a	10,471,143.28	13,658.40	Hardyston Fm	Crystalline	103,485.00
CCT25a	10,471,143.28	13,658.40	Granitic Gneiss	Crystalline	2,957,431.00
CCT25a	10,471,143.28	13,658.40	Hornblende Gneiss	Crystalline	380,135.00
				Total (sq-ft)	**4,969,343.00**
				Total (acres)	**124.23**
				Percentage	**47.46%**
CCT25a	10,471,143.28	13,658.40	Brunswick Fm	Brunswick	744,703.00
CCT25a	10,471,143.28	13,658.40	Quartz Fanoglomerate	Brunswick	4,757,096.00

				Total (sq-ft)	**5,501,799.00**
				Total (acres)	**137.54**
Areas CCT25a:	**261.78**	**acres**		**Percentage**	**52.54%**
CCT26a	15,559,999.47	17,743.82	Leithsville Fm	Limestone	222,935.00
CCT26a	15,559,999.47	17,743.82	Limestone Fanoglomer	Limestone	384,793.00
				Total (sq-ft)	**607,728.00**
				Total (acres)	**15.19**
				Percentage	**3.91%**
CCT26a	15,559,999.47	17,743.82	Hardyston Fm	Crystalline	5,592,891.00
CCT26a	15,559,999.47	17,743.82	Granitic Gneiss	Crystalline	3,486,761.00
				Total (sq-ft)	**9,079,652.00**
				Total (acres)	**226.99**
				Percentage	**58.35%**
CCT26a	15,559,999.47	17,743.82	Quartz Fanoglomerate	Brunswick	4,532,752.00
CCT26a	15,559,999.47	17,743.82	Brunswick Fm	Brunswick	1,339,867.00
				Total (sq-ft)	**5,872,619.00**
				Total (acres)	**146.82**
Area CCT26a:	**389.00**	**acres**		**Percentage**	**37.74%**
CCT27a	5,156,819.33	11,639.43	Brunswick Fm	Brunswick	2,779,112.00
				Total (sq-ft)	**2,779,112.00**
				Total (acres)	**69.48**
				Percentage	**53.89%**
CCT27a	5,156,819.33	11,639.43	Diabase	Diabase	2,377,708.00
				Total (sq-ft)	**2,377,708.00**
				Total (acres)	**59.44**
Area CCT27a:	**128.92**	**acres**		**Percentage**	**46.11%**
CCT29a	6,287,733.97	10,797.57	Quartz Fanoglomerate	Brunswick	959,464.00
CCT29a	6,287,733.97	10,797.57	Brunswick Fm	Brunswick	5,328,270.00
				Total (sq-ft)	**6,287,734.00**
				Total (acres)	**157.19**
Area CCT29a:	**157.19**	**acres**		**Percentage**	**100.00%**
CCT30a	4,339,722.76	9,563.43	Brunswick Fm	Brunswick	1,992,547.00
				Total (sq-ft)	**1,992,547.00**
				Total (acres)	**49.81**
				Percentage	**45.92%**
CCT30a	4,339,722.76	9,563.43	Diabase	Diabase	2,347,176.00

				Total (sq-ft)	**2,347,176.00**
				Total (acres)	**58.68**
Area CCT30a:	**108.49**	**acres**		**Percentage**	**54.08%**
CCT31a	4,609,981.03	12,135.14	Quartz Fanoglomerate	Brunswick	2,221,663.00
CCT31a	4,609,981.03	12,135.14	Brunswick Fm	Brunswick	2,388,318.00
				Total (sq-ft)	**4,609,981.00**
				Total (acres)	**115.25**
Area CCT31a:	**115.25**	**acres**		**Percentage**	**100.00%**
CCT32a	7,351,739.98	14,779.17	Quartz Fanoglomerate	Brunswick	2,472,367.00
CCT32a	7,351,739.98	14,779.17	Brunswick Fm	Brunswick	3,834,044.00
CCT32a	7,351,739.98	14,779.17	Lockatong Fm	Brunswick	1,045,329.00
	183.79			**Total (sq-ft)**	**7,351,740.00**
Area CCT32a:	**183.79**	**acres**		**Total (acres)**	**183.79**
				Percentage	**100.00%**

Table 6 (Continued)
Area 4

SUBBASIN ID	SUBBASIN AREA_	SUBBASIN PERIMETER_	GEOLOGIC FORMATION	HYDROGEOLOGIC UNITS	AREA
SC2a	12,321,788.43	18,983.31	Leithsville Fm	Limestone	492,641.00
				Total (sq-ft)	**492,641.00**
				Total (acres)	**12.32**
				Percentage	**4.00%**
SC2a	12,321,788.43	18,983.31	Granitic Gneiss	Crystalline	11,829,148.00
				Total (sq-ft)	**11,829,148.00**
				Total (acres)	**295.73**
Area SC2a:	**308.04**	**acres**		**Percentage**	**96.00%**
SC3a	4,460,811.92	12,547.89	Leithsville Fm	Limestone	406,948.00
				Total (sq-ft)	**406,948.00**
				Total (acres)	**10.17**
				Percentage	**9.12%**
SC3a	4,460,811.92	12,547.89	Granitic Gneiss	Crystalline	4,053,864.00
				Total (sq-ft)	**4,053,864.00**
				Total (acres)	**101.35**
Area SC3a:	**111.52**	**acres**		**Percentage**	**90.88%**
SCN2a	17,767,983.94	22,557.99	Leithsville Fm	Limestone	5,440,529.00
	444.20				
				Total (sq-ft)	**5,440,529.00**
				Total (acres)	**136.01**
				Percentage	**30.62%**
SCN2a	17,767,983.94	22,557.99	Granitic Gneiss	Crystalline	2,191,374.00
SCN2a	17,767,983.94	22,557.99	Hornblende Gneiss	Crystalline	638,324.00
				Total (sq-ft)	**2,829,698.00**
				Total (acres)	**70.74**
				Percentage	**15.93%**
SCN2a	17,767,983.94	22,557.99	Quartz Fanoglomerate	Brunswick	9,497,757.00

					Total (sq-ft)	**9,497,757.00**
					Total (acres)	**237.44**
Area SCN2a:	**444.20**	**acres**			**Percentage**	**53.45%**
SCN3a	4,785,559.01		10,933.15	Leithsville Fm	Limestone	1,098,969.00
					Total (sq-ft)	**1,098,969.00**
					Total (acres)	**27.47**
					Percentage	**22.96%**
SCN3a	4,785,559.01		10,933.15	Quartz Fanoglomerate	Brunswick	3,686,590.00
					Total (sq-ft)	**3,686,590.00**
					Total (acres)	**92.16**
Area SCN3a:	**119.64**	**acres**			**Percentage**	**77.04%**
SCS2a	6,894,998.12		12,280.80	Quartz Fanoglomerate	Brunswick	6,325,995.00
SCS2a	6,894,998.12		12,280.80	Brunswick Fm	Brunswick	569,003.00
					Total (sq-ft)	**6,894,998.00**
					Total (acres)	**172.37**
Area SCS2a:	**172.37**	**acres**			**Percentage**	**100.00%**
SCS3a	23,636,950.47		25,581.02	Quartz Fanoglomerate	Brunswick	19,823,338.00
SCS3a	23,636,950.47		25,581.02	Brunswick Fm	Brunswick	3,813,613.00
	590.92				**Total (sq-ft)**	**23636951**
					Total (acres)	**590.92**
Area SCS3a:	**590.92**	**acres**			**Percentage**	**100%**

Table 6 (Continued)
Area 5

SUBBASIN ID	SUBBASIN AREA	SUBBASIN PERIMETER	GEOLOGIC FORMATION	HYDROGEOLOGIC UNITS	AREA
CC14	67,282,517.85	64,252.49	Leithsville Fm	Limestone	5,680,276.00
CC14	67,282,517.85	64,252.49	Limestone Fanoglomerate	Limestone	2,021,236.00
				Total (sq-ft)	**7,701,512.00**
				Total (acres)	**192.54**
				Percentage	**11.45%**
CC14	67,282,517.85	64,252.49	Hardyston Fm	Crystalline	892,870.00
CC14	67,282,517.85	64,252.49	Granitic Gneiss	Crystalline	354,149.00
CC14	67,282,517.85	64,252.49	Hardyston Fm	Crystalline	1,122,274.00
CC14	67,282,517.85	64,252.49	Granitic Gneiss	Crystalline	5,023,488.00
				Total (sq-ft)	**7,392,781.00**
				Total (acres)	**184.82**
				Percentage	**10.99%**
CC14	67,282,517.85	64,252.49	Brunswick Fm	Brunswick	49,726,595.00
				Total (sq-ft)	**49,726,595.00**
				Total (acres)	**1,243.16**
				Percentage	**73.90%**
CC14	67,282,517.85	64,252.49	Diabase	Diabase	1,483,021.00
CC14	67,282,517.85	64,252.49	Diabase	Diabase	978,608.00
				Total (sq-ft)	**2,461,629.00**
				Total (acres)	**61.54**
Area CC14:	**1,682.06**	**acres**		**Percentage**	**3.66%**
CCT13	6,950,666.14	17,397.31	Leithsville Fm	Limestone	2,255,027.00
CCT13	6,950,666.14	17,397.31	Limestone Fanoglomerate	Limestone	1,696,295.00
				Total (sq-ft)	**3,951,322.00**
				Total (acres)	**98.78**
				Percentage	**56.85%**
CCT13	6,950,666.14	17,397.31	Hardyston Fm	Crystalline	607,898.00
CCT13	6,950,666.14	17,397.31	Granitic Gneiss	Crystalline	118,853.00
CCT13	6,950,666.14	17,397.31	Granitic Gneiss	Crystalline	18,055.00
				Total (sq-ft)	**744,806.00**
				Total (acres)	**18.62**
				Percentage	**10.71%**
CCT13	6,950,666.14	17,397.31	Brunswick Fm	Brunswick	2,254,539.00

				Total (sq-ft)	**2,254,539.00**
				Total (acres)	**56.36**
Area CCT13:	**173.77**	**acres**		**Percentage**	**32.44%**
CCT28	13,483,712.46	24,540.52	Brunswick Fm	Brunswick	9,973,263.00
				Total (sq-ft)	**9,973,263.00**
				Total (acres)	**249.33**
				Percentage	**73.97%**
CCT28	13,483,712.46	24,540.52	Diabase	Diabase	3,510,449.00
				Total (sq-ft)	**3,510,449.00**
				Total (acres)	**87.76**
Area CCT28:	**337.09**	**acres**		**Percentage**	**26.03%**
SC1	14,751,635.81	22,566.00	Leithsville Fm	Limestone	9,508,368.00
				Total (sq-ft)	**9,508,368.00**
				Total (acres)	**237.71**
				Percentage	**64.46%**
SC1	14,751,635.81	22,566.00	Granitic Gneiss	Crystalline	1,563,932.00
SC1	14,751,635.81	22,566.00	Hardyston Fm	Crystalline	2,877,834.00
SC1	14,751,635.81	22,566.00	Granitic Gneiss	Crystalline	801,503.00
				Total (sq-ft)	**5,243,269.00**
				Total (acres)	**131.08**
Area SC1:	**368.79**	**acres**		**Percentage**	**35.54%**
SCN1	34,579,629.51	25,082.55	Leithsville Fm	Limestone	12,570,198.00
				Total (sq-ft)	**12,570,198.00**
				Total (acres)	**314.25**
				Percentage	**36.35%**
SCN1	34,579,629.51	25,082.55	Granitic Gneiss	Crystalline	14,266,082.00
SCN1	34,579,629.51	25,082.55	Hornblende Gneiss	Crystalline	2,977,763.00
SCN1	34,579,629.51	25,082.55	Hardyston Fm	Crystalline	736,217.00
SCN1	34,579,629.51	25,082.55	Hornblende Gneiss	Crystalline	5,641.00
				Total (sq-ft)	**17,985,703.00**
				Total (acres)	**449.64**
				Percentage	**52.01%**
SCN1	34,579,629.51	25,082.55	Quartz Fanoglomerate	Brunswick	4,023,728.00

				Total (sq-ft)	**4,023,728.00**
				Total (acres)	**100.59**
Area SCN1:	**864.49**	**acres**		**Percentage**	**11.64%**
SCS1	17,686,242.50	25,211.81	Leithsville Fm	Limestone	7,316,628.00
SCS1	17,686,242.50	25,211.81	Limestone Fanoglomerate	Limestone	1,169,022.00
				Total (sq-ft)	**8,485,650.00**
				Total (acres)	**212.14**
				Percentage	**47.98%**
SCS1	17,686,242.50	25,211.81	Hardyston Fm	Crystalline	1,563,579.00
SCS1	17,686,242.50	25,211.81	Hardyston Fm	Crystalline	1,112,447.00
SCS1	17,686,242.50	25,211.81	Hornblende Gneiss	Crystalline	201,683.00
				Total (sq-ft)	**2,877,709.00**
				Total (acres)	**71.94**
				Percentage	**16.27%**
SCS1	17,686,242.50	25,211.81	Quartz Fanoglomerate	Brunswick	4,924,875.00
SCS1	17,686,242.50	25,211.81	Brunswick Fm	Brunswick	1,398,008.00
				Total (sq-ft)	**6,322,883.00**
				Total (acres)	**158.07**
Area SCS1:	**442.16**	**acres**		**Percentage**	**35.75%**

Table 6 (Continued)
Area 6

SUBBASIN ID	SUBBASIN AREA_	SUBBASIN PERIMETER_	GEOLOGIC FORMATION	HYDROGEOLOGIC UNITS	AREA
CC18a	20,926,830.09	18,260.54	Brunswick Fm	Brunswick	14,009,329.00
				Total (sq-ft)	**14,009,329.00**
				Total (acres)	**350.23**
				Percentage	**66.94%**
CC18a	20,926,830.09	18,260.54	Diabase	Diabase	6,917,501.00
				Total (sq-ft)	**6,917,501.00**
				Total (acres)	**172.94**
Area CC18a:	**523.17**	**acres**		**Percentage**	**33.06%**
CC19a	21,358,039.35	22,496.85	Brunswick Fm	Brunswick	20,986,857.00
				Total (sq-ft)	**20,986,857.00**
				Total (acres)	**524.67**
				Percentage	**98.26%**
CC19a	21,358,039.35	22,496.85	Diabase	Diabase	371,183.00
				Total (sq-ft)	**371,183.00**
				Total (acres)	**9.28**
Area CC19a:	**533.95**	**acres**		**Percentage**	**1.74%**
CC20a	101,454,375.26	62,795.67	Quartz Fanoglomerat	Brunswick	21,580,179.00
CC20a	101,454,375.26	62,795.67	Brunswick Fm	Brunswick	67,559,596.00
				Total (sq-ft)	**89,139,775.00**
				Total (acres)	**2,228.49**
				Percentage	**87.86%**
CC20a	101,454,375.26	62,795.67	Diabase	Diabase	3,843,843.00
CC20a	101,454,375.26	62,795.67	Diabase	Diabase	8,470,758.00
				Total (sq-ft)	**12,314,601.00**
				Total (acres)	**307.87**
Area CC20a:	**2,536.36**	**acres**		**Percentage**	**12.14%**
CC21a	30,114,438.51	40,419.57	Quartz Fanoglomerat	Brunswick	12,574,232.00
CC21a	30,114,438.51	40,419.57	Brunswick Fm	Brunswick	17,540,206.00

				Total (sq-ft)	**30,114,438.00**
				Total (acres)	**752.86**
Area CC21a:	**752.86**	**acres**		**Percentage**	**#DIV/0!**
CC22a	33,456,702.23	26,082.35	Quartz Fanoglomerat	Brunswick	10,770,158.00
CC22a	33,456,702.23	26,082.35	Brunswick Fm	Brunswick	22,686,545.00
				Total (sq-ft)	**33456703**
				Total (acres)	**836.42**
Area CC22a:	**836.42**	**acres**		**Percentage**	**100.00%**

Table 6 (Continued)
Area 7

SUBBASIN ID	SUBBASIN AREA	SUBBASIN PERIMETER	GEOLOGIC FORMATION	HYDROGEOLOGIC UNITS	AREA
CC15a	20,458,437.17	19,858.70	Leithsville Fm	Limestone	1,686,504.00
CC15a	20,458,437.17	19,858.70	Limestone Fanoglomerate	Limestone	2,731,719.00
				Total (sq-ft)	**4,418,223.00**
				Total (acres)	**110.46**
				Percentage	**21.60%**
CC15a	20,458,437.17	19,858.70	Hardyston Fm	Crystalline	906,397.00
				Total (sq-ft)	**906,397.00**
				Total (acres)	**22.66**
				Percentage	**4.43%**
CC15a	20,458,437.17	19,858.70	Brunswick Fm	Brunswick	15,133,817.00
				Total (sq-ft)	**15,133,817.00**
				Total (acres)	**378.35**
Area CC15a:	**511.46**	**acres**		**Percentage**	**73.97%**
CC16a	32,247,017.72	27,354.26	Quartz Fanoglomerate	Brunswick	6,430,055.00
CC16a	32,247,017.72	27,354.26	Brunswick Fm	Brunswick	25,816,963.00
				Total (sq-ft)	**32,247,018.00**
				Total (acres)	**806.18**
AreaCC16a:	**806.18**	**acres**		**Percentage**	**100.00%**
CC17a	7,068,638.71	11,257.63	Brunswick Fm	Brunswick	7,068,639.00
				Total (sq-ft)	**7,068,639.00**
				Total (acres)	**176.72**
Area CC17a:	**176.72**	**acres**		**Percentage**	**100.00%**

Table 6 (Continued)
Summary

GEOLOGIC FORMATION	HYDROGEOLOGIC UNITS	AREA
Leithsville Fm	Limestone	117,497,476.00
Allentown Fm	Limestone	17,666,321.00
Limestone Fanoglomerate	Limestone	3,900,741.00
Limestone Fanoglomerate	Limestone	4,102,324.00
	Total (sq-ft)	**143,166,862.00**
	Total (acres)	**3,579.17**
	Percentage	**17.29%**
Hardyston Fm	Crystalline	408,229.00
Hornblende Gneiss	Crystalline	19,485,877.00
Hardyston Fm	Crystalline	12,386,729.00
Granitic Gneiss	Crystalline	84,169,753.00
Granitic Gneiss	Crystalline	1,076,340.00
Granitic Gneiss	Crystalline	79,425.00
Hornblende Gneiss	Crystalline	23,208.00
Hornblende Gneiss	Crystalline	5,658,737.00
Hornblende Gneiss	Crystalline	8,695,541.00
Hornblende Gneiss	Crystalline	5,345,162.00
Hornblende Gneiss	Crystalline	28,049,352.00
Hardyston Fm	Crystalline	307,117.00
Hardyston Fm	Crystalline	40,618,624.00
Granitic Gneiss	Crystalline	2,201,139.00
Hardyston Fm	Crystalline	2,915,953.00
Hornblende Gneiss	Crystalline	3,616,088.00
Granitic Gneiss	Crystalline	12,173,044.00
Granitic Gneiss	Crystalline	164,275.00
Hornblende Gneiss	Crystalline	380,135.00
Hardyston Fm	Crystalline	6,470,083.00
Granitic Gneiss	Crystalline	5,843,045.00
Hardyston Fm	Crystalline	1,848,664.00
Hornblende Gneiss	Crystalline	207,324.00
	Total (sq-ft)	**242,123,844.00**
	Total (acres)	**6,053.10**
	Percentage	**29.25%**
Brunswick Fm	Brunswick	7,752,185.00
Quartz Fanoglomerate	Brunswick	2,167,691.00
Quartz Fanoglomerate	Brunswick	25,489,247.00
Quartz Fanoglomerate	Brunswick	99,636,906.00
Brunswick Fm	Brunswick	276,199,192.00
Lockatong Fm	Brunswick	1,045,329.00

	Total (sq-ft)	**412,290,550.00**
	Total (acres)	**10,307.26**
	Percentage	**49.80%**
Diabase	Diabase	8,400,522.00
Diabase	Diabase	9,213,941.00
Diabase	Diabase	3,843,843.00
Diabase	Diabase	8,841,940.00
	Total (sq-ft)	**30,300,246.00**
	Total (acres)	**757.51**
	Percentage	**3.66%**

Hydrogeologic Units	Percentage
Limestone	17.29%
Crystalline	29.25%
Brunswick	49.80%
Diabase	3.66%

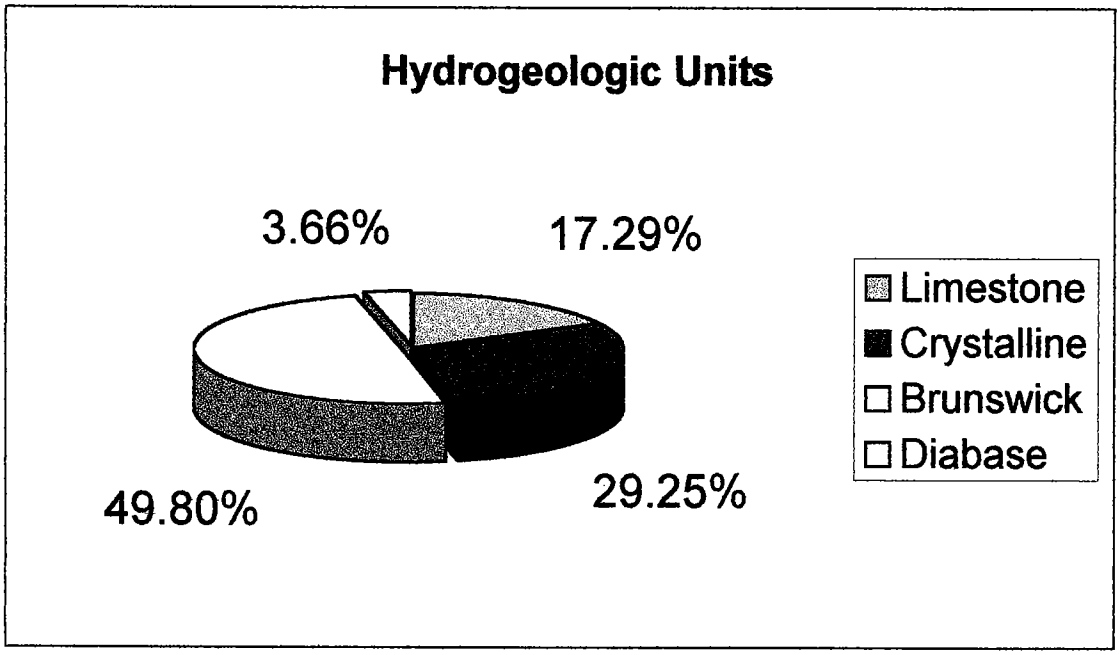


Table 7

EXISTING WATER USE BY SUBBASIN - AREA 1

SUBBASIN ID	SUBBASIN AREA (acres)	HYDROGEOLOGIC UNITS	BASE FLOW CONTRIBUTIONS (gpd/acre)	AREA (acres)	SUBBASIN APPROXIMATE EDUs	WATER USE (gpd)	ON - SITE WASTEWATER (gpd)	COMSUMPTIVE LOSS (20%) (gpd)	50% of SUBBASIN FORMATIONS CONTRIBUTIONS (gpd)	EXCEEDS LOSS GW SUBBASIN FORMATIONS CONTRIBUTIONS 1 Yes (Bad), 2 No (Good)	NITRATE LOAD (lb/yr)	NITRATE LIMIT (lb/yr)
CC2a	634.40	Carbonate Rocks	264	217	77	7,847		1,569	28,631	2		
CC2a		Crystalline	196	417		15,103		3,021	40,915			
Total:				634		22,950	18,360	4,590	69,546		2,516	19,399
CC6a	612.26	Carbonate Rocks	264	121	38	2,233		447	15,916	2		
CC6a		Crystalline	196	492		9,107		1,821	48,185			
Total:				612		11,340	9,072	2,268	64,101		1,243	18,722
CC9a	662.22	Carbonate Rocks	264	52	9	212		42	6,848	2		
CC9a		Crystalline	196	610		2,488		498	59,814			
Total:				662		2,700	2,160	540	66,662		296	20,250
CCT33a	220.65	Carbonate Rocks	264	8	17	185		37	1,081	2		
CCT33a		Crystalline	196	212		4,795		959	20,821			
Total:				221		4,980	3,984	996	21,902		546	6,747
CCT34a	269.04	Carbonate Rocks	264	46	20	1,034		207	6,028	2		
CCT34a		Crystalline	196	223		5,056		1,011	21,891			
Total:				269		6,090	4,872	1,218	27,919		668	8,227

Table 7

EXISTING WATER USE BY SUBBASIN - AREA 2

SUBBASIN ID	SUBBASIN AREA (acres)	HYDROGEOLOGIC UNITS	BASE FLOW CONTRIBUTIONS (gpd/acre)	AREA (acres)	SUBBASIN APPROXIMATE EDUs	WATER USE (gpd)	ON - SITE WASTEWATER (gpd)	COMSUMPTIVE LOSS (20%) (gpd)	50% of SUBBASIN FORMATIONS CONTRIBUTIONS (gpd)	EXCEEDS LOSS GW SUBBASIN FORMATIONS CONTRIBUTIONS 1 Yes (Bad), 2 No (Good)	NITRATE LOAD (lb/yr)	NITRATE LIMIT (lb/yr)
CC1	2,643	Carbonate Rocks	264	1,378	409	63,993		12,799	181,935	2		
CC1		Crystalline	196	1,264		58,707		11,741	123,917			
Total:				2,643		122,700	98,160	24,540	305,852		13,454	80,813
CCT10	61	Crystalline	196	41	4	773		155	4,046	2		
CCT10		Brunswick	214	20		367		73	2,098			
Total:				61		1,140	912	228	6,144		125	1,862
CCT8	539	Carbonate Rocks	264	78	33	1,448		290	10,318	2		
CCT8		Crystalline	196	387		7,168		1,434	37,925			
CCT8		Brunswick	214	74		1,374		275	7,934			
Total:				539		9,990	7,992	1,998	56,177		1,095	16,492

Table 7

EXISTING WATER USE BY SUBBASIN - AREA 3

SUBBASIN ID	SUBBASIN AREA (acres)	HYDROGEOLOGIC UNITS	BASE FLOW CONTRIBUTIONS (gpd/acre)	AREA (acres)	SUBBASIN APPROXIMATE EDUs	WATER USE (gpd)	ON - SITE WASTEWATER (gpd)	COMSUMPTIVE LOSS (20%) (gpd)	50% of SUBBASIN FORMATIONS CONTRIBUTIONS (gpd)	EXCEEDS LOSS GW SUBBASIN FORMATIONS CONTRIBUTIONS 1 Yes (Bad), 2 No (Good)	NITRATE LOAD (lb/yr)	NITRATE LIMIT (lb/yr)
CC11a	552.28	Carbonate Rocks	264	219	38	4,513		903	28,936	2		
CC11a		Crystalline	196	333		6,857		1,371	32,641			
Total:				552		11,370	9,096	2,274	61,577		1,247	16,888
CC12a	447	Carbonate Rocks	264	63	34	1,416		283	8,258	2		
CC12a		Crystalline	196	279		6,321		1,264	27,374			
CC12a		Brunswick	214	105		2,373		475	11,222			
Total:				447		10,110	8,088	2,022	46,853		1,109	13,661
CC4a	124.13	Carbonate Rocks	264	31	8	570		114	4,043	2		
CC4a		Crystalline	196	93		1,740		348	9,163			
Total:				124		2,310	1,848	462	13,206		253	3,796
CCT23a	140.79	Crystalline	196	1	9	23		5	121	2		
CCT23a		Brunswick	214	140		2,587		517	14,932			
Total:				141		2,610	2,088	522	15,054		286	4,305
CCT24a	154.91	Crystalline	196	0	11	2		0.3	8	2		
CCT24a		Brunswick	214	155		3,178		636	16,567			
Total:				155		3,180	2,544	636	16,575		349	4,737
CCT25a	261.78	Crystalline	196	124	18	2,548		510	12,175	2		
CCT25a		Brunswick	214	138		2,822		564	14,717			
Total:				262		5,370	4,296	1,074	26,892		589	8,005
CCT26a	389	Carbonate Rocks	264	15	29	343		69	2,006	2		
CCT26a		Crystalline	196	227		5,129		1,026	22,245			
CCT26a		Brunswick	214	147		3,318		664	15,709			
Total:				389		8,790	7,032	1,758	39,960		964	11,895
CCT27a	128.92	Brunswick	214	69	10	1,568		314	7,434	2		
CCT27a		Diabase	90	59		1,342		268	2,675			
Total:				129		2,910	2,328	582	10,109		319	3,942
CCT29a	157.19	Brunswick	214	157	12	3,540		708	16,820	2		
Total:				157		3,540	2,832	708	16,820		388	4,807
CCT30a	108.49	Brunswick	214	50	8	1,129		226	5,330	2		
CCT30a		Diabase	74	59		1,331		266	2,171			
Total:				108		2,460	1,968	492	7,501		270	3,318
CCT31a	115.25	Brunswick	214	115	9	2,610		522	12,332	2		
Total:				115		2,610	2,088	522	12,332		286	3,524
CCT32a	183.79	Brunswick	214	184	14	4,140		828	19,666	2		
Total:				184		4,140	3,312	828	19,666		454	5,620

Table 7

EXISTING WATER USE BY SUBBASIN - AREA 4

SUBBASIN ID	SUBBASIN AREA (acres)	HYDROGEOLOGIC UNITS	BASE FLOW CONTRIBUTIONS (gpd/acre)	AREA (acres)	SUBBASIN APPROXIMATE EDUs	WATER USE (gpd)	ON - SITE WASTEWATER (gpd)	COMSUMPTIVE LOSS (20%) (gpd)	50% of SUBBASIN FORMATIONS CONTRIBUTIONS (gpd)	EXCEEDS LOSS GW SUBBASIN FORMATIONS CONTRIBUTIONS 1 Yes (Bad), 2 No (Good)	NITRATE LOAD (lb/yr)	NITRATE LIMIT (lb/yr)
SC2a	308.04	Carbonate Rocks	264	12	58	700		140	1,626	2		
SC2a		Crystalline	196	296		16,820		3,364	28,981			
				308		17,520	14,016	3,504	30,607		1,921	9,420
SC3a	111.52	Carbonate Rocks	264	10	21	577		115	1,343	2		
SC3a		Crystalline	196	101		5,753		1,151	9,932			
				112		6,330	5,064	1,266	11,275		694	3,410
SCN2a	444	Carbonate Rocks	264	136	34	3,077		615	17,954	2		
SCN2a		Crystalline	196	71		1,601		320	6,933			
SCN2a		Brunswick	214	237		5,372		1,074	25,406			
				444		10,050	8,040	2,010	50,293		1,102	13,583
SCN3a	119.64	Carbonate Rocks	264	27	9	620		124	3,627	2		
SCN3a		Brunswick	214	92		2,080		416	9,862			
				120		2,700	2,160	540	13,488		296	3,658
SCS2a	172.37	Brunswick	214	172	13	3,900		780	18,444	2		
				172		3,900	3,120	780	18,444		428	5,271
SCS3a	590.92	Brunswick	214	591	57	16,950		3,390	63,229	2		
				591		16,950	13,560	3,390	63,229		1,858	18,070

Table 7

EXISTING WATER USE BY SUBBASIN - AREA 5

SUBBASIN ID	SUBBASIN AREA (acres)	HYDROGEOLOGIC UNITS	BASE FLOW CONTRIBUTIONS (gpd/acre)	AREA (acres)	SUBBASIN APPROXIMATE EDUs	WATER USE (gpd)	ON - SITE WASTEWATER (gpd)	COMSUMPTIVE LOSS (20%) (gpd)	50% of SUBBASIN FORMATIONS CONTRIBUTIONS (gpd)	EXCEEDS LOSS GW SUBBASIN FORMATIONS CONTRIBUTIONS 1 Yes (Bad), 2 No (Good)	NITRATE LOAD (lb/yr)	NITRATE LIMIT (lb/yr)
CC14	1,682.06	Carbonate Rocks	214	193	119	4,076		815	20,602	2		
CC14	1,682	Crystalline	196	185		2,075		415	18,112			
CC14	1,682	Brunswick	214	1243		14,822		2,964	133,019			
CC14	1,682	Diabase	90	62		1,257		251	2,769			
				1682		18,154	14,523	3,631	153,900		1,990	51,436
CCT13	174	Carbonate Rocks	264	99	13	2,234		447	13,039	2		
CCT13	174	Crystalline	196	19		421		84	1,825			
CCT13	174	Brunswick	214	56		1,275		255	6,031			
				174		3,930	3,144	786	20,895		431	5,314
CCT28	337.09	Brunswick	214	249	25	5,636		1,127	26,678	2		
CCT28	337.09	Diabase	90	88		1,984		397	3,949			
				337		7,620	6,096	1,524	30,628		835	10,308
SC1	368.79	Carbonate Rocks	264	238	70	13,516		2,703	31,378	2		
SC1	368.79	Crystalline	196	131		7,454		1,491	12,846			
				369		20,970	16,776	4,194	44,224		2,299	11,277
SCN1	864	Carbonate Rocks	264	314	164	17,863		3,573	41,482	2		
SCN1	864	Crystalline	196	450		25,559		5,112	44,065			
SCN1	864	Brunswick	214	101		5,718		1,144	10,763			
				864		49,140	39,312	9,828	96,310		5,388	26,435
SCS1	442	Carbonate Rocks	264	212	21	3,037		607	28,003	2		
SCS1	442	Crystalline	196	72		1,030		206	7,050			
SCS1	442	Brunswick	214	158		2,263		453	16,914			
				442		6,330	5,064	1,266	51,967		694	13,521

Table 7

EXISTING WATER USE BY SUBBASIN - AREA 6

SUBBASIN ID	SUBBASIN AREA (acres)	HYDROGEOLOGIC UNITS	BASE FLOW CONTRIBUTIONS (gpd/acre)	AREA (acres)	SUBBASIN APPROXIMATE EDUs	WATER USE (gpd)	ON - SITE WASTEWATER (gpd)	COMSUMPTIVE LOSS (20%) (gpd)	50% of SUBBASIN FORMATIONS CONTRIBUTIONS (gpd)	EXCEEDS LOSS GW SUBBASIN FORMATIONS CONTRIBUTIONS 1 Yes (Bad), 2 No (Good)	NITRATE LOAD (lb/yr)	NITRATE LIMIT (lb/yr)
CC18a	523.17	Brunswick	214	350	39	7,913		1,583	37,475	2		
CC18a	523.17	Diabase	90	173		3,907		781	7,782			
				523		11,820	9,456	2,364	45,257		1,296	15,998
CC19a	533.95	Brunswick	214	525	40	11,859		2,372	56,140	2		
CC19a	533.95	Diabase	90	9		210		42	418			
				534		12,069	9,655	2,414	56,557		1,323	16,328
CC20a	2,536.36	Brunswick	214	2228	243	63,972		12,794	238,449	2		
CC20a	2,536.36	Diabase	90	308		8,838		1,768	13,854			
				2,536		72,810	58,248	14,562	252,303		7,983	77,559
CC21a	752.86	Brunswick	214	753	72	21,600		4,320	80,556	2		
				753		21,600	17,280	4,320	80,556			
CC22a	836.42	Brunswick	214	836	80	24,000		4,800	89,497	2		
				836		24,000	19,200	4,800	89,497		2,631	25,577

Table 7

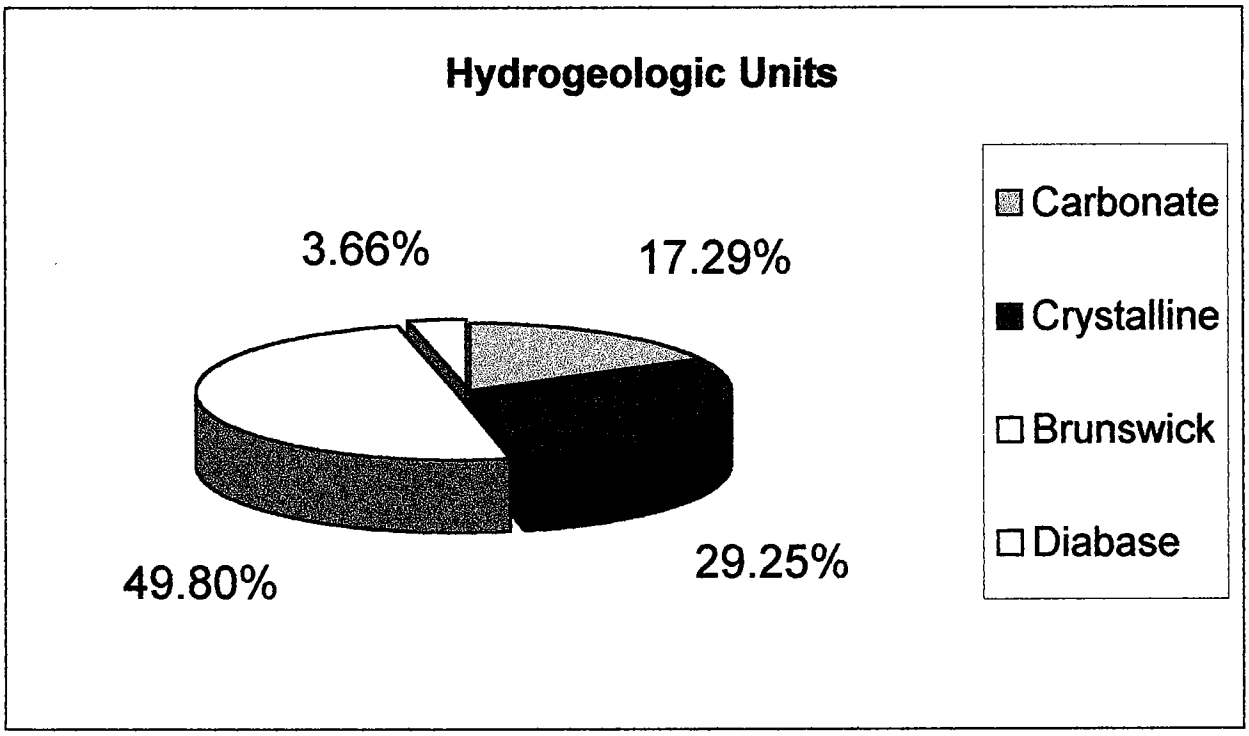
EXISTING WATER USE BY SUBBASIN - AREA 7

SUBBASIN ID	SUBBASIN AREA (acres)	HYDROGEOLOGIC UNITS	BASE FLOW CONTRIBUTIONS (gpd/acre)	AREA (acres)	SUBBASIN APPROXIMATE EDUs	WATER USE (gpd)	ON - SITE WASTEWATER (gpd)	COMSUMPTIVE LOSS (20%) (gpd)	50% of SUBBASIN FORMATIONS CONTRIBUTIONS (gpd)	EXCEEDS LOSS GW SUBBASIN FORMATIONS CONTRIBUTIONS 1 Yes (Bad), 2 No (Good)	NITRATE LOAD (lb/yr)	NITRATE LIMIT (lb/yr)
CC15a	511	Carbonate	264	110	24	1,583		317	14,580	2		
CC15a	511	Crystalline	196	23		325		65	2,221			
CC15a	511	Brunswick	214	378		5,422		1,084	40,483			
				511		7,329	5,863	1,466	57,284		804	15,640
CC16a	806.18	Brunswick	214	806	57	17,070		3,414	86,261	2		
				806		17,070	13,656	3,414	86,261		1,872	24,652
CC17a	176.72	Brunswick	214	177	17	5,070		1,014	18,909	2		
				177		5,070	4,056	1,014	18,909		556	5,404

GEOLOGIC FORMATION	HYDROGEOLOGIC UNITS	AREA
Leithsville Fm	Carbonate	117,497,476.00
Allentown Fm	Carbonate	17,666,321.00
Limestone Fanoglomerate	Carbonate	3,900,741.00
Limestone Fanoglomerate	Carbonate	4,102,324.00
	Total (sq-ft)	**143,166,862.00**
	Total (acres)	**3,579.17**
	Percentage	**17.29%**
Hardyston Fm	Crystalline	408,229.00
Hornblende Gneiss	Crystalline	19,485,877.00
Hardyston Fm	Crystalline	12,386,729.00
Granitic Gneiss	Crystalline	84,169,753.00
Granitic Gneiss	Crystalline	1,076,340.00
Granitic Gneiss	Crystalline	79,425.00
Hornblende Gneiss	Crystalline	23,208.00
Hornblende Gneiss	Crystalline	5,658,737.00
Hornblende Gneiss	Crystalline	8,695,541.00
Hornblende Gneiss	Crystalline	5,345,162.00
Hornblende Gneiss	Crystalline	28,049,352.00
Hardyston Fm	Crystalline	307,117.00
Hardyston Fm	Crystalline	40,618,624.00
Granitic Gneiss	Crystalline	2,201,139.00
Hardyston Fm	Crystalline	2,915,953.00
Hornblende Gneiss	Crystalline	3,616,088.00
Granitic Gneiss	Crystalline	12,173,044.00
Granitic Gneiss	Crystalline	164,275.00
Hornblende Gneiss	Crystalline	380,135.00
Hardyston Fm	Crystalline	6,470,083.00
Granitic Gneiss	Crystalline	5,843,045.00
Hardyston Fm	Crystalline	1,848,664.00
Hornblende Gneiss	Crystalline	207,324.00
	Total (sq-ft)	**242,123,844.00**
	Total (acres)	**6,053.10**
	Percentage	**29.25%**
Brunswick Fm	Brunswick	7,752,185.00
Quartz Fanoglomerate	Brunswick	2,167,691.00
Quartz Fanoglomerate	Brunswick	25,489,247.00
Quartz Fanoglomerate	Brunswick	99,636,906.00
Brunswick Fm	Brunswick	276,199,192.00
Lockatong Fm	Brunswick	1,045,329.00
	Total (sq-ft)	**412,290,550.00**
	Total (acres)	**10,307.26**
	Percentage	**49.80%**

Diabase	Diabase	8,400,522.00
Diabase	Diabase	9,213,941.00
Diabase	Diabase	3,843,843.00
Diabase	Diabase	8,841,940.00
	Total (sq-ft)	**30,300,246.00**
	Total (acres)	**757.51**
	Percentage	**3.66%**

Hydrogeologic Units	Percentage
Carbonate	17.29%
Crystalline	29.25%
Brunswick	49.80%
Diabase	3.66%



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.

IX. MANAGEMENT OPTIONS AND RECOMMENDATIONS

The overall goal of the Cooks Creek Watershed Conservation Plan is to formulate a management program that truly sustains water resource through utilization of Best Management Practices (BMPs). 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. Ensuring a Sustainable Watershed Management

Based upon a set of assumptions with respect to the number of dwelling units in each sub-watershed the consumptive water use per dwelling unit was calculated to be 300 gallon per day per dwelling unit (GPD/DU). This calculation does not reflect any concern based upon existing zoning with respect to water resources. If zoning restrictions were to be changed, the current calculations with respect to the Equivalent Dwelling Unit (EDU) would require re-investigation. Water demands for agriculture are also not included in the current estimate. Additional work must be completed to assess the agricultural component of the EDU equation. Continued work should be considered to maintain a Sustainable Watershed Management plan.

2. Monitoring Cooks Creek Flow

The critical base flow condition (Q7-10) values are used in the Water Balance Model. The Q7-10 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 the Rating Curve for the Red Bridge Road Gauging Station.* The Rating Curve requires:
    - riverbed profile measurements; and,
    - stream flow velocity.

- *Hourly River Stage Recording* – This data is periodically downloaded from the monitoring station in WAMOS computer application.

- *A Second Stream Gauging Station should be Installed* – A second stream gauge station should be installed in the eastern edge of the sub 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. Monthly Water Level Measurements

Water levels should be measured monthly at 4 to 6 residential wells. This data is used in groundwater storage and water budget calculations. These calculations are also included in the WAMOS application.

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 should be measured for depth to water to upgrade the water table map.

5. Expand the GIS Database and Computer Application WAMOS

As more watershed related data becomes available, GIS and computer applications should be expanded to incorporate all new data.

6. Maintain a Water Quality Monitoring Program

The visual stream assessment results indicated marginal and poor conditions in the areas of the watershed that were studied. In order to expand water quality monitoring information and track improvement, the following community programs should be encouraged:

- School students workshop;
- Visual assessment Snap- Shot, DRBC Program.

7. 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:

- Stream water quality monitoring;
- Maintaining current or limited ground water levels in order to protect against excessive groundwater draw down;
- 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.

- Public awareness of non-point source pollution;
- Minimization practices for point and non-point source pollutants;
- Implementation of animal nutrient management plans;
- Improving farming practices especially with respect to livestock stream crossings and stream corridor livestock fencing initiatives; and,
- Improving riparian buffer management along tributaries.

8. 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.

9. Ordinance Preparation

The following GIS database related features should be considered for zoning ordinance and Comprehensive Plan preparation.

- Aquifer recharge& flood control;
- Conservation easements;
- 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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APPENDIX A

Previous Cooks Creek Watershed Investigations

Summary of:
Cooks Creek, Bucks, Lehigh, and Northampton Counties, Special Protection Evaluation Report, Water Quality Standards Review,
Quality Assessment Unit, Division of Water Quality, Bureau of Water Quality Management, PADER, July 1990.

Surface Water

Water chemistry from surveys of the Cooks Creek basin by the Pennsylvania Fish Commission and the Bureau of Water Quality Management reveal excellent water quality, which is better than all applicable criteria. These surveys demonstrate that the main stem of Cooks Creek is a naturally fertile, slightly alkaline, well-buffered limestone-influenced stream. Most of the limestone influence can be attributed to springs and tributaries in the vicinity of Springtown. For all samples collected from the basin, pH values are between 7 and 9.5, with hardness and alkalinity values ranging from 40 to 160 mg/1 and 20 to 110 mg/1, respectively.

No permitted discharges are located within the basin, however, a number of potential agricultural related non-point sources of pollution do exist. Given the vast extent of agricultural lands (pasture and cropland) in the basin, Cooks Creek would appear to be highly susceptible to runoff of fertilizers and manure; however, water quality samples do not indicate any serious problems. Unfortunately, the same cannot be said for livestock access to stream channels. Within a number of tributary basins, most notably UNTs 7 and 15 (Figure 1), livestock have complete and unrestricted access to the stream. The results are increased erosion, loss of riparian vegetation, and reduced instream habitat diversity. Although livestock only have access to a very limited %age of the total miles of stream channel in the watershed, aquatic biota within the Cooks Creek basin would benefit from eliminating these sources of water quality and habitat degradation.

Aquatic Biota

Terrestrial Biota

Wetlands and Species of Special Concern

The value of the wetlands includes their function in stabilizing stream flow, maintaining water quality, and as habitat for numerous plant and wildlife species. At least one wetland in the basin is of exceptional ecological significance, supporting numerous rare and endangered wildlife and plant species. In response to both state and federal actions, the Department is placing a high priority on the protection of ecologically valuable wetlands. In light of this, it is appropriate that the Bureau of Water Quality Management provide the highest

degree of protection available to the water resources supporting wetlands in the Cooks Creek basin.

Ten species of special concern in Pennsylvania have been recorded from the Cooks Creek Watershed (Table 8). Although six plant species have not been officially observed in over sixty years, it is possible that they are still present but have not been recently observed. The Nature Conservancy has documented the current existence of several endangered herpetofaunal species in the basin, including the bog turtle, the eastern mud salamander, and the red-bellied turtle. These three species have been located in a single palustrine (open water, forested, and emergent) wetland which also supports spotted and wood turtles and a number of significant wildflowers and shrub species. The landowners, in recognition of the site's significant natural resources, have entered the wetland into a conservation easement.

Summary of:
PA Fish and Boat Commission,
Comments and Recommendations,
Cooks Creek, Bucks County, June 1992

Adult trout were first stocked in Cooks Creek. in 1939. The PFBC continued to stock adult trout in Cooks Creek until 1975, when trout stocking was discontinued due to landowner posting. The stream sections stocked with trout varied over the years, and ranged from near the source to one mile upstream from the mouth. Numbers and species of trout stocked also varied, with brown trout (Salmo trutta), brook trout (Salvelinus fontinalis), and rainbow trout (Oncorhynchus mykiss) all being stocked at one time or another.

Cooks Creek. was divided into three sections for fisheries management purposes. The sectioning strategy was based on water quality, physical habitat, wild trout density, and accessibility differences among the three sections. Physical and social data were collected for these sections, but parking counts were not made. The %age of private land open to public fishing was determined by contacting landowners in the sections.

Discussion

Cooks Creek. is a moderately alkaline, well-buffered limestone stream that supports excellent aquatic macroinvertebrate populations and a Class A wild brown trout population. Class A wild trout populations are also present in Silver Creek. and Coon Hollow Run, small tributary streams to Cooks Creek. The wild brown trout populations in the Cooks Creek. basin are unique in Bucks County, and the wild brook trout population in Coon Hollow Run is not only unique in Bucks County, but is also very rare in the entire Area 6 fisheries management region. Both surface and groundwater resources in the basin, on which the Class A wild trout populations depend, are very susceptible to contamination due to the limestone nature of the underlying geology. Because of its uniqueness, its proximity to heavily developed areas, the sensitivity of its environment, and its scenic and historical qualities, the DER should continue to protect the Cooks Ck. basin with EV-CWF designation.

No trout longer than 350-374 mm (14.5 in.) were seen or captured during the survey, indicating that trophy size fish reported by anglers are truly rare fish in Cooks Creek. Habitat for large trout is limited by relatively low flows for a limestone spring creek and a very scanty distribution of deep channels and pools. Physical habitat improvement, especially in Section 03 (between Red Bridge Road bridge and the mouth of Cooks Creek), would benefit wild trout populations in Cooks Creek. Physical habitat improvement should be directed toward narrowing and deepening the channel, which can best be accomplished through the use of various current deflector devices and rip-rap.

Summary of:
Pa Fish and Boat Commission,
Comments and Recommendations,
Cooks Creek, Bucks County, April 1993

Discussion

Coon Hollow Run is a dolomitic limestone spring run that boasts excellent water quality. The presences of some pollution sensitive aquatic macroinvertebrate taxa and fish species reflect its excellent water quality. Excessive siltation is currently the only major source of pollution in the basin. The fish community is dominated by a Class A wild brook trout population and an abundant mottled sculpin population. Because of its excellent water quality and rare (for southeastern Pennsylvania) wild brook trout and mottled sculpin populations, Coon Hollow Run merits its EV-CWF designation.

Coon Hollow Run is not listed separately in the Pennsylvania Department of Environmental Resources (DER) chapter 93 Water Quality Standards. Coon Hollow Run is considered part of the Cooks Creek basin, which is designated as an exceptional value coldwater fishery (HV-CWF) Currently permitted discharges to Coon Hollow Run are not known and the Pennsylvania Fish and boat commission (PFBC) has no pollution reports on file for the stream.
The objective of the investigation was to gather baseline data on the physical, social, chemical, and biological characteristics of Coon Hollow Run, and to formulate a fisheries management plan based oh the survey results.

Results

Water quality in Coon Hollow Run was excellent, with excessive siltation the only major source of pollution noted during the survey. The limestone nature of the stream was a product of the underlying geology of the watershed, and provided excellent buffering capacity and good fertility. Aquatic macroinvertebrate community composition was reflective of the excellent water quality, as some pollution intolerant forms were present in the stream. While aquatic macroinvertebrate diversity was only rated as fair, this is typical of limestone spring runs.

Fish community composition also reflected Coon Hollow Run's excellent water quality, Coon Hollow Run supported the only documented Class A wild brook trout population in Bucks Counnty, and one of the few documented Class A wild brook trout populations in southeastern Pennsylvania. Because of its excellent water quality and rare limestone brook trout and mottled sculpin populations, Coon Hollow Run merits its EV-CWF designation.

Statewide angling regulations are adequate to protected this Class A wild brook trout population. The stream is narrow, making fishing difficult, and access is limited. Thus, angling pressure is presumably low.

Summary of:
Final Report, Bioassessment of Cook's Creek, Rodges Run, Coon Hollow Run and the Unnamed Brook, Durham, PA
W. Scott Douglas Symbiosis Environmental, September 1998

Discussion

The objectives of the surveys were 1) to determine the overall health of the benthic communities relative to historical data, and; 2) to determine if Rodges Run And Unnamed Brook are worthy of detailed studies in support of petitions for upgrades in water quality status. The surveys were conducted during spring, summer and fall of 1997, with additional samples taken during the spring of 1998. A taxonomic expert processed samples and the communities assessed the utilizing standard USEPA (1989) procedures.

The purpose of the survey was to monitor the condition of the benthic communities in the Township's Exceptional Value streams and to evaluate the benthic communities in the remainder of the Township's surface waters. Taxonomic analysis was performed by Symbiosis Environmental and the results are detailed in four interim reports (Symbiosis Environmental 1997a,b,c and 1998). Benthic communities in the Townships exceptional value streams: Cooks Creek and Coon Hollow Run were compared to historical data.

Comparisons of the communties found at different locations within watershed were also made to assess potential impacts of localized land use within each watershed. It was planned that these data could be used by the DTEAC to gauge the surface water quality in the Township, as well as to assess the effectiveness of local land use policies in the protection of these valuable resources.

Results

Habitat Evaluation, Cooks Creek

Upstream: The samples were taken in the mainstem of Cooks Creek, approximately ½ mile after the creek enters Durham Township, just downstream from the confluence of Frye's Run (see Figure 1): Surrounding land use is forested and agriculture (tree farm). The canopy was mature with-oaks, maples and sycamores predominant. Light penetration was moderate. The banks were steep on the south side with signs of erosion. The banks on the north side were gently sloped with wetlands and natural understory vegetation. Both banks had adequate natural buffer. Samples were taken in the riffles, where substrate was large cobble, gravel and sand. Some amount of settled particulate matter was observed in the area, notably so in the nearby run habitat. Rocks were covered with moss and algae, but there were relatively little filamentous green algae present. The velocity ranged from 0.7 to 1.3 m/s with a wetted width varying from 20 to 25 meters. Benthic kick samples were taken in the middle, north and south sides and then composited.

Downstream: samples were taken in the mainstem of Cooks Creek, approximately 1/2 mile downstream from where Stout's Valley Road crosses the creek and adjacent to Red Bridge Road (see Figure 1). Surrounding land use was forested and rural residential. The canopy was mature with oaks, maples and sycamores predominant. Light penetration was good, with the trees overhanging the streambanks. The banks on both sides were relatively steep, with signs of erosion, but less so than observed at the upstream station. The north bank was more natural, with a relatively stable bank, but naturally quite steep. The south bank was bordered closely by Red Bridge Road with little or no natural buffer remaining. The result was a somewhat channelized stream flow and little natural filter for stormwater runoff from the development on the south bank and no capacity for attenuation. Samples were taken in the riffle area, where the substrate was medium cobble, gravel and sand. Some amount of settled particulate matter was observed, notably more in the slower run habitats. The rocks held no moss, but some were covered with brownish-green algae and aufwuchs. The velocity ranged from 0.71 to 2.0 m/s with a wetted width varying from 25 to 30 meters. Benthic kick samples were taken in the middle, north and south banks and then composited. The middle sample was in shallow water, with the bank samples being in relatively deeper and faster moving water. Coarse particulate matter was collected from leaf packs and in the slower moving run upstream of the riffle area.

Habitat Evaluation, Coon Hollow Run

Headwater: The headwater sample was taken on the south side of Lehnenburg Road just upstream from the culvert, immediately west of the intersection of Lehnenburg Road and Coon Hollow Road (see Figure 1). The banks on both sides were steep, with a paved driveway bordering the east bank and a secondary tree stand of birch and oak bordering the west. The wetted width was only approximately 1.0 meter or less, with velocity of 0.22 m/s. The landowner had mown down to the water on the east bank, but natural vegetation predominated on the west. Light penetration varied from open to partly shaded. Signs of slight erosion was present with some amount of silt present in slower moving pools. Surrounding land use was residential and unused pasture. Substrate was small cobble, gavel and sand. Three benthic kick samples were taken in three riffle areas and composited.

A second headwater site was sampled during the spring of 1998, in order to further characterize the headwaters and to assure the township that the proximity of the first station to the driveway was not impacting the overall interpretation of the survey. This site was located at the intersection of Gallows Hill Road and Lehnenburg Road and is approximately in the location of previous PADER sampling. The station is on the northwest corner of the intersection and is characterized by overgrown pasture and alder. The stream banks are heavily vegetated and shaded. Light penetration ranged from partly open to shaded. No signs of erosion were visible. The stream was approximately 1-2 meters in width, with a velocity of 0.4 meters per second. Rifle areas varied from 2 to 5 inches in

depth with cobble and gravel substrate. Runs were 9-13 inches in depth with some deep pools (greater than 24 inches). Substrate in pools was sandy silt with pockets of organic detritus.

Upstream: The upstream sample was taken approximately ½ mile down Coon Hollow Road from Lehnenburg Road just upstream from a landowner residing on the west bank across a small private bridge (see Figure 1). The stream enters mature woods at this point comprised of oaks, maples and sycamores. Light penetration was moderate, with adequate bank shading. The unpaved road followed the stream closely on the east bank, with only about 5 meters of buffer. The west bank was naturally steeply sloped, with the flat areas taken by rural residences. The landowner mowed almost up to the stream banks, but natural understory vegetation (gasses, shrubs, berry bushes) predominated outside of a small yard area. Erosion was not apparent, although some silt was present in pools. This silt was more organic in nature than that observed lower in the watershed. The wetted width was 2-3 meters, with a velocity of 0.33 to 0.5 m/s. Substrate was boulders and large cobble, gravel and sand. The rocks were covered with moss and algae, but very little filamentous green algae were observed. Kick net samples were taken in three rifle areas moving upstream during sampling.

Downstream: The downstream samples were taken approximately 100 yards upstream of route 212 in unused pasture surrounded by rural residential development (see Figure 1). The stream bank is well buffered, with very little sign of localized erosion. Some mature trees line the stream bank, and understory vegetation approaches and overhangs the banks. Substrate is medium cobble, gravel and sand. The light penetration is partly shaded. Silt was not present in riffle areas, but became deep in pool areas, indicating an upstream source (possibly the unpaved road). The wetted width was 2.0 to 7.0 meters with a velocity of 0.3 to 0.5 m/s. Rocks are covered with moss and algae, but very little filamentous green algae was observed. Kick net samples were taken in three riffles, with attempts to sample the middle, and both banks when sufficient width was available. Coarse particulate matter was taken from leaf packs and from pool litter.

Benthic Community Bioassessment

A summary was prepared of the community metrics calculated during each of the sampling periods, for each watershed (Appendix ___, 5-8). These data were used to answer several questions concerning the health of the benthic communities in each watershed. To determine if current land use practices have altered the water quality of Cooks Creek and Coon Hollow Run compared to the water quality present at the time that Exceptional Value status was granted, comparisons were made to historical data. To determine if localized land use in a watershed was impacting water quality, comparisons of downstream stations to upstream stations within a watershed were made. In order to determine the potential impacts of drought conditions observed in the summer and fall of 1997, comparisons of benthic community structure were made using the Spring

sampling as a reference. Additional sampling in the spring of 1998 allowed for determination of recovery of the Unnamed Brook community by using the spring 1997 sampling as a reference.

In Cooks Creek, low flow conditions in the fall resulted in slight to moderate impacts (Appendix ____, Table 9). The changes observed include a significant loss of sensitive mayfly, caddisfly and stonefly taxa and a shift in the scraper/filterer ratio to more filterers. Also observed was an increase in the %age of the most dominant taxa. There were no observed impacts to benthic community structure when comparing upstream and downstream stations, indicating that Township land use practices do not impact the benthic community in Cooks Creek. Comparisons to historical data indicate that there has been no change (or slight improvement) in the quality of the benthic community over time.

In Coon Hollow Run, low flow conditions resulted in lower impacts to the benthic community than in Cooks Creek, but slight impacts were observed in the downstream station (Appendix ___ , Table 10). Localized land use practices appear to impact the creek slightly as it flows through the township, however comparison to historical data indicate no changes over time.

Summary of:
Natural Areas Inventory of Bucks County, Pennsylvania
Ann F. Rhoads & Timothy A. Block,
Morris Arboretum of the University of Pennsylvania, June 30, 1999

Discussion

An inventory of natural features of Bucks County has been carried out. Starting with records from Pennsylvania Natural Diversity Inventory (PNDI) and other historical data, 240 individual sites were surveyed for unusual plants, animals, natural communities, and geological and hydrological features. Criteria were developed to evaluate and prioritize the sites. Of the total sites surveyed, some were grouped into larger "megasites" and 29 were eliminated from consideration.The result of 115 sites prioritized at four levels of importance. All sites listed have important resources. In the highest priority levels, Bucks County contains natural resources of statewide importance.

In Upper Bucks the diabase zone that stretches across the county remains mostly forested. This region is also very important because of its continuous forest cover and unusual geology. It provides habitat for birds and other species that depend on extensive tree-covered areas, and is likely the source of some of the bird diversity seen elsewhere in the county. Several complete stream valleys (i.e. Cooks Creek) were also included in the high-priority site lists due to their high quality aquatic resources, ecological integrity, and the diversity of species they contain.

The evaluation of sites was based on biological, ecological, geological, and hydrological criteria. We did not distinguish between sites that are already protected entirely or in part, and those that are not. Some partially protected sites require additional measures to secure important adjacent areas. In other cases the information gathered in our survey will assist in determining management needs or strategies.

Flora

Human Impact

Few early descriptions of the flora exist, and those that are available are fragmentary. However, it is clear that Bucks County originally was completely forested. Native American tribes created small clearings to grow corn and beans and may have used fire to manage game on a larger scale, but when the earliest European settlers arrived, the county was still primarily forest covered. Bucks County was one of the earliest parts of the state to be settled by Europeans beginning in the 1670s. The land was cleared for agriculture and settlements until the only forested lands remaining were those unsuited for agriculture due to steepness, excessive rockiness, or the presence of a high water table. There are no intact old growth forests remaining in the county, however individual old trees

persist. The Bucks County Audubon Society maintains a big tree register, which contains records of the largest examples of each species.

Towns sprang up along early roads and later the Delaware Canal which was in use for approximately 100 years beginning in 1832. The industrial revolution and improved rail transportation followed by the automobile brought changes leading to the development of the county as a vacation destination or location for a country home. As of 1990, the latest year for which data are available, the % of land classified as agricultural or vacant by region was 62% in Upper Bucks (BCPC 1994). In recent years the most intensive development pressure has shifted from the lower part of the county to central areas and is spreading northward.

Role of natural resources

The natural features of Bucks County provided the needs of the early residents and attracted the attention of waves of settlers who established productive farms. Local mineral and forest resources supported the development of early industry such as the Durham Iron Works, which used nearby deposits of iron ore and limestone plus charcoal made from forest trees. Later, as a modern transportation-based economy developed, the natural setting of the county remained an attraction leading to the development of a strong tourism segment in the local economy dependent on natural beauty, clean air, and clean water.

From the earliest human use to the present, natural systems in the form of fields, forests, streams, and wetlands have provided essential ecosystem services without which human communities could not continue to exist. Its easy to forget that when we send partially treated wastewater into streams we are counting on natural systems to finish the job of cleaning up; or when we emit carbon dioxide and other pollutants into the atmosphere from our cars and smokestacks we expect those pollutants to be absorbed and transformed. Supplies of air and water are finite and must be recycled again and again. Only when we overwhelm the ability of natural systems to absorb and transform our wastes do we begin to appreciate the role of these essential ecological services. The functioning of natural systems depends on their remaining intact with all their interacting parts. The loss of species threatens the functioning of the whole. Rare species serve as the proverbial "canary in the mine", warning us that ecosystems are stressed and may be reaching a point where they can no longer function.

A goal of an open space protection program must be to preserve ecosystem functions such as air, water, and mineral recycling, photosynthesis, pollination, climate moderation, and soil formation (Daily 1997) and thus earth's ability to support future generations of humans.

Results

Analysis and evaluation of the data available for the 240 sites considered in this survey for the entire Bucks County resulted in classification at four levels of importance (see prioritized lists below) based on the criteria described above. Twenty-nine sites were eliminated from further consideration. All sites listed have significant biological, ecological, geological, or hydrological features. Differences between sites within each category are not significant. In arriving at decisions regarding site categorization, the authors emphasized ecologically sustainable sites to the extent that we could make that judgment; hence the number of large forested areas, wooded ridge tops, and entire stream valleys. For the most part it was not included small isolated sites that, although they contain remnant populations of rare species, are not part of a sustainable natural community or system.

Out of 115 sites, six sites are located entirely or partially within Cooks Creek Watershed.

Summary of:
Cooks Creek Watershed Monitoring and Planning Program, Wetlands Management Plan, DTEAC / MJE, May 22, 2000

Discussion

The goal of the project was to provide information to the DTEAC for a wetlands conservation plan that would be supported by the municipalities and will be integrated with a total water resources management plan of the hydrologic system within the project area.

The principal objectives of the project included:

- Wetland delineation and determining the soils characteristics of the study area;
- Delineating Karst features, and other hydrogeologic properties of the geologic formations in the study area;
- Determining the important hydrologic characteristics and preparing a water budget of the study area;
- Cooks Creek continuous stage recording and computation of discharge; and,
- Initial GIS development, structured to allow for the inclusion of additional information collected in the future.

The central element of the fieldwork for this project was collecting data to develop a Wetland Management Plan for the study area. This was accomplished through review of available literature for the study area, site reconnaissance, and field measurements. This phase of the project does not include any sampling and analysis of surface water, groundwater, or soil to determine "water quality".

Surface water bodies and wetlands in the Cooks Creek Watershed, within Durham Township and Springfield Township, were identified using the existing National Wetlands Inventory Maps (NWI), the existing County Soil Survey, and using field techniques consistent with the U.S. Army Corps of Engineers Wetlands Delineation Manual (1987). The fieldwork targeted potential wetland areas that do not appear on the NWI maps, such as areas with hydric soils that are not delineated. Wetland functions and values were also identified by using the Wetland Evaluation Technique (WET II) developed by the US Army Corps of Engineers (1987). Finally, a database search and field reconnaissance was conducted of threatened and endangered species within the Cooks Creek Watershed.

The geological survey task included a desktop study and follow-up field reconnaissance. The existing database of groundwater wells in this area from The Pennsylvania Department of Conservation and Natural Resources (PaDCNR) was reviewed. Selection of wells to be surveyed included those that

provided a spatial distribution in relation to main topographic features. These features include: divides, Cooks Creek tributaries, wetlands, flat areas, side hills, etc.

Water level measurements were collected at selected wells. The measurements were based on depth to water from the ground surface (USGS Quadrangle Maps, scale1:24,000 determined the ground surface elevation of selected wells.). One round of water level was collected over a three-day period. A drawing of the groundwater table map was generated for a 20-foot contour interval and was included in the GIS graphics and 3-D block diagram representation.

The preliminary water budget was estimated as the amount of water entering and leaving the basin, plus or minus changes in storage, for a given period of time. Water enters as precipitation and leaves in several ways: as stream flow, ground-water underflow, diversion of groundwater from the basin where it was pumped, and evapotranspiration, plus or minus interbasin flow and changes in groundwater and soil-moisture storage. During dry periods, streamflow is sustained by base flow, which is groundwater discharge to streams. The water budget evaluation has been designed and developed as a computer application under the name of Water Monitoring System (WAMOS).

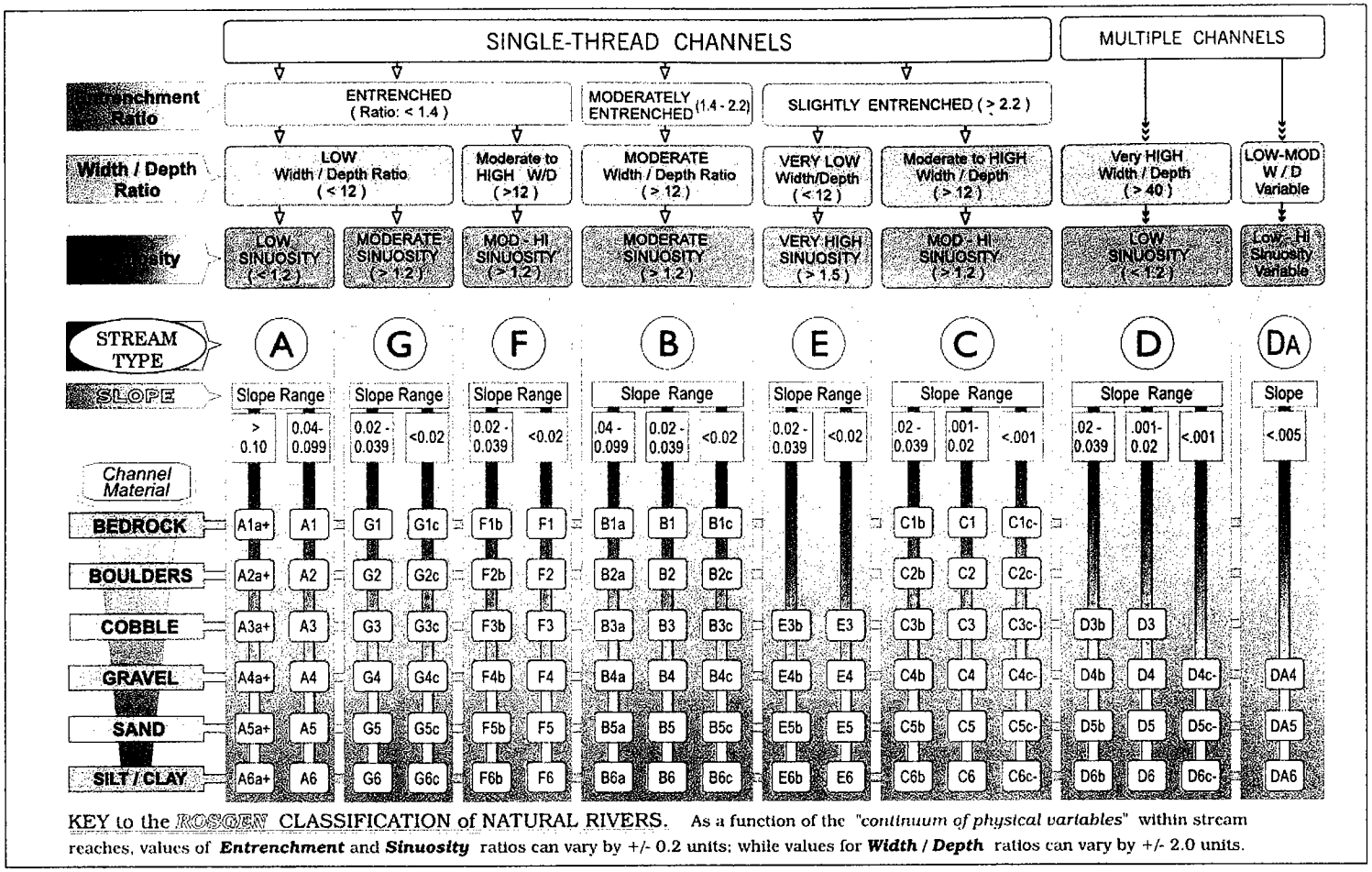
WAMOS software package is a computer friendly-user interface designed for downloading stage data, calibrating and develop rating curves for the stream gauge, maintaining database and calculating flows, statistics analysis, water budget, and finally integration of the monitoring stream gauge data in the Township Management Plan.

Water quality impacts

Water quality impacts from wastewater effluent discharges downstream can be extremely harmful. In addition to these direct water quality impacts, development typically translates into removal or partial removal of riparian vegetation, which serves multiple critical functions for overall stream quality. Stream temperature regimes are adversely affected as the result of reduction in stream shading. All of these pollution impacts combine to adversely affect the stream system

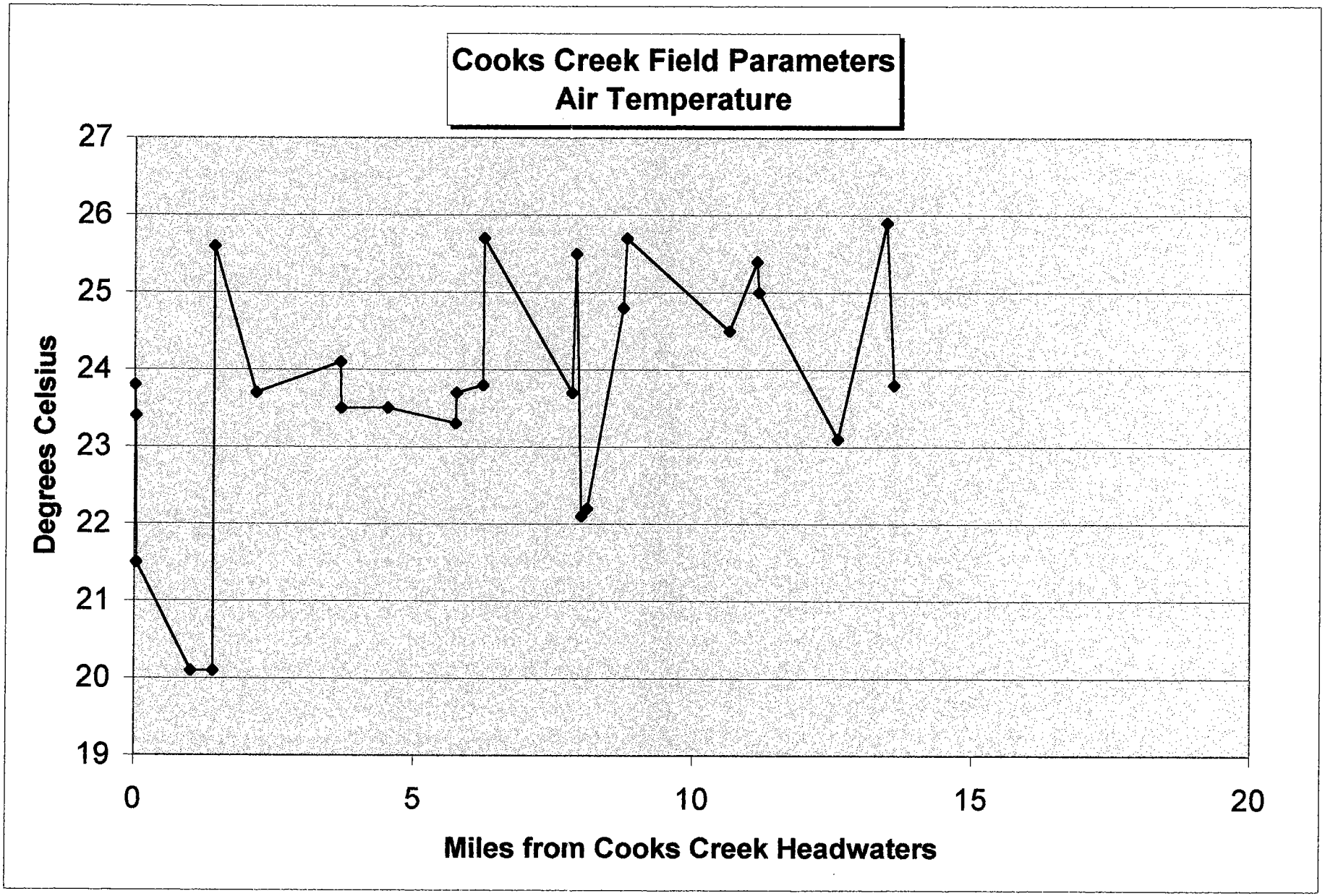
APPENDIX B

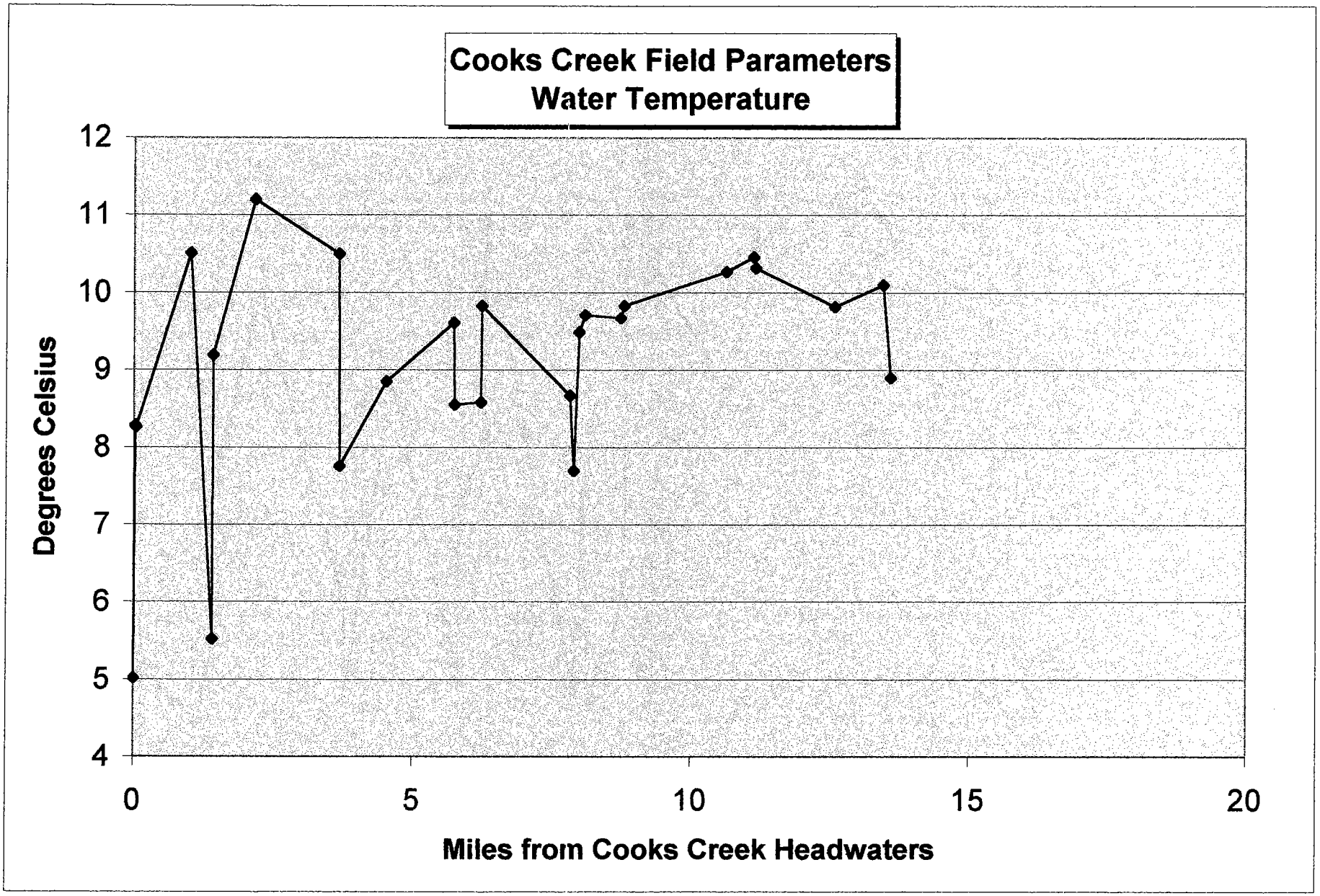
Stream Visual Assessment
Water Quality Evaluation
Stream Morphology Assessment

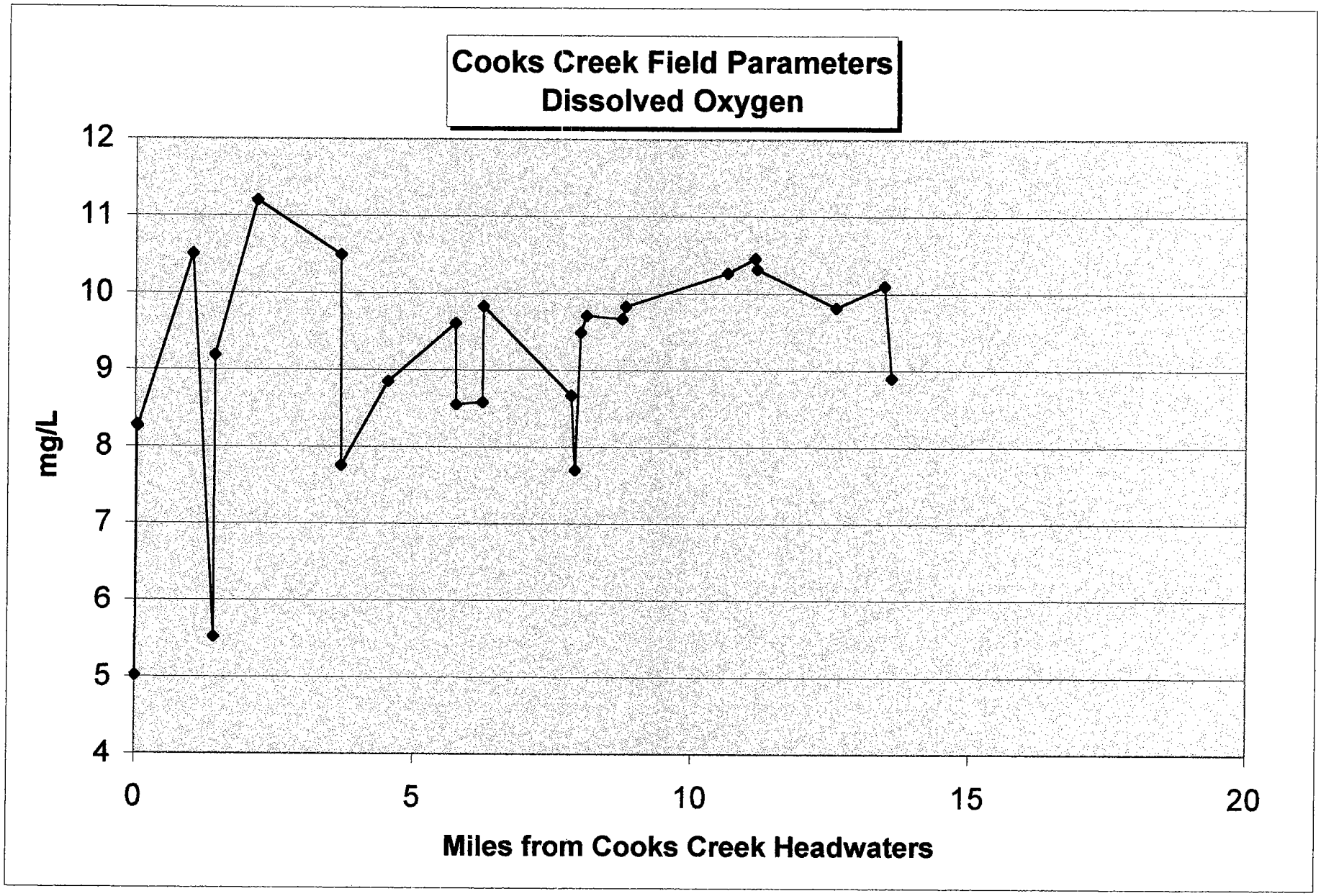


KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the *"continuum of physical variables"* within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

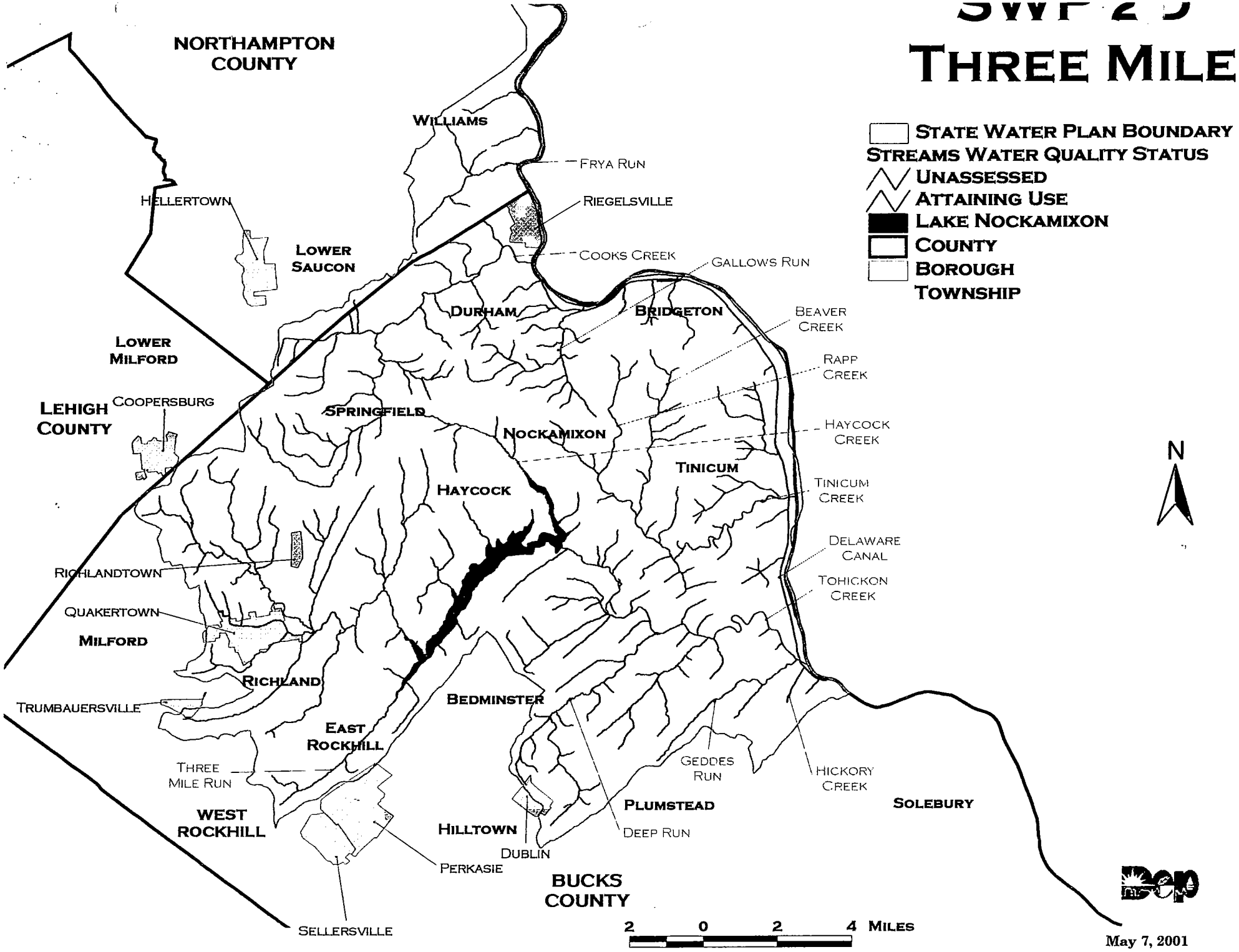
FIGURE 20. Classification key for natural rivers.


Cooks Creek Field Parameters
Air Temperature
Degrees Celsius
27
26
25
24
23
22
21
20
19
0
5
10
15
20
Miles from Cooks Creek Headwaters


Cooks Creek Field Parameters
Water Temperature
Degrees Celsius
12
11
10
9
8
7
6
5
4
0
5
10
15
20
Miles from Cooks Creek Headwaters


Cooks Creek Field Parameters
Dissolved Oxygen
mg/L
12
11
10
9
8
7
6
5
4
0
5
10
15
20
Miles from Cooks Creek Headwaters

THREE MILE



May 7, 2001

EPA United States Environmental Protection Agency

Index of Watershed Indicators

Enviromapper for Watersheds

IWI Home | Mapper Home | Surf Home

Mapping Features

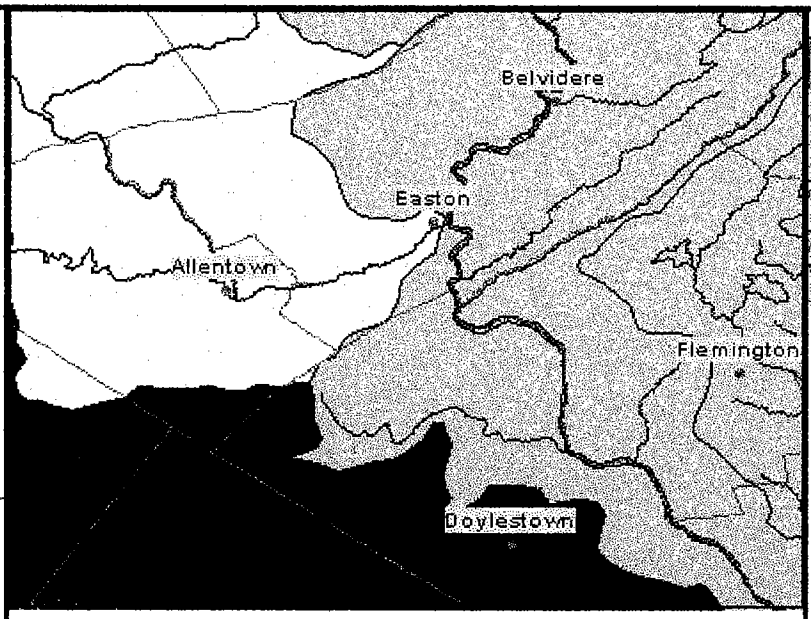
- STORET(IWI-3C)
- STORET(IWI-5)
- STORET(IWI-6)
- Major Roads
- Railroads
- Rivers
- Indian Lands
- Federal Lands
- Counties
- States
- Watershed

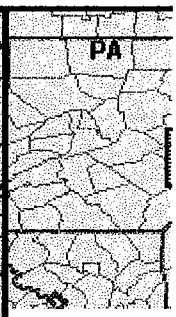
Current IWI Data Layer:

0: Overall Watershed Characterization

Watershed Classification

- Better Water Quality - Low Vulnerability
- Better Water Quality - High Vulnerability
- Less Serious Water Quality Problems - Low Vulnerability
- Less Serious Water Quality Problems - High Vulnerability
- More Serious Water Quality Problems - Low Vulnerability
- More Serious Water Quality Problems - High Vulnerability
- Data Sufficiency Threshold Not Met





Zoom-In By 2X Radius

Zoom-Out E 2X

Recenter M

Identify

Show Locat

Select an IWI Data Layer for the color display:

- 0: Overall Watershed Characterization
- 1: Designated Use Attainment
- 2: Fish Consumption Advisories
- 3: Sources of Drinking Water

Redraw Map

64 mi across. Tips: Click on the map or choose another option.

On-

You can also zoom in by geography.

EPA United States Environmental Protection Agency

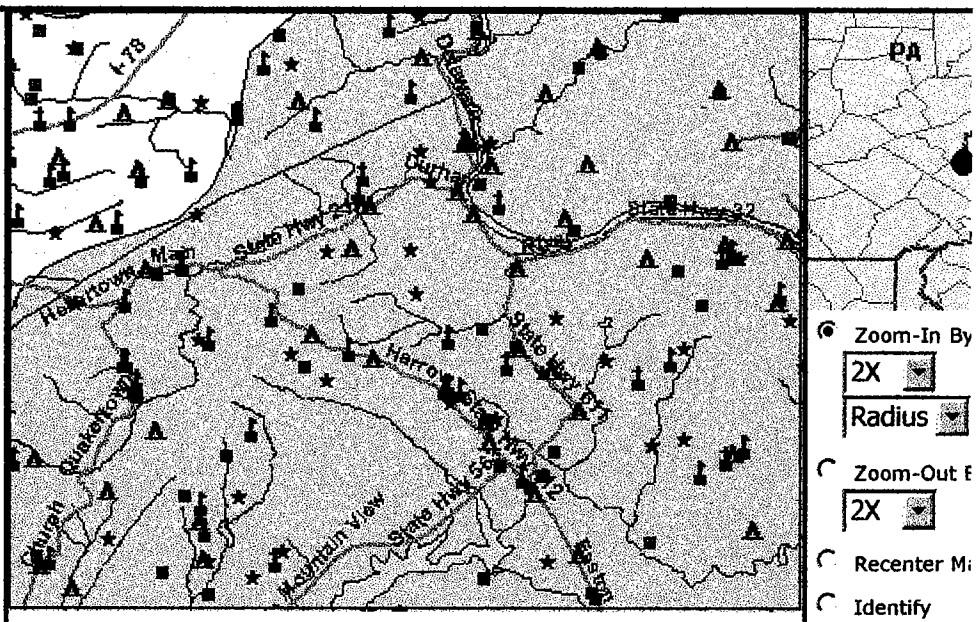
Index of Watershed Indicators

Enviromapper for Watersheds

IWI Home | Mapper Home | Surf Home

Mapping Features

- Discharges to water
- Superfund sites
- Hazardous waste handler
- Toxic releases
- Air releases
- Others
- STORET(IWI-3C)
- STORET(IWI-5)
- STORET(IWI-6)
- Schools
- Hospitals
- Churches
- Populated Places
- Streets
- Streams
- Indian Lands
- Water Bodies
- Zipcodes
- Counties
- Watershed



Zoom-In By 2X Radius

Zoom-Out B 2X

Recenter M

Identify

Show Locat

Select an IWI Data Layer for the color display:

- 0: Overall Watershed Characterization
- 1: Designated Use Attainment
- 2: Fish Consumption Advisories
- 3: Sources of Drinking Water

Current IWI Data Layer:

0: Overall Watershed Characterization

Watershed Classification

- Better Water Quality - Low Vulnerability
- Better Water Quality - High Vulnerability
- Less Serious Water Quality Problems - Low Vulnerability
- Less Serious Water Quality Problems - High Vulnerability
- More Serious Water Quality Problems - Low Vulnerability
- More Serious Water Quality Problems - High Vulnerability
- Data Sufficiency Threshold Not Met

Redraw Map

16 mi across. Tips: Click on the map or choose another option.

On-

You can also zoom in by geography.

Hampton-Clarke, Inc.
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175 Route 46 West, Unit D
Fairfield, NJ 07004
(973) 244-9770
Federal ID: 222679402

DTEAC

Format: NJDEP-S

Project: 99-0011
PO Number:

Samples submitted on: 05/04/2000

AB07059
AB07060
AB07061
AB07062
AB07063
AB07064

Date: 06/05/2000
HCI Project: 05042106

4,6,7,12,15,16,17

Veritech Sample Key

05-Jun-00

Lab#	SampleID
AB07059	S1
AB07060	SW1
AB07061	S2
AB07062	SW2
AB07063	SW14
AB07064	SW8

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Lab Number	Sample Description
AB07059	S1

% Solids SM2540G	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
% Solids				05/07/2000	SP	SM 2540G

Chlorinated Herbicides 8151	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
2,4,5-T	05/10/2000	Matt	EPA 8151	05/10/2000	AHD	EPA 8151
Silvex	05/10/2000	Matt	EPA 8151	05/10/2000	AHD	EPA 8151
2,4-D	05/10/2000	Matt	EPA 8151	05/10/2000	AHD	EPA 8151
Dicamba	05/10/2000	Matt	EPA 8151	05/10/2000	AHD	EPA 8151

Mercury (soil/waste) 7471A	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
Mercury	05/09/2000	johns	EPA 7471A	05/12/2000	johns	EPA 7471A

Organochlorine Pesticides 8081	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
Gamma-BHC	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Aldrin	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Beta-BHC	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Delta-BHC	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
P,P'-DDE	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
P,P'-DDT	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Dieldrin	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Endosulfan Sulfate	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Endosulfan I	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Endosulfan II	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Endrin	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Alpha-BHC	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Endrin Ketone	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Chlordane	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Heptachlor	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Heptachlor Epoxide	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Methoxychlor	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Toxaphene	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Endrin Aldehyde	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
P,P'-DDD	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081

TAL Metals 6010	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
Calcium	05/09/2000	johns	EPA 3050	05/10/2000	MG	EPA 6010
Silver	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Aluminum	05/09/2000	johns	EPA 3050	05/10/2000	MG	EPA 6010
Arsenic	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Beryllium	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Thallium	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Cadmium	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Cobalt	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Chromium	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Copper	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Iron	05/09/2000	johns	EPA 3050	05/10/2000	MG	EPA 6010
Magnesium	05/09/2000	johns	EPA 3050	05/10/2000	MG	EPA 6010
Manganese	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Sodium	05/09/2000	johns	EPA 3050	05/10/2000	MG	EPA 6010
Vanadium	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Nickel	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Barium	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Lead	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Antimony	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Selenium	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Zinc	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Potassium	05/09/2000	johns	EPA 3050	05/10/2000	MG	EPA 6010

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Lab Number	Sample Description
AB07060	SW1

Chlorinated Herbicides 8151	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
Silvex	05/09/2000	Matt	EPA 8151	05/10/2000	AHD	EPA 8151
2,4-D	05/09/2000	Matt	EPA 8151	05/10/2000	AHD	EPA 8151
2,4,5-T	05/09/2000	Matt	EPA 8151	05/10/2000	AHD	EPA 8151
Dicamba	05/09/2000	Matt	EPA 8151	05/10/2000	AHD	EPA 8151

Mercury (water) 245.1	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
Mercury	05/08/2000	johns	EPA 245.1	05/08/2000	JDS	EPA 245.1

Nitrate-N	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
Nitrate				05/05/2000	APL	EPA 352

Organochlorine Pesticides 608	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
Endosulfan Sulfate	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Alpha-BHC	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Aldrin	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Beta-BHC	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Chlordane	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Delta-BHC	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
P,P'-DDD	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
P,P'-DDE	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
P,P'-DDT	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Dieldrin	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Endosulfan I	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Endosulfan II	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Endrin	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Endrin Aldehyde	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Endrin Ketone	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Gamma-BHC	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Heptachlor	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Heptachlor Epoxide	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Methoxychlor	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608
Toxaphene	05/05/2000	SteveB	EPA 608	05/08/2000	AHD	EPA 608

Phosphorus (Total) EPA 365	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
Phosphorus (Total)				05/08/2000	APL	EPA 365

TAL Metals 200.7	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
Beryllium	05/08/2000	johns	EPA 200.7	05/11/2000	SB	EPA 200.7
Iron	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7
Silver	05/08/2000	johns	EPA 200.7	05/11/2000	SB	EPA 200.7
Aluminum	05/08/2000	johns	EPA 200.7	05/11/2000	SB	EPA 200.7
Barium	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7
Calcium	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7
Cadmium	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7
Cobalt	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7
Chromium	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7
Copper	05/08/2000	johns	EPA 200.7	05/11/2000	SB	EPA 200.7
Zinc	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7
Magnesium	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7
Manganese	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7
Sodium	05/08/2000	johns	EPA 200.7	05/11/2000	MG	EPA 200.7
Nickel	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7
Lead	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7
Antimony	05/08/2000	johns	EPA 200.7	05/11/2000	SB	EPA 200.7
Arsenic	05/08/2000	johns	EPA 200.7	05/11/2000	SB	EPA 200.7

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Selenium	05/08/2000	johns	EPA 200.7	05/11/2000	SB	EPA 200.7
Potassium	05/08/2000	johns	EPA 200.7	05/11/2000	MG	EPA 200.7
Thallium	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7
Vanadium	05/08/2000	johns	EPA 200.7	05/10/2000	SB	EPA 200.7

Lab Number	Sample Description
AB07061	S2

% Solids SM2540G	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
% Solids				05/07/2000	SP	SM 2540G

Chlorinated Herbicides 8151	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
2,4,5-T	05/10/2000	Matt	EPA 8151	05/10/2000	AHD	EPA 8151
Dicamba	05/10/2000	Matt	EPA 8151	05/10/2000	AHD	EPA 8151
Silvex	05/10/2000	Matt	EPA 8151	05/10/2000	AHD	EPA 8151
2,4-D	05/10/2000	Matt	EPA 8151	05/10/2000	AHD	EPA 8151

Mercury (soil/waste) 7471A	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
Mercury	05/09/2000	johns	EPA 7471A	05/12/2000	johns	EPA 7471A

Organochlorine Pesticides 8081	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
Endosulfan I	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Chlordane	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Beta-BHC	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Delta-BHC	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Aldrin	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
P,P'-DDD	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
P,P'-DDE	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
P,P'-DDT	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Dieldrin	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Endosulfan Sulfate	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Endosulfan II	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Endrin	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Endrin Aldehyde	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Endrin Ketone	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Toxaphene	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Gamma-BHC	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Heptachlor Epoxide	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Methoxychlor	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Alpha-BHC	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081
Heptachlor	05/05/2000	JohnK	EPA 3550	05/09/2000	AHD	EPA 8081

TAL Metals 6010	Preparation Date	Preparation By	Preparation Method	Analysis Date	Analysis By	Analysis Method
Barium	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Copper	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Silver	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Aluminum	05/09/2000	johns	EPA 3050	05/10/2000	MG	EPA 6010
Arsenic	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Beryllium	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Cadmium	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Calcium	05/09/2000	johns	EPA 3050	05/10/2000	MG	EPA 6010
Chromium	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Zinc	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Iron	05/09/2000	johns	EPA 3050	05/10/2000	MG	EPA 6010
Selenium	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Cobalt	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Thallium	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Potassium	05/09/2000	johns	EPA 3050	05/10/2000	MG	EPA 6010
Antimony	05/09/2000	johns	EPA 3050	05/11/2000	SB	EPA 6010
Lead	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Nickel	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Sodium	05/09/2000	johns	EPA 3050	05/10/2000	MG	EPA 6010

Laboratory Chronicle

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Manganese	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010
Magnesium	05/09/2000	johns	EPA 3050	05/10/2000	MG	EPA 6010
Vanadium	05/09/2000	johns	EPA 3050	05/10/2000	SB	EPA 6010

Lab Number	Sample Description
AB07062	SW2

	Preparation			Analysis		
Nitrate-N	Date	By	Method	Date	By	Method
Nitrate				05/05/2000	APL	EPA 352
Phosphorus (Total) EPA 365	Date	By	Method	Date	By	Method
Phosphorus (Total)				05/08/2000	APL	EPA 365

Lab Number	Sample Description
AB07063	SW14

	Preparation			Analysis		
Nitrate-N	Date	By	Method	Date	By	Method
Nitrate				05/05/2000	APL	EPA 352
Phosphorus (Total) EPA 365	Date	By	Method	Date	By	Method
Phosphorus (Total)				05/08/2000	APL	EPA 365

Lab Number	Sample Description
AB07064	SW8

	Preparation			Analysis		
Nitrate-N	Date	By	Method	Date	By	Method
Nitrate				05/05/2000	APL	EPA 352
Phosphorus (Total) EPA 365	Date	By	Method	Date	By	Method
Phosphorus (Total)				05/08/2000	APL	EPA 365

METALS ANALYSIS NONCONFORMANCE SUMMARY

	NO	Yes
1. Calibration summary meets criteria		X
2. ICP Interference Check Samples Results Summary Submitted (if applicable) Meet Criteria		X
3. Serial Dilution Summary Submitted (if applicable) Meet Criteria Ca,V,Na	X	
4. Laboratory Control Sample Summary Submitted (if applicable) Meets Criteria		X
5. Blank Contamination lower than MDL/PQL - If No, list compound and concentration in each blank: MB 2816 Na=0.554 mg/L. The concentration of Na is less than 2.2 times the MDL.	X	
6. Matrix Spike / Matrix Spike Duplicate Recoveries Meet Criteria (if not, list those compounds and their recoveries which fall outside the acceptable range)		X
7. Extraction Holding Time Met (if not, list number of days exceeded for each sample)	N	A
8. Analysis Holding Time Met (if not, list number of days exceeded for each sample)		X

Additional Comments:

Metals Supervisor: [signature] Date: 5/16/00

Batch: 2816 ICP OPTIMA and ARL 3560

METALS ANALYSIS NONCONFORMANCE SUMMARY

	NO	Yes
1. Calibration summary meets criteria		X
2. ICP Interference Check Samples Results Summary Submitted (if applicable) Meet Criteria		X
3. Serial Dilution Summary Submitted (if applicable) Meet Criteria Al, Ca, Fe, Mg, Na	X	
4. Laboratory Control Sample Summary Submitted (if applicable) Meets Criteria		X
5. Blank Contamination lower than MDL/PQL - If No, list compound and concentration in each blank: MB 2827 Cu=4.866 mg/kg. The concentration of Cu is less than 5% of the regulatory limit.	X	
6. Matrix Spike / Matrix Spike Duplicate Recoveries Meet Criteria (if not, list those compounds and their recoveries which fall outside the acceptable range) Sb MS1=70%, MS2=47%, Al MS1=139%, MS2=170%, Fe MS1=0%, MS2=1.4%, Mn MS1=68% MS2=50%. The batch was passed for Sb due to the LCS and LCS MR recoveries. The sample concentrations for Al, Fe and Mn were greater than 4 times the spiking level.	X	
7. Extraction Holding Time Met (if not, list number of days exceeded for each sample)	N	A
8. Analysis Holding Time Met (if not, list number of days exceeded for each sample)		X

Additional Comments:

Metals Supervisor: [signature] Date: 5/12/00

Batch: 2827 ICP OPTIMA and ARL 3560

METAL ANALYSIS CONFORMANCE / NON-CONFORMANCE SUMMARY

	NO	YES
1. Calibration Summary Meet Criteria?		x
2. ICP Interference Check Sample Results Summary Submited (if applicable) / Meet Criteria	na	na
3. Serial Dilution Summary Submitted (if applicable) / Meet Criteria	na	na
4. Laboratory Control Sample Summary Submitted (if applicable) / Meet Criteria		x
5. Blank Concentration lower than MDL/PQL - If no, list compounds and concentrations in each blank:		x
6. Matrix Spikes/Matrix Duplicate Recoveries Meet Criteria (if not met, list those compounds and their recoveries which fall outside the acceptable range) AB07052 MS 1 = 53 % Hg retrieval, AB07052 MS 2 = 57% Hg retrieval; due to matrix suppression.		x
7. Extraction Holding Time Met (TCLP only) (If not met, list number of days exceeded for each sample:	na	na
8. Analysis Holding Time Met (If not met, list number of days exceeded for each sample:		x

Additional Comments:

Metals Supervisor: [signature] Date: 5/16/00

Batch # 2816
FIMS 100 CV
05/10/00 JDS

CT #: PH-0671
MA #: NJ386
NJ #: 14622
NY #: 11408
PA #: 68-463

Report Of Analysis
veritech laboratories

To: DTEAC

3450 Route 212

Riegelsville PA 18077

Attention: Scott Douglas
Project: 99-0011

Date Collected: 05/03/2000
Date Submitted: 05/04/2000
Date Reported: 06/05/2000

Lab#	SampleID	TestGroup	Analyte	Units	MDL/PQL	Result
AB07059	S1					
		% Solids SM2540G				
			% Solids	Percent		52
		Chlorinated Herbicides 8151				
			2,4,5-T	mg/Kg	0.0077	ND
			2,4-D	mg/Kg	0.0077	.014
			Dicamba	mg/Kg	0.0077	ND
			Silvex	mg/Kg	0.0077	ND
		Mercury (soil/waste) 7471A				
			Mercury	mg/Kg	0.16	.97
		Organochlorine Pesticides 8081				
			Aldrin	mg/Kg	0.0064	ND
			Alpha-BHC	mg/Kg	0.0064	ND
			Beta-BHC	mg/Kg	0.0064	ND
			Chlordane	mg/Kg	0.013	ND
			Delta-BHC	mg/Kg	0.0064	ND
			Dieldrin	mg/Kg	0.0064	ND
			Endosulfan I	mg/Kg	0.0064	ND
			Endosulfan II	mg/Kg	0.0064	ND
			Endosulfan Sulfate	mg/Kg	0.0064	ND
			Endrin	mg/Kg	0.0064	ND
			Endrin Aldehyde	mg/Kg	0.0064	ND
			Endrin Ketone	mg/Kg	0.0064	ND
			Gamma-BHC	mg/Kg	0.0064	ND
			Heptachlor	mg/Kg	0.0064	ND
			Heptachlor Epoxide	mg/Kg	0.0064	ND
			Methoxychlor	mg/Kg	0.0064	ND
			P,P'-DDD	mg/Kg	0.0064	ND
			P,P'-DDE	mg/Kg	0.0064	ND
			P,P'-DDT	mg/Kg	0.0064	ND
			Toxaphene	mg/Kg	0.064	ND
		TAL Metals 6010				
			Aluminum	Mg/Kg	580	12000
			Antimony	Mg/Kg	2.8	ND
			Arsenic	Mg/Kg	3.8	7.5
			Barium	Mg/Kg	19	120
			Beryllium	Mg/Kg	0.77	1.3
			Cadmium	Mg/Kg	0.58	ND
			Calcium	Mg/Kg	960	3900
			Chromium	Mg/Kg	7.7	27
			Cobalt	Mg/Kg	3.2	12
			Copper	Mg/Kg	7.3	31
			Iron	Mg/Kg	520	30000
			Lead	Mg/Kg	7.7	42
			Magnesium	Mg/Kg	700	5100
			Manganese	Mg/Kg	31	580
			Nickel	Mg/Kg	4.7	20
			Potassium	Mg/Kg	210	1200
			Selenium	Mg/Kg	4.8	ND
			Silver	Mg/Kg	0.96	ND
			Sodium	Mg/Kg	770	ND
			Thallium	Mg/Kg	2.3	ND
			Vanadium	Mg/Kg	9	40
			Zinc	Mg/Kg	19	130

MDL used for 600 and 200 series methods. PQL used for SW846 methods.
ND = Not Detected

Lab#	SampleID		Units	MDL/PQL	Result
	TestGroup	Analyte			
AB07060	SW1				
	Chlorinated Herbicides 8151				
		2,4,5-T	ug/L	0.2	ND
		2,4-D	ug/L	0.2	ND
		Dicamba	ug/L	0.2	ND
		Silvex	ug/L	0.2	ND
	Mercury (water) 245.1				
		Mercury	Ug/L	0.22	ND
	Nitrate-N				
		Nitrate	mg/L as N	0.2	1.70
	Organochlorine Pesticides 608				
		Aldrin	ug/L	0.02	ND
		Alpha-BHC	ug/L	0.02	ND
		Beta-BHC	ug/L	0.02	ND
		Chlordane	ug/L	0.2	ND
		Delta-BHC	ug/L	0.02	ND
		Dieldrin	ug/L	0.02	ND
		Endosulfan I	ug/L	0.02	ND
		Endosulfan II	ug/L	0.02	ND
		Endosulfan Sulfate	ug/L	0.02	ND
		Endrin	ug/L	0.02	ND
		Endrin Aldehyde	ug/L	0.02	ND
		Endrin Ketone	ug/L	0.02	ND
		Gamma-BHC	ug/L	0.02	ND
		Heptachlor	ug/L	0.02	ND
		Heptachlor Epoxide	ug/L	0.02	ND
		Methoxychlor	ug/L	0.02	ND
		P,P'-DDD	ug/L	0.02	ND
		P,P'-DDE	ug/L	0.02	ND
		P,P'-DDT	ug/L	0.02	ND
		Toxaphene	ug/L	1	ND
	Phosphorus (Total) EPA 365				
		Phosphorus (Total)	mg/L as P	0.05	ND
	TAL Metals 200.7				
		Aluminum	ug/L	58	ND
		Antimony	ug/L	3.3	ND
		Arsenic	ug/L	3.6	ND
		Barium	ug/L	23	28
		Beryllium	ug/L	2.5	ND
		Cadmium	ug/L	1.4	ND
		Calcium	ug/L	380	25000
		Chromium	ug/L	16	ND
		Cobalt	ug/L	4.6	ND
		Copper	ug/L	20	ND
		Iron	ug/L	88	ND
		Lead	ug/L	3.4	ND
		Magnesium	ug/L	260	12000
		Manganese	ug/L	12	ND
		Nickel	ug/L	15	ND
		Potassium	ug/L	140	1700
		Selenium	ug/L	20	ND
		Silver	ug/L	5.2	ND
		Sodium	ug/L	390	6700
		Thallium	ug/L	3.1	ND
		Vanadium	ug/L	4.3	ND
		Zinc	ug/L	20	ND

MDL used for 600 and 200 series methods. PQL used for SW846 methods.
ND = Not Detected

Lab#	SampleID	TestGroup	Analyte	Units	MDL/PQL	Result
AB07061	S2					
		% Solids SM2540G				
			% Solids	Percent		69
		Chlorinated Herbicides 8151				
			2,4,5-T	mg/Kg	0.0058	ND
			2,4-D	mg/Kg	0.0058	.0071
			Dicamba	mg/Kg	0.0058	ND
			Silvex	mg/Kg	0.0058	ND
		Mercury (soil/waste) 7471A				
			Mercury	mg/Kg	0.12	.48
		Organochlorine Pesticides 8081				
			Aldrin	mg/Kg	0.0048	ND
			Alpha-BHC	mg/Kg	0.0048	ND
			Beta-BHC	mg/Kg	0.0048	ND
			Chlordane	mg/Kg	0.0097	ND
			Delta-BHC	mg/Kg	0.0048	ND
			Dieldrin	mg/Kg	0.0048	ND
			Endosulfan I	mg/Kg	0.0048	ND
			Endosulfan II	mg/Kg	0.0048	ND
			Endosulfan Sulfate	mg/Kg	0.0048	ND
			Endrin	mg/Kg	0.0048	ND
			Endrin Aldehyde	mg/Kg	0.0048	ND
			Endrin Ketone	mg/Kg	0.0048	ND
			Gamma-BHC	mg/Kg	0.0048	ND
			Heptachlor	mg/Kg	0.0048	ND
			Heptachlor Epoxide	mg/Kg	0.0048	ND
			Methoxychlor	mg/Kg	0.0048	ND
			P,P'-DDD	mg/Kg	0.0048	ND
			P,P'-DDE	mg/Kg	0.0048	ND
			P,P'-DDT	mg/Kg	0.0048	ND
			Toxaphene	mg/Kg	0.048	ND
		TAL Metals 6010				
			Aluminum	Mg/Kg	430	6700
			Antimony	Mg/Kg	2.1	ND
			Arsenic	Mg/Kg	2.9	6.2
			Barium	Mg/Kg	14	100
			Beryllium	Mg/Kg	0.58	.96
			Cadmium	Mg/Kg	0.43	ND
			Calcium	Mg/Kg	720	11000
			Chromium	Mg/Kg	5.8	15
			Cobalt	Mg/Kg	2.4	8.9
			Copper	Mg/Kg	5.5	26
			Iron	Mg/Kg	390	21000
			Lead	Mg/Kg	5.8	52
			Magnesium	Mg/Kg	520	6900
			Manganese	Mg/Kg	23	600
			Nickel	Mg/Kg	3.5	14
			Potassium	Mg/Kg	160	760
			Selenium	Mg/Kg	3.6	ND
			Silver	Mg/Kg	0.72	ND
			Sodium	Mg/Kg	580	ND
			Thallium	Mg/Kg	1.7	ND
			Vanadium	Mg/Kg	6.8	30
			Zinc	Mg/Kg	14	140
AB07062	SW2					
		Nitrate-N				
			Nitrate	mg/L as N	0.2	1.60
		Phosphorus (Total) EPA 365				
			Phosphorus (Total)	mg/L as P	0.05	ND
AB07063	SW14					
		Nitrate-N				
			Nitrate	mg/L as N	0.2	1.00
		Phosphorus (Total) EPA 365				
			Phosphorus (Total)	mg/L as P	0.05	ND

MDL used for 600 and 200 series methods. PQL used for SW846 methods.
ND = Not Detected

Lab#	SampleID		Units	MDL/PQL	Result
	TestGroup	Analyte			
AB07064	SW8				
	Nitrate-N				
		Nitrate	mg/L as N	0.2	1.40
	Phosphorus (Total) EPA 365				
		Phosphorus (Total)	mg/L as P	0.05	ND

This report is a true report of results obtained from our tests of this material. In lieu of a formal contract document, the total aggregate liability of Veritech to all parties shall not exceed Veritech's total fee for analytical services rendered.

Robin Jetter - Quality Assurance Director

Or

Stanley Gilewicz - Laboratory Director

MDL used for 600 and 200 series methods. PQL used for SW846 methods.
ND = Not Detected

Form1

ORGANICS PESTICIDES REPORT

Sample Number: AB07060 | *Matrix:* Water

Client Id: SW1 | *Initial Volume:* 1000ml

Data File: GB2150 | *Final Volume:* 10ml

Date Analyzed: 8 May 2000 17:19 | *Dilution Factor:* 1

Date Received/Extracted: 05/04/2000-05/05/2000 | *Percent Solids:* 0

Column: J&W-Scientific db-608/1701 30m .32mmID

CAS #	*Compound*	*PQL/MDL*	*Concentration (Units: ug/L)*
309002	Aldrin	0.020	U
319846	Alpha-BHC	0.020	U
319857	Beta-BHC	0.020	U
57749	Chlordane	0.20	U
319868	Delta-BHC	0.020	U
60571	Dieldrin	0.020	U
959988	Endosulfan I	0.020	U
33213659	Endosulfan II	0.020	U
1031078	Endosulfan Sulfate	0.020	U
72208	Endrin	0.020	U
7421934	Endrin Aldehyde	0.020	U
53494705	Endrin Ketone	0.020	U
58899	Gamma-BHC	0.020	U
76448	Heptachlor	0.020	U
1024573	Heptachlor Epoxide	0.020	U
72435	Methoxychlor	0.020	U
72548	P,P'-DDD	0.020	U
72559	P,P'-DDE	0.020	U
50293	P,P'-DDT	0.020	U
8001352	Toxaphene	1.0	U

Total Target Concentration 0

U - Indicates the compound was analyzed but not detected.
J - Indicates an estimated value when a compound is detected at less than the specified detection limit.
B - Indicates the analyte was found in the blank as well as in the sample.
E - Indicates the analyte concentration exceeds the calibration range of the instrument.

Control File h:\import\62609.txt

Quantitation Report (QT Reviewed)

Signal #1 : G:\GCDATA\GC_3\05-08-00\GB2150.D\ECD1A.CH Vial: 15
Signal #2 : G:\GCDATA\GC_3\05-08-00\GB2150.D\ECD2B.CH
Acq On : 8 May 2000 17:19 Operator: AHD
Sample : AB07060 Inst : GC_3
Misc : A,PEST Multiplr: 1.00
IntFile Signal #1: PEST1.E IntFile Signal #2: Pest2.e
Quant Time: May 9 10:08 2000 Quant Results File: M3_8081.RES

Quant Method : G:\GCDATA\METHODS\M3_8081.M (Chemstation Integrator)
Title : @GC_3
Last Update : Mon May 08 16:21:59 2000
Response via : Initial Calibration
DataAcq Meth : GC3_8081.M

Volume Inj. : 1ul
Signal #1 Phase : db-1701 Signal #2 Phase: db-608
Signal #1 Info : .32 Signal #2 Info : .32

	Compound	RT#1	RT#2	Resp#1	Resp#2	pg#1	pg#2
	Target Compounds						
1)	TCMX-Surrogate	2.80	2.86	1614012	552229	151.485	177.006
22)	DCB-Surrogate	10.88	11.82	685164	303501	144.676	165.335

AHD 5/9/00

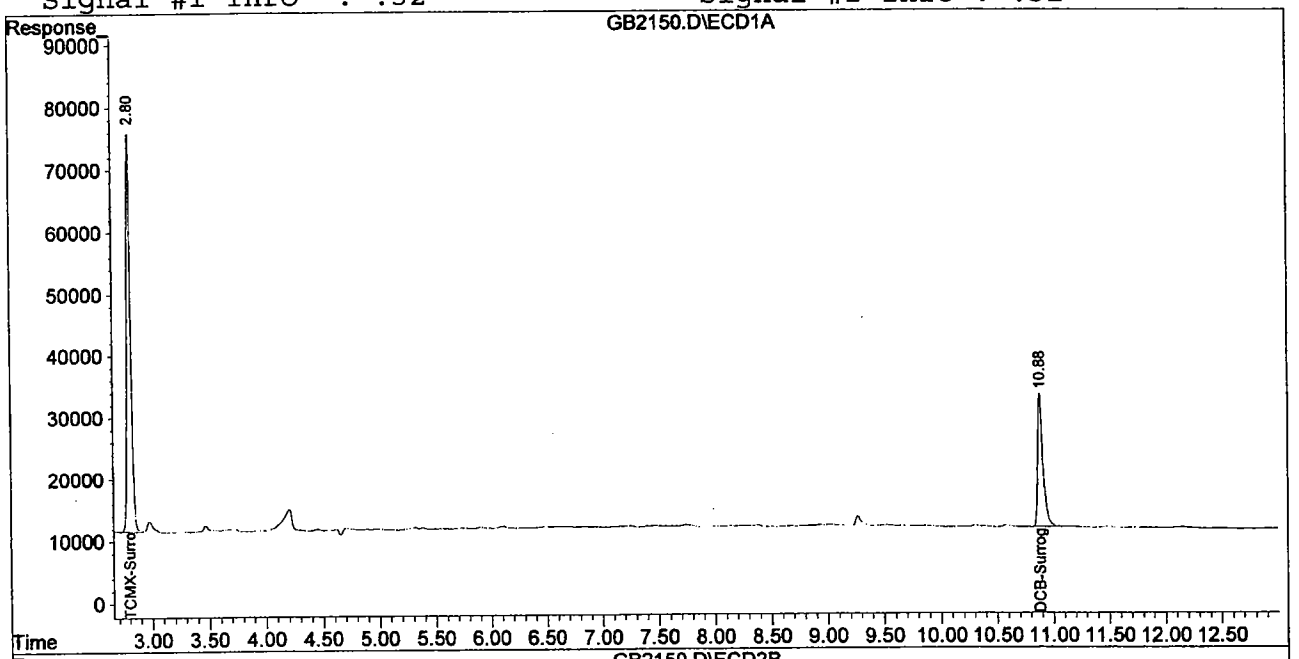
(f)=RT Delta > 1/2 Window (#)=Amounts differ by > 25% (m)=manual int.

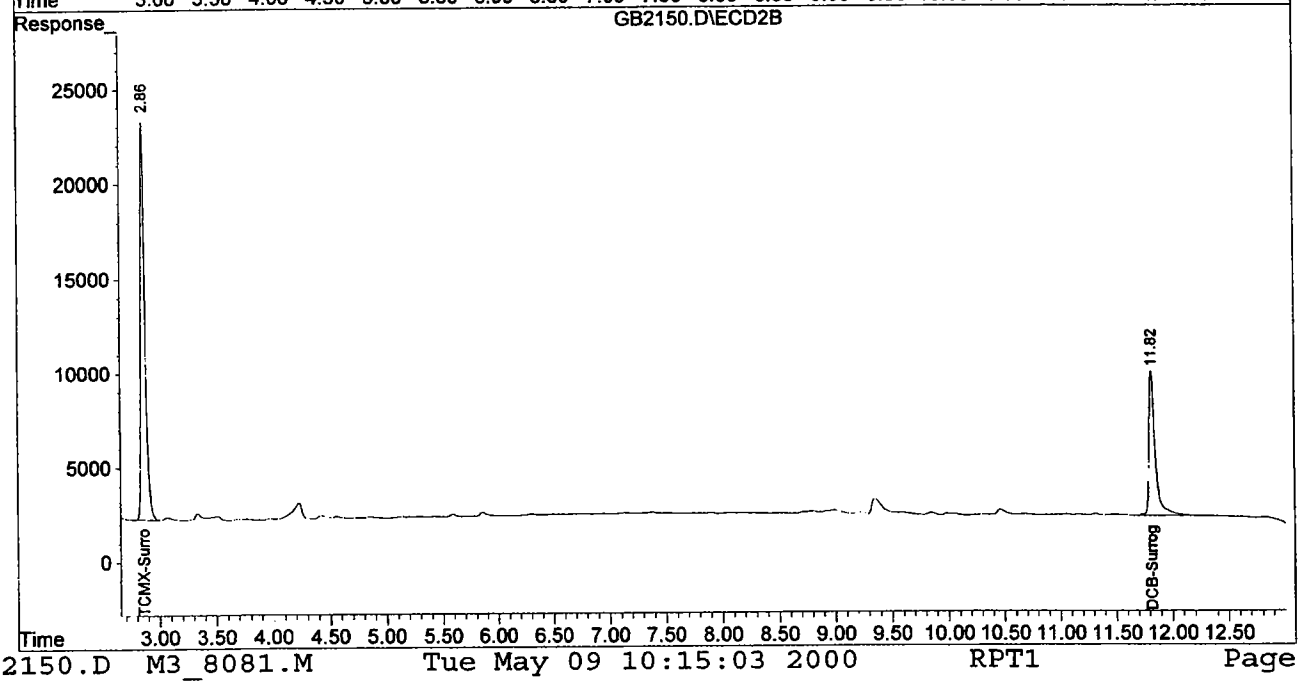
Quantitation Report

Signal #1 : G:\GCDATA\GC_3\05-08-00\GB2150.D\ECD1A.CH Vial: 15
Signal #2 : G:\GCDATA\GC_3\05-08-00\GB2150.D\ECD2B.CH
Acq On : 8 May 2000 17:19 Operator: AHD
Sample : AB07060 Inst : GC_3
Misc : A,PEST Multiplr: 1.00
IntFile Signal #1: PEST1.E IntFile Signal #2: Pest2.e
Quant Time: May 9 10:08 2000 Quant Results File: M3_8081.RES

Quant Method : G:\GCDATA\METHODS\M3_8081.M (Chemstation Integrator)
Title : @GC_3
Last Update : Mon May 08 16:21:59 2000
Response via : Multiple Level Calibration
DataAcq Meth : GC3_8081.M

Volume Inj. : 1ul
Signal #1 Phase : db-1701 Signal #2 Phase: db-608
Signal #1 Info : .32 Signal #2 Info : .32





Form1

ORGANICS PESTICIDES REPORT

Sample Number: AB07059 ***Matrix:*** Soil

Client Id: S1 ***Initial Volume:*** 30g

Data File: GB2170 ***Final Volume:*** 10ml

Date Analyzed: 9 May 2000 14:26 ***Dilution Factor:*** 1

Date Received/Extracted: 05/04/2000-05/05/2000 ***Percent Solids:*** 52

Column: J&W-Scientific db-608/1701 30m .32mmID

CAS #	*Compound*	*PQL/MDL*	*Concentration (Units: mg/Kg)*
309002	Aldrin	0.0064	U
319846	Alpha-BHC	0.0064	U
319857	Beta-BHC	0.0064	U
57749	Chlordane	0.013	U
319868	Delta-BHC	0.0064	U
60571	Dieldrin	0.0064	U
959988	Endosulfan I	0.0064	U
33213659	Endosulfan II	0.0064	U
1031078	Endosulfan Sulfate	0.0064	U
72208	Endrin	0.0064	U
7421934	Endrin Aldehyde	0.0064	U
53494705	Endrin Ketone	0.0064	U
58899	Gamma-BHC	0.0064	U
76448	Heptachlor	0.0064	U
1024573	Heptachlor Epoxide	0.0064	U
72435	Methoxychlor	0.0064	U
72548	P,P'-DDD	0.0064	U
72559	P,P'-DDE	0.0064	U
50293	P,P'-DDT	0.0064	U
8001352	Toxaphene	0.064	U

Total Target Concentration 0

U - Indicates the compound was analyzed but not detected.
J - Indicates an estimated value when a compound is detected at less than the specified detection limit.
B - Indicates the analyte was found in the blank as well as in the sample.
E - Indicates the analyte concentration exceeds the calibration range of the instrument.

Control File h:\import\105557.txt

Quantitation Report (QT Reviewed)

Signal #1 : G:\GCDATA\GC_3\05-09-00\GB2170.D\ECD1A.CH Vial: 10
Signal #2 : G:\GCDATA\GC_3\05-09-00\GB2170.D\ECD2B.CH
Acq On : 9 May 2000 14:26 Operator: AHD
Sample : AB07059 Inst : GC_3
Misc : S,PEST Multiplr: 1.00
IntFile Signal #1: PEST1.E IntFile Signal #2: Pest2.e
Quant Time: May 10 8:58 2000 Quant Results File: M3_8081.RES

Quant Method : G:\GCDATA\METHODS\M3_8081.M (Chemstation Integrator)
Title : @GC_3
Last Update : Mon May 08 16:21:59 2000
Response via : Initial Calibration
DataAcq Meth : GC3_8081.M

Volume Inj. : 1ul
Signal #1 Phase : db-1701 Signal #2 Phase: db-608
Signal #1 Info : .32 Signal #2 Info : .32

	Compound	RT#1	RT#2	Resp#1	Resp#2	pg#1	pg#2
	Target Compounds						
1)	TCMX-Surrogate	2.80	2.86	1069904	430973	100.417	138.140 #
22)	DCB-Surrogate	10.88	11.82	582469	239687	122.991m	130.572m

AHD 5/19/00

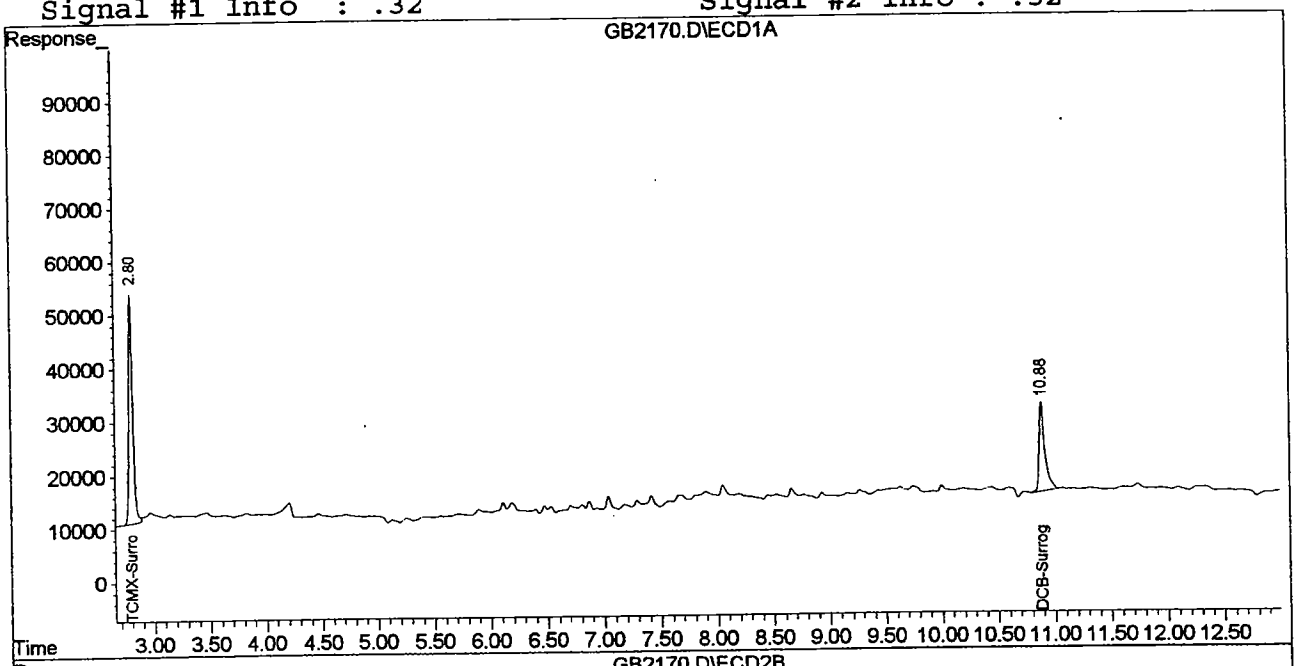
(f)=RT Delta > 1/2 Window (#)=Amounts differ by > 25% (m)=manual int.

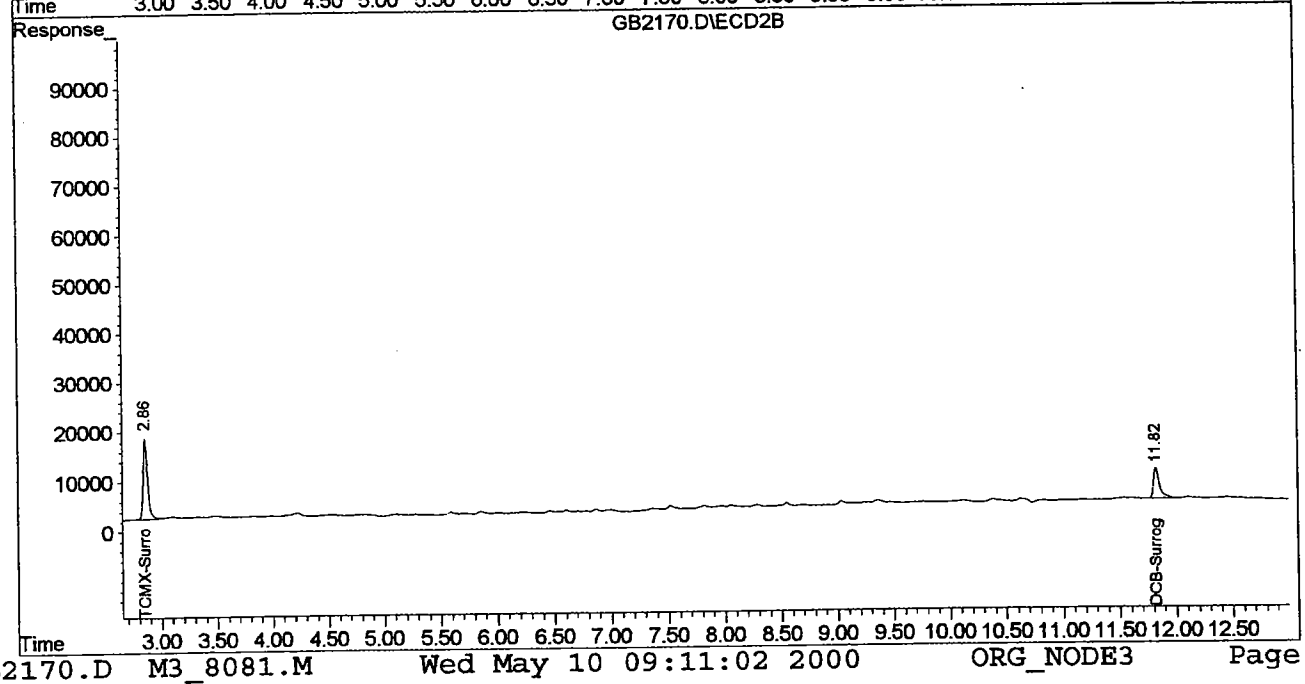
Quantitation Report

Signal #1 : G:\GCDATA\GC_3\05-09-00\GB2170.D\ECD1A.CH Vial: 10
Signal #2 : G:\GCDATA\GC_3\05-09-00\GB2170.D\ECD2B.CH
Acq On : 9 May 2000 14:26 Operator: AHD
Sample : AB07059 Inst : GC_3
Misc : S,PEST Multiplr: 1.00
IntFile Signal #1: PEST1.E IntFile Signal #2: Pest2.e
Quant Time: May 10 8:58 2000 Quant Results File: M3_8081.RES

Quant Method : G:\GCDATA\METHODS\M3_8081.M (Chemstation Integrator)
Title : @GC_3
Last Update : Mon May 08 16:21:59 2000
Response via : Multiple Level Calibration
DataAcq Meth : GC3_8081.M

Volume Inj. : 1ul
Signal #1 Phase : db-1701 Signal #2 Phase: db-608
Signal #1 Info : .32 Signal #2 Info : .32





Form1

ORGANICS PESTICIDES REPORT

Sample Number: AB07061 ***Matrix:*** Soil

Client Id: S2 ***Initial Volume:*** 30g

Data File: GB2169 ***Final Volume:*** 10ml

Date Analyzed: 9 May 2000 14:09 ***Dilution Factor:*** 1

Date Received/Extracted: 05/04/2000-05/05/2000 ***Percent Solids:*** 69

Column: J&W-Scientific db-608/1701 30m .32mmID

CAS #	*Compound*	*PQL/MDL*	*Concentration (Units: mg/Kg)*
309002	Aldrin	0.0048	U
319846	Alpha-BHC	0.0048	U
319857	Beta-BHC	0.0048	U
57749	Chlordane	0.0097	U
319868	Delta-BHC	0.0048	U
60571	Dieldrin	0.0048	U
959988	Endosulfan I	0.0048	U
33213659	Endosulfan II	0.0048	U
1031078	Endosulfan Sulfate	0.0048	U
72208	Endrin	0.0048	U
7421934	Endrin Aldehyde	0.0048	U
53494705	Endrin Ketone	0.0048	U
58899	Gamma-BHC	0.0048	U
76448	Heptachlor	0.0048	U
1024573	Heptachlor Epoxide	0.0048	U
72435	Methoxychlor	0.0048	U
72548	P,P'-DDD	0.0048	U
72559	P,P'-DDE	0.0048	U
50293	P,P'-DDT	0.0048	U
8001352	Toxaphene	0.048	U

Total Target Concentration 0

U - Indicates the compound was analyzed but not detected.
J - Indicates an estimated value when a compound is detected at less than the specified detection limit.
B - Indicates the analyte was found in the blank as well as in the sample.
E - Indicates the analyte concentration exceeds the calibration range of the instrument.

Control File h:\import\105557.txt

Quantitation Report (QT Reviewed)

Signal #1 : G:\GCDATA\GC_3\05-09-00\GB2169.D\ECD1A.CH Vial: 9
Signal #2 : G:\GCDATA\GC_3\05-09-00\GB2169.D\ECD2B.CH
Acq On : 9 May 2000 14:09 Operator: AHD
Sample : AB07061 Inst : GC_3
Misc : S,PEST Multiplr: 1.00
IntFile Signal #1: PEST1.E IntFile Signal #2: Pest2.e
Quant Time: May 10 8:57 2000 Quant Results File: M3_8081.RES

Quant Method : G:\GCDATA\METHODS\M3_8081.M (Chemstation Integrator)
Title : @GC_3
Last Update : Mon May 08 16:21:59 2000
Response via : Initial Calibration
DataAcq Meth : GC3_8081.M

Volume Inj. : 1ul
Signal #1 Phase : db-1701 Signal #2 Phase: db-608
Signal #1 Info : .32 Signal #2 Info : .32

	Compound	RT#1	RT#2	Resp#1	Resp#2	pg#1	pg#2
	Target Compounds						
1)	TCMX-Surrogate	2.80	2.86	1350776	468725	126.779	150.241m
22)	DCB-Surrogate	10.89	11.82	701277	272583	148.078	148.492

AHD 5/10/00

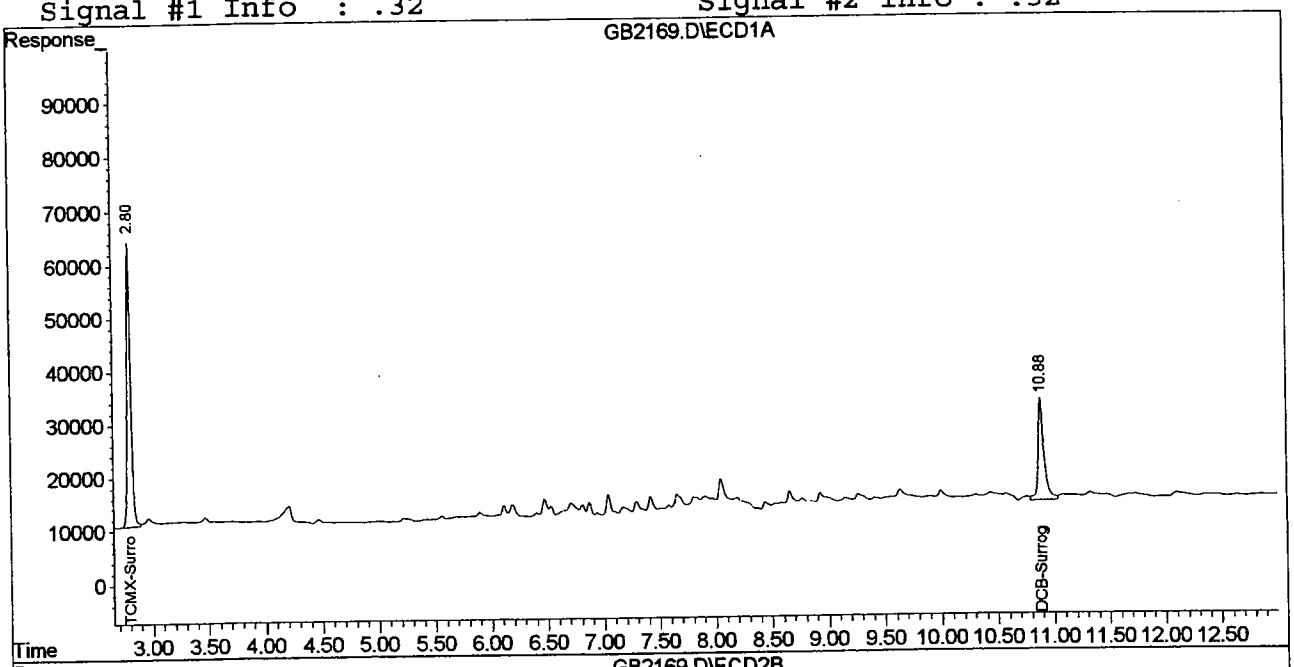
(f)=RT Delta > 1/2 Window (#)=Amounts differ by > 25% (m)=manual int.

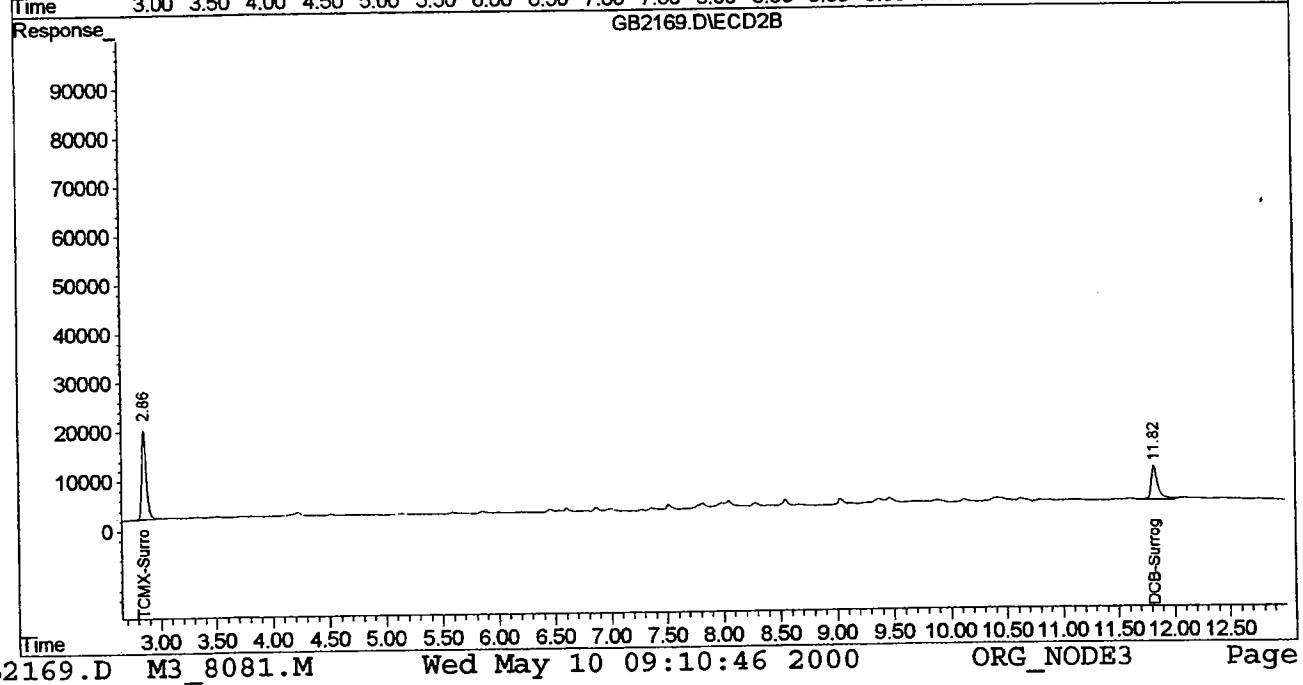
Quantitation Report

Signal #1 : G:\GCDATA\GC_3\05-09-00\GB2169.D\ECD1A.CH Vial: 9
Signal #2 : G:\GCDATA\GC_3\05-09-00\GB2169.D\ECD2B.CH
Acq On : 9 May 2000 14:09 Operator: AHD
Sample : AB07061 Inst : GC_3
Misc : S,PEST Multiplr: 1.00
IntFile Signal #1: PEST1.E IntFile Signal #2: Pest2.e
Quant Time: May 10 8:57 2000 Quant Results File: M3_8081.RES

Quant Method : G:\GCDATA\METHODS\M3_8081.M (Chemstation Integrator)
Title : @GC_3
Last Update : Mon May 08 16:21:59 2000
Response via : Multiple Level Calibration
DataAcq Meth : GC3_8081.M

Volume Inj. : 1ul
Signal #1 Phase : db-1701 Signal #2 Phase: db-608
Signal #1 Info : .32 Signal #2 Info : .32





Form1

ORGANICS HERBICIDES REPORT

Sample Number: AB07059 ***Matrix:*** Soil

Client Id: S1 ***Initial Volume:*** 50g

Data File: GC19936 ***Final Volume:*** 10ml

Date Analyzed: 10 May 2000 15:36 ***Dilution Factor:*** 1

Date Received/Extracted: 05/04/2000-05/10/2000 ***Percent Solids:*** 52

Column: J&W-Scientific db-608/1701 30m .32mmID

CAS #	*Compound*	*PQL/MDL*	*Concentration (Units: mg/Kg)*
93765	2,4,5-T	0.0077	U
94757	2,4-D	0.0077	0.014
1918009	Dicamba	0.0077	U
93721	Silvex	0.0077	U

Total Target Concentration 0.014

U - Indicates the compound was analyzed but not detected.
J - Indicates an estimated value when a compound is detected at less than the specified detection limit.
B - Indicates the analyte was found in the blank as well as in the sample.
E - Indicates the analyte concentration exceeds the calibration range of the instrument.

Control File h:\import\31629.txt

Quantitation Report (QT Reviewed)

Signal #1 : G:\GCDATA\GC_2\05-10-00\GC19936.D\ECD1A.CH Vial: 17
Signal #2 : G:\GCDATA\GC_2\05-10-00\GC19936.D\ECD2B.CH
Acq On : 10 May 2000 15:36 Operator: AHD
Sample : AB07059 Inst : GC_2
Misc : S,HERB Multiplr: 1.00
IntFile Signal #1: autoint1.e IntFile Signal #2: autoint2.e
Quant Time: May 11 15:07 2000 Quant Results File: M_8151A.RES

Quant Method : G:\GCDATA\METHODS\M_8151A.M (Chemstation Integrator)
Title : @GC_2
Last Update : Tue Mar 14 09:36:48 2000
Response via : Initial Calibration
DataAcq Meth : M_8081H.M

Volume Inj. :
Signal #1 Phase : Signal #2 Phase:
Signal #1 Info : Signal #2 Info :

	Compound	RT#1	RT#2	Resp#1	Resp#2	ng#1	ng#2
	Target Compounds						
2)	Dcaa-Surrogate	5.96	5.98	2599959	1590699	1198.033m	1066.969m
5)	2,4-D	7.06	6.98	474453	106223	120.767m	36.680m#

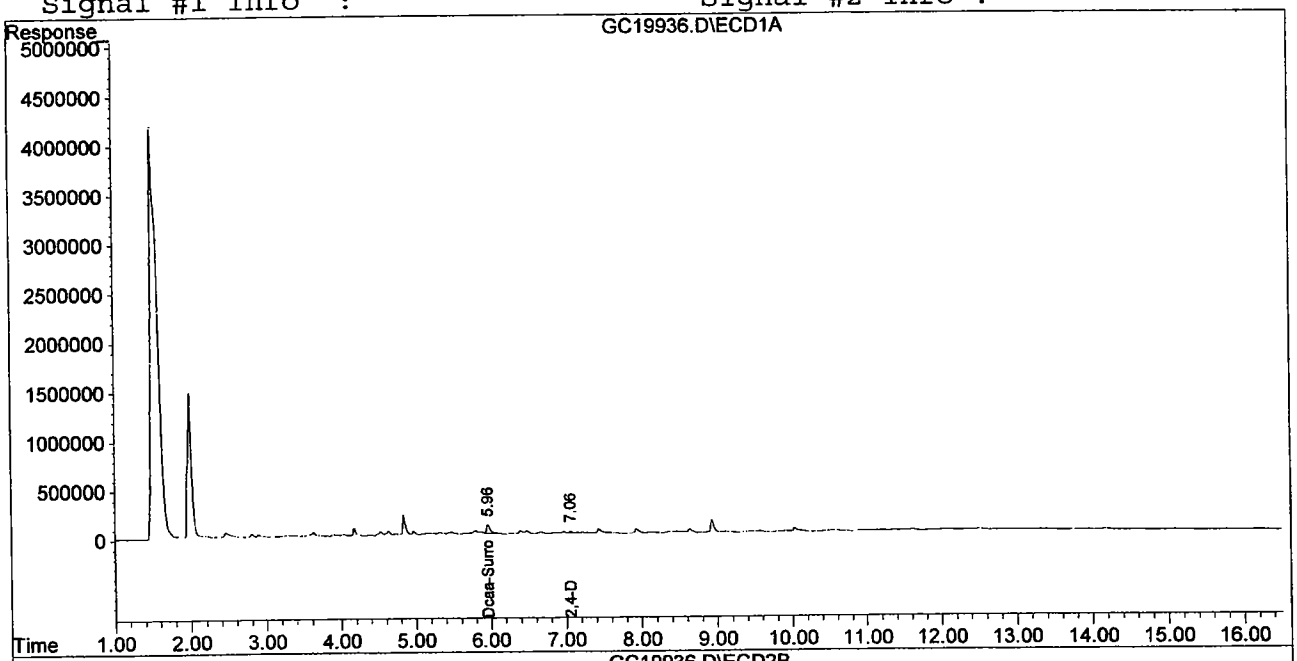
(f)=RT Delta > 1/2 Window (#)=Amounts differ by > 25% (m)=manual int.

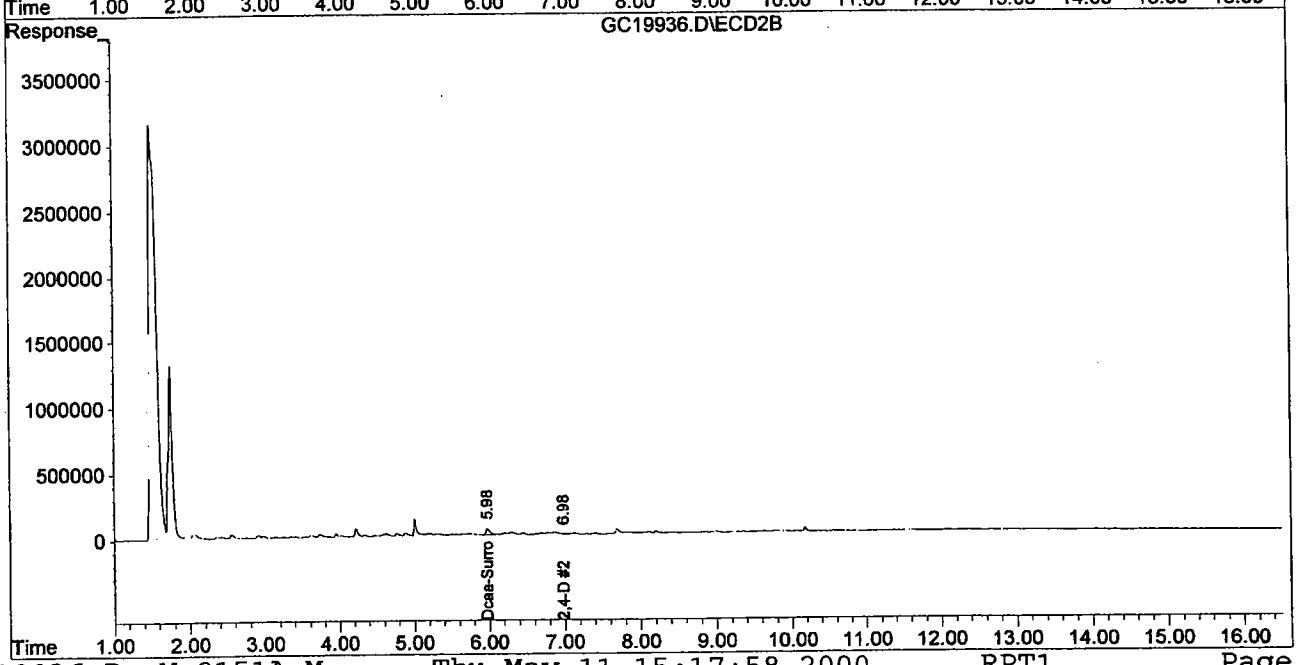
Quantitation Report

Signal #1 : G:\GCDATA\GC_2\05-10-00\GC19936.D\ECD1A.CH Vial: 17
Signal #2 : G:\GCDATA\GC_2\05-10-00\GC19936.D\ECD2B.CH
Acq On : 10 May 2000 15:36 Operator: AHD
Sample : AB07059 Inst : GC_2
Misc : S,HERB Multiplr: 1.00
IntFile Signal #1: autoint1.e IntFile Signal #2: autoint2.e
Quant Time: May 11 15:07 2000 Quant Results File: M_8151A.RES

Quant Method : G:\GCDATA\METHODS\M_8151A.M (Chemstation Integrator)
Title : @GC_2
Last Update : Tue Mar 14 09:36:48 2000
Response via : Multiple Level Calibration
DataAcq Meth : M_8081H.M

Volume Inj. :
Signal #1 Phase : Signal #2 Phase:
Signal #1 Info : Signal #2 Info :





Form1

ORGANICS HERBICIDES REPORT

Sample Number: AB07060
Client Id: SW1
Data File: GC19924
Date Analyzed: 10 May 2000 10:34
Date Received/Extracted: 05/04/2000-05/09/2000

Matrix: Water
Initial Volume: 1000ml
Final Volume: 10ml
Dilution Factor: 1
Percent Solids: 0

Column: J&W-Scientific db-608/1701 30m .32mmID

CAS #	*Compound*	*PQL/MDL*	*Concentration (Units: ug/L)*
93765	2,4,5-T	0.20	U
94757	2,4-D	0.20	U
1918009	Dicamba	0.20	U
93721	Silvex	0.20	U

Total Target Concentration 0

U - Indicates the compound was analyzed but not detected.
J - Indicates an estimated value when a compound is detected at less than the specified detection limit.
B - Indicates the analyte was found in the blank as well as in the sample.
E - Indicates the analyte concentration exceeds the calibration range of the instrument.

Control File h:\import\33120.txt

Quantitation Report (QT Reviewed)

Signal #1 : G:\GCDATA\GC_2\05-10-00\GC19924.D\ECD1A.CH Vial: 5
Signal #2 : G:\GCDATA\GC_2\05-10-00\GC19924.D\ECD2B.CH
Acq On : 10 May 2000 10:34 Operator: AHD
Sample : AB07060 Inst : GC_2
Misc : A,HERB Multiplr: 1.00
IntFile Signal #1: autoint1.e IntFile Signal #2: autoint2.e
Quant Time: May 10 14:02 2000 Quant Results File: M_8151A.RES

Quant Method : G:\GCDATA\METHODS\M_8151A.M (Chemstation Integrator)
Title : @GC_2
Last Update : Tue Mar 14 09:36:48 2000
Response via : Initial Calibration
DataAcq Meth : M_8081H.M

Volume Inj. :
Signal #1 Phase : Signal #2 Phase:
Signal #1 Info : Signal #2 Info :

	Compound	RT#1	RT#2	Resp#1	Resp#2	ng#1	ng#2
	Target Compounds						
2)	Dcaa-Surrogate	5.96	5.98	2800982	1572967	1290.662	1055.075

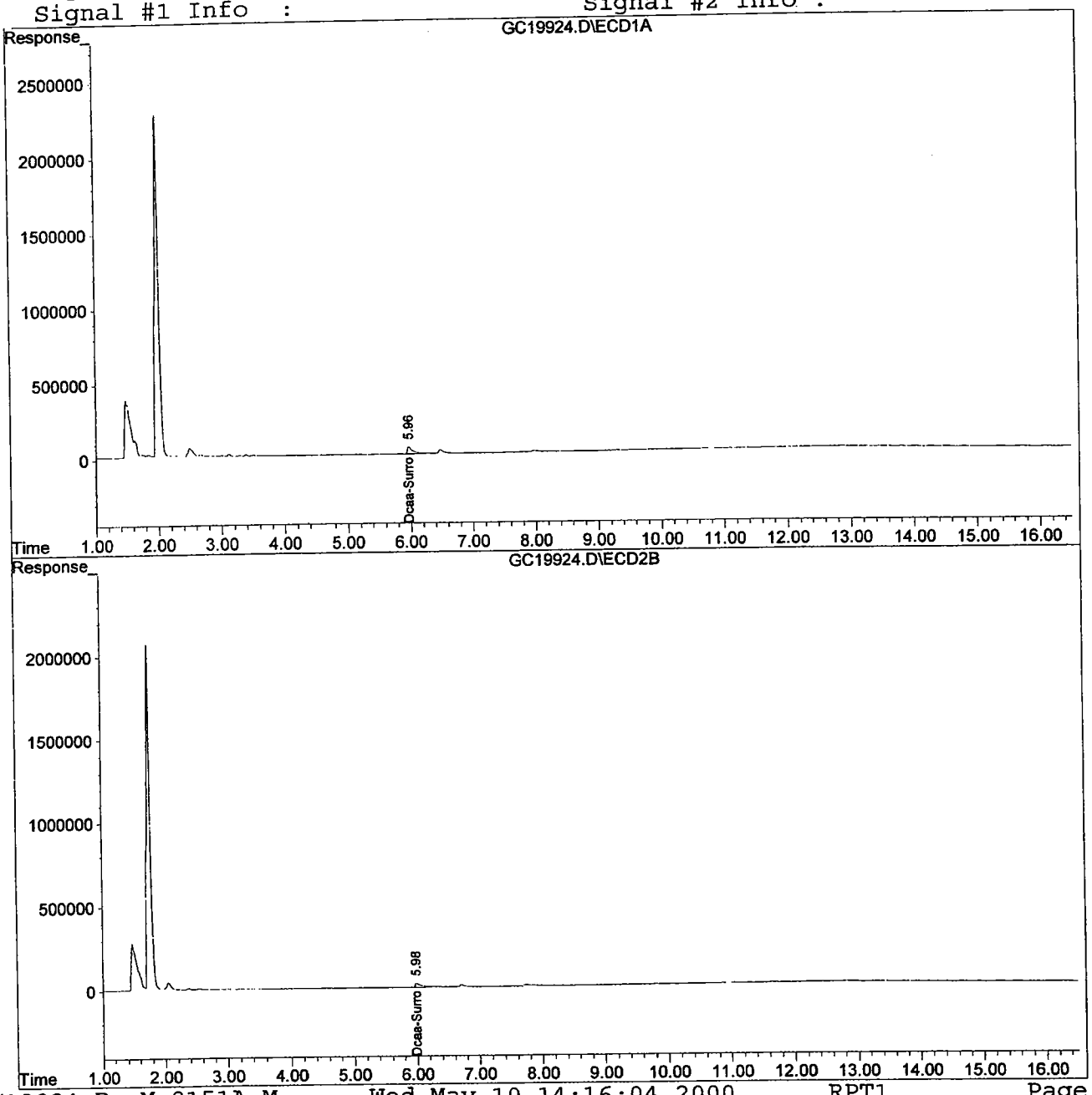
(f)=RT Delta > 1/2 Window (#)=Amounts differ by > 25% (m)=manual int.

Quantitation Report

Signal #1 : G:\GCDATA\GC_2\05-10-00\GC19924.D\ECD1A.CH Vial: 5
Signal #2 : G:\GCDATA\GC_2\05-10-00\GC19924.D\ECD2B.CH
Acq On : 10 May 2000 10:34 Operator: AHD
Sample : AB07060 Inst : GC_2
Misc : A,HERB Multiplr: 1.00
IntFile Signal #1: autoint1.e IntFile Signal #2: autoint2.e
Quant Time: May 10 14:02 2000 Quant Results File: M_8151A.RES

Quant Method : G:\GCDATA\METHODS\M_8151A.M (Chemstation Integrator)
Title : @GC_2
Last Update : Tue Mar 14 09:36:48 2000
Response via : Multiple Level Calibration
DataAcq Meth : M_8081H.M

Volume Inj. :
Signal #1 Phase : Signal #2 Phase:
Signal #1 Info : Signal #2 Info :



Form1

ORGANICS HERBICIDES REPORT

Sample Number: AB07061 | *Matrix:* Soil

Client Id: S2 | *Initial Volume:* 50g

Data File: GC19937 | *Final Volume:* 10ml

Date Analyzed: 10 May 2000 15:57 | *Dilution Factor:* 1

Date Received/Extracted: 05/04/2000-05/10/2000 | *Percent Solids:* 69

Column: J&W-Scientific db-608/1701 30m .32mmID

CAS #	*Compound*	*PQL/MDL*	*Concentration (Units: mg/Kg)*
93765	2,4,5-T	0.0058	U
94757	2,4-D	0.0058	0.0071
1918009	Dicamba	0.0058	U
93721	Silvex	0.0058	U

Total Target Concentration 0.0071

U - Indicates the compound was analyzed but not detected.
J - Indicates an estimated value when a compound is detected at less than the specified detection limit.
B - Indicates the analyte was found in the blank as well as in the sample.
E - Indicates the analyte concentration exceeds the calibration range of the instrument.

Control File h:\import\31629.txt

Quantitation Report (QT Reviewed)

Signal #1 : G:\GCDATA\GC_2\05-10-00\GC19937.D\ECD1A.CH Vial: 18
Signal #2 : G:\GCDATA\GC_2\05-10-00\GC19937.D\ECD2B.CH
Acq On : 10 May 2000 15:57 Operator: AHD
Sample : AB07061 Inst : GC_2
Misc : S,HERB Multiplr: 1.00
IntFile Signal #1: autoint1.e IntFile Signal #2: autoint2.e
Quant Time: May 11 15:09 2000 Quant Results File: M_8151A.RES

Quant Method : G:\GCDATA\METHODS\M_8151A.M (Chemstation Integrator)
Title : @GC_2
Last Update : Tue Mar 14 09:36:48 2000
Response via : Initial Calibration
DataAcq Meth : M_8081H.M

Volume Inj. :
Signal #1 Phase : Signal #2 Phase:
Signal #1 Info : Signal #2 Info :

	Compound	RT#1	RT#2	Resp#1	Resp#2	ng#1	ng#2
	Target Compounds						
2)	Dcaa-Surrogate	5.96	5.98	3096560	1664752	1426.862m	1116.640m
5)	2,4-D	7.06	6.98	517436	71126	131.707m	24.561m#

AHF 5/11/2

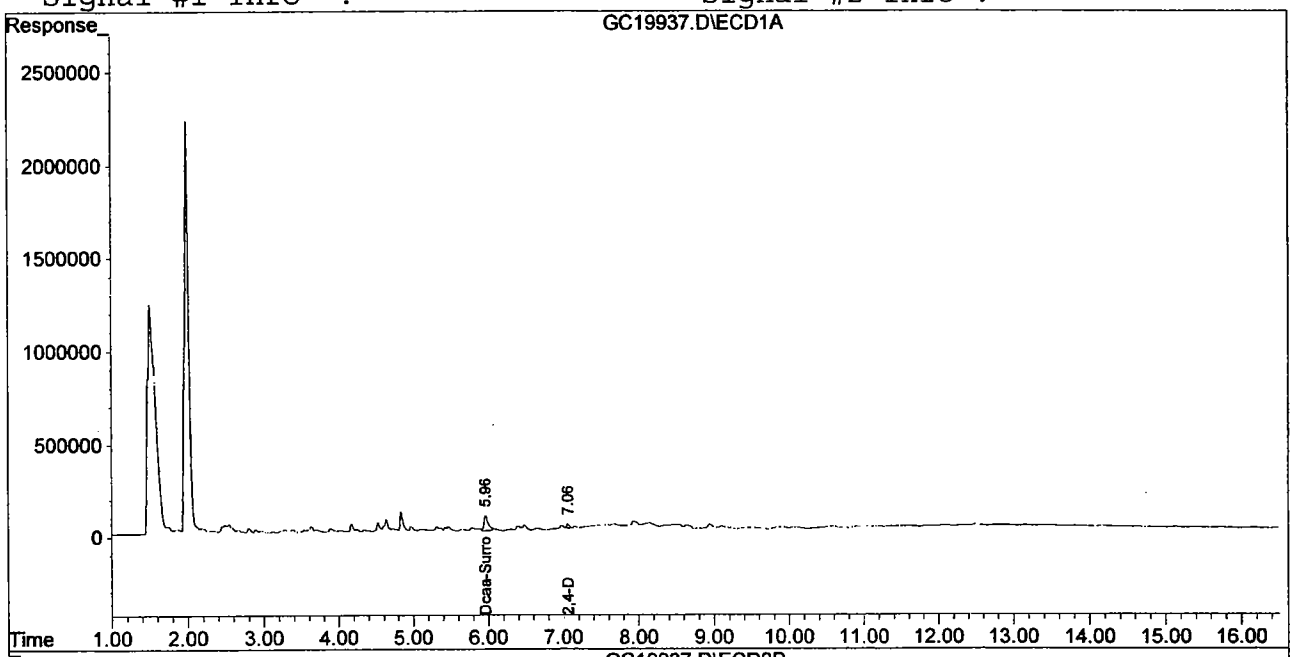
(f)=RT Delta > 1/2 Window (#)=Amounts differ by > 25% (m)=manual int.

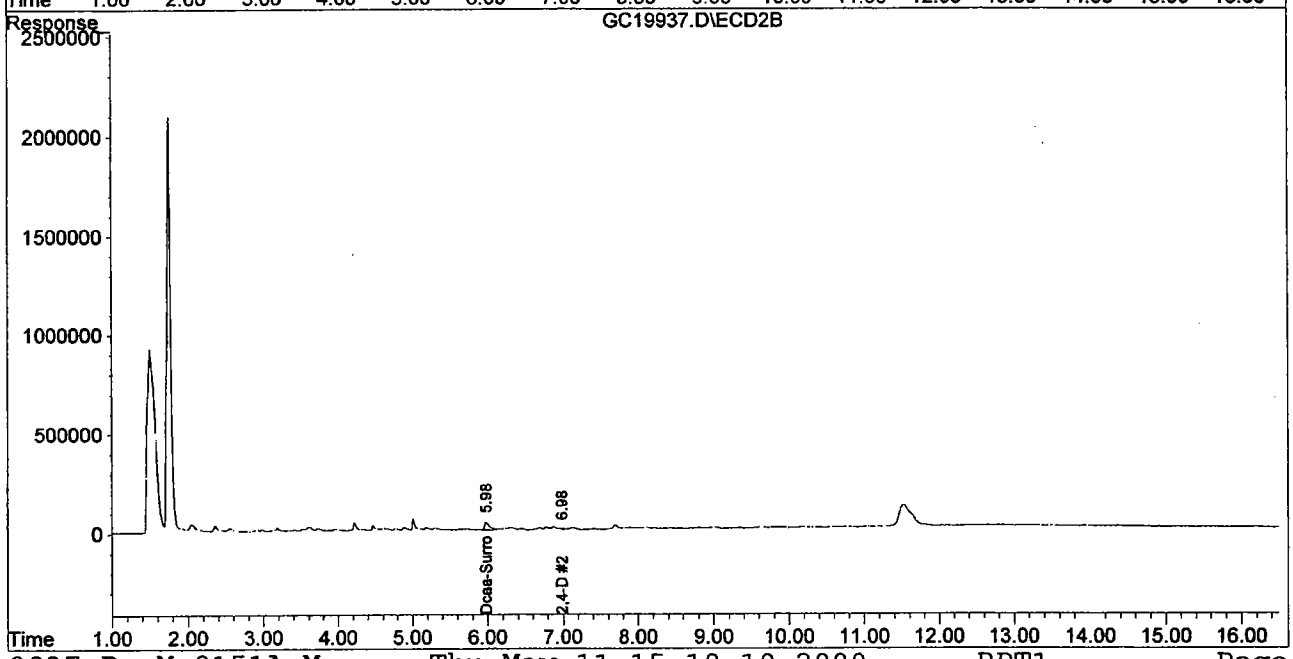
Quantitation Report

Signal #1 : G:\GCDATA\GC_2\05-10-00\GC19937.D\ECD1A.CH Vial: 18
Signal #2 : G:\GCDATA\GC_2\05-10-00\GC19937.D\ECD2B.CH
Acq On : 10 May 2000 15:57 Operator: AHD
Sample : AB07061 Inst : GC_2
Misc : S,HERB Multiplr: 1.00
IntFile Signal #1: autoint1.e IntFile Signal #2: autoint2.e
Quant Time: May 11 15:09 2000 Quant Results File: M_8151A.RES

Quant Method : G:\GCDATA\METHODS\M_8151A.M (Chemstation Integrator)
Title : @GC_2
Last Update : Tue Mar 14 09:36:48 2000
Response via : Multiple Level Calibration
DataAcq Meth : M_8081H.M

Volume Inj. :
Signal #1 Phase : Signal #2 Phase:
Signal #1 Info : Signal #2 Info :





05042106

Veritech, 175 Route 46 West, Fairfield, NJ 07004
A Division of HAMPTON-CLARKE, Inc. NJDEPE #14622

CHAIN OF CUSTODY RECORD

PHONE (973) 244-9770
FAX (973) 244-9787

CUSTOMER INFORMATION

CUSTOMER: MJE/DTEC
ADDRESS:
TELEPHONE:
PROJECT:
PROJECT MANAGER:
PROJECT LOCATION:
STATE:
PO NUMBER:

REPORT INFORMATION

SEND REPORT TO: DTEAC

SEND INVOICE TO: MJE

PROJECT INFORMATION

TURNAROUND (CONFIRM RUSH TAT'S WITH LAB)
STANDARD X RUSH

DELIVERABLES (PLEASE CIRCLE):
STANDARD ISRA BUST
WASTE REGULATORY
OTHER (Specify)

ANALYTICAL REQUESTS

LAB SAMPLE NUMBER	SAMPLE IDENTIFICATION	DATE COLLECTED	TIME COLLECTED	SAMPLE TYPE: COMPOSITE (C)	SAMPLE TYPE: GRAB (G)	SAMPLE MATRIX	NO. OF BOTTLES: H_2SO_4	HNO3	HCL	NaOH	ZnAc + NaOH	Ascorbic	NONE	OTHER	ANALYSIS
AB07059	S1	5/3/00	14:00		X	S							1		METALS(TAL), PESTICIDES, HERBICIDES
AB07060	SW1	5/3/00	13:30		X	W	1								PHOSPHORUS
	SW1	5/3/00	13:35		X	W							1		NITRATE
	SW1	5/3/00	13:40		X	W							2		PESTICIDES
	SW1	5/3/00			X	W							2		HERBICIDES
	SW1	5/3/00	13:50		X	W		1							METALS(TAL)
AB07061	S2	5/3/00	14:30		X	S							1		METALS(TAL), PESTICIDES, HERBICIDES
AB07062	SW2	5/3/00	15:15		X	W							1		NITRATE
	SW2	5/3/00	15:20		X	W	1								PHOSPHORUS

SAMPLER CERTIFIES THAT EACH SAMPLE RECEIVED PROPER FIELD PRESERVATION (IF REQUIRED) (INITIALS)

SAMPLE HAZARDS: ☐ FLAMMABLE ☐ SKIN IRRITANT ☐ NON-HAZARD ☐ UNKNOWN ☐ NOXIOUS FUMES

SPECIAL INSTRUCTIONS:

TEMPERATURE UPON RECEIPT: 5.7°C

Relinquished by: / Agent of:	DATE/TIME	Received by: / Agent of:	DATE/TIME
MITTCOPAN JOSAN / MJE		Fed Ex	
Fed Ex		[illegible]	5/4/00 1200

Veritech, 175 Route 46 West, Fairfield, NJ 07004
A Division of HAMPTON-CLARKE, Inc. NJDEPE #14622

CHAIN OF CUSTODY RECORD

PHONE (973) 244-9770
FAX (973) 244-9787

CUSTOMER INFORMATION

CUSTOMER: MJE/DREAC
ADDRESS:
TELEPHONE:
PROJECT:
PROJECT MANAGER:
PROJECT LOCATION:
STATE:
PO NUMBER:

REPORT INFORMATION

SEND REPORT TO: DREAC

SEND INVOICE TO: MJE

PROJECT INFORMATION

TURNAROUND (CONFIRM RUSH TAT'S WITH LAB)
STANDARD X RUSH

DELIVERABLES (PLEASE CIRCLE):
STANDARD ISRA BUST
WASTE REGULATORY
OTHER (Specify)

ANALYTICAL REQUESTS

LAB SAMPLE NUMBER	SAMPLE IDENTIFICATION	DATE COLLECTED	TIME COLLECTED	SAMPLE TYPE: COMPOSITE (C)	SAMPLE TYPE: GRAB (G)	SAMPLE MATRIX	NO. OF BOTTLES: H_2SO_4	HNO_3	HCL	NaOH	ZnAc + NaOH	Ascorbic	NONE	OTHER	ANALYSIS
AB07063	SW14	3/5/00	15:58		X	W	1								PHOSPHORUS
↓	SW14		16:02		X	W							1		NITRATE
AB07064	SW8	3/5/00	16:28		X	W	1								PHOSPHORUS
↓	SW8		16:30		X	W							1		NITRATE

SAMPLER CERTIFIES THAT EACH SAMPLE RECEIVED PROPER FIELD PRESERVATION (IF REQUIRED) (INITIALS)

SAMPLE HAZARDS: ☐ FLAMMABLE ☐ SKIN IRRITANT ☐ NON-HAZARD ☐ UNKNOWN ☐ NOXIOUS FUMES

SPECIAL INSTRUCTIONS:

TEMPERATURE UPON RECEIPT: 5.7°C

Relinquished by: / Agent of:	DATE/TIME	Received by: / Agent of:	DATE/TIME
MITCHAN JOSAN / MJE		FedEx	
FedEx		Joseph Kh... / Hel	3/4/00 1200

APL

Veritech, 175 Route 46 West, Fairfield, NJ 07004
A Division of HAMPTON-CLARKE, Inc. NJDEPE #14622

CHAIN OF CUSTODY RECORD

PHONE (973) 244-9770
FAX (973) 244-9787

CUSTOMER INFORMATION

CUSTOMER:
ADDRESS:
TELEPHONE:
PROJECT: DTEAC
PROJECT MANAGER:
PROJECT LOCATION:
STATE:
PO NUMBER:

REPORT INFORMATION

SEND REPORT TO: Veritech

SEND INVOICE TO: Veritech

PROJECT INFORMATION

TURNAROUND (CONFIRM RUSH TAT'S WITH LAB)
STANDARD ✓ RUSH

DELIVERABLES (PLEASE CIRCLE):
STANDARD ISRA BUST
WASTE REGULATORY
OTHER (Specify)

ANALYTICAL REQUESTS

LAB SAMPLE NUMBER	SAMPLE IDENTIFICATION	DATE COLLECTED	TIME COLLECTED	SAMPLE TYPE: COMPOSITE (C)	SAMPLE TYPE: GRAB (G)	SAMPLE MATRIX	NO. OF BOTTLES: H2SO4	HNO3	HCL	NaOH	ZnAc + NaOH	Ascorbic	NONE	OTHER	ANALYSIS
	AB07060	5/3/00				Aq	1						1		NO_3 & tot P
	07062														
	07063														
	07064														

SAMPLER CERTIFIES THAT EACH SAMPLE RECEIVED PROPER FIELD PRESERVATION (IF REQUIRED) (INITIALS)

SAMPLE HAZARDS: ☐ FLAMMABLE ☐ SKIN IRRITANT ☐ NON-HAZARD ☐ UNKNOWN ☐ NOXIOUS FUMES

SPECIAL INSTRUCTIONS:

TEMPERATURE UPON RECEIPT:

Relinquished by: / Agent of:	DATE/TIME	Received by: / Agent of:	DATE/TIME
Angel Kim / HCI	5/5/00 855	[illegible] / ACL	5/5/00 0855

CONDITION UPON RECEIPT FORM **Veritech**

Date Received: 5/4/00 Filed By: JK
Client: MJE Project/Account:
Veritech Project #

YES	NO		INITIAL CONDITIONS
✓		[1]	Is there a corresponding Chain of Custody included with the samples?
✓		[2]	Are the samples in a container such as a cooler or ice chest?
	✓	[3]	Are the custody seals intact? IF NO, please circle one of the following: missing broken (N.A)
5.7 °C		[4]	Please specify the temperature inside the container.

YES	NO		SAMPLE INFORMATION
✓		[5]	Are the samples properly refrigerated (where required), have they arrived on ice?
✓		[6]	Are the samples within holding times for the parameters listed on the COC? If NO, list parameters and associated samples:
✓		[7]	Are all of the sample bottles intact? If NO, specify sample numbers below: broken: leaking:
✓		[8]	Are all of the sample labels or numbers legible? If NO, specify:
✓		[9]	Do the contents of the container match the COC? If NO, specify:
✓		[10]	Is there enough sample sent for the analyses listed on the COC? If NO, specify:
✓		[11]	Are the samples preserved correctly (see Preservation Form for actual pH readings)?
		[12]	Are all soil VO(NJ) samples properly preserved in methanol with the correct soil weights (8g - 12g) and accompanied by dry soil?

OTHER

[13] Specify:

NO.	ACTION	CORRECTIVE ACTIONS

veritech laboratories

PRESERVATION DOCUMENTATION

Date Received: 5/4/00

Client: MJE

Veritech Project #:

Filed By: JK

Project:

SAMPLE ID:	CONTAINER SIZE	CONTAINER TYPE (PG)	PARAMETER	PRESERVATIVE	pH
SW1	500mL	P	Phosphorus	H_2SO_4	1
SW1	1L	P	Metals (TAL)	HNO_3	1.
SW2	500mL	P	Phosphorus	H_2SO_4	1
SW14	500mL	P	Phosphorus	H_2SO_4	1
SW8	500mL	P	Phosphorus	H_2SO_4	1

Form1

ORGANICS PESTICIDES REPORT

Sample Number: WMB981
Client Id:
Data File: GB2147
Date Analyzed: 8 May 2000 16:25
Date Received/Extracted: -05/05/00

Matrix: Water
Initial Volume: 1000ml
Final Volume: 10ml
Dilution Factor: 1
Percent Solids: 0

Column: J&W-Scientific db-608/1701 30m .32mmID

CAS #	*Compound*	*PQL/MDL*	*Concentration (Units: ug/L)*
309002	Aldrin	0.020	U
319846	Alpha-BHC	0.020	U
319857	Beta-BHC	0.020	U
57749	Chlordane	0.20	U
319868	Delta-BHC	0.020	U
60571	Dieldrin	0.020	U
959988	Endosulfan I	0.020	U
33213659	Endosulfan II	0.020	U
1031078	Endosulfan Sulfate	0.020	U
72208	Endrin	0.020	U
7421934	Endrin Aldehyde	0.020	U
53494705	Endrin Ketone	0.020	U
58899	Gamma-BHC	0.020	U
76448	Heptachlor	0.020	U
1024573	Heptachlor Epoxide	0.020	U
72435	Methoxychlor	0.020	U
72548	P,P'-DDD	0.020	U
72559	P,P'-DDE	0.020	U
50293	P,P'-DDT	0.020	U
8001352	Toxaphene	1.0	U

Total Target Concentration 0

U - Indicates the compound was analyzed but not detected.
J - Indicates an estimated value when a compound is detected at less than the specified detection limit.
B - Indicates the analyte was found in the blank as well as in the sample.
E - Indicates the analyte concentration exceeds the calibration range of the instrument.

Control File h:\import\62609.txt

Quantitation Report (QT Reviewed)

Signal #1 : G:\GCDATA\GC_3\05-08-00\GB2147.D\ECD1A.CH Vial: 12
Signal #2 : G:\GCDATA\GC_3\05-08-00\GB2147.D\ECD2B.CH
Acq On : 8 May 2000 16:25 Operator: AHD
Sample : WMB981 Inst : GC_3
Misc : A,PEST Multiplr: 1.00
IntFile Signal #1: PEST1.E IntFile Signal #2: Pest2.e
Quant Time: May 9 10:03 2000 Quant Results File: M3_8081.RES

Quant Method : G:\GCDATA\METHODS\M3_8081.M (Chemstation Integrator)
Title : @GC_3
Last Update : Mon May 08 16:21:59 2000
Response via : Initial Calibration
DataAcq Meth : GC3_8081.M

Volume Inj. : 1ul
Signal #1 Phase : db-1701 Signal #2 Phase: db-608
Signal #1 Info : .32 Signal #2 Info : .32

	Compound	RT#1	RT#2	Resp#1	Resp#2	pg#1	pg#2
	Target Compounds						
1)	TCMX-Surrogate	2.80	2.85	1563019	526714	146.699	168.828
22)	DCB-Surrogate	10.88	11.82	687605	286730	145.191	156.199

MH 5/9/00

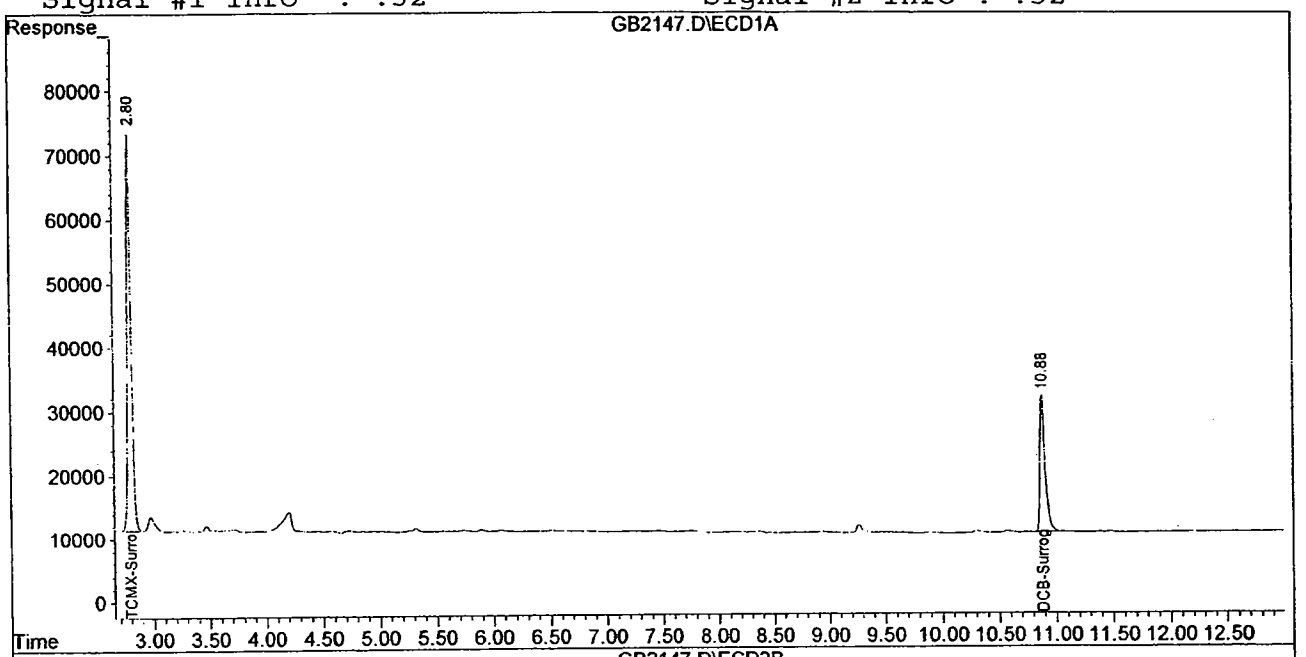
(f)=RT Delta > 1/2 Window (#)=Amounts differ by > 25% (m)=manual int.

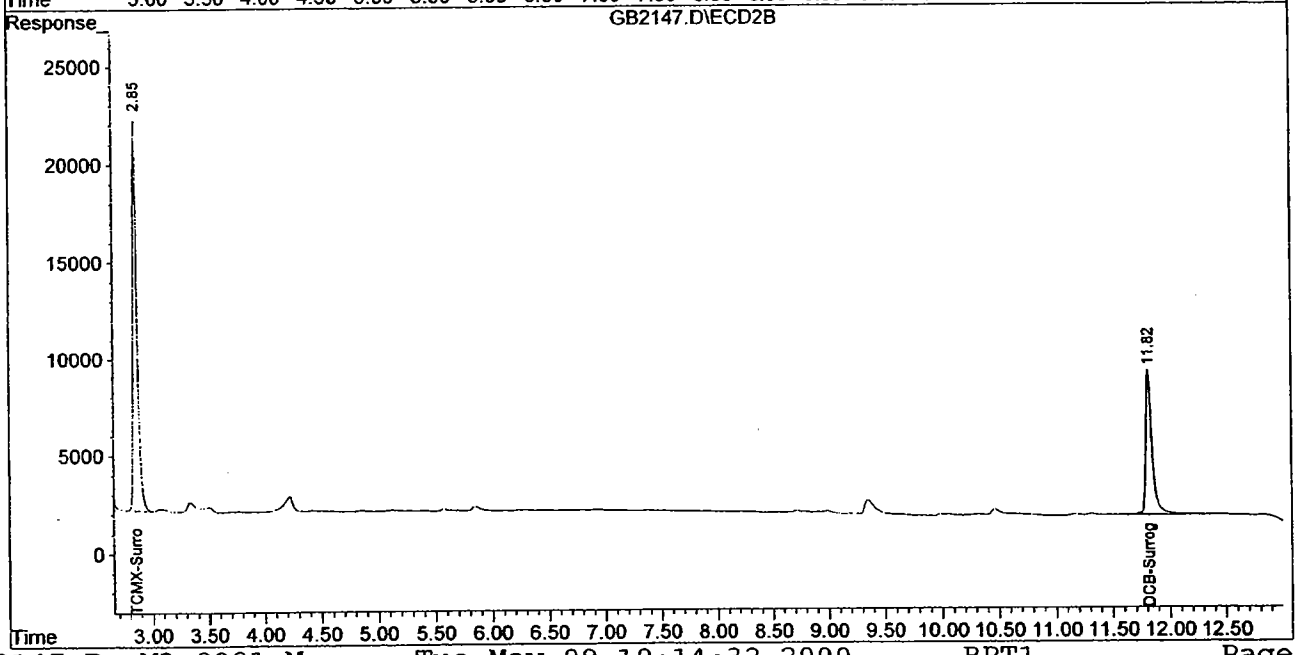
Quantitation Report

Signal #1 : G:\GCDATA\GC_3\05-08-00\GB2147.D\ECD1A.CH Vial: 12
Signal #2 : G:\GCDATA\GC_3\05-08-00\GB2147.D\ECD2B.CH
Acq On : 8 May 2000 16:25 Operator: AHD
Sample : WMB981 Inst : GC_3
Misc : A,PEST Multiplr: 1.00
IntFile Signal #1: PEST1.E IntFile Signal #2: Pest2.e
Quant Time: May 9 10:03 2000 Quant Results File: M3_8081.RES

Quant Method : G:\GCDATA\METHODS\M3_8081.M (Chemstation Integrator)
Title : @GC_3
Last Update : Mon May 08 16:21:59 2000
Response via : Multiple Level Calibration
DataAcq Meth : GC3_8081.M

Volume Inj. : 1ul
Signal #1 Phase : db-1701 Signal #2 Phase: db-608
Signal #1 Info : .32 Signal #2 Info : .32





Form1

ORGANICS PESTICIDES REPORT

Sample Number: SMB1209
Client Id:
Data File: GB2165
Date Analyzed: 9 May 2000 12:57
Date Received/Extracted: -05/05/00

Matrix: Soil
Initial Volume: 30g
Final Volume: 10ml
Dilution Factor: 1
Percent Solids: 100

Column: J&W-Scientific db-608/1701 30m .32mmID

CAS #	*Compound*	*PQL/MDL*	*Concentration (Units: mg/Kg)*
309002	Aldrin	0.0033	U
319846	Alpha-BHC	0.0033	U
319857	Beta-BHC	0.0033	U
57749	Chlordane	0.0067	U
319868	Delta-BHC	0.0033	U
60571	Dieldrin	0.0033	U
959988	Endosulfan I	0.0033	U
33213659	Endosulfan II	0.0033	U
1031078	Endosulfan Sulfate	0.0033	U
72208	Endrin	0.0033	U
7421934	Endrin Aldehyde	0.0033	U
53494705	Endrin Ketone	0.0033	U
58899	Gamma-BHC	0.0033	U
76448	Heptachlor	0.0033	U
1024573	Heptachlor Epoxide	0.0033	U
72435	Methoxychlor	0.0033	U
72548	P,P'-DDD	0.0033	U
72559	P,P'-DDE	0.0033	U
50293	P,P'-DDT	0.0033	U
8001352	Toxaphene	0.033	U

Total Target Concentration 0

U - Indicates the compound was analyzed but not detected.
J - Indicates an estimated value when a compound is detected at less than the specified detection limit.
B - Indicates the analyte was found in the blank as well as in the sample.
E - Indicates the analyte concentration exceeds the calibration range of the instrument.

Control File h:\import\110045.txt

Quantitation Report (QT Reviewed)

Signal #1 : G:\GCDATA\GC_3\05-09-00\GB2165.D\ECD1A.CH Vial: 5
Signal #2 : G:\GCDATA\GC_3\05-09-00\GB2165.D\ECD2B.CH
Acq On : 9 May 2000 12:57 Operator: AHD
Sample : SMB1209 Inst : GC_3
Misc : S,PEST Multiplr: 1.00
IntFile Signal #1: PEST1.E IntFile Signal #2: Pest2.e
Quant Time: May 10 8:51 2000 Quant Results File: M3_8081.RES

Quant Method : G:\GCDATA\METHODS\M3_8081.M (Chemstation Integrator)
Title : @GC_3
Last Update : Mon May 08 16:21:59 2000
Response via : Initial Calibration
DataAcq Meth : GC3_8081.M

Volume Inj. : 1ul
Signal #1 Phase : db-1701 Signal #2 Phase: db-608
Signal #1 Info : .32 Signal #2 Info : .32

	Compound	RT#1	RT#2	Resp#1	Resp#2	pg#1	pg#2
	Target Compounds						
1)	TCMX-Surrogate	2.80	2.87	1407071	454937	132.062	145.821m
22)	DCB-Surrogate	10.89	11.83	654943	255051	138.294m	138.942

AHD 5/10/00

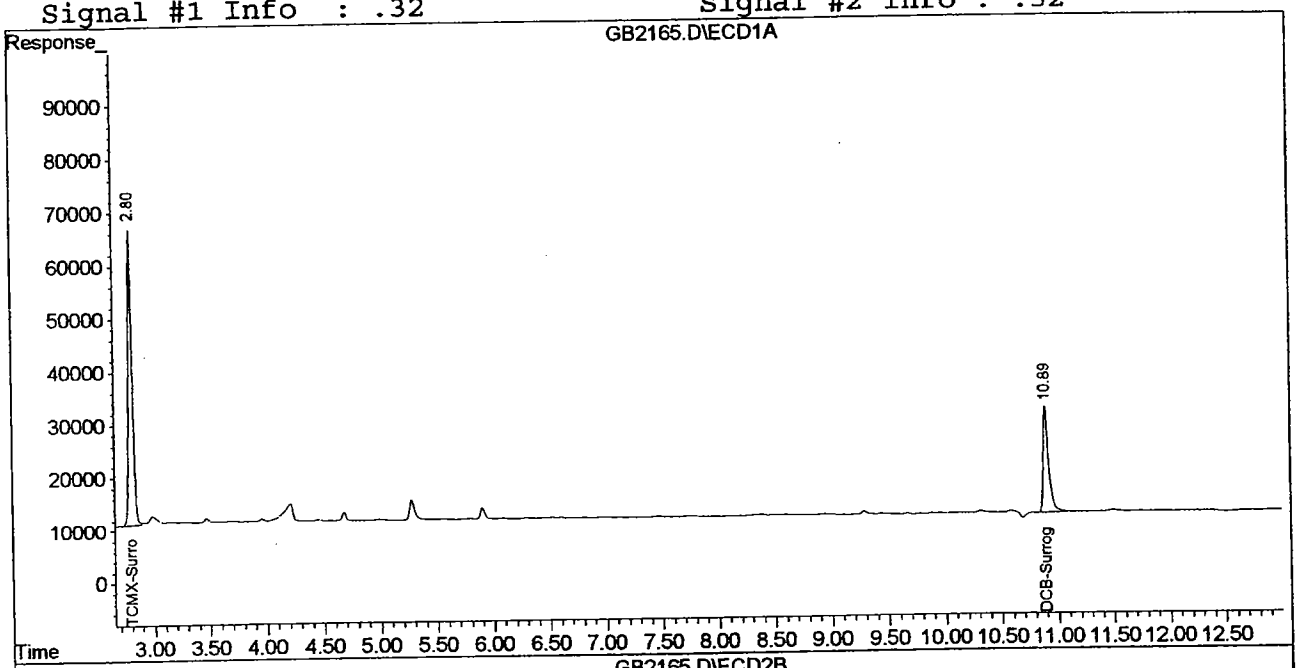
(f)=RT Delta > 1/2 Window (#)=Amounts differ by > 25% (m)=manual int.

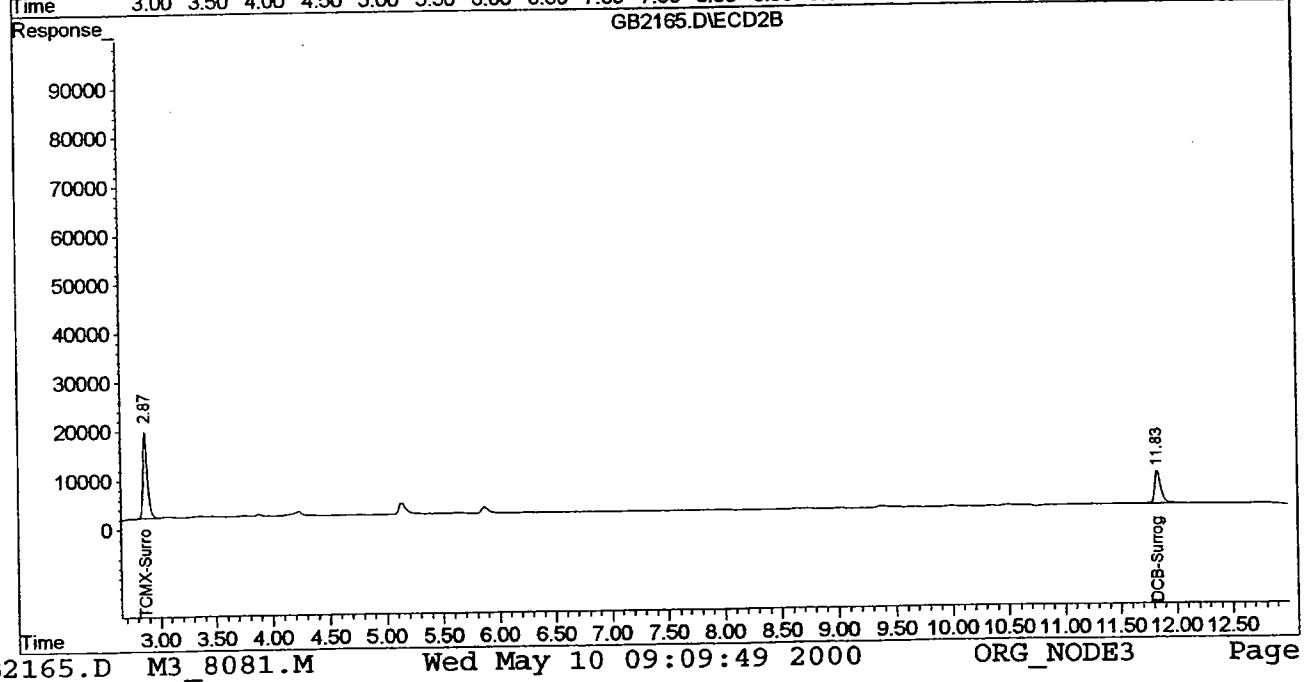
Quantitation Report

Signal #1 : G:\GCDATA\GC_3\05-09-00\GB2165.D\ECD1A.CH Vial: 5
Signal #2 : G:\GCDATA\GC_3\05-09-00\GB2165.D\ECD2B.CH
Acq On : 9 May 2000 12:57 Operator: AHD
Sample : SMB1209 Inst : GC_3
Misc : S,PEST Multiplr: 1.00
IntFile Signal #1: PEST1.E IntFile Signal #2: Pest2.e
Quant Time: May 10 8:51 2000 Quant Results File: M3_8081.RES

Quant Method : G:\GCDATA\METHODS\M3_8081.M (Chemstation Integrator)
Title : @GC_3
Last Update : Mon May 08 16:21:59 2000
Response via : Multiple Level Calibration
DataAcq Meth : GC3_8081.M

Volume Inj. : 1ul
Signal #1 Phase : db-1701 Signal #2 Phase: db-608
Signal #1 Info : .32 Signal #2 Info : .32





Form1

ORGANICS HERBICIDES REPORT

Sample Number: WMB982
Client Id:
Data File: GC19933
Date Analyzed: 10 May 2000 14:14
Date Received/Extracted: -05/09/00

Matrix: Water
Initial Volume: 1000ml
Final Volume: 10ml
Dilution Factor: 1
Percent Solids: 0

Column: J&W-Scientific db-608/1701 30m .32mmID

CAS #	*Compound*	*PQL/MDL*	*Concentration (Units: ug/L)*
93765	2,4,5-T	0.20	U
94757	2,4-D	0.20	U
1918009	Dicamba	0.20	U
93721	Silvex	0.20	U

Total Target Concentration 0

U - Indicates the compound was analyzed but not detected.
J - Indicates an estimated value when a compound is detected at less than the specified detection limit.
B - Indicates the analyte was found in the blank as well as in the sample.
E - Indicates the analyte concentration exceeds the calibration range of the instrument.

Control File h:\import\33120.txt

Quantitation Report (QT Reviewed)

Signal #1 : G:\GCDATA\GC_2\05-10-00\GC19933.D\ECD1A.CH Vial: 14
Signal #2 : G:\GCDATA\GC_2\05-10-00\GC19933.D\ECD2B.CH
Acq On : 10 May 2000 14:14 Operator: AHD
Sample : WMB982 Inst : GC_2
Misc : A,HERB Multiplr: 1.00
IntFile Signal #1: autoint1.e IntFile Signal #2: autoint2.e
Quant Time: May 10 14:43 2000 Quant Results File: M_8151A.RES

Quant Method : G:\GCDATA\METHODS\M_8151A.M (Chemstation Integrator)
Title : @GC_2
Last Update : Tue Mar 14 09:36:48 2000
Response via : Initial Calibration
DataAcq Meth : M_8081H.M

Volume Inj. :
Signal #1 Phase : Signal #2 Phase:
Signal #1 Info : Signal #2 Info :

	Compound	RT#1	RT#2	Resp#1	Resp#2	ng#1	ng#2
	Target Compounds						
2)	Dcaa-Surrogate	5.97	5.99	2842926	1529936	1309.990	1026.212

MH 5/19/00

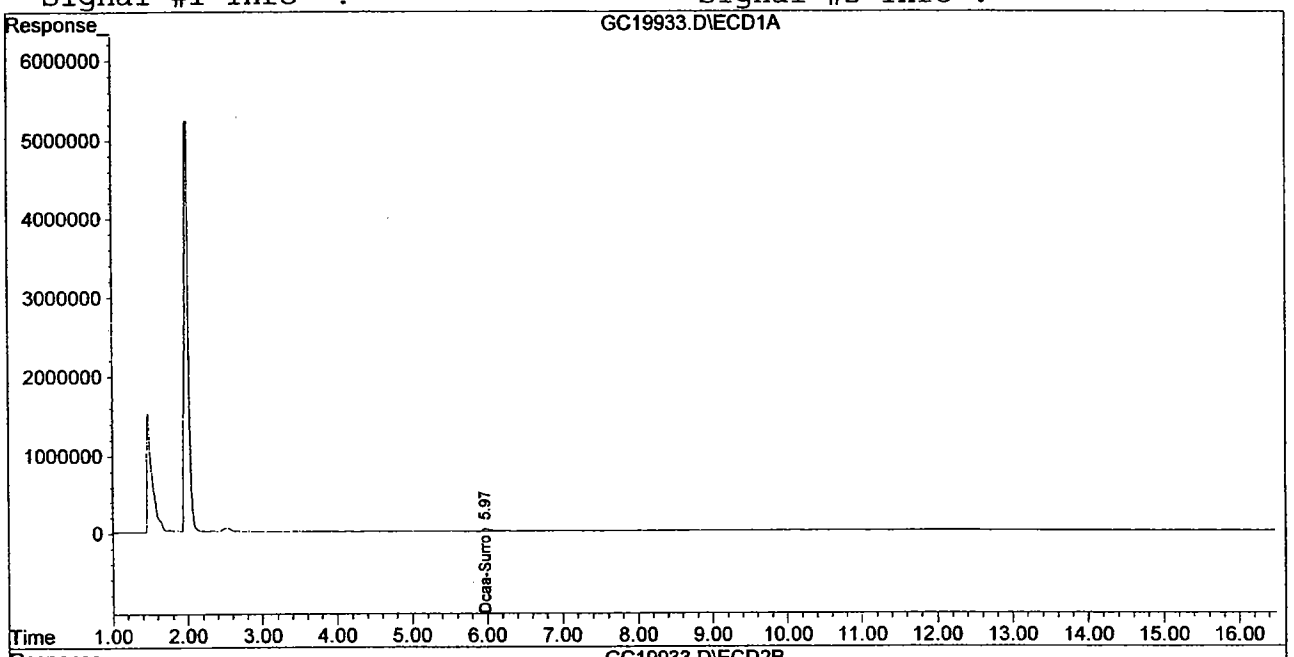
(f)=RT Delta > 1/2 Window (#)=Amounts differ by > 25% (m)=manual int.

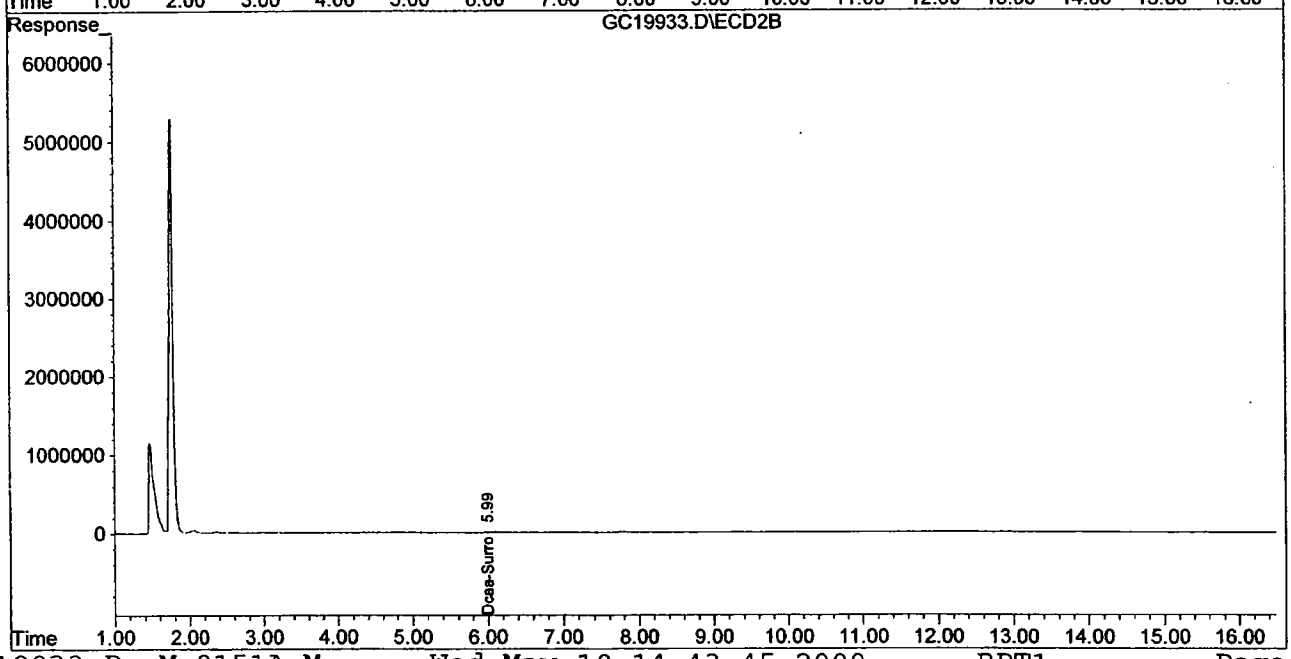
Quantitation Report

Signal #1 : G:\GCDATA\GC_2\05-10-00\GC19933.D\ECD1A.CH Vial: 14
Signal #2 : G:\GCDATA\GC_2\05-10-00\GC19933.D\ECD2B.CH
Acq On : 10 May 2000 14:14 Operator: AHD
Sample : WMB982 Inst : GC_2
Misc : A,HERB Multiplr: 1.00
IntFile Signal #1: autoint1.e IntFile Signal #2: autoint2.e
Quant Time: May 10 14:43 2000 Quant Results File: M_8151A.RES

Quant Method : G:\GCDATA\METHODS\M_8151A.M (Chemstation Integrator)
Title : @GC_2
Last Update : Tue Mar 14 09:36:48 2000
Response via : Multiple Level Calibration
DataAcq Meth : M_8081H.M

Volume Inj. :
Signal #1 Phase : Signal #2 Phase:
Signal #1 Info : Signal #2 Info :





Form1

ORGANICS HERBICIDES REPORT

Sample Number: SMB1212 ***Matrix:*** Soil

Client Id: ***Initial Volume:*** 50g

Data File: GC19935 ***Final Volume:*** 10ml

Date Analyzed: 10 May 2000 15:14 ***Dilution Factor:*** 1

Date Received/Extracted: -05/10/00 ***Percent Solids:*** 100

Column: J&W-Scientific db-608/1701 30m .32mmID

CAS #	*Compound*	*PQL/MDL*	*Concentration (Units: mg/Kg)*
93765	2,4,5-T	0.0040	U
94757	2,4-D	0.0040	U
1918009	Dicamba	0.0040	U
93721	Silvex	0.0040	U

Total Target Concentration 0

U - Indicates the compound was analyzed but not detected.
J - Indicates an estimated value when a compound is detected at less than the specified detection limit.
B - Indicates the analyte was found in the blank as well as in the sample.
E - Indicates the analyte concentration exceeds the calibration range of the instrument.

Control File h:\import\31629.txt

Quantitation Report (QT Reviewed)

Signal #1 : G:\GCDATA\GC_2\05-10-00\GC19935.D\ECD1A.CH Vial: 16
Signal #2 : G:\GCDATA\GC_2\05-10-00\GC19935.D\ECD2B.CH
Acq On : 10 May 2000 15:14 Operator: AHD
Sample : SMB1212 Inst : GC_2
Misc : S,HERB Multiplr: 1.00
IntFile Signal #1: autoint1.e IntFile Signal #2: autoint2.e
Quant Time: May 11 15:03 2000 Quant Results File: M_8151A.RES

Quant Method : G:\GCDATA\METHODS\M_8151A.M (Chemstation Integrator)
Title : @GC_2
Last Update : Tue Mar 14 09:36:48 2000
Response via : Initial Calibration
DataAcq Meth : M_8081H.M

Volume Inj. :
Signal #1 Phase : Signal #2 Phase:
Signal #1 Info : Signal #2 Info :

	Compound	RT#1	RT#2	Resp#1	Resp#2	ng#1	ng#2
	Target Compounds						
2)	Dcaa-Surrogate	5.97	5.99	2636119	1510682	1214.695	1013.297

RMT 5/11/00

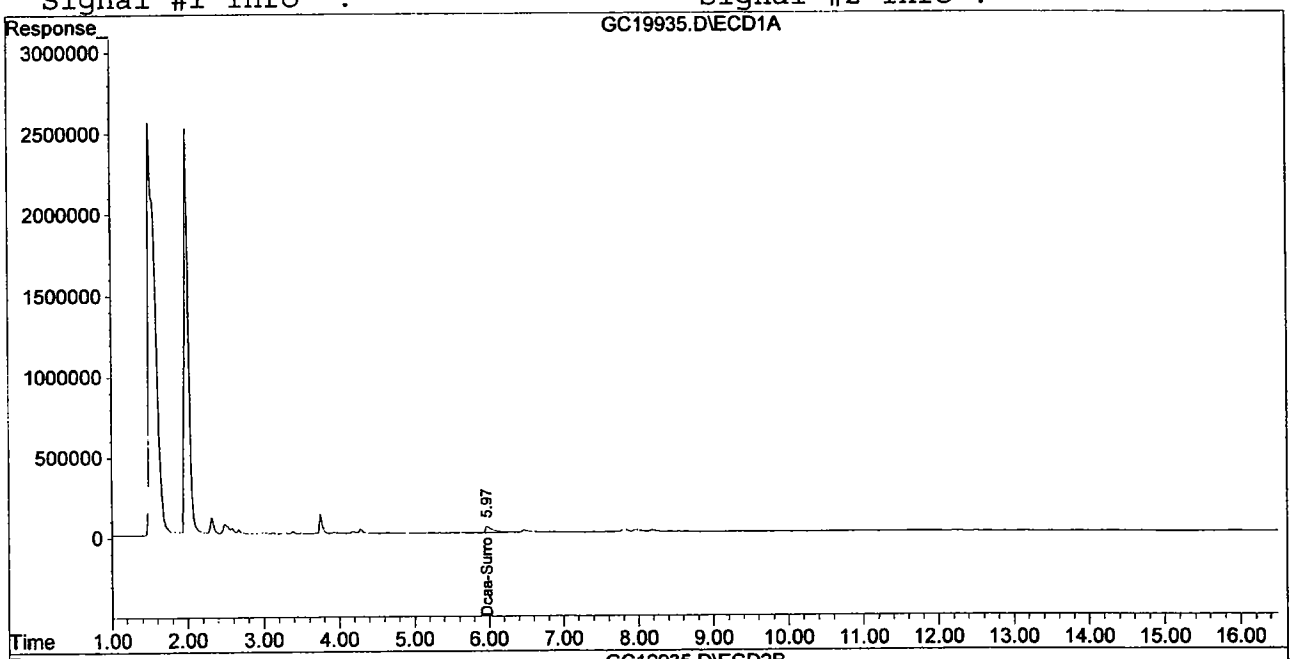
(f)=RT Delta > 1/2 Window (#)=Amounts differ by > 25% (m)=manual int.

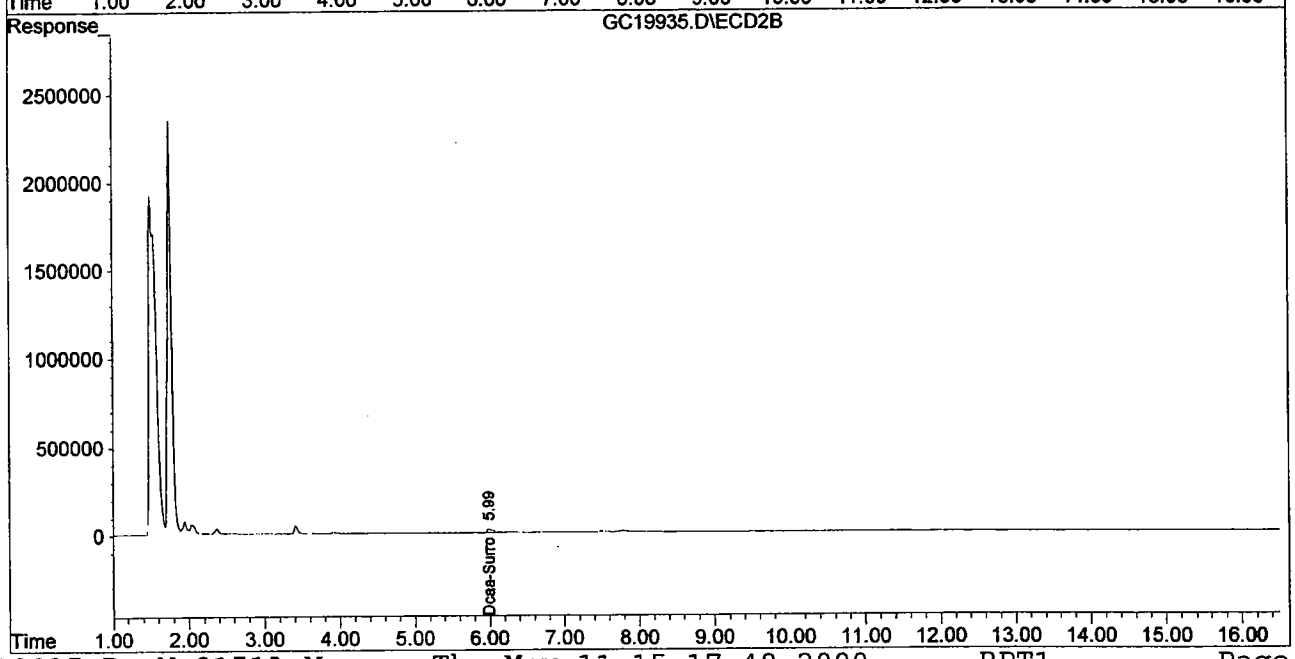
Quantitation Report

Signal #1 : G:\GCDATA\GC_2\05-10-00\GC19935.D\ECD1A.CH Vial: 16
Signal #2 : G:\GCDATA\GC_2\05-10-00\GC19935.D\ECD2B.CH
Acq On : 10 May 2000 15:14 Operator: AHD
Sample : SMB1212 Inst : GC_2
Misc : S,HERB Multiplr: 1.00
IntFile Signal #1: autoint1.e IntFile Signal #2: autoint2.e
Quant Time: May 11 15:03 2000 Quant Results File: M_8151A.RES

Quant Method : G:\GCDATA\METHODS\M_8151A.M (Chemstation Integrator)
Title : @GC_2
Last Update : Tue Mar 14 09:36:48 2000
Response via : Multiple Level Calibration
DataAcq Meth : M_8081H.M

Volume Inj. :
Signal #1 Phase : Signal #2 Phase:
Signal #1 Info : Signal #2 Info :





3
BLANKS

Lab Name: Veritech

Data File Name: A2816A

Lab Code: 14622

Analysis Date: 05/10/2000

Batch: 2816

All Concentration Units in PPM except Mercury in PPB

Analyte	MB 2816(.5)	ICB M-00-BL	CCB	CCB	CCB				M
Barium	0.0228000 U	0.0456000 U	0.0456000 U	0.0456000 U	0.0456000 U				P
Cadmium	0.0014000 U	0.0028000 U	0.0028000 U	0.0028000 U	0.0028000 U				P
Calcium	0.3790000 U	0.7580000 U	0.7580000 U	0.7580000 U	0.7580000 U				P
Chromium	0.0157500 U	0.0315000 U	0.0315000 U	0.0315000 U	0.0315000 U				P
Cobalt	0.0046050 U	0.0092100 U	0.0092100 U	0.0092100 U	0.0092100 U				P
Iron	0.0880000 U	0.1760000 U	0.1760000 U	0.1760000 U	0.1760000 U				P
Lead	0.0034350 U	0.0068700 U	0.0068700 U	0.0068700 U	0.0068700 U				P
Magnesium	0.2575000 U	0.5150000 U	0.5150000 U	0.5150000 U	0.5150000 U				P
Manganese	0.0117500 U	0.0235000 U	0.0235000 U	0.0235000 U	0.0235000 U				P
Nickel	0.0151000 U	0.0302000 U	0.0302000 U	0.0302000 U	0.0302000 U				P
Thallium	0.0031200 U	0.0062400 U	0.0062400 U	0.0062400 U	0.0062400 U				P
Vanadium	0.0042700 U	0.0085400 U	0.0085400 U	0.0085400 U	0.0085400 U				P
Zinc	0.0200500 U	0.0401000 U	0.0401000 U	0.0401000 U	0.0401000 U				P

FORM III - IN ILM02.0

3
BLANKS

Lab Name: Veritech

Data File Name: S2827B

Lab Code: 14622

Analysis Date: 05/11/2000

Batch: 2816

All Concentration Units in PPM except Mercury in PPB

Analyte	MB 2816(.5)	ICB M-00-BL	CCB	CCB	CCB	CCB	CCB	CCB	M
Aluminum	0.0580000 U	0.1160000 U	0.1160000 U	0.1160000 U	0.1160000 U	0.1160000 U	0.1160000 U	0.1160000 U	P
Antimony	0.0032550 U	0.0065100 U	0.0065100 U	0.0065100 U	0.0065100 U	0.0065100 U	0.0065100 U	0.0065100 U	P
Arsenic	0.0036150 U	0.0072300 U	0.0072300 U	0.0072300 U	0.0072300 U	0.0072300 U	0.0072300 U	0.0072300 U	P
Beryllium	0.0024600 U	0.0049200 U	0.0049200 U	0.0049200 U	0.0049200 U	0.0049200 U	0.0049200 U	0.0049200 U	P
Copper	0.0199000 U	0.0398000 U	0.0398000 U	0.0398000 U	0.0398000 U	0.0398000 U	0.0398000 U	0.0398000 U	P
Selenium	0.0196500 U	0.0393000 U	0.0393000 U	0.0393000 U	0.0393000 U	0.0393000 U	0.0393000 U	0.0393000 U	P
Silver	0.0051500 U	0.0103000 U	0.0103000 U	0.0103000 U	0.0103000 U	0.0103000 U	0.0103000 U	0.0103000 U	P

FORM III - IN ILM02.0

BLANKS

Lab Name: Veritech

Data File Name: A2816Z

Lab Code: 14622

Analysis Date: 05/11/00

Batch: 2816

All Concentration Units in PPM except Mercury in PPB

Analyte	MB 2816(.5)	ICB M-00-BL	CCB	CCB					M
Potassium	0.1415000 U	0.2830000 U	0.2830000 U	0.2830000 U					P
Sodium	0.5540000	0.7700000 U	0.7700000 U	0.7700000 U					P

3
BLANKS

Lab Name: Veritech

Data File Name: S2827A

Lab Code: 14622

Analysis Date: 05/10/2000

Batch: 2827

All Concentration Units in PPM except Mercury in PPB

Analyte	MB2827Mg/Kg	ICB M-00-BL	CCB	CCB	CCB	CCB			M
Barium	10.000000 U	0.1000000 U	0.1000000 U	0.1000000 U	0.1000000 U	0.1000000 U			P
Cadmium	0.3000000 U	0.0030000 U	0.0030000 U	0.0030000 U	0.0030000 U	0.0030000 U			P
Chromium	4.0000000 U	0.0400000 U	0.0400000 U	0.0400000 U	0.0400000 U	0.0400000 U			P
Cobalt	1.6500000 U	0.0165000 U	0.0165000 U	0.0165000 U	0.0165000 U	0.0165000 U			P
Lead	4.0000000 U	0.0400000 U	0.0400000 U	0.0400000 U	0.0400000 U	0.0400000 U			P
Manganese	16.200000 U	0.1620000 U	0.1620000 U	0.1620000 U	0.1620000 U	0.1620000 U			P
Nickel	2.4400000 U	0.0244000 U	0.0244000 U	0.0244000 U	0.0244000 U	0.0244000 U			P
Vanadium	10.000000 U	0.1000000 U	0.1000000 U	0.1000000 U	0.1000000 U	0.1000000 U			P
Zinc	10.000000 U	0.1000000 U	0.1000000 U	0.1000000 U	0.1000000 U	0.1000000 U			P

FORM III - IN ILM02.0

5/12/00

BLANKS

Lab Name: Veritech

Data File Name: S2827B

Lab Code: 14622

Analysis Date: 05/11/2000

Batch: 2827

All Concentration Units in PPM except Mercury in PPB

Analyte	MB2827Mg/Kg	ICB M-00-BL	CCB	CCB	CCB				M
Antimony	1.4500000 U	0.0145000 U	0.0145000 U	0.0145000 U	0.0145000 U				P
Arsenic	2.0000000 U	0.0200000 U	0.0200000 U	0.0200000 U	0.0200000 U				P
Beryllium	0.4000000 U	0.0040000 U	0.0040000 U	0.0040000 U	0.0040000 U				P
Copper	4.8663140	0.0380000 U	0.0380000 U	0.0380000 U	0.0380000 U				P
Selenium	2.5000000 U	0.0250000 U	0.0250000 U	0.0250000 U	0.0250000 U				P
Silver	0.5000000 U	0.0050000 U	0.0050000 U	0.0050000 U	0.0050000 U				P
Thallium	1.2000000 U	0.0120000 U	0.0120000 U	0.0120000 U	0.0120000 U				P

FORM III - IN ILM02.0

5/17

3
BLANKS

Lab Name: Veritech

Data File Name: S2827Z

Lab Code: 14622

Analysis Date: 05/10/00

Batch: 2827

All Concentration Units in PPM except Mercury in PPB

Analyte	MB2827Mg/Kg	ICB M-00-IC	CCB	CCB					M
Aluminum	300.00000 U	3.0000000 U	3.0000000 U	3.0000000 U					P
Calcium	500.00000 U	5.0000000 U	5.0000000 U	5.0000000 U					P
Iron	271.00000 U	2.7100000 U	2.7100000 U	2.7100000 U					P
Magnesium	362.00000 U	3.6200000 U	3.6200000 U	3.6200000 U					P
Potassium	109.00000 U	1.0900000 U	1.0900000 U	1.0900000 U					P
Sodium	399.00000 U	3.9900000 U	3.9900000 U	3.9900000 U					P

FORM III - IN ILM02.0

3
BLANKS

Lab Name: Veritech

Data File Name: 2816.TXT

Lab Code: 14622

Analysis Date: 05/08/2000

All Concentration Units in PPM except Mercury in PPB

Analyte	MB 2816	ICB	CCB						M
Mercury	0.2200000 U	0.2200000 U	0.2200000 U						C

FORM III - IN ILM02.0

DDS 5/10/00

3
BLANKS

Lab Name: Veritech

Data File Name: 2827.TXT

Lab Code: 14622

Analysis Date: 05/12/2000

All Concentration Units in PPM except Mercury in PPB

Analyte	MB 2827 mg/kg	ICB	CCB	CCB					M
Mercury	0.0820000 U	0.4900000 U	0.4900000 U	0.4900000 U					C

FORM III - IN ILM02.0

DPS 5/15/00

APL
AQUA PRO-TECH LABORATORIES

CERTIFICATIONS
NJ DEP 07010 / NY DOH 11634 / CT PH-0233
US ARMY CORPS (USACE)

ANALYTICAL RESULTS SUMMARY

Client Veritech
175 Rt. 46 West
Fairfield, NJ 07004
Contact Tracey Batelli
Project
Report Date 05/17/2000 15:23

APL Order ID Number 20050281
Date Sampled 05/03/2000
Date Received 05/05/2000 8:55
Matrix Wastewater
Site DTEAC
Customer Service Rep.

Sample Number/ Parameter		Method	Analysis Time	Analyst	Result	Units	MDL
20050281-001	AB07060						
Nitrates		EPA 300	05/05/2000 9:10	JEN	1.70	mg/L	0.2
Phosphorus, Total		EPA365.2/SM4500P-E	05/08/2000 15:00	RAISA	<0.05	mg/L	0.05
20050281-002	AB07062						
Nitrates		EPA 300	05/05/2000 9:10	JEN	1.60	mg/L	0.2
Phosphorus, Total		EPA365.2/SM4500P-E	05/08/2000 15:00	RAISA	<0.05	mg/L	0.05
20050281-003	AB07063						
Nitrates		EPA 300	05/05/2000 9:10	JEN	1.00	mg/L	0.2
Phosphorus, Total		EPA365.2/SM4500P-E	05/08/2000 15:00	RAISA	<0.05	mg/L	0.05
20050281-004	AB07064						
Nitrates		EPA 300	05/05/2000 9:10	JEN	1.40	mg/L	0.2
Phosphorus, Total		EPA365.2/SM4500P-E	05/08/2000 15:00	RAISA	<0.05	mg/L	0.05

SA: See attached report

Brian Wood

Brian Wood
Laboratory Director

QA

1275 BLOOMFIELD AVENUE, BLDG. 6, FAIRFIELD, NJ 07004 TEL 973 227 0422 FAX 973 227 2813

ANALYSIS	METHOD BLANK
PHOSPHORUS,TOTAL	<0.05 mg/L
NITRATE	<0.2 mg/L

Veritech, 175 Route 46 West, Fairfield, NJ 07004
A Division of HAMPTON-CLARKE, Inc. NJDEPE #14622

CHAIN OF CUSTODY RECORD

PHONE (973) 244-9770
FAX (973) 244-9787

CUSTOMER INFORMATION

CUSTOMER:
ADDRESS:
TELEPHONE:
PROJECT: DTEAC
PROJECT MANAGER:
PROJECT LOCATION:
STATE:
PO NUMBER:

REPORT INFORMATION

SEND REPORT TO: Veritech

SEND INVOICE TO: Veritech

PROJECT INFORMATION

TURNAROUND (CONFIRM RUSH TAT'S WITH LAB)
STANDARD ✓ RUSH
DELIVERABLES (PLEASE CIRCLE):
STANDARD ISRA BUST
WASTE REGULATORY
OTHER (Specify)

ANALYTICAL REQUESTS

LAB SAMPLE NUMBER	SAMPLE IDENTIFICATION 20050881	DATE COLLECTED	TIME COLLECTED	SAMPLE TYPE: COMPOSITE (C)	SAMPLE TYPE: GRAB (G)	SAMPLE MATRIX	NO. OF BOTTLES: H_2SO_4	HNO_3	HCL	NaOH	ZnAc + NaOH	Ascorbic	NONE	OTHER	ANALYSIS
001	AB07060	5/3/00				Aq	1						1		NO_3 & tot P
002	07062														
003	07063														
004	07064														

SAMPLER CERTIFIES THAT EACH SAMPLE RECEIVED PROPER FIELD PRESERVATION (IF REQUIRED) (INITIALS)

SAMPLE HAZARDS: ☐ FLAMMABLE ☐ SKIN IRRITANT ☐ NON-HAZARD ☐ UNKNOWN ☐ NOXIOUS FUMES

SPECIAL INSTRUCTIONS:

TEMPERATURE UPON RECEIPT:

		DATE/TIME			DATE/TIME
Relinquished by:	George Kh	5/5/00 855	Received by:	J Nazzerson	5/5/00 0855
Agent of:	HCI		Agent of:	ACL	
Relinquished by:		DATE/TIME	Received by:		DATE/TIME
Agent of:			Agent of:		

SAMPDATE	SAMPNUM	LABID	DANALYZ	ANALPARAM	CONC	CONCUNITS	QAQUAL	QUANTTY	QUANTLE	ANLYS MTHD
05/03/00	S1	AB07059	05/07/00	% Solids	52	Percent		PQL		SM 2540G
05/03/00	S1	AB07059	05/10/00	2,4,5-T	0	MG/KG	U	PQL	0.0077	EPA 8151
05/03/00	S1	AB07059	05/10/00	Silvex	0	MG/KG	U	PQL	0.0077	EPA 8151
05/03/00	S1	AB07059	05/10/00	2,4-D	0.014	MG/KG		PQL	0.0077	EPA 8151
05/03/00	S1	AB07059	05/10/00	Dicamba	0	MG/KG	U	PQL	0.0077	EPA 8151
05/03/00	S1	AB07059	05/12/00	Mercury	0.97	MG/KG		PQL	0.16	EPA 7471A
05/03/00	S1	AB07059	05/11/00	Silver	0	MG/KG	U	PQL	0.96	EPA 6010
05/03/00	S1	AB07059	05/10/00	Aluminum	12000	MG/KG		PQL	580	EPA 6010
05/03/00	S1	AB07059	05/11/00	Arsenic	7.5	MG/KG		PQL	3.8	EPA 6010
05/03/00	S1	AB07059	05/10/00	Barium	120	MG/KG		PQL	19	EPA 6010
05/03/00	S1	AB07059	05/11/00	Beryllium	1.3	MG/KG		PQL	0.77	EPA 6010
05/03/00	S1	AB07059	05/10/00	Calcium	3900	MG/KG		PQL	960	EPA 6010
05/03/00	S1	AB07059	05/10/00	Cadmium	0	MG/KG	U	PQL	0.58	EPA 6010
05/03/00	S1	AB07059	05/10/00	Cobalt	12	MG/KG		PQL	3.2	EPA 6010
05/03/00	S1	AB07059	05/10/00	Chromium	27	MG/KG		PQL	7.7	EPA 6010
05/03/00	S1	AB07059	05/11/00	Copper	31	MG/KG		PQL	7.3	EPA 6010
05/03/00	S1	AB07059	05/10/00	Iron	30000	MG/KG		PQL	520	EPA 6010
05/03/00	S1	AB07059	05/10/00	Potassium	1200	MG/KG		PQL	210	EPA 6010
05/03/00	S1	AB07059	05/10/00	Magnesium	5100	MG/KG		PQL	700	EPA 6010
05/03/00	S1	AB07059	05/10/00	Manganese	580	MG/KG		PQL	31	EPA 6010
05/03/00	S1	AB07059	05/10/00	Sodium	0	MG/KG	U	PQL	770	EPA 6010
05/03/00	S1	AB07059	05/10/00	Nickel	20	MG/KG		PQL	4.7	EPA 6010
05/03/00	S1	AB07059	05/10/00	Lead	42	MG/KG		PQL	7.7	EPA 6010
05/03/00	S1	AB07059	05/11/00	Antimony	0	MG/KG	U	PQL	2.8	EPA 6010
05/03/00	S1	AB07059	05/11/00	Selenium	0	MG/KG	U	PQL	4.8	EPA 6010
05/03/00	S1	AB07059	05/11/00	Thallium	0	MG/KG	U	PQL	2.3	EPA 6010
05/03/00	S1	AB07059	05/10/00	Vanadium	40	MG/KG		PQL	9	EPA 6010
05/03/00	S1	AB07059	05/10/00	Zinc	130	MG/KG		PQL	19	EPA 6010
05/03/00	S1	AB07059	05/09/00	Alpha-BHC	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Aldrin	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Beta-BHC	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Chlordane	0	MG/KG	U	PQL	0.013	EPA 8081
05/03/00	S1	AB07059	05/09/00	Delta-BHC	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	P,P'-DDD	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	P,P'-DDE	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	P,P'-DDT	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Dieldrin	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Endosulfan Sulfat	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Endosulfan I	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Endosulfan II	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Endrin	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Endrin Aldehyde	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Endrin Ketone	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Gamma-BHC	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Heptachlor	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Heptachlor Epoxic	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Methoxychlor	0	MG/KG	U	PQL	0.0064	EPA 8081
05/03/00	S1	AB07059	05/09/00	Toxaphene	0	MG/KG	U	PQL	0.064	EPA 8081

SAMPDATE	SAMPNUM	LABID	DANALYZ	ANALPARAM	CONC	CONCUNITS	QAQUAL	QUANTTY	QUANTLE	ANLYS MTHD
05/03/00	SW1	AB07060	05/10/00	2,4,5-T	0	UG/L	U	PQL	0.2	EPA 8151
05/03/00	SW1	AB07060	05/10/00	Silvex	0	UG/L	U	PQL	0.2	EPA 8151
05/03/00	SW1	AB07060	05/10/00	2,4-D	0	UG/L	U	PQL	0.2	EPA 8151
05/03/00	SW1	AB07060	05/10/00	Dicamba	0	UG/L	U	PQL	0.2	EPA 8151
05/03/00	SW1	AB07060	05/08/00	Mercury	0	UG/L	U	N/A	N/A	EPA 245.1
05/03/00	SW1	AB07060	05/11/00	Silver	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/11/00	Aluminum	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/11/00	Arsenic	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Barium	28	UG/L		N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/11/00	Beryllium	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Calcium	25000	UG/L		N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Cadmium	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Cobalt	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Chromium	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/11/00	Copper	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Iron	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/11/00	Potassium	1700	UG/L		N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Magnesium	12000	UG/L		N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Manganese	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/11/00	Sodium	6700	UG/L		N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Nickel	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Lead	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/11/00	Antimony	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/11/00	Selenium	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Thallium	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Vanadium	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/10/00	Zinc	0	UG/L	U	N/A	N/A	EPA 200.7
05/03/00	SW1	AB07060	05/08/00	Alpha-BHC	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Aldrin	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Beta-BHC	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Chlordane	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Delta-BHC	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	P,P'-DDD	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	P,P'-DDE	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	P,P'-DDT	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Dieldrin	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Endosulfan Sulfat	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Endosulfan I	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Endosulfan II	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Endrin	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Endrin Aldehyde	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Endrin Ketone	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Gamma-BHC	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Heptachlor	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Heptachlor Epoxi	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Methoxychlor	0	UG/L	U	N/A	N/A	EPA 608
05/03/00	SW1	AB07060	05/08/00	Toxaphene	0	UG/L	U	N/A	N/A	EPA 608

2171T
410 749 0513 F
Bob McKenna

SAMPDATE	SAMPNUM	LABID	DANALYZ	ANALPARAM	CONC	CONCUNITS	QAQUAL	QUANTTY	QUANTLE'	ANLYS MTHD
05/03/00	S2	AB07061	05/07/00	% Solids	69	Percent		PQL		SM 2540G
05/03/00	S2	AB07061	05/10/00	2,4,5-T	0	MG/KG	U	PQL	0.0058	EPA 8151
05/03/00	S2	AB07061	05/10/00	Silvex	0	MG/KG	U	PQL	0.0058	EPA 8151
05/03/00	S2	AB07061	05/10/00	2,4-D	0.0071	MG/KG		PQL	0.0058	EPA 8151
05/03/00	S2	AB07061	05/10/00	Dicamba	0	MG/KG	U	PQL	0.0058	EPA 8151
05/03/00	S2	AB07061	05/12/00	Mercury	0.48	MG/KG		PQL	0.12	EPA 7471A
05/03/00	S2	AB07061	05/11/00	Silver	0	MG/KG	U	PQL	0.72	EPA 6010
05/03/00	S2	AB07061	05/10/00	Aluminum	6700	MG/KG		PQL	430	EPA 6010
05/03/00	S2	AB07061	05/11/00	Arsenic	6.2	MG/KG		PQL	2.9	EPA 6010
05/03/00	S2	AB07061	05/10/00	Barium	100	MG/KG		PQL	14	EPA 6010
05/03/00	S2	AB07061	05/11/00	Beryllium	0.96	MG/KG		PQL	0.58	EPA 6010
05/03/00	S2	AB07061	05/10/00	Calcium	11000	MG/KG		PQL	720	EPA 6010
05/03/00	S2	AB07061	05/10/00	Cadmium	0	MG/KG	U	PQL	0.43	EPA 6010
05/03/00	S2	AB07061	05/10/00	Cobalt	8.9	MG/KG		PQL	2.4	EPA 6010
05/03/00	S2	AB07061	05/10/00	Chromium	15	MG/KG		PQL	5.8	EPA 6010
05/03/00	S2	AB07061	05/11/00	Copper	26	MG/KG		PQL	5.5	EPA 6010
05/03/00	S2	AB07061	05/10/00	Iron	21000	MG/KG		PQL	390	EPA 6010
05/03/00	S2	AB07061	05/10/00	Potassium	760	MG/KG		PQL	160	EPA 6010
05/03/00	S2	AB07061	05/10/00	Magnesium	6900	MG/KG		PQL	520	EPA 6010
05/03/00	S2	AB07061	05/10/00	Manganese	600	MG/KG		PQL	23	EPA 6010
05/03/00	S2	AB07061	05/10/00	Sodium	0	MG/KG	U	PQL	580	EPA 6010
05/03/00	S2	AB07061	05/10/00	Nickel	14	MG/KG		PQL	3.5	EPA 6010
05/03/00	S2	AB07061	05/10/00	Lead	52	MG/KG		PQL	5.8	EPA 6010
05/03/00	S2	AB07061	05/11/00	Antimony	0	MG/KG	U	PQL	2.1	EPA 6010
05/03/00	S2	AB07061	05/11/00	Selenium	0	MG/KG	U	PQL	3.6	EPA 6010
05/03/00	S2	AB07061	05/11/00	Thallium	0	MG/KG	U	PQL	1.7	EPA 6010
05/03/00	S2	AB07061	05/10/00	Vanadium	30	MG/KG		PQL	6.8	EPA 6010
05/03/00	S2	AB07061	05/10/00	Zinc	140	MG/KG		PQL	14	EPA 6010
05/03/00	S2	AB07061	05/09/00	Alpha-BHC	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Aldrin	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Beta-BHC	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Chlordane	0	MG/KG	U	PQL	0.0097	EPA 8081
05/03/00	S2	AB07061	05/09/00	Delta-BHC	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	P,P'-DDD	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	P,P'-DDE	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	P,P'-DDT	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Dieldrin	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Endosulfan Sulfat	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Endosulfan I	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Endosulfan II	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Endrin	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Endrin Aldehyde	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Endrin Ketone	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Gamma-BHC	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Heptachlor	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Heptachlor Epoxic	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Methoxychlor	0	MG/KG	U	PQL	0.0048	EPA 8081
05/03/00	S2	AB07061	05/09/00	Toxaphene	0	MG/KG	U	PQL	0.048	EPA 8081

COOKS CREEK MONITORING PROGRAM
WATER QUALITY BASELINE MAY 2000

DATE	LOCATION	LAB ID	PARAMETER	CONC	UNITS	PQL	METHOD
05/03/00	SW3	AB06914	Fecal Coliform, Mpn	38	cfu/100 mL	2	Stand. Methods
05/03/00	SW5	AB06917	Fecal Coliform, Mpn	38	cfu/100 mL	2	Stand. Methods
05/03/00	SW9	AB06919	Fecal Coliform, Mpn	72	cfu/100 mL	2	Stand. Methods
05/03/00	SW10	AB06915	Fecal Coliform, Mpn	4	cfu/100 mL	2	Stand. Methods
05/03/00	SW11	AB06913	Fecal Coliform, Mpn	640	cfu/100 mL	2	Stand. Methods
05/03/00	SW13	AB06912	Fecal Coliform, Mpn	30	cfu/100 mL	2	Stand. Methods
05/03/00	SW18	AB06918	Fecal Coliform, Mpn	110	cfu/100 mL	2	Stand. Methods
05/03/00	SW19	AB06916	Fecal Coliform, Mpn	4	cfu/100 mL	2	Stand. Methods

DATE	LOCATION	LAB ID	PARAMETER	CONC	UNITS	PQL	METHOD
05/03/00	SW1	AB07060	Nitrate	1700	UG/L	200	EPA 352
05/03/00	SW2	AB07062	Nitrate	1600	UG/L	200	EPA 352
05/03/00	SW3	AB06914	Nitrate	1500	UG/L	200	EPA 352
05/03/00	SW5	AB06917	Nitrate	1400	UG/L	200	EPA 352
05/03/00	SW8	AB07064	Nitrate	1400	UG/L	200	EPA 352
05/03/00	SW9	AB06919	Nitrate	600	UG/L	200	EPA 352
05/03/00	SW10	AB06915	Nitrate	500	UG/L	200	EPA 352
05/03/00	SW11	AB06913	Nitrate	3000	UG/L	200	EPA 352
05/03/00	SW13	AB06912	Nitrate	1300	UG/L	200	EPA 352
05/03/00	SW14	AB07063	Nitrate	1000	UG/L	200	EPA 352
05/03/00	SW18	AB06918	Nitrate	2800	UG/L	200	EPA 352
05/03/00	SW19	AB06916	Nitrate	1900	UG/L	200	EPA 352

DATE	LOCATION	LAB ID	PARAMETER	CONC	UNITS	PQL	METHOD
05/03/00	SW1	AB07060	Phosphorus (Total)	0	UG/L	50	EPA 365
05/03/00	SW2	AB07062	Phosphorus (Total)	0	UG/L	50	EPA 365
05/03/00	SW3	AB06914	Phosphorus (Total)	0	UG/L	50	EPA 365
05/03/00	SW5	AB06917	Phosphorus (Total)	0	UG/L	50	EPA 365
05/03/00	SW8	AB07064	Phosphorus (Total)	0	UG/L	50	EPA 365
05/03/00	SW9	AB06919	Phosphorus (Total)	0	UG/L	50	EPA 365
05/03/00	SW10	AB06915	Phosphorus (Total)	0	UG/L	50	EPA 365
05/03/00	SW11	AB06913	Phosphorus (Total)	60	UG/L	50	EPA 365
05/03/00	SW13	AB06912	Phosphorus (Total)	0	UG/L	50	EPA 365
05/03/00	SW14	AB07063	Phosphorus (Total)	0	UG/L	50	EPA 365
05/03/00	SW18	AB06918	Phosphorus (Total)	0	UG/L	50	EPA 365
05/03/00	SW19	AB06916	Phosphorus (Total)	0	UG/L	50	EPA 365

Veritech Sample Key

30-May-00

Lab#	SampleID
AB06912	SW13
AB06913	SW11
AB06914	SW3
AB06915	SW10
AB06916	SW19
AB06917	SW5
AB06918	SW18
AB06919	SW9

Laboratory Chronicle

veritech

Lab Number	Sample Description
AB06912	SW13

Bacteriological	Preparation Date	By	Method	Analysis Date	By	Method
Fecal Coliform, Mpn				05/03/2000	Aqua Pro Te	Subcontract
Nitrate-N	**Preparation Date**	**By**	**Method**	**Analysis Date**	**By**	**Method**
Nitrate				05/04/2000	Aqua Pro Te	EPA 352
Phosphorus (Total) EPA 365	**Preparation Date**	**By**	**Method**	**Analysis Date**	**By**	**Method**
Phosphorus (Total)				05/04/2000	Aqua Pro Te	EPA 365

Lab Number	Sample Description
AB06913	SW11

Bacteriological	Preparation Date	By	Method	Analysis Date	By	Method
Fecal Coliform, Mpn				05/03/2000	Aqua Pro Te	Subcontract
Nitrate-N	**Preparation Date**	**By**	**Method**	**Analysis Date**	**By**	**Method**
Nitrate				05/04/2000	Aqua Pro Te	EPA 352
Phosphorus (Total) EPA 365	**Preparation Date**	**By**	**Method**	**Analysis Date**	**By**	**Method**
Phosphorus (Total)				05/04/2000	Aqua Pro Te	EPA 365

Lab Number	Sample Description
AB06914	SW3

Bacteriological	Preparation Date	By	Method	Analysis Date	By	Method
Fecal Coliform, Mpn				05/03/2000	Aqua Pro Te	Subcontract
Nitrate-N	**Preparation Date**	**By**	**Method**	**Analysis Date**	**By**	**Method**
Nitrate				05/04/2000	Aqua Pro Te	EPA 352
Phosphorus (Total) EPA 365	**Preparation Date**	**By**	**Method**	**Analysis Date**	**By**	**Method**
Phosphorus (Total)				05/04/2000	Aqua Pro Te	EPA 365

Lab Number	Sample Description
AB06915	SW10

Bacteriological	Preparation Date	By	Method	Analysis Date	By	Method
Fecal Coliform, Mpn				05/03/2000	Aqua Pro Te	Subcontract
Nitrate-N	**Preparation Date**	**By**	**Method**	**Analysis Date**	**By**	**Method**
Nitrate				05/04/2000	Aqua Pro Te	EPA 352
Phosphorus (Total) EPA 365	**Preparation Date**	**By**	**Method**	**Analysis Date**	**By**	**Method**
Phosphorus (Total)				05/04/2000	Aqua Pro Te	EPA 365

Lab Number	Sample Description
AB06916	SW19

Laboratory Chronicle

veritech

Bacteriological	Preparation Date	By	Method	Analysis Date	By	Method
Fecal Coliform, Mpn				05/03/2000	Aqua Pro Te	Subcontract
Nitrate-N						
Nitrate				05/04/2000	Aqua Pro Te	EPA 352
Phosphorus (Total) EPA 365						
Phosphorus (Total)				05/04/2000	Aqua Pro Te	EPA 365

Lab Number	Sample Description
AB06917	SW5

Bacteriological	Preparation Date	By	Method	Analysis Date	By	Method
Fecal Coliform, Mpn				05/03/2000	Aqua Pro Te	Subcontract
Nitrate-N						
Nitrate				05/04/2000	Aqua Pro Te	EPA 352
Phosphorus (Total) EPA 365						
Phosphorus (Total)				05/04/2000	Aqua Pro Te	EPA 365

Lab Number	Sample Description
AB06918	SW18

Bacteriological	Preparation Date	By	Method	Analysis Date	By	Method
Fecal Coliform, Mpn				05/03/2000	Aqua Pro Te	Subcontract
Nitrate-N						
Nitrate				05/04/2000	Aqua Pro Te	EPA 352
Phosphorus (Total) EPA 365						
Phosphorus (Total)				05/04/2000	Aqua Pro Te	EPA 365

Lab Number	Sample Description
AB06919	SW9

Bacteriological	Preparation Date	By	Method	Analysis Date	By	Method
Fecal Coliform, Mpn				05/03/2000	Aqua Pro Te	Subcontract
Nitrate-N						
Nitrate				05/04/2000	Aqua Pro Te	EPA 352
Phosphorus (Total) EPA 365						
Phosphorus (Total)				05/04/2000	Aqua Pro Te	EPA 365

CT #: PH-0671
MA #: NJ386
NJ #: 14622
NY #: 11408
PA #: 68-463

Report Of Analysis
veritech laboratories

To: DTEAC

3450 Route 212

Riegelsville PA 18077

Attention: Scott Douglas
Project: 99-0011

Date Collected: 05/03/2000
Date Submitted: 05/03/2000
Date Reported: 05/30/2000

Lab#	SampleID / TestGroup	Analyte	Units	MDL/PQL	Result
AB06912	SW13				
	Bacterialogical				
		Fecal Coliform, Mpn	cfu/100 mL	2	30
	Nitrate-N				
		Nitrate	mg/L as N	0.2	1.30
	Phosphorus (Total) EPA 365				
		Phosphorus (Total)	mg/L as P	0.05	ND
AB06913	SW11				
	Bacterialogical				
		Fecal Coliform, Mpn	cfu/100 mL	2	640
	Nitrate-N				
		Nitrate	mg/L as N	0.2	3.00
	Phosphorus (Total) EPA 365				
		Phosphorus (Total)	mg/L as P	0.05	0.06
AB06914	SW3				
	Bacterialogical				
		Fecal Coliform, Mpn	cfu/100 mL	2	38
	Nitrate-N				
		Nitrate	mg/L as N	0.2	1.50
	Phosphorus (Total) EPA 365				
		Phosphorus (Total)	mg/L as P	0.05	ND
AB06915	SW10				
	Bacterialogical				
		Fecal Coliform, Mpn	cfu/100 mL	2	4
	Nitrate-N				
		Nitrate	mg/L as N	0.2	0.500
	Phosphorus (Total) EPA 365				
		Phosphorus (Total)	mg/L as P	0.05	ND
AB06916	SW19				
	Bacterialogical				
		Fecal Coliform, Mpn	cfu/100 mL	2	4
	Nitrate-N				
		Nitrate	mg/L as N	0.2	1.90
	Phosphorus (Total) EPA 365				
		Phosphorus (Total)	mg/L as P	0.05	ND

MDL used for 600 and 200 series methods. PQL used for SW846 methods.
ND = Not Detected

Lab#	SampleID	TestGroup	Analyte	Units	MDL/PQL	Result
AB06917	SW5					
		Bacterialogical				
			Fecal Coliform, Mpn	cfu/100 mL	2	38
		Nitrate-N				
			Nitrate	mg/L as N	0.2	1.40
		Phosphorus (Total) EPA 365				
			Phosphorus (Total)	mg/L as P	0.05	ND
AB06918	SW18					
		Bacterialogical				
			Fecal Coliform, Mpn	cfu/100 mL	2	110
		Nitrate-N				
			Nitrate	mg/L as N	0.2	2.80
		Phosphorus (Total) EPA 365				
			Phosphorus (Total)	mg/L as P	0.05	ND
AB06919	SW9					
		Bacterialogical				
			Fecal Coliform, Mpn	cfu/100 mL	2	72
		Nitrate-N				
			Nitrate	mg/L as N	0.2	0.600
		Phosphorus (Total) EPA 365				
			Phosphorus (Total)	mg/L as P	0.05	ND

This report is a true report of results obtained from our tests of this material. In lieu of a formal contract document, the total aggregate liability of Veritech to all parties shall not exceed Veritech's total fee for analytical services rendered.

Robin Jetter - Quality Assurance Director

Or

Stanley Gilewicz - Laboratory Director

MDL used for 600 and 200 series methods. PQL used for SW846 methods.
ND = Not Detected

HPL 050312

V. ech, 175 Route 46 West, Fairfield, NJ 07004
A Division of HAMPTON-CLARKE, Inc NJDEPE #14622

CHAIN OF CUSTODY RECORD

PHONE (973) 244-9770
FAX (973) 244-9787

CUSTOMER INFORMATION

CUSTOMER: MJE/DTEAC
ADDRESS: 132 EATON WAY, CHERRY HILL
TELEPHONE: 856-856-0660
PROJECT: 99-0011
PROJECT MANAGER: SCOTT DOUGLASS
PROJECT LOCATION: DURHAM TWP.
STATE: PA
PO NUMBER:

REPORT INFORMATION

SEND REPORT TO: DTEAC
ATTN: SCOTT W. DOUGLAS
3450 ROUTE 212
RIEGELSVILLE, PA 18077

SEND INVOICE TO: MJE
132 EATON WAY, CHERRY HILL, NJ 08003

PROJECT INFORMATION

TURNAROUND (CONFIRM RUSH TAT'S WITH LAB)
STANDARD X RUSH

DELIVERABLES (PLEASE CIRCLE):
STANDARD ISRA BUST
WASTE REGULATORY
OTHER (Specify)

ANALYTICAL REQUESTS

LAB SAMPLE NUMBER	SAMPLE IDENTIFICATION	DATE COLLECTED	TIME COLLECTED	SAMPLE TYPE: COMPOSITE (C)	SAMPLE TYPE: GRAB (G)	SAMPLE MATRIX	NO. OF BOTTLES: H_2SO_4	HNO_3	HCL	NaOH	ZnAc + NaOH	Ascorbic	NONE	OTHER	ANALYSIS
AB06912	SW3	5/3/00	8:18		X	W	1								PHOSPHORUS
↓	SW3				X	W							1		NITRATE
↓	SW3				X	W							1		FECAL COLIFORM
AB06913	SW11	5/3/00	8:35		X	W	1								PHOSPHORUS
↓	SW11				X	W							1		NITRATE
↓	SW11				X	W							1		FECAL COLIFORM
AB06914	SW3	5/3/00	9:10		X	W	1								PHOSPHORUS
↓	SW3												1		NITRATE
↓	SW3												1		FECAL COLIFORM

SAMPLER CERTIFIES THAT EACH SAMPLE RECEIVED PROPER FIELD PRESERVATION (IF REQUIRED) (INITIALS)

SAMPLE HAZARDS: ☐ FLAMMABLE ☐ SKIN IRRITANT ☐ NON-HAZARD ☐ UNKNOWN ☐ NOXIOUS FUMES

SPECIAL INSTRUCTIONS:

TEMPERATURE UPON RECEIPT:

Relinquished by:	DATE/TIME	Received by:	DATE/TIME
MITROFAN JOSAN Agent of:	5/3 12:15	MITROFAN JOSAN Agent of: MJE	5/3 12:30
MITROFAN JOSAN Agent of: MJE	5/3	Agent of:	5/3 1400

5/3/00 1415

5/3/00 2:15 PM

API

Ver..ech, 175 Route 46 West, Fairfield, NJ 07004
A Division of HAMPTON-CLARKE, Inc. NJDEPE #14622

CHAIN OF CUSTODY RECORD

PHONE (973) 244-9770
FAX (973) 244-9787

CUSTOMER INFORMATION

CUSTOMER: MJE/STEAC
ADDRESS:
TELEPHONE:
PROJECT:
PROJECT MANAGER:
PROJECT LOCATION:
STATE:
PO NUMBER:

REPORT INFORMATION

SEND REPORT TO: ~~STEAC~~ VERITECH
SEND INVOICE TO: ~~MJE~~ Veritech

PROJECT INFORMATION

TURNAROUND (CONFIRM RUSH TAT'S WITH LAB)
STANDARD X RUSH
DELIVERABLES (PLEASE CIRCLE):
STANDARD ISRA BUST
WASTE REGULATORY
OTHER (Specify)

ANALYTICAL REQUESTS

LAB SAMPLE NUMBER	SAMPLE IDENTIFICATION	DATE COLLECTED	TIME COLLECTED	SAMPLE TYPE: COMPOSITE (C)	SAMPLE TYPE: GRAB (G)	SAMPLE MATRIX	NO. OF BOTTLES: H_2SO_4	HNO_3	HCL	NaOH	ZnAc + NaOH	Ascorbic	NONE	OTHER	ANALYSIS
AB06915	SW 10	5/3/00	11:35		X	W									PHOSPHORUS
	SW 10				X	W									NITRATE
	SW10				X	W									FECAL COLIFORM
AB06916	SW19	5/3/00	11:45		X	W									PHOSPHORUS
	SW19				X	W									NITRATE
	SW19				X	W									FECAL COLIFORM

SAMPLER CERTIFIES THAT EACH SAMPLE RECEIVED PROPER FIELD PRESERVATION (IF REQUIRED) (INITIALS)

SAMPLE HAZARDS: ☐ FLAMMABLE ☐ SKIN IRRITANT ☐ NON-HAZARD ☐ UNKNOWN ☐ NOXIOUS FUMES

SPECIAL INSTRUCTIONS:

TEMPERATURE UPON RECEIPT:

Relinquished by: MITROTAN JASAN Agent of:	DATE/TIME 5/3/00 12:00	Received by: C. Lara Agent of:	DATE/TIME 5/3 12:00
Relinquished by: C. Lara Agent of:	DATE/TIME 5/3/00	Received by: Agent of:	DATE/TIME 5/3/1400

5/3/00 14/5

NA

5/3 2:15PM

Ve ch, 175 Route 46 West, Fairfield, NJ 07004
A Division of HAMPTON-CLARKE, Inc. NJDEPE #14622

CHAIN OF CUSTODY RECORD

PHONE (973) 244-9770
FAX (973) 244-9787

CUSTOMER INFORMATION

CUSTOMER: MJE/DTEAC
ADDRESS:
TELEPHONE:
PROJECT:
PROJECT MANAGER:
PROJECT LOCATION:
STATE:
PO NUMBER:

REPORT INFORMATION

SEND REPORT TO: ~~DTEAC~~ LA
Verilech
SEND INVOICE TO: ~~MJE~~ LA

PROJECT INFORMATION

TURNAROUND (CONFIRM RUSH TAT'S WITH LAB)
STANDARD X RUSH
DELIVERABLES (PLEASE CIRCLE):
STANDARD ISRA BUST
WASTE REGULATORY
OTHER (Specify)

ANALYTICAL REQUESTS

LAB SAMPLE NUMBER	SAMPLE IDENTIFICATION	DATE COLLECTED	TIME COLLECTED	SAMPLE TYPE: COMPOSITE (C)	SAMPLE TYPE: GRAB (G)	SAMPLE MATRIX	NO. OF BOTTLES: H_2SO_4	HNO_3	HCL	NaOH	ZnAc + NaOH	Ascorbic	NONE	OTHER	ANALYSIS
AB06917	SW5	5/3/00	9:48		X	W	1								PHOSPHORUS
↓	SW5				X	W							1		NITRATE
↓	SW5				X	W							1		FECAL COLIFORM
AB06918	SW18	5/3/00	10:10		X	W	1								PHOSPHORUS
↓	SW18				X	W							1		NITRATE
↓	SW18				X	W							1		FECAL COLIFORM
AB06919	SW9	5/3/00	10:45		X	W	1								PHOSPHORUS
↓	SW9												1		NITRATE
↓	SW9												1		FECAL COLIFORM

SAMPLER CERTIFIES THAT EACH SAMPLE RECEIVED PROPER FIELD PRESERVATION (IF REQUIRED) (INITIALS)

SAMPLE HAZARDS: ☐ FLAMMABLE ☐ SKIN IRRITANT ☐ NON-HAZARD ☐ UNKNOWN ☐ NOXIOUS FUMES

SPECIAL INSTRUCTIONS:

TEMPERATURE UPON RECEIPT:

Relinquished by / Agent of	DATE/TIME	Received by / Agent of	DATE/TIME
Mirdufan Jusan	5-3-00 12:15		5-3-00 12:15
	5-3-00		5/3/00 1400

5/3/00 1415 5/3 2:15 PM

APL

AQUA PRO-TECH LABORATORIES

CERTIFICATIONS

NJ DEP 07010 / NY DOH 11634 / CT PH-0233
US ARMY CORPS (USACE)

ANALYTICAL RESULTS SUMMARY

Client	**Veritech** 175 Rt. 46 West Fairfield, NJ 07004	**APL Order ID Number**	**20050190**
		Date Sampled	05/03/2000 8:18
		Date Received	05/03/2000 14:15
Contact	Tracey Batelli	**Matrix**	Wastewater
Project		**Site**	Durham Twp
Report Date	05/16/2000 10:28	**Customer Service Rep.**	

Sample Number/ Parameter		Method	Analysis Time	Analyst	Result	Units	MDL
20050190-001	SW13						
Phosphorus, Total		EPA365.2/SM4500P-E	05/04/2000 16:00	RAISA	<0.05	mg/L	0.05
20050190-002	SW13						
Nitrates		EPA 300	05/04/2000 7:30	JEN	1.30	mg/L	0.2
20050190-003	SW13						
Fecal Coliform		SM 9222 D	05/03/2000 14:20	JOYCE	30	cfu/100ml	2
20050190-004	SW11						
Phosphorus, Total		EPA365.2/SM4500P-E	05/04/2000 16:00	RAISA	0.06	mg/L	0.05
20050190-005	SW11						
Nitrates		EPA 300	05/04/2000 7:30	JEN	3.00	mg/L	0.2
20050190-006	SW11						
Fecal Coliform		SM 9222 D	05/03/2000 14:20	JOYCE	640	cfu/100ml	2
20050190-007	SW3						
Phosphorus, Total		EPA365.2/SM4500P-E	05/04/2000 16:00	RAISA	<0.05	mg/L	0.05
20050190-008	SW3						
Nitrates		EPA 300	05/04/2000 7:30	JEN	1.50	mg/L	0.2
20050190-009	SW3						
Fecal Coliform		SM 9222 D	05/03/2000 14:20	JOYCE	38	cfu/100ml	2

SA: See attached report

Brian Wood

Brian Wood
Laboratory Director

QA

1275 BLOOMFIELD AVENUE, BLDG. 6, FAIRFIELD, NJ 07004 TEL 973 227 0422 FAX 973 227 2813

ANALYSIS	METHOD BLANK
PHOSPHORUS,TOTAL	<0.05 mg/L
NITRATE	<0.2 mg/L
FECAL COLIFORM	<2 CFU/100mL

APL

AQUA PRO-TECH LABORATORIES

CERTIFICATIONS

NJ DEP 07010 / NY DOH 11634 / CT PH-0233
US ARMY CORPS (USACE)

ANALYTICAL RESULTS SUMMARY

Client	**Veritech** 175 Rt. 46 West Fairfield, NJ 07004	**APL Order ID Number**	**20050191**
		Date Sampled	05/03/2000 11:35
		Date Received	05/03/2000 11:35
Contact	Tracey Batelli	**Matrix**	Wastewater
Project		**Site**	Durham Twp
Report Date	05/16/2000 10:28	**Customer Service Rep.**	

Sample Number/ Parameter		Method	Analysis Time	Analyst	Result	Units	MDL
20050191-001	SW10						
Phosphorus, Total		EPA365.2/SM4500P-E	05/04/2000 16:00	RAISA	<0.05	mg/L	0.05
20050191-002	SW10						
Nitrates		EPA 300	05/04/2000 7:30	JEN	0.500	mg/L	0.2
20050191-003	SW10						
Fecal Coliform		SM 9222 D	05/03/2000 14:20	JOYCE	4	cfu/100ml	2
20050191-004	SW19						
Phosphorus, Total		EPA365.2/SM4500P-E	05/04/2000 16:00	RAISA	<0.05	mg/L	0.05
20050191-005	SW19						
Nitrates		EPA 300	05/04/2000 7:30	JEN	1.90	mg/L	0.2
20050191-006	SW19						
Fecal Coliform		SM 9222 D	05/03/2000 14:20	JOYCE	4	cfu/100ml	2

SA: See attached report

Brian Wood

Brian Wood
Laboratory Director

QA

1275 BLOOMFIELD AVENUE, BLDG. 6, FAIRFIELD, NJ 07004 TEL 973 227 0422 FAX 973 227 2813

ANALYSIS	METHOD BLANK
PHOSPHORUS,TOTAL	<0.05 mg/L
NITRATE	<0.2 mg/L
FECAL COLIFORM	<2 CFU/100mL

APL

AQUA PRO-TECH LABORATORIES

CERTIFICATIONS

NJ DEP 07010 / NY DOH 11634 / CT PH-0233

US ARMY CORPS (USACE)

ANALYTICAL RESULTS SUMMARY

Client	**Veritech** 175 Rt. 46 West Fairfield, NJ 07004	**APL Order ID Number**	**20050193**
		Date Sampled	05/03/2000 9:48
		Date Received	05/03/2000 14:15
Contact	Tracey Batelli	**Matrix**	Wastewater
Project		**Site**	Durham Twp
Report Date	05/16/2000 10:28	**Customer Service Rep.**	

Sample Number/ Parameter		Method	Analysis Time	Analyst	Result	Units	MDL
20050193-001	SW5						
Phosphorus, Total		EPA365.2/SM4500P-E	05/04/2000 16:00	RAISA	<0.05	mg/L	0.05
20050193-002	SW5						
Nitrates		EPA 300	05/04/2000 7:30	JEN	1.40	mg/L	0.2
20050193-003	SW5						
Fecal Coliform		SM 9222 D	05/03/2000 14:20	JOYCE	38	cfu/100ml	2
20050193-004	SW18						
Phosphorus, Total		EPA365.2/SM4500P-E	05/04/2000 16:00	RAISA	<0.05	mg/L	0.05
20050193-005	SW18						
Nitrates		EPA 300	05/04/2000 7:30	JEN	2.80	mg/L	0.2
20050193-006	SW18						
Fecal Coliform		SM 9222 D	05/03/2000 14:20	JOYCE	110	cfu/100ml	2
20050193-007	SW9						
Phosphorus, Total		EPA365.2/SM4500P-E	05/04/2000 16:00	RAISA	<0.05	mg/L	0.05
20050193-008	SW9						
Nitrates		EPA 300	05/04/2000 7:30	JEN	0.600	mg/L	0.2
20050193-009	SW9						
Fecal Coliform		SM 9222 D	05/03/2000 14:20	JOYCE	72	cfu/100ml	2

SA: See attached report

Brian Wood

Brian Wood
Laboratory Director

QA

1275 BLOOMFIELD AVENUE, BLDG. 6, FAIRFIELD, NJ 07004 TEL 973 227 0422 FAX 973 227 2813

ANALYSIS	METHOD BLANK
PHOSPHORUS,TOTAL	<0.05 mg/L
NITRATE	<0.2 mg/L
FECAL COLIFORM	<2 CFU/100mL

APPENDIX C

Threatened and Endangered Species Information

Bog Turtle

Clemmys muhlenbergii

Photo Credit: Clark Shiffer

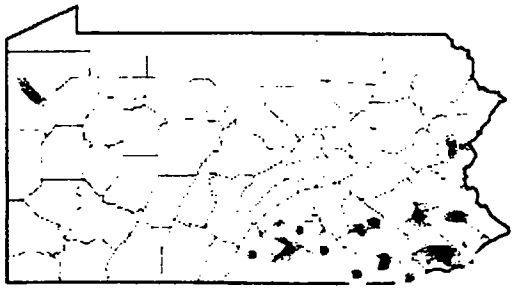
IDENTIFYING CHARACTERISTICS: The bog turtle is among the smallest North American turtles. Adults are four to 4 1/2 inches long. The upper shell is dark brown with yellow to orange markings and covered with ridged plates that are eventually worn smooth; the lower shell is dark brown or black, sometimes with scattered light markings. A large red-orange or yellow blotch behind each eye is the most conspicuous color feature of an otherwise brown body lightly marked with orange or yellow.

BIOLOGY-NATURAL HISTORY: Mating takes place in May and early June. Each female then digs a nest and lays a clutch of three to five eggs during June or July. Eggs receive no parental care, and hatchlings leave the nest several months later. Adults and young feed on a variety of plant and animal food, such as berries, insects and even carrion. They do not wander far from hibernating sites in spring seepage, which they leave in April or May and return to in late summer. Summer hibernation (aestivation) may occur during July and August; individuals are otherwise encountered basking on sedge tussocks or moving slowly about in spring runs under concealing vegetation. When danger threatens, individuals burrow rapidly into the mucky bottom of spring runs.

PREFERRED HABITAT: Bog turtles live in relatively open portions of sphagnum bogs, swamps or marshy meadows with slow moving, spring fed streams or spring runs with soft bottoms.

REASONS FOR BEING ENDANGERED: The primary reason for the bog turtle's status is the draining or other destruction of its habitat. Because bog turtles have always been considered the rarest of North American turtles, they are highly valued by turtle fanciers in this country, and possibly twice as much overseas. Many, therefore, have been illegally removed for commercial purposes. Since their habitats are widely separated, other turtles are not likely to move in and replace those removed.

MANAGEMENT PRACTICES: Informal agreements concerning the continued occurrence of the turtles have been made with owners of private property where bog turtles exist. Field surveys have determined the status of historical and new sites. Also, permit review and commentary concerning public use projects where bog turtle habitat is involved is ongoing.



● - verified after 1980 ● = historical occurrences

Invertebrates | Birds & Mammals | Fish, Reptiles & Amphibians | Plants

Eared False-Foxglove

Tomanthera auriculata (Michx.) Raf.

Photo Credit: Kathy Regan, The Nature Conservancy

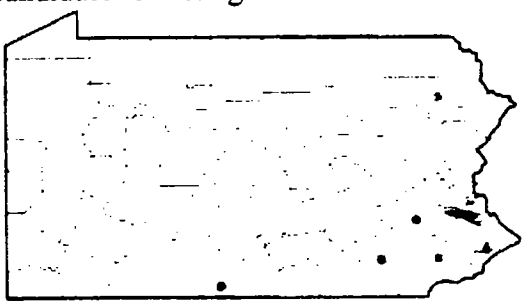
IDENTIFYING CHARACTERISTICS: Eared false foxglove is an herb with a simple hairy stem 12 to 16 inches high. The purple, one-inch flowers bloom in the upper leaf axils, forming a leafy spike. Bloosoms are funnel-shaped with five lobes and four stamens. One pair of stamens is longer than the other. The fruit is a capsule about 1/2-inch long. Eared false-foxglove is so-named because the uppermost leaves have lobes that stick out at the base, reminding botanists of earlobes.

BIOLOGY-NATURAL HISTORY: Eared false-foxglove, an annual, is a member of the Figwort Family *(Scrophulariaceae)*. The flowers resemble the garden foxgloves of the genus *Digitalis* to which they are related. Eared false-foxglove blooms in August and September.

PREFERRED HABITAT: This plant grows in prairies, open dry woods and fields. In Pennsylvania, it is currently surviving at only two locations, on limestone gravel on the edge of an abandoned zinc mine. This species is extremely uncommon, with an historical range extending from northern New Jersey, across Pennsylvania and Ohio, to southern Minnesota, south to Virginia, Alabama, Tennessee and Missouri. A second species of *Tomanthera* grows from Kansas south to Texas.

REASONS FOR BEING ENDANGERED: Of 16 known Pennsylvania locations, populations of eared false-foxglove can be found today at only two. Several populations were destroyed during road construction. Many of the historical sites in eastern Pennsylvania may have suffered the same fate. This species is endangered or threatened in nine other states. Eared false-foxglove has been extirpated from Indiana, Maryland, New Jersey and possibly Wisconsin. Habitat destruction for development is the leading cause of this species decline.

MANAGEMENT PROGRAMS: Eared false foxglove is a candidate for listing under the Federal Endangered Species Act. It is one of five species in Pennsylvania to receive funding for status survey and monitoring work through a cooperative agreement with the USF&WS. A 5 year plan has been developed to search for historical populations and to protect known sites. Environmental assessments using PNDI will help to avoid impacts to any new and existing plant locations.



● - verified after 1983 ● = historical occurrences

Spreading Globeflower

Trollius laxus Salisb. ssp. laxus

Photo Credit: Paul Wiegman, Western Pennsylvania Conservancy

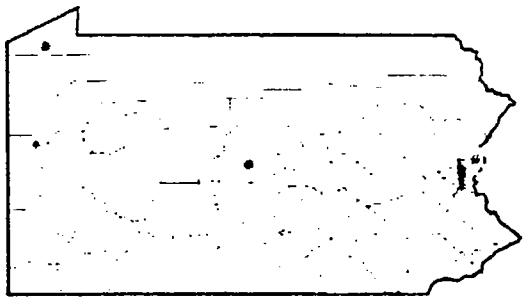
IDENTIFYING CHARACTERISTICS: Spreading globeflower is a showy plant with palmately cut, lobed leaves, three to five inches wide. Large terminal flowers, up to 1 1/2 inches in diameter, are yellow or cream-colored. The petals are tiny, but the five to seven large sepals are brightly colored. The plant grows from five to 20 inches.

BIOLOGY-NATURAL HISTORY: Spreading globeflower is a member of the Buttercup Family (Ranunculaceae) with flowers that appear like large buttercups. *Trollius is* a perennial herb that blooms in mid-April. The leaf size increases significantly after blooming. The distinction between eastern and western spreading globeflowers is not clear. The western plants, extending from the Rocky Mountains to the west coast, are thought to be members of a subspecies (ssp. *albiflora)* which have white flowers and are less rare.

PREFERRED HABITAT: Spreading globe flower grows in rich swamps, wet meadows and wet woods from Connecticut and New Jersey west through New York and Pennsylvania to Ohio. In Pennsylvania, its range is limited to the glaciated sections, where wetland habitats are calcareous (alkaline).

REASONS FOR BEING ENDANGERED: Eight of 15 historically documented spreading globeflower sites have been destroyed because the wetlands where they existed were drained or filled for agriculture and housing development.

MANAGEMENT PROGRAMS: Spreading globeflower is a candidate for listing under the Federal Endangered Species Act. One site has been acquired by the Western Pennsylvania Conservancy. The Nature Conservancy is trying to protect four sites in eastern Pennsylvania. A coal mine was modified to prevent disruption of the hydrology at a western Pennsylvania location. Surveys for this and other wetland plant species of special concern continue to be concentrated in the glaciated sections of the state.



● - verified after 1920 ● = historical occurences

Invertebrates | Birds & Mammals | Fish, Reptiles & Amphibians | Plants

Red-Bellied Turtle

Pseudemys rubriventris

Photo Credit: Robert T. Zappalorti, Nature's Images

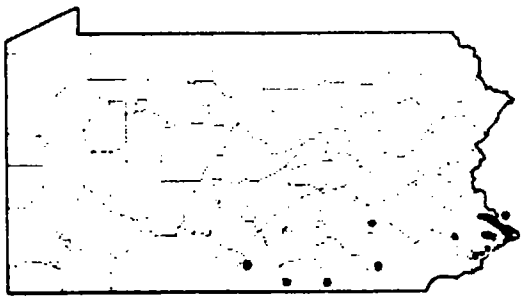
IDENTIFYING CHARACTERISTICS: Next to snapping turtle and spiny soft shell turtle, this is the largest of Pennsylvania's turtles. Fully grown individuals are 10 to 12 1/2 inches in length (record— 15 3/4 inches) and resemble an overgrown painted turtle. Males especially may be almost entirely black, but there is usually a trace of reddish lines on the medially flattened upper shell and yellowish head stripes. The tip of the upper jaw is notched with toothed cusps on each side. The lower shell ranges in color from coral-pink to red, with darker markings in the young.

BIOLOGY-NATURAL HISTORY: Red-bellied turtles are active from May until October, spending much time sunning (basking) on logs or rocks. During June and July, females dig nests in cultivated open tracts, sometimes some distance from water. Usually 10 to 12 eggs are deposited four inches below the surface, and the nest is then covered by the female. Some females may nest more than once a year. The time of hatching is believed to be in late summer, and young may overwinter in the nest. Young and adults feed on a variety of aquatic animals and plants, but fish are not normally part of the diet.

PREFERRED HABITAT: Relatively large, deep creeks, rivers, ponds, lakes and marshes with ample basking sites are preferred. The species tolerates brackish water conditions, but is usually a freshwater turtle, found close to the coast from southern Massachusetts to northeastern North Carolina.

REASONS FOR BEING THREATENED: The limited habitat required by red-bellied turtles is under threat from industrial uses, the demand for property in a heavily urbanized area of the state, drainage or filing of wetlands and pollution.

MANAGEMENT PRACTICES: Red-bellied turtle habitat is being monitored by various government agencies. A long-standing population of this species in Bucks County is studied each year by county perk personnel under permit from the Fish and Boat Commission. The species is protected by regulation, as are all other state endangered and threatened species.



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Invertebrates | Birds & Mammals | Fish, Reptiles & Amphibians | Plants

Least Bittern

Ixobrychus exilis

Photo Credit: A. & E. Morris, VIREO

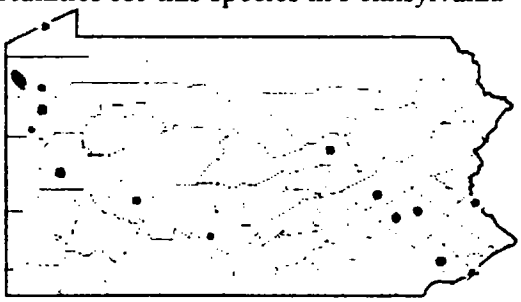
IDENTIFYING CHARACTERISTICS: The smallest member of the heron family, the least bittern is 11 to 14 inches in length and has a 16- to 18-inch wingspan. This primarily black and tan bird has a blackish-green cap and back, brown neck and underparts, and a white throat. The least bittern is most readily identified in flight by conspicuous, light, chestnut-colored wing patches. A rare, darker phase also exists. When disturbed, the least bittern is more likely to run than fly, and like its relative, the American bittern, it also has the habit of freezing with its bill pointed straight up when alarmed.

BIOLOGY-NATURAL HISTORY: The least bittern nests in wetland areas throughout the eastern United States and along the Pacific coast. It spends the winter from our southern states south to Columbia, South America. This species is a regular migrant through the state, but it nests here only in our northwest and southeast corners, and possibly in a few other locations, but not regularly or in significant numbers. The least bittern arrives in Pennsylvania in April and builds its platform nest of reeds and grasses near open water. Four or five pale blue or green eggs are laid in the 6-inch nest in mid or late May. The young hatch in slightly under three weeks.

PREFERRED HABITAT: Least bitterns thrive in dense marshland environments containing cattails and reeds, along the coast and inland, where they feed primarily on small fish, amphibians, insects and small mammals.

REASONS FOR BEING THREATENED: Nesting opportunities for this species in Pennsylvania are limited and decreasing as the wetland habitat it needs have been extensively drained or impounded.

MANAGEMENT PROGRAMS: Areas where this species is known to nest should be protected. Surveys are being conducted to determine where it does actually nest, and marshland habitats can be managed to provide additional nesting habitat.



● = verified after 1980 ● = historical occurrences

Peregrine Falcon

Falco peregrinus

Photo Credit: F.K. Schleicher, VIREO

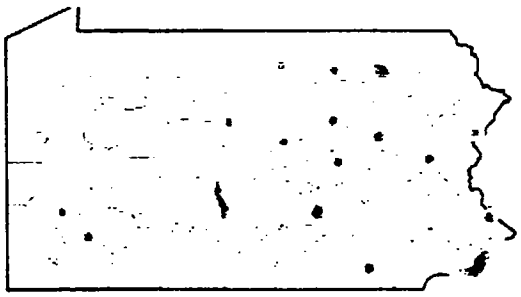
IDENTIFYING CHARACTERISTICS: A 15- to 22-inch falcon, adults have dark-bluish gray upperparts and wings. Underparts are whitish to buffy colored, broken by horizontal bars. The head has a nearly black "helmet." Like all falcons, the peregrine has long pointed wings and rapid, steady wing beats in flight.

BIOLOGY-NATURAL HISTORY: The peregrine nests in many parts of the world. In Pennsylvania, peregrines once nested on high cliffs along the Delaware, Susquehanna and Juniata rivers. Nesting records come from at least 21 counties. They feed primarily on other birds, typically by striking them in flight. A clutch of four eggs is normally laid, and the birds may remain in Pennsylvania the year round.

PREFERRED HABITAT: Historically, this falcon nested on high cliffs overlooking river systems. Today, peregrines are more apt to be found nesting on high bridges and tall buildings within cities. As a result, they frequently feed on pigeons and other urban birds. After an absence of 30 years, the return of breeding peregrines to Pennsylvania was first documented on bridges spanning the Delaware and Schuylkill rivers in the Philadelphia area. In 1990, a pair began nesting in Pittsburgh.

REASONS FOR BEING ENDANGERED: By 1961, peregrines were no longer found in Pennsylvania. Their decline and extirpation has been attributed to egg collecting, falconry and shooting, but chiefly to pesticides – particularly DDT.

MANAGEMENT PRACTICES: The plan to restore this species includes annual surveys for new nest sites; protection of known nest sites, including hazard reduction to increase survival of young peregrines; restoration of peregrines at suitable historic sites; and promotion of public support. A reintroduction program has released birds in Harrisburg, Reading, and Williamsport.



● - verified after 1960 ● = historical occurrences

Invertebrates | Birds & Mammals | Fish, Reptiles & Amphibians | Plants

Sedge Wren

Cistothorus platensis

Photo Credit: Lang Elliot, Cornell Lab of Ornithology

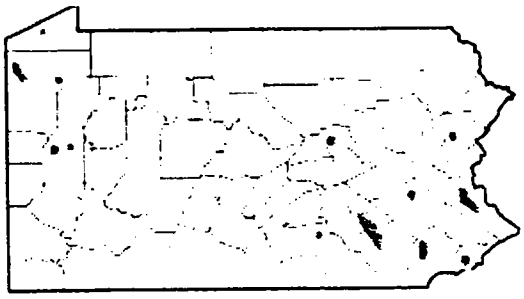
IDENTIFYING CHARACTERISTICS: The sedge wren, formerly known as the short-billed marsh wren, can best be distinguished from other wrens by its relatively small size. It's only 4 ½ inches high and has a 6-inch wingspan, streaked crown and back, faint buffy eye stripes, and a short tail which is often held upright.

BIOLOGY-NATURAL HISTORY: In summer, sedge wrens are found from southern Saskatchewan and Minnesota across the Great Lake States to the east. They winter along the Atlantic and Gulf coasts, down into Mexico. Sedge wrens arrive in Pennsylvania in April and May, and migrate south to brackish coastal marshes from August to October. Among the last birds to nest in the state, sedge wrens may be found nesting here as late as August. They nest in wetland areas; a typical clutch of six or seven white eggs is laid in a globular nest built up to two feet off the ground. Young hatch in 12 to 14 days, and leave the nest at two weeks of age. Two broods can be produced each year.

PREFERRED HABITAT: For nesting, sedge wrens require damp meadows and marshes where sedges and grasses are interspersed with small shrubs. They apparently don't do well in cattail marshes.

REASONS FOR BEING THREATENED: Sedge wrens are rare throughout their range. They used to be found nesting in scattered locations across Pennsylvania. Over the past several decades, however, they have disappeared from many former haunts, and numbers have dropped significantly in others. The loss of habitat and changing agricultural practices are thought to be responsible for this decline.

MANAGEMENT PROGRAMS: The specific locations where sedge wrens currently nest in the state need to be determined and then, where feasible, protected.



● = verified after 1980 ● = historical occurrences

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Pennsylvania Field Office
315 South Allen Street, Suite 322
State College, Pennsylvania 16801-4850

May 5. 1999

Ms. Nadine Strack
Environmental, Engineering,
and Educational Solutions
P.O. Box 354
Montpelier, VA 23192

Dear Ms. Strack:

This responds to your April 29, 1999, request for information about federally listed and proposed endangered and threatened species within the area being reviewed for a wetlands conservation plan for the Cooks Creek watershed, which encompasses portions of Bucks, Lehigh and Northampton Counties, Pennsylvania. The following comments are provided pursuant to the Endangered Species Act of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq.*) to ensure the protection of endangered and threatened species.

The Cooks Creek watershed is known to be occupied by bog turtles (*Clemmys muhlenbergii*), a species that is federally listed as threatened. Bog turtles usually occur in small, discrete populations occupying suitable wetland habitat dispersed along a watershed. Bog turtles inhabit shallow, spring-fed fens, sphagnum bogs, swamps, marshy meadows, and pastures characterized by soft, muddy bottoms; clear, cool, slow-flowing water, often forming a network of rivulets; high humidity; and an open canopy. The occupied "intermediate successional stage" wetland habitat is usually a mosaic of micro-habitats ranging from dry pockets, to areas that are saturated with water, to areas that are periodically flooded. Some wetlands occupied by bog turtles are located in agricultural areas and are subject to grazing by livestock.

If planned conservation activities include construction or restoration of wetlands, their potential suitability as bog turtle habitat should first be assessed, as described under Step 2 of the enclosed *Guidelines for Bog Turtle Surveys*. This habitat survey could easily be conducted by a wetland biologist concurrent with a routine wetland identification and delineation. If any wetlands are identified as potential bog turtle habitat, efforts should be made to avoid any direct or indirect impacts to those wetlands. If adverse effects to these wetlands cannot be avoided, a more detailed and thorough survey will be necessary, as described under Step 3 of the *Guidelines for Bog Turtle Surveys*. The Step 3 survey should be conducted by a qualified biologist with bog turtle field survey experience (see enclosed list of qualified surveyors). Survey results should be submitted to the Fish and Wildlife Service for review and concurrence. If project activities might adversely affect bog turtles, additional consultation with the Service will be required.

Except for the bog turtle and occasional transient species, no other federally listed or proposed threatened or endangered species under our jurisdiction are known to occur within the project impact area. An updated compilation of certain federal status species in Pennsylvania is enclosed for your information.

Requests for information regarding State-listed endangered or threatened species should be directed to the Pennsylvania Game Commission (birds and mammals), the Pennsylvania Fish and Boat Commission (fish, reptiles. amphibians and aquatic invertebrates), and the Pennsylvania Department of Conservation and Natural Resources (plants).

Please contact Michael McCarthy of my staff at 814-234-4090 if you have any questions or require further assistance.

Sincerely,

David Densmore
Supervisor

Enclosures

FEDERALLY LISTED, PROPOSED AND CANDIDATE SPECIES
(in Pennsylvania)

COMMON NAME	SCIENTIFIC NAME	STATUS*	DISTRIBUTION
FISHES			
Shortnose sturgeon**	*Acipenser brevirostrum*	E	Delaware River and other Atlantic coastal waters
REPTILES & AMPHIBIANS			
Bog turtle	*Clemmys muhlenbergii*	T	Current - Adams, Berks, Bucks, Chester, Cumberland, Delaware, Franklin, Lancaster, Lebanon, Lehigh, Monroe, Montgomery, Northampton and York Counties. Historic - Crawford, Mercer and Philadelphia Counties
BIRDS			
Bald eagle	*Haliaeetus leucocephalus*	T	Suitable habitats across the state. Recent nesting in Butler, Crawford, Dauphin, Erie, Forest, Lancaster, Mercer, Northumberland, Pike, Tioga, Venango, Warren and York Counties. Wintering concentrations occur in association with ice-free sections of rivers, lakes and reservoirs, including the Delaware River.
Peregrine falcon (American)	*Falco peregrinus anatum*	E	Recent nesting in and around Philadelphia and Pittsburgh (Allegheny, Delaware, Philadelphia and Bucks Counties); also Dauphin, Luzerne and Lycoming Counties.
Piping plover	*Charadrius melodus*	E	Presque Isle (Erie County). Migratory. No nesting in Pennsylvania since mid-1950s.
MAMMALS			
Indiana bat	*Myotis sodalis*	E	Summer range: Blair, Elk, and McKean Counties. Winter hibernacula: Blair, Luzerne, Mifflin and Somerset Counties.
MOLLUSKS			
Clubshell mussel	*Pleurobema clava*	E	French Creek and Allegheny River watersheds; Clarion, Crawford, Erie, Forest, Mercer, Venango and Warren Counties
Northern riffleshell	*Epioblasma torulosa rangiana*	E	French Creek and Allegheny River watersheds; Clarion, Crawford, Erie, Forest, Mercer, Venango and Warren Counties
PLANTS			
Northeastern bulrush	*Scirpus ancistrochaetus*	E	Current - Adams, Bedford, Blair, Carbon, Centre, Clinton, Cumberland, Dauphin, Franklin, Huntingdon, Lackawanna, Lehigh, Lycoming, Mifflin, Monroe, Perry, Snyder and Union Counties. Historic - Northampton County
Small-whorled pogonia	*Isotria medeoloides*	T	Current - Centre and Venango Counties. Historic - Berks, Chester, Greene, Monroe, Montgomery and Philadelphia Counties

** E = Endangered, T = Threatened, PE = Proposed Endangered, PT = Proposed Threatened, C = Candidate* *Revised 3/19/99*
*** Shortnose sturgeon is under the jurisdiction of the National Marine Fisheries Service*

U.S. FISH AND WILDLIFE SERVICE
315 SOUTH ALLEN ST., SUITE 322, STATE COLLEGE, PA 16801

GUIDELINES FOR BOG TURTLE SURVEYS

(revised May 11, 1998)

STEP 1 Contact the U.S. Fish and Wildlife Service (USFWS), Pennsylvania Fish and Boat Commission (PFBC), or Pennsylvania Natural Diversity Inventory (PNDI) to find out if the wetland is *known* to support bog turtles (wetlands in Adams, Berks, Bucks, Chester, Cumberland, Delaware, Franklin, Lancaster, Lebanon, Lehigh, Monroe, Montgomery, Northampton and York Counties). If the wetland is known to support bog turtles, measures must be taken to avoid impacts to the species. The PFBC and USFWS will work with federal, state and local regulatory agencies, permit applicants and project proponents to ensure that bog turtles will not be adversely affected.

STEP 2 If it is *not* a known bog turtle wetland but has an emergent and/or scrub-shrub wetland component, then conduct a survey to determine if the wetland is *potential* bog turtle habitat.

Conditions (Note: these apply only to determine if it is *potential* habitat):

1. Surveys can be performed any month of the year.

2. Potential bog turtle habitat is recognized by three criteria:

   a) **suitable hydrology** - typically spring-fed with shallow surface water or saturated soils present year-round, although in summer the wet area(s) may be restricted to near spring head(s). Typically these wetlands are interspersed with dry and wet pockets. There is often subsurface flow.

   b) **suitable soils** - a bottom substrate of soft muck. You will usually sink to your ankles or deeper in muck, although in summers of dry years this may be limited to areas near spring head(s). This is the critical criterion.

   c) **suitable vegetation** - dominant vegetation of low grasses and sedges (emergent wetland), often with a scrub-shrub wetland component. Common emergent vegetation includes: tussock sedge (*Carex stricta*), soft rush (*Juncus effusus*), rice cut grass (*Leersia oryzoides*), sensitive fern (*Onoclea sensibilis*), tearthumbs (*Polygonum spp.*), jewelweeds (*Impatiens spp.*), arrowheads (*Sagittaria spp.*), skunk cabbage (*Symplocarpus foetidus*), Panic grasses (*Panicum spp.*), other sedges (*Carex spp.*), and in disturbed sites, reed canary grass (*Phalaris arundinacea*). Common scrub-shrub species include alder (*Alnus spp.*), red maple (*Acer rubrum*), and in disturbed sites, multiflora rose (*Rosa multiflora*).

3. The USFWS and the PFBC should be sent a copy of survey results including: a USGS topographic map indicating location of site; project design map, including location of wetlands and streams; color photographs of the site; surveyor's name; date of visit; opinion on potential/not potential habitat; a description of the hydrology, soils, and vegetation.

STEP 3 If the wetland is identified as potential bog turtle habitat (see STEP 2), then either (1) completely avoid all direct and indirect project impacts to the wetland, in consultation with the USFWS and PFBC, or (2) conduct a survey to determine the presence of bog turtles. (Note--this is not a survey to estimate population size; a long-term mark/recapture study would be required for that.)

Conditions:

1. Surveys should only be performed during the period from April 15-June 15. This coincides with the period of greatest annual turtle activity (spring emergence and breeding) and before vegetation gets too dense to accurately survey. While turtles may be found outside of these dates, a result of no turtles would be considered inconclusive. Surveys beyond June also have a higher likelihood of disruption/destruction of nests or newly hatched young.

2. Water temperatures should be a minimum of 55° F. Air temperatures should be a minimum of 60° F.

3. Cloud cover should be <50 percent, and surveys should not be done during or immediately following rain events, unless it clears rapidly and is sunny.

4. Three (3) people should survey each wetland together. At least one (1) of these should be a USFWS/PFBC-recognized qualified bog turtle surveyor, who will instruct the other surveyors in survey technique. To maintain survey effort consistency and increase the probability of encountering turtles, the same survey team should be used per wetland.

   A scientific collector's permit valid for the location and period of the survey must be obtained from the Pennsylvania Fish and Boat Commission by at least one of the surveyors prior to conducting the survey.

5. A *minimum* of three (3) surveys per wetland site are needed to accurately assess the site for presence of bog turtles. <u>At least two of these surveys should be performed in May</u>. From mid-April to mid-May, surveys should be separated by six or more days. From mid-May to mid-June, surveys should be separated by three or more days. The shorter period between surveys during late May and June is needed to ensure that surveys are carried out during the optimum window of time (i.e., before wetland vegetation becomes too thick).

   Note that bog turtles are more likely to be encountered by spreading the surveys out over a longer period. For example, erroneous survey results could be obtained if surveys were conducted on three successive days in late April due to possible late spring emergence, or during periods of extreme weather because turtles may be buried in mud and difficult to find. If turtles are found on the first or second visit, the site does not need to be revisited.

6. Survey time should be a minimum of two hours (6 person-hours) per acre of wetland per site visit unless a bog turtle is found before this time has elapsed. Both random opportunistic searching and transect surveys should be used at each wetland.

7. The USFWS and PFBC should be sent a copy of survey results, including the following: dates of site visits; time spent per wetland per visit; names of surveyors; a site map; a description of the wetlands within the project area (e.g., acreage, vegetation, soils, hydrology); an explanation of which wetlands or portions of wetlands were or were not surveyed, and why; survey methodology; weather per visit (air temperature, water temperature, percent cloud cover, wind, and precipitation); presence or absence of bog turtles, including number of turtles found and date, and age/sex of turtles found; and other reptile and amphibian species found and date.

RECOGNIZED QUALIFIED BOG TURTLE SURVEYORS*

Jack Cover
704 Sharps Court
Fallston, MD 21047
(H) 410-877-7239
(W) 410-576-3835 (National Aquarium)

Tim Hoen
1376 Rock Ridge Road
Jarretsville, MD 21084
(H) 410-557-6879
(W) 410-516-6596 (Johns Hopkins Univ.)

Jennifer Kureen
18515 Prettyboy Dam Road
Parkton, MD 21120
(H) 410-343-1541
(W) 410-396-6013 (Baltimore Zoo)

Jim McGibney
1441 Heaps Road
P.O. Box 183
Whiteford, MD 21160
(H) 410-452-8494 (leave msg.)

Joe McSharry
4304 Parkwood Avenue
Baltimore, MD 21206
(H) 410-483-3132 (leave msg.)

Janis Seegar
12265 Harford Road
Glen Arm, MD 21057
(H) 410-592-6122
(W) 410-671-4912 (Aberdeen Proving Ground)

Anthony Wisniewski
Reptile House - Baltimore Zoo
Druid Hill Park
Baltimore, MD 21217
(W) 410-396-0441
(W) 410-462-4398

Bob Zappalorti
536 Seaman Avenue
Beachwood, NJ 08722
(W) 732-341-8822

Martin Lidie
1829 Ellinwood Road
Baltimore, MD 21237
(H) 410-866-6135

Gian L. Rocco
322 Amblewood Way
State College, PA 16803
email: gxr124@psu.edu
(H) 814-237-2313

Dr. Rudolf Arndt
The Richard Stockton College
Jim Leeds Road
Pomona, NJ 08240-0195
(609) 652-1776

Gabrielle Borin
ENSR
281 Centenniel Ave.
Piscataway, NJ 08854
(732) 457-0500

*This list includes professional and amateur herpetologists the U.S. Fish and Wildlife Service and the Pennsylvania Fish and Boat Commission recognize as qualified to identify bog turtle habitat and survey for the presence of bog turtles. This list may not include all individuals qualified to survey for this species. Inclusion of names on this list does not constitute endorsement by the Service or any other U.S. Government agency or State agency.

List revised 4/29/98

Fish of the Great Lakes
Wisconsin Sea Grant

Alewife

Atlantic Salmon

Bloater

Brook Trout

Brown Trout

Burbot

Carp

Chinook Salmon

Coho Salmon

Freshwater Drum

Lake Herring

Lake Sturgeon

Lake Trout

Lake Whitefish

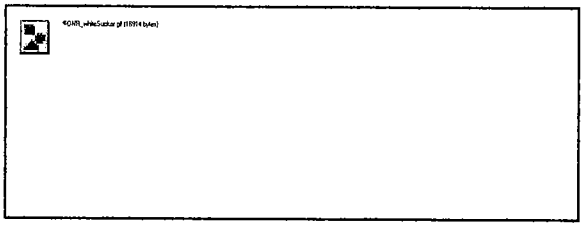
Longnose

White Sucker

Catostomus commersoni

- **Length:** 12 to 20 inches
- **Weight:** 2 to 4 pounds
- **Coloring:** grey, coppery brown through brown to black on back; creamy white on lower sides and below
- **Common Names:** common sucker, eastern sucker, grey sucker, mullet, black mullet, bay fish
- **Found in Lakes:** Michigan, Huron, Ontario, Erie, and Superior

These round robust fish browse in the warm shallows of estuaries and bays. With their



fleshy mouth aimed downward, they vacuum up worms, clams and, some say, the eggs of other fish. But most biologists doubt that Lake Michigan's suckers has any

Longnose Sucker

Muskellunge

Northern Pike

Pink Salmon

Rainbow Smelt

Rainbow Trout

Round Goby

Round Whitefish

Ruffe

Sea Lamprey

Smallmouth Bass

Walleye

White Perch

White Sucker

Yellow Perch

that Lake Michigan's suckers has any significant effect on the populations of such valued fish as trout, bass, and sturgeon.

Fishermen--who dipnet large numbers of suckers during their spring spawning runs up Great Lakes tributaries--often regard the suckers' arrival as the beginning of the fishing season.

Though the meat is firm and good tasting, white sucker seldom appears on a restaurant menu -- perhaps because the name lacks market appeal. As a result, white sucker is processed in a variety of ways for the market, often under the name "mullet." They are good either fresh or smoked and can be prepared in fish sticks or soups and chowders.

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Last updated by Seaman

Wildlife Fact Sheets

RED-EARED SLIDER

Trachemys scripta elegans

Description

The Red-eared Slider is perhaps the best known and most recognizable of turtles. The top of the shell (carapace) is smooth and gently curved and is olive to black with yellow stripes and bars. It is a medium -sized turtle that is best identified by a red or sometimes yellow patch that is found just behind its eye.

Life History

The Red-eared Slider is almost exclusively aquatic. It rarely ventures out of the water except to lay its eggs or to migrate to a new water body, should the need arise. As a water dweller, the adult turtle feeds primarily on aquatic plants. Young turtles are mostly carnivorous, gradually switching to vegetation as they age.

This slider is commonly seen basking in the sun, on logs or masses of vegetation. When basking sites are in short supply, they may even pile on top of each other, up to three turtles deep. The Red-eared Slider very easily is spooked and will slide directly into the water from its sunning spot at the least provocation.

During the breeding season between March and July, the female may find herself swept away by a persistent suitor. The male Red-eared Sliders attempt to win over a female by engaging in courtship activities include swimming backwards in front of the female with their forelegs stretched out, palm side up.

Red-eared Sliders may produce up to three clutches of four to 23 eggs in a single year. With each nest, the female will go on shore and dig a shallow hole that is three to 10 inches wide. She deposits her eggs in these excavations and subsequently covers them up with soil and materials to seal in the eggs for protection from predators and the elements. The young turtles hatch 60 to 75 days later, although they may spend the winter in the nest.

Habitat and Distribution

The Red-eared Slider is at home in quiet, freshwater systems that have muddy bottoms and abundant aquatic vegetation. They range from Indiana to New Mexico down through Texas to the Gulf of Mexico. They are widely distributed throughout Texas except for the far western region.

Please send comments, suggestions, or questions to:

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or click on the address to send an E-mail message.

Fish of the Great Lakes
Wisconsin Sea Grant

Alewife

Atlantic Salmon

Bloater

Brook Trout

Brown Trout

Burbot

Carp

Chinook Salmon

Coho Salmon

Freshwater Drum

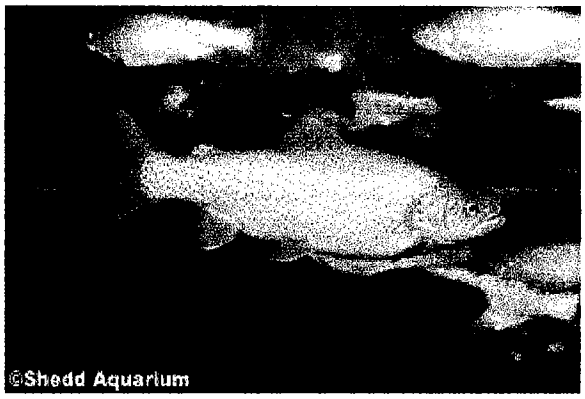
Lake Herring

Lake Sturgeon

Lake Trout

Lake Whitefish

Longnose Sucker



Rainbow Trout

Oncorhynchus mykiss

Identification tips for trouts and salmons

- **Length:** 20 to 30 inches
- **Weight:** 2 to 8 pounds
- **Coloring:** steel-blue, blue-green, yellow-green to almost brown on back; silvery sides; silvery white below
- **Common Names:** steelhead trout, coast rainbow trout, silver trout
- **Found in Lakes:** Stocked in Michigan, Huron, Ontario, Erie, and Superior

These attractive game fish strike aggressively, fight valiantly and are an angler's joy. The first rainbow trout planted in the Great Lakes were probably

"steelheads." This is a strain of rainbow trout that migrates into the ocean before returning to spawn in their freshwater

Sucker

Muskellunge

Northern Pike

Pink Salmon

Rainbow Smelt

Rainbow Trout

Round Goby

Round Whitefish

Ruffe

Sea Lamprey

Smallmouth Bass

Walleye

White Perch

White Sucker

Yellow Perch

returning to spawn in their freshwater home streams. Rainbows have adapted well, moving in and out of the Great Lakes much as they would the ocean. As might be expected, they range widely throughout Lake Michigan and Lake Huron. Tagging has revealed that some migrate as far north as the Canadian tributaries of Lake Superior.

Rainbow trout seldom swim deeper than 35 feet along the Great Lakes shores and are easily located. In forage-rich Lake Michigan, they grow 30-32 inches long and may reach 16 pounds by the time they are five years old.

Rainbow trout reproduce naturally in Lake Superior's tributaries and in some Lake Michigan tributaries as well. Unlike Pacific salmon, the rainbow survives after spawning and may spawn two or three times during its life.

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Brook Trout illustration copyright 1998 Gina Mikel
Rainbow trout photograph (c) Shedd Aquarium (e-mail)
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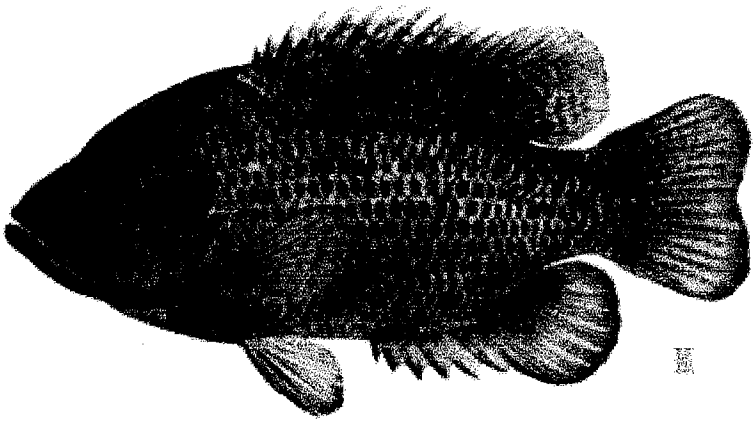
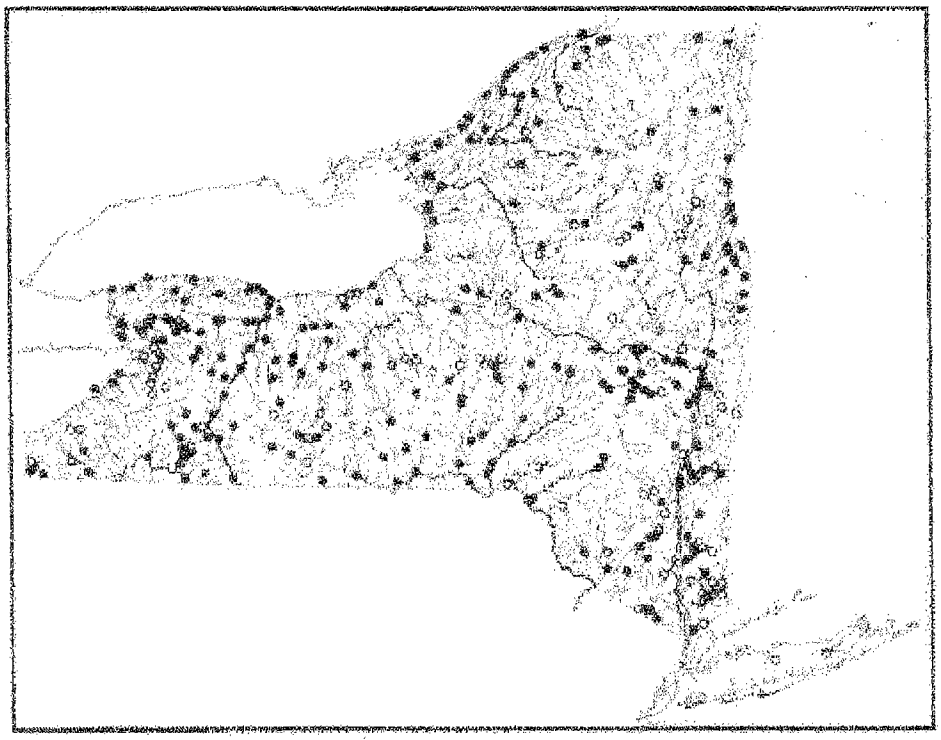
Last updated by Seaman



Rock Bass (*Ampbloplites rupestris*)

Rock bass are present in most areas of New York except in the uniformly cold, high-altitude lakes of the Adirondacks. They prefer large lakes with rocky bottoms and streams with sluggish or moderate currents. They often are found in the same habitats as smallmouth bass.

Rock bass are usually 6 to 8 inches in length. They sometimes reach lengths of 10 to 12 inches and weigh 1 pound or more. These fish readily take lures and natural bait; they are scrappy fighters and fine panfish.

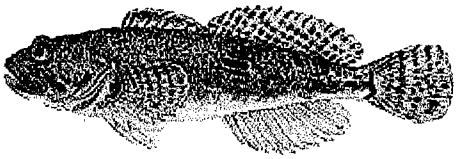


Distribution of rock bass in NY state. Dark dots represent where actual samples of rock bass were taken. White dots represent historic distributions.

A 356k jpeg of the rock bass is also available for download.

Back to the Sunfish Family | Back to Fish Images

Slimy Sculpin



Cottus cognatus

- **Characteristics** - head and anterior flattened dorso-ventrally; terminal mouth with numerous teeth in narrow bands on the upper and lower jaws; two lobed, narrowly connected dorsal fins; head, back, and sides olive brown with dark mottling; lower region of head and belly lighter to whitish
- **Distribution** - coldwater streams in northeast Iowa
- **Foods** - larval aquatic insects, invertebrates

More Slimy Sculpin Info

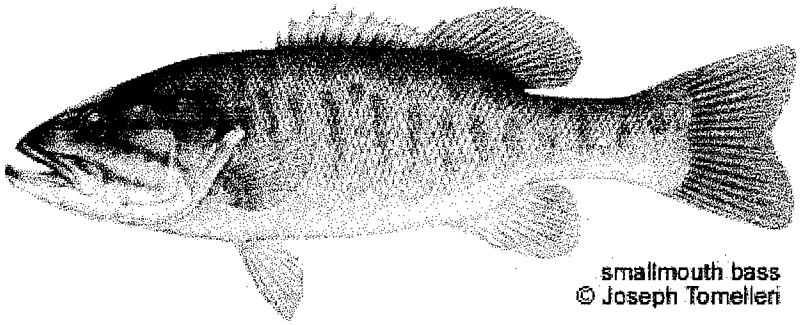
Back to the Sculpin Family

Smallmouth Bass

Regulations

Management

STATE RECORD
8 pounds, West Battle Lake (Otter Tail County), 1948.



smallmouth bass
© Joseph Tomelleri

Sometimes called a "bronzeback" for its brassy brown hue, the smallmouth is one of the strongest fish for its weight. Many anglers who hook a 2-pounder will swear it's twice that big until the fish is in the net. Smallmouth are native to the Mississippi River watershed. They are abundant in warm southeast Minnesota rivers, central Minnesota lakes, and in northern waters such as Vermilion Lake and big Boundary Waters Canoe Area Wilderness lakes, where the species was introduced in the late 1800s.

Smallmouth bass look similar to their close cousin, the largemouth. Often they are found in the same waters. To tell the two apart, look at the closed mouth. If it extends only to the middle of the eye, it's a smallmouth. If it goes way beyond the back of the eye, the fish is a largemouth. Get more information.

DNR Information Center
500 Lafayette Road
St. Paul, MN 55155-4040
driving directions

Phone: 651-296-6157 or 888-MINNDNR
TTY: 651-296-5484 or 800-657-3929
For DNR Info: info@dnr.state.mn.us
Site Comments: webmaster@dnr.state.mn.us

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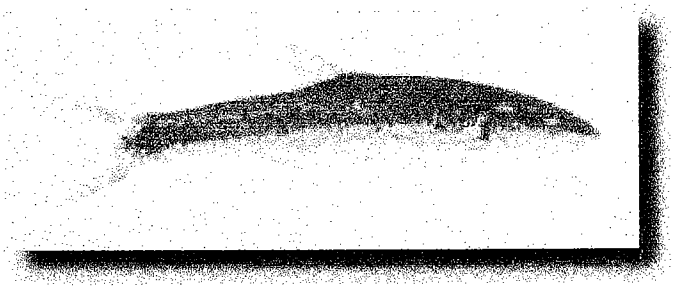
Longnose dace
Scientific Name: Rhinichthys cataractae
Family: Minnows
Native



The longnose dace is widely distributed across northcentral North America from the Atlantic to the Pacific. In Idaho, it is common in every river system in the state. They prefer the riffle areas of streams, but can be found along the shoreline of lakes where the substrate is composed of small rubble. It is a benthic species, living among the stones on the bottoms of streams. Longnose dace spawn in late spring/early summer on gravel bottoms of shallow riffles. Eggs, about 400 to 3,300 per female, are adhesive and are scattered on the substrate. The food of this species is primarily aquatic insect larvae. They reach a size of 3 to 6 inches. The fry of this dace may serve as food for game fishes and it has been used as a bait fish in parts of its range.

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TEXAS PARKS & WILDLIFE

TPW MAIN PAGE

Fishing

TEXAS LAKES

REGS & INFO

FISHING REPORTS

FISH RECORDS

FISH ID

TROUT STOCKING

Water Levels

- U.S.G.S.
- U.S. ARMY CORPS OF ENGINEERS

KIDFISH

ANGLER EDUCATION

SPORT FISH RESTORATION

RELATED LINKS

Redbreast Sunfish
Lepomis auritus

Large image

Other Names: Yellowbelly sunfish, Longear bream, redbreasted bream

Description

This sunfish possesses a yellow belly that is sometimes an orange or a rusty color. It might have been better named the longear as its opercle flap or ear is considerably longer than the opercle flap of the longear sunfish. In adults, the ear often reaches a length of one inch or more; it is narrow and usually not wider than the eye. The lower margin of the flap is usually pale. The redbreast is one of our larger sunfish, occasionally attaining weights of one pound.

Biology

In typical sunfish fashion, the redbreast spawns in beds of colonies on sand or gravel where the water is one to three feet deep. After hatching, the young may remain schooled for several weeks before scattering. Adults feed on insects, snails, crayfish, and small fish.

Distribution

Redbreast sunfish were introduced into Texas from its original range, the streams of the Eastern U.S. that drain into the Atlantic Ocean. This species now occurs throughout the eastern and southern parts of Texas as far west as some streams of the Pecos drainage.

Angler Importance

At one time, this sunfish was raised by state hatcheries and widely distributed. Good populations of large redbreast, however, can be found in the clear streams of central Texas, primarily in the San Marcos area.

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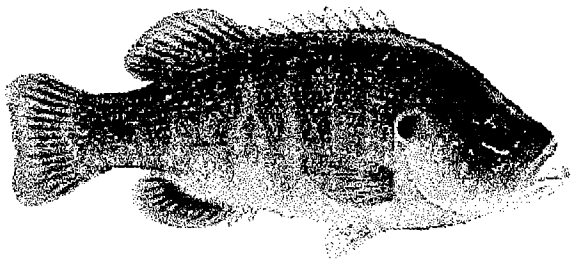
RELATED LINKS

Green Sunfish
Lepomis cyanellus



Large image

Description

The green sunfish, like warmouth, has a large mouth and a heavy, black bass body shape. The body is dark green, almost blue, dorsally, fading to lighter green on the sides, and yellow to white ventrally. Faint vertical bars are apparent on the sides. Some scales have turquoise spots. Lepomis, the generic name, is Greek and means "scaled gill cover". The species epithet cyanellus is also Greek and means "blue"

Biology

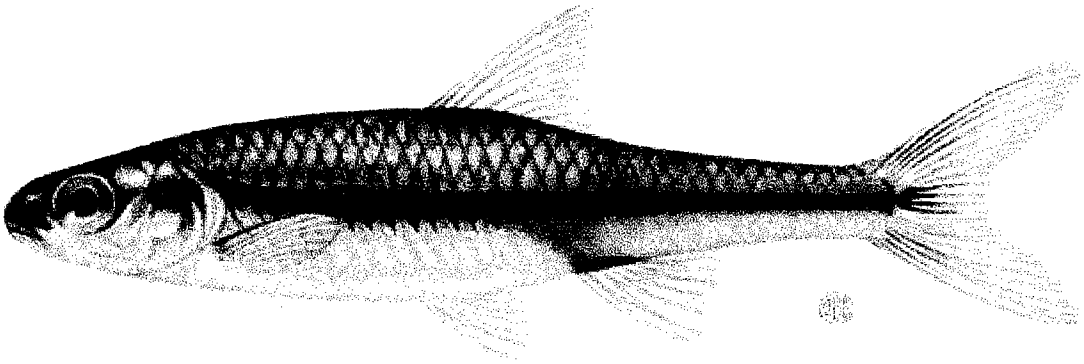
The green sunfish is a very versatile species, able to tolerate a wide range of environmental conditions, and tends to do very well when competition with other sunfish is minimal. Its ability to tolerate environmental extremes makes it ideal for survival in Prairie streams where conditions are not stable, and they are often the first sunfish species to repopulate depleted areas. Green sunfish nest in shallow water colonies where nests are often closely packed. Gravel or rocky bottom sites are usually preferred for nest building. Spawning occurs in late spring, when water temperatures rise above 70 °F, and may continue throughout the summer. Hybridization with other sunfish species is very common. Males aggressively defend their nests for 6-7 days after eggs are deposited, at which time fry are usually free-swimming. Because of their enormous reproductive potential green sunfish often overpopulate small lakes and ponds. Adults feed on insects and small fish.

Distribution

Originally the distribution of green sunfish appears to have been limited to the central plains west of the Appalachian Mountains and east of the Rocky Mountains, including northeastern Mexico. However, due to introductions the species has become nearly ubiquitous over much of the U.S. the the exception of Florida and parts of the northwest. Green sunfish are found throughout Texas

Angler Importance

Due to their propensity to overpopulate and so become stunted, they rarely reach a desirable size for angling. The largest reported specimen in Texas to date was only 0.75 pounds.



Swallowtail Shiner (*Notropis procne*)

Two subspecies are recognized. *N. p. procne* ranges from the Delaware and Susquehanna systems in New York south to the James River in Virginia. It also has been reported from Catharine Creek, the inlet to Seneca Lake, and this has been ascribed to the old Seneca Canal or possibly to a postglacial invasion at the time the Finger Lakes still drained into the Susquehanna. A third possibility is a post glacial stream capture. The other subspecies, *N. procne longiceps* (Cope), ranges from the Roanoke River in Virginia to the Santee River in South Carolina.

The preferred habitat of the swallowtail shiner is upland streams and small rivers. It is tolerant of sandy bottom and turbid water conditions, but it avoids deeper pools and torrential rapids. It is usually seen in schools near the bottom.

The breeding habits of the swallowtail shiner were studied in the Covington River near Washington, D.C. Spawning took place in a riffle 4 to 12 inches deep over sand and fine gravel when the water temperature was about 78 F. Males and females were about the same size but the males were darker and more active. Males guarded territories, maintaining distances of 4 to 18 inches. Courtship consisted of the male making a series of figure-eight movements over an area of clean gravel that presumably had been swept by the fish's movements. Invading males were chased with a quick rush. Females hovered downstream or at the side until ready to spawn, then moved into the male's territory and stopped within 2 to 4 inches of the male. The male then backed downstream and placed his pectoral fin beneath her head while throwing his caudal peduncle over hers. Together the pair dropped to the bottom and vibrated, stirring up sand as the eggs were laid and fertilized. After spawning, the pair separated gently and the female drifted downstream while the male returned to guarding his territory. Spawning continued after a few minutes and Raney estimated that it would take several days to deposit all of a female's complement of eggs. Yearlings averaged 33 to 39mm and 2- and 3-year-olds were 43 to 52 mm. Few fish live through the third winter.

APPENDIX D

Water Budget - Stream Gauge Data

Furthermore, water quality impacts of wastewater effluent discharges downstream can be extremely harmful. In addition to these direct water quality impacts, development typically translates into removal or partial removal of riparian vegetation, which serves multiple critical functions for overall stream quality. Stream temperature regimes are adversely affected as the result of reduction in stream shading. All of these pollution impacts combine to adversely affect the stream system and its biota in a variety of ways.

The concept of Sustainable Watershed Management (Sustainable Watershed Management at the Rapidly Growing Urban Fringe, T. H. Cahill, et al., Watershed 96 Proceedings) proposes as fundamental resource management objective to measure the tolerance limits of the natural system and balance the human use of these land and water resources so that we live within the carrying capacity of these natural systems. 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 (Q7-10).
- Maintain ground water levels in order to protect existing/future wells.
- Assure that stream flooding is not increased.
- Prevent ground water contamination, particularly from nitrate.
- Minimize additional point and non-point source pollutant inputs into surface waters.

7.1 Preparing the Water Budget

Quantification of the flow system concept with respect to the occurrence and distribution of groundwater requires the introduction of a hydrologic budget equation, or water balance, that describes the hydrologic regime in a drainage basin (Freeze and Cherry, 1979). However, the application of steady-state hydrologic budget equations provides only a crude approximation of the hydrologic regime in a drainage basin.

If we limit ourselves to drainage basins in which the surface water divides and groundwater divides coincide, and for which there are no external inflows or outflows of groundwater, the water-balance equation for an annual period would take the form

$$P = SF + dGWS + dSWS + ET \qquad (1)$$

where P = precipitation

SF = streamflow

ET = evapotranspiration

dSWS = change in surface-water storage

dGWS = change in groundwater storage

Averaged over many years of record, dSWS = dGWS = 0, and Eq. (1) becomes

P = SF + ET (2)

Considering an ideal drainage basin, wherein the discharge area constitutes a very small percentage of the total basin area, then

Q = QS + QG (3)

where QS is the surface water component of average annual runoff and QG is the groundwater component, or average annual baseflow. Equation (3) suggests that it might be possible to separate streamflow hygrographs into their surface-water and groundwater components.

Baseflow separation and water budget analysis performed for Cooks Creek stream gage data (1991, 1992 and 2000) indicate that the watershed basin has a large storage capacity (low discharge ratio discharge ratio = (O25/Q75)^0.5= 1.56), sustaining up to 92.29 percent of Cooks Creek streamflow (still 7 cfs) during dry seasons (July 2000).

Ground-water contribution to streamflow through 2000 year, from January to September is presented in Figure A-13. The analysis indicated that, for Cooks Creek over the 10 months period, an average of 65.95 percent of the streamflow was contributed by ground water. Ground-water contributions ranged from 58.13 percent to 92.29 percent, and the median was 68.24 percent. For a complete analyze for the existing data between 1990 and 1999 see Appendix A.

The capacity of a basin to store ground water can be illustrated by flow duration curves. Flow duration curve for Cooks Creek, 1991-92 period is shown in figure F-1. A flow duration curve is a cumulative frequency curve that shows the percentage of time specified discharges were equaled or exceeded during a given period.

The curve describe the flow characteristics of a stream without regard to the sequence of occurrence. Flow duration curves in figure F-1 are mean daily discharge in cubic feet per second per square mile so that drainage basins of different sizes can easily be compared. Although the flow duration curves for 1991-92 represent flow for a period of slightly below normal precipitation and are not representative of the long term probability distribution, they give an indication of the variability of streamflow among the basins. Flatter slopes, particularly at the lower end of the flow duration curve, indicate streamflow contributions from the ground water system. The flow duration curves in figure F-1 shows that the flow of Cooks Creek is better sustained by ground water discharge at the low end of the discharge range than the flow in other basins. The flow of Tinicum Creek is poorly sustained by ground water discharge at the low end of the discharge range, largely because 54 percent of the basin is underlain by diabase.

Discharge ratios taken from the flow duration curves can be used to quantitatively evaluate the capacity of the basin to store ground water (Walton, 1970). The discharge ratio is calculated by the following equation:

discharge ratio = (O25/Q75)0.5 (3)

where Q25 is discharge that is equaled or exceeded 25 percent of the time, and

Q75 is discharge that is equaled or exceeded 75 percent of the time.

Small ratios represent relatively permeable basins with a large storage capacity; larger ratios represent less permeable basins with a smaller storage capacity. Discharge ratios are given in table F-T1. The smallest discharge ratio was calculated for the Cooks Creek Basin, indicating that it has the largest storage capacity. The largest discharge ratio was calculated for the Tinicum Creek Basin, indicating that it has the smallest storage capacity.

The calculation of a hydrologic budget is relatively simple, involving only the subtraction of total outflow from total inflow, plus or minus the change in storage within the study region. However, the application of the steady-state hydrologic-budget equation provides only a crude approximation of the hydrologic regime in a drainage basin and estimation of values for the individual variables within the equation may be difficult.

Of all these variables, it is the evapotranspiration estimates that pose the greatest problem since it includes water evaporated from water surfaces, soils, and other surfaces, as well as that transpired by vegetation. The most widely used methods of calculation utilize the concept of potential evapotranspiration (PET), which is defined as the amount of water that would be removed from the land surface by evaporation and transpiration processes if sufficient water were available in the soil to meet the demand.

In a discharge area where upward rising groundwater provides a continuous moisture supply, actual evapotranspiration (AET) may closely approach potential evapotranspiration. In a recharge area, actual evapotranspiration is always considerably less than potential evapotranspiration.

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. The potential evapotranspiration (PET) per month is given by

PET = E x C (4)

Where: E = unadjusted potential evapotranspiration equal to 16(10t/TE)a

a = 0.000000675(TE)3 - 0.0000771(TE)2 + 0.01792(TE) + 0.49239

TE =temperature-efficiency index, being equal to the sum of twelve monthly values of heat index i = (t/5)1.514, where t is the mean monthly temperature in oC

C = correction coefficient, function of the latitude and month as given in the table of PET calculations.

Equation (4) provides an estimate of monthly "potential" evapotranspiration (PET) that represents the evaporating power of the atmosphere observed on the ground in a plant-covered area where there is at all times sufficient water in the soil for the needs of the vegetation. If there were a shortage of water, the actual evapotranspiration (AET) would be a function of the PET and the quantity of available water.

As a first approximation, one imagines that the upper layer of the soil constitutes a reservoir, the maximum capacity of which is estimated (St). In this reservoir, evapotranspiration may occur freely at the potential evapotranspiration (PET) rate. When it is empty, the evapotranspiration can only feed on the precipitation of the given month. When it is full, the excess moisture generates infiltration towards the aquifer. During a given month, one calculates the balance of the rainfall, the PET and the soil moisture storage (St), which makes it possible to compute the AE and the moisture surplus (N), that water available for runoff and/or groundwater recharge.

The attached table, Table 7-2, gives the results for the climatological station located at the Doylestown using the Thornthwaite formula to calculate PET. Thus we can estimate, as a first approximation, that the moisture surplus in 1999 ranged between –2.67 inches (deficit), August 1999, and 5.45 inches, September 1999. In 2000 the moisture surplus ranged between –1.18 inches (deficit), June 2000, and 3.56 inches, March 1999.

7.2 Water Balance

The concept of a groundwater regime is based on the fact that the occurrence and distribution of groundwater is not merely a product of chance, but the consequence of a finite combination of climatic, hydrologic, geologic, topographic, ecologic and soil-forming factors that together form an integrated dynamic system. These factors are interrelated in such a way that each provides some insight into the functioning of the total system and thus serves as an indicator of local conditions of groundwater occurrence. It is possible, therefore, to evaluate the general potential of an area for groundwater development by appraising as many of the factors listed above as practical and then by interpreting the local regime on the basis of known relationships among the factors and their effect on the groundwater regime.

Most important among the preceding relationships are the physical characteristics of the framework in which the groundwater system occurs, the balance between groundwater recharge and discharge and the consequent hydrologic and lithologic implications that may be drawn, and the relationship among the factors affecting the movement of groundwater from the point of recharge to the point of discharge.

Obviously the groundwater regime must be viewed as a dynamic system in which water is absorbed at the land surface and eventually recycled back to that surface. Groundwater may be visualized as occurring in a subsurface reservoir, the boundaries of which are formed by adjacent less permeable or impermeable geological materials. The reservoir may be open everywhere to the

WATERSHED MONITORING SYSTEM

1. WAMOS General Description

The software package is designed for downloading stage data, calibrating and develop rating curves for the stream gauge, maintaining database and calculating flows, statistics analysis, and finally integration the monitoring stream gauge data in the Township Management Plan.

2. WAMOS Applications

2.1 Hardware Configuration and Application Functions

The software is a graphical Windows 95/98/NT application, having a simple and user-friendly operator interface. The system requirements for current IBM compatible PC and the minimum hardware configuration would bee:

- Pentium 100MHz
- 2GB HDD
- 16MB RAM
- 1MB video RAM
- 14" SVGA color monitor
- 2 serial & 1 parallel ports
- keyboard & mouse

WAMOS application has two screens, Analysis and Calibration. Pressing the CALIBRATE button in the Analysis screen will switch to the Calibration screen and pressing the ANALYSIS button in the Calibrate screen will switch back to the Analysis screen.
NOTE: The Calibration screen is used only if the creek bed profile is changed which is expected to be very seldom.

2.2. WAMOS User Interface

WAMOS consists of two screens, i.e. the Analysis screen (Figure 2.1) and Calibration screen (Figure 2.2). The application starts up displaying the Analysis screen.

The elements contained by the Analysis screen are:

1. The screen title and subtitle;
2. Stream flow chart;
3. Time base selection control;
4. Results table; and,
5. Command buttons.

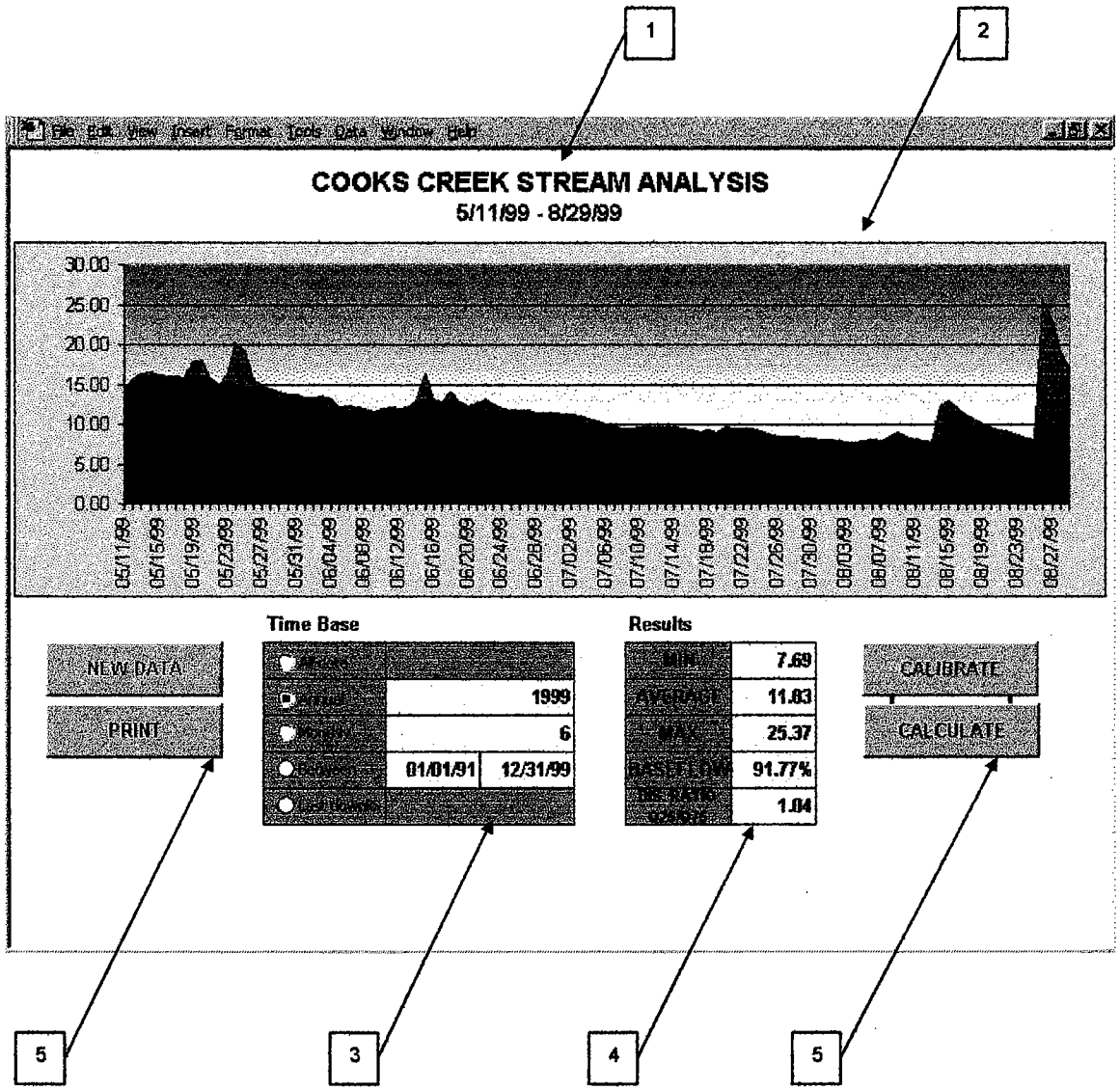


Figure 2.1 The Analysis screen.

The Calibration screen contains the following elements:

1. The screen title;
2. The river bed profile chart;
3. The flow rating curve chart;
4. The general parameters table;
5. The corelation parameters table;
6. The river bed profile tables;
7. The river bed profile controls; and,
8. The command buttons.

E. Analysis Screen. The Command Buttons

The Analysis screen contains four command buttons, as follows:

- NEW DATA – to enter new data acquired from the stream gauge data logger;
- PRINT – to printout graphical and tabular reports;
- CALIBRATE – to switch to the Calibration screen; and,
- CALCULATE – to display and calculate stream flow parameters according with the selected time interval.

(a) The NEW DATA Command

Pressing the NEW DATA button it launches a Windows standard open dialog box entitled "Open Data Logger File" (Figure 2.6). Enter or select a data logger file name and press the "Open" button.

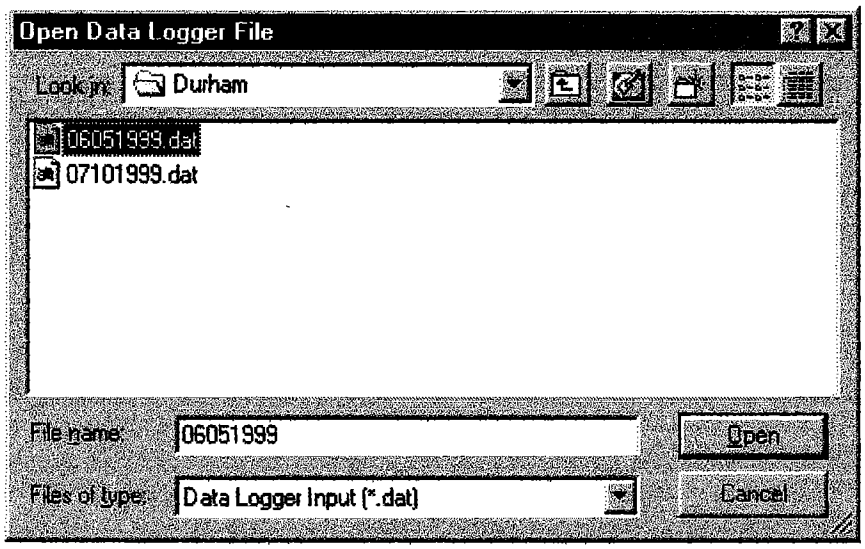


Figure 2.6 "Open Data Logger File" dialog box.

After several seconds required for data reading and processing a confirmation Windows standard message box will be issued (Figure 2.7). Press the "OK" button to complete the new data loading.

Figure 2.7. Confirmation message box.

(b) The PRINT Command

Graphical and tabular reports can be obtained pressing the PRINT button.

A typical report contains the following information:

- The stream flow chart and the analysis results for the selected time interval (Figure 2.8);
- The annual stream flow and estimated base flow table (Figure 2.9); and,
- The monthly water budgets table (Figure 2.10).

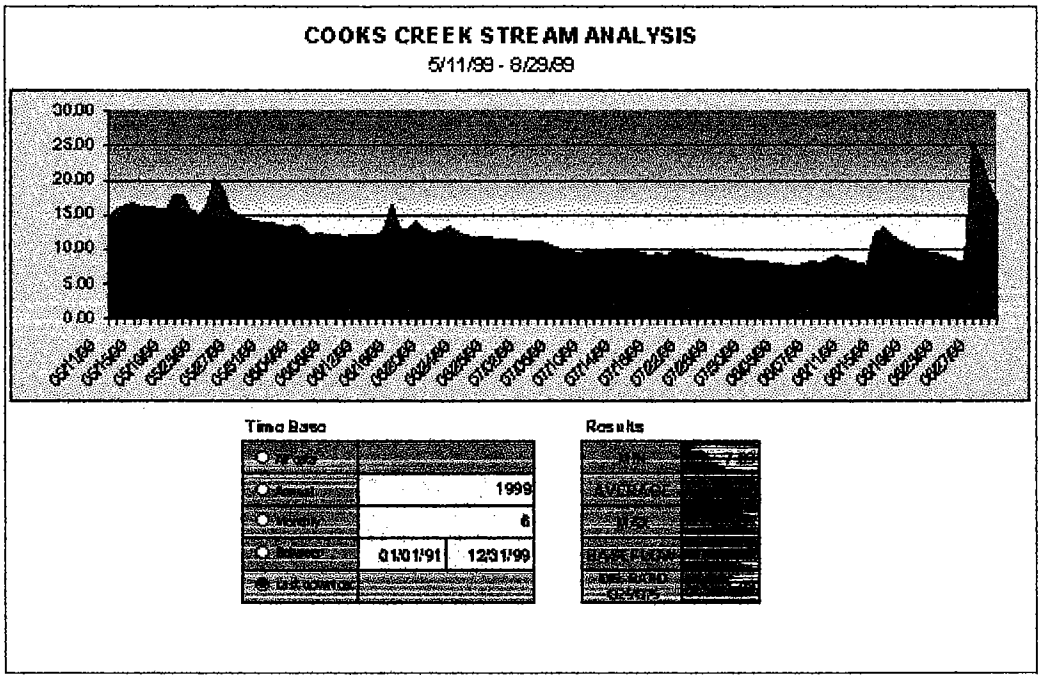


Figure 2.8 The stream flow chart and analysis results Report.

Year	Total streamflow (inches)	Base flow (inches)	Percentage of streamflow as base flow	Surface runoff (inches)	Percentage of streamflow as surface runoff
1990	32.33	14.48	45%	17.85	55%
1991	18.19	11.17	61%	7.02	39%
1992	19.01	8.29	44%	10.73	56%
1993	4.35	3.96	87%	0.39	13%
1999	5.35	4.91	92%	0.44	8%

Figure 2.9.The annual stream flow and estimated base flow Report.

Year	Precipitation (inches)	Percentage of Precipitation As streamflow	Change in Groundwater Storage (inches)	Percentage of precipitation as change in groundwater storage	Evapotranspiration and other losses (inches)	Percentage of precipitation as evapotranspiration
19991	41.1	18.6 %	-0.7	2 %	23.2	56 %
1992	43.9	19.4 %	+0.3	1 %	24.3	55 %
Average	42.5	19.0 %	-0.2	<1 %	23.8	56 %

Figure 2.10. The monthly water budgets Report.

(c) The CALIBRATE Command

Press the CALIBRATE button to switch to the Calibration screen.

(d) The CALCULATE Command

Press the CALCULATE button to display the analysis results according with the selected time base.

2.2.2. The Calibration Screen

A. The Calibration Screen Title

The Calibration screen title is "COOKS CREEK STREAM CALIBRATION"

B. The River Bed Profile Chart

The River bed profile chart (Figure 2.11) displays the a graphical reprezentation of the river's bed cross section at the stream gauge location (item 1).

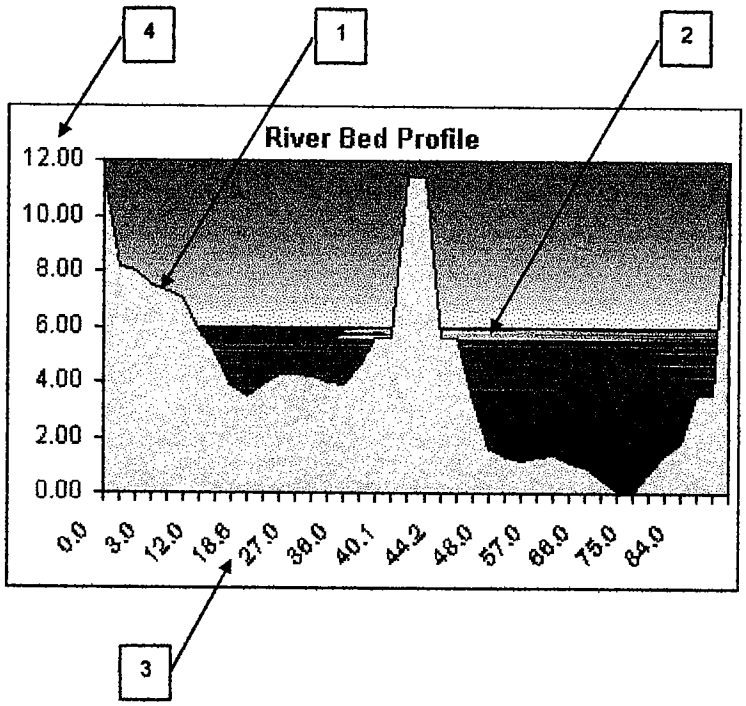


Figure 2.11 River Bed Profile chart.

The cross section is expressed in riverbed levels (item 4) versus distance from a reference point on the riverbank (item 3). The measurement units are feet on both axes.

An arbitrary water level was graphically represented by item 2. This arbitrary water level does not change when input the actual data.

C. The Flow Rating Curve Chart

According with the appliable methodology, the measured stream levels (H) are converted to flow values (Q) using a power correlation function having the following expression:

$$Q = aH^b,$$

where a and b parameters are experimentally determinated.

The Flow rating curve chart (Figure 2.12) displays the experimental measured values (item 1, brown continuous curve) and the correlation power function (item 2, the blue dashed curve) as flow (item 3) in cubic feet per second versus stream level in feet (item 3).

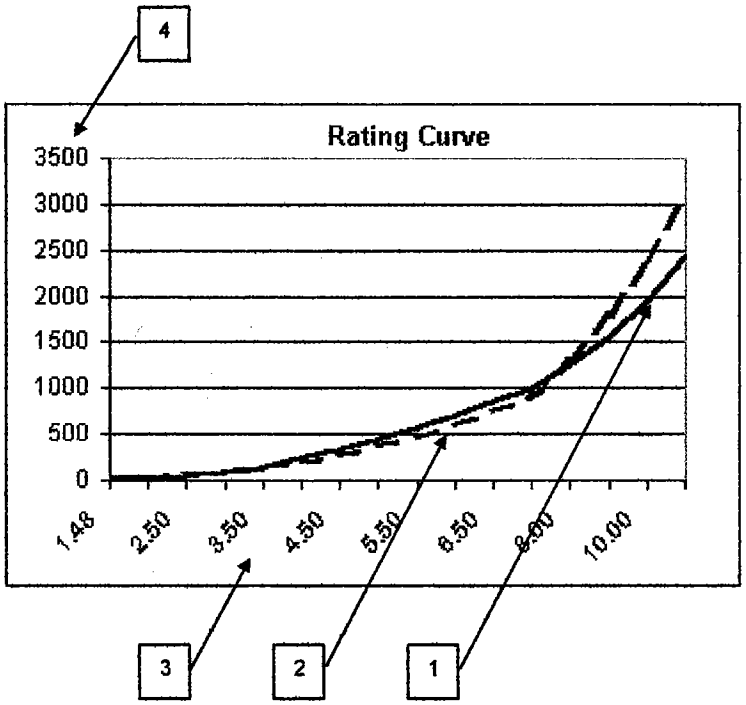


Figure 2.12. The flow-rating curve chart.

D. The General Parameters Table

The General parameters table (Figure 2.13) contains two values:

- Flood cross section area in square feet. The flood cross section area is calculated from the river's bed profile data; and,
- Drainage area in square miles. The drainage area is enetred by the user and is considered in the analysis phase.

General Parameters	
Flood Cross Sect. Area [ft²]	679.63
Drainage Area [mi²]	30

Figure 2.13 The General parameters table.

E. The Correlation Parameters Table

The Correlation parameters table (Figure 2.14) contains the calculated values of the power function parameters that interpolets the experimental measured values.

Corelation Parameters		
$Q = aH^b$	a =	4.6144
	b =	2.7118

Figure 2.14. The Correlation parameters table.

The flow function (Q) is represented together with the experimental measured values on the Flow rating curve chart (Figure 2.12).

F. The River Bed Profile Tables

The River bed profile tables are:

- The river's bed definition table (Figure 2.15); and,
- The rivers's bed characterization table (Figure 2.16).

The creek bed definition table contains a list of mesurement points that define the reiver's bed profile as shown in the creek bed profile chart (Figure 2.11). The user can enter, remove or modify any point from the list.

Each point in the list is a pair of distance from a reference point and the corresponding level on the staff gage, both expressed in feet.

Measurement Point	33
Distance from Ref. Point [ft]	75.00
Level on Staff Gage [ft]	11.42

Figure 2.15. The creek bed definition table.

The second table, river's bed characterization (Figure 2.16) contains the resultants of the above creek bed characterization table, i.e:

- The number of the mesurement points in the above list;
- The river's bed with in feet, i.e. the maximum mesured distance from the origin point in the above list; and,
- The river's flood level in feet, i.e. the highest level on the staff gage that water can ever reach.

Number of Measurement Points	40
River Bed Width [ft]	86.30
Highest Level Value [ft]	11.42

Figure 2.16. Creek bed characterization table.

G. The Rivers Bed Profile Controls

The points defining the creek bed profile, issued by the chart presented in Figure 2.11 and listed in the tabel presented if Figure 2.15, can be entered, modified and erased using the river bed profile controls presented in Figure 2.17.

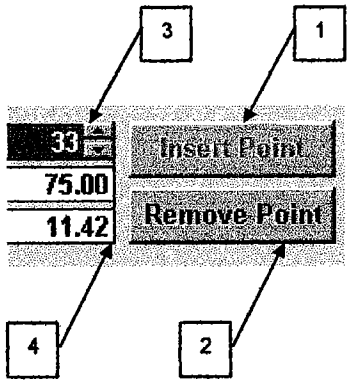


Figure 2.17 The creek bed profile controls.

The spin control (item 3) is used to select a point in the list. The point coordinates, i.e. distance from the refference point and level on the staff gage are displayed in the yellow cells (item 4). Pressing spin button's up and down arrows, the user can scroll the list and select the appropriate point.

Once a point selected, the user can modify either of the point's coordinates, simply overwriting the corresponding value.

Alternately, the user can remove the selected point pressing rhe "Remove Point" button (item 2). To remove the point the user has to press the "Yes" button of the confirmation dialog issued (Figure 2.18). Otherwise (if "No" button is pressed), the operation is canceled.

To insert a new point in the list, the user has to press the "Insert Point" button (item 1) and fill the blank yellow cells (item 4).

Any modification of the points list will be reflected both in the River bed profile chart and River bed profile tables. Eventually, the Flood cross area (in the general parameters table) will be modified too.

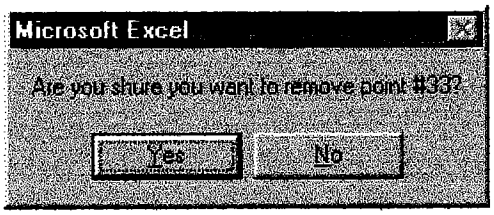


Figure 2.18. The point removal confirmation dialog.

H. Calibration Screen. The Command Buttons

The Calibration screen contains three command buttons, as follows:

- WATER BUDGET – to enter water budget parameters;

- SAMPLE DATA – to enter measured stream levels versus velocity; and,
- ANALYSIS – to switch to the Analysis screen.

(a) The WATER BUDGET Command

Pressing the WATER BUDGER will lunch the dialog window presented in fig.II.19.

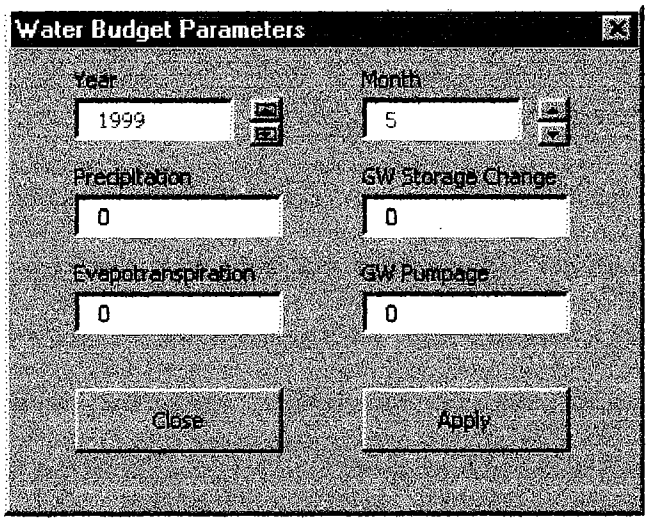


Figure 2.19. Water budget parameters dialog window.

This dialog window allows the user to enter or modify the following measured parameters all expressed in inches:

- Precipitation;
- Ground water storage change;
- Evapotranspiration; and,
- Ground water pumpage.

The parameters are given on monthly time base. The corresponding year and month are selected using the two spin controls.

To set new values for the water budget parameters the user has to press the "Apply" button. The "Close" button will close the window

(b) The SAMPLE DATA Command

Pressing the SAMPLE DATA button will lunch the "Measured Velocity per Cross Section" dialog window (Figure 2.20).

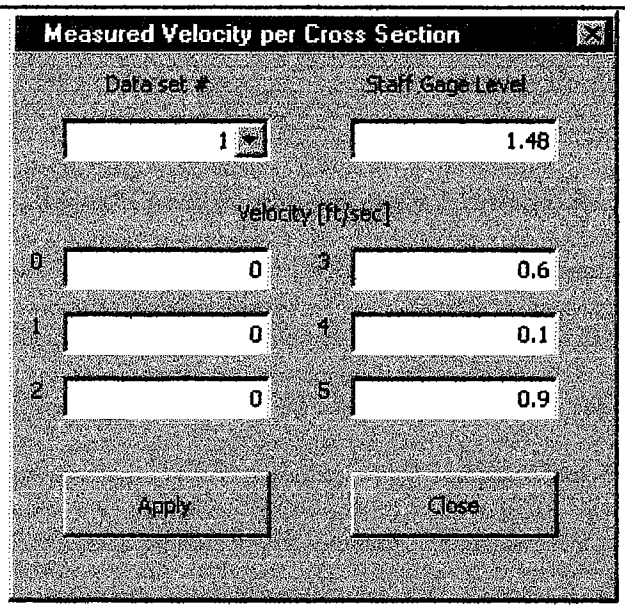


Figure 2.20. Measured velocity per cross section dialog window.

This dialog window allows the user to enter or modify up to 16 sets of water velocities (in feet per second), measured in 6 different points of the river bed profile, together with the stream level (in feet) measured on the staff gage:

- One of the 16 data sets are selected using the "Data set #" drop down list;
- The "Apply" button will set the 6 velocities and staff gage level values; and,
- The "Close" button will close the window.

(c) The ANALYSIS Command

Press the ANALYSIS button to switch to the Analysis screen

2.3. Procedure for Usage of WAMOS

A. Entering New Data

Step 1. Download the data logger data according with the data logger user manual.

NOTE: It is recommended to name the new data file using the pattern "mmddyyyy.dat" (ex. 06051999.dat, corresponding to the download date June 5th, 1999). Also it is recommended to use the same directory for the downloaded files.

Step 2. Press the "NEW DATA" button on the analysis screen of the application. A Windows standard dialog box entitled "Open Data Logger File" will be issued (Figure 2.21). Enter the file name and press the "Open" button. After several seconds required for data reading and processing a confirmation Windows standard message box will be issued (Figure 2.22). Press the "OK" button to complete the procedure.

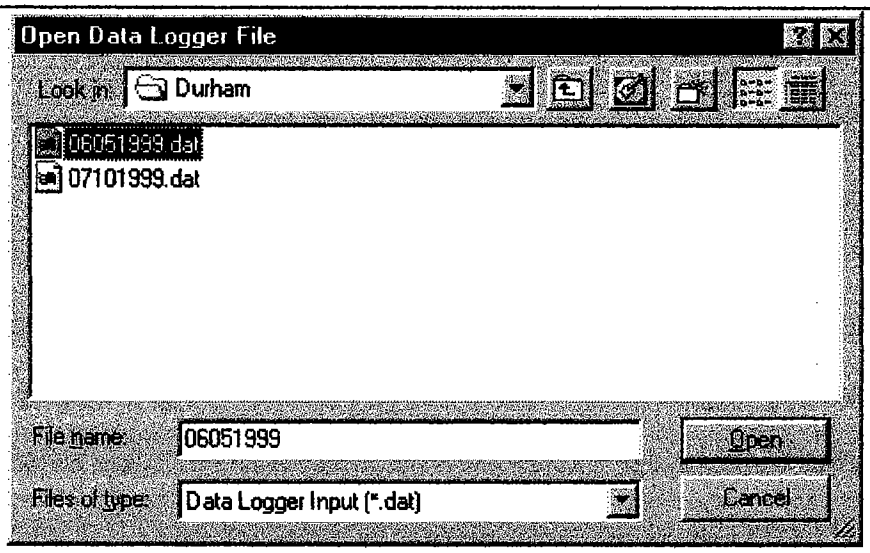


Figure 2.21. "Open Data Logger File" dialog box..

Figure 2.22 Confirmation message box..

B. Display and Calculations

Step 1.Select the time base by clicking the left mous button on the desired option of the Windows standard radio button in the left table (Figure 2.23).

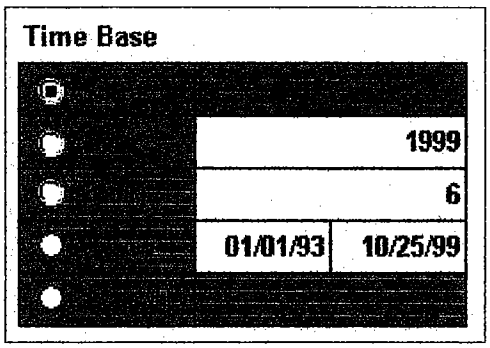


Figure 2.23 Tame base table.

Step 2. If "Annual", "Monthly" or "Between" time bases were selected then the corresponding right values (on the yellow background, see Figure 2.23) will take effect. If the displayed values are not the appropriate ones, then they have to be modified as in standard Excel mode (click the cell, type the new value then press the Enter key).
NOTE: If "Monthly" time base selected then it reffers to the corresponding month of the above year.

Step 3. Press the "CALCULATE" button. The chart, subtitle (issuing the selected time interval) and the results (right) table (Figure 2.24) will be updated according with the selected time base.

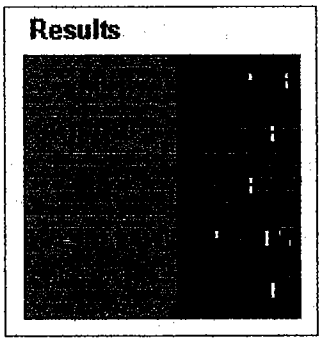


Figure 2.24 Results table.

C. Printing

Step 1. Diplay and calculate the desired data as described above in the Section 2.3.

Step 2. Press the PRINT button.

D. Entering the Creek Drainage Area

Step 1. Enter the creek drainage area in square miles, modifying the yellow backgroun cell as in standard Excel mode (click the cell, type the new value then press the Enter key), in the "General Parameters" table (upper left, see Figure 2.25).

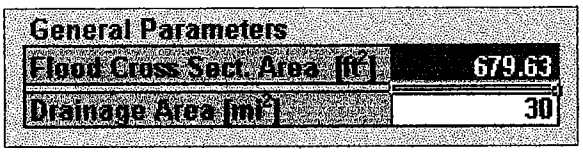


Figure 2.25 General Parameters table.

E. Defining the River's Bed Profile

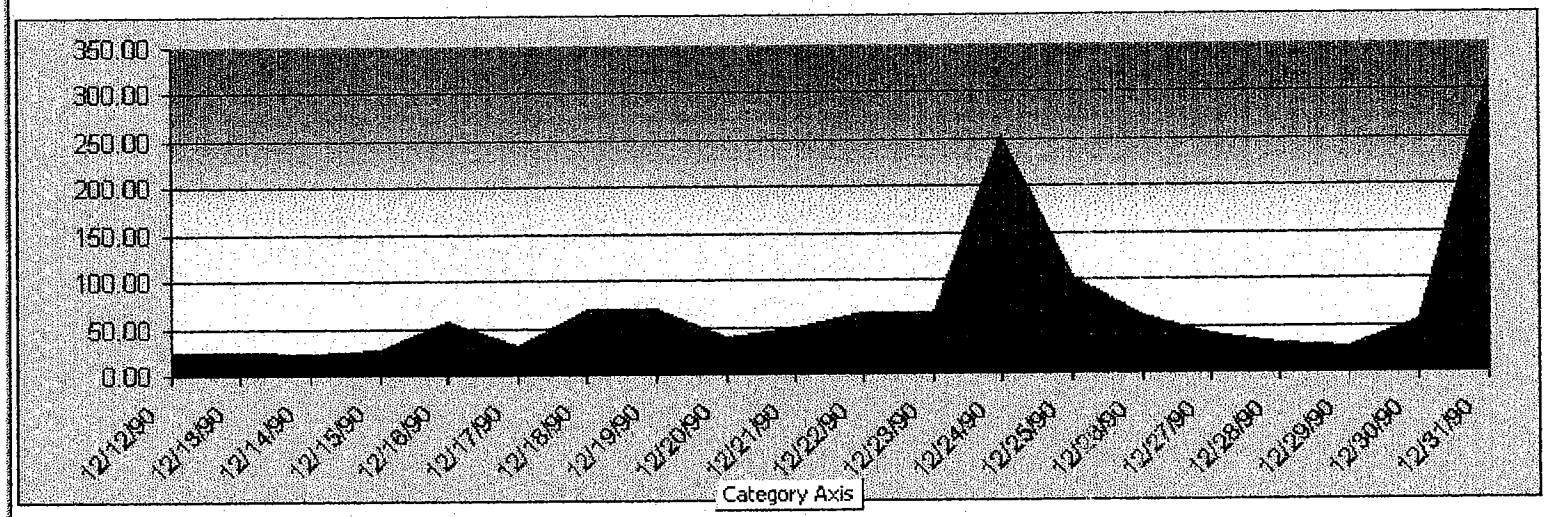
Step 1. Use the Windows standard spin button (see Figure 2.26) to select a measurement point of the creek bed profile (pressing the up-arrow will increase the point number up to the maximum number of points defined, while pressing the down-arrow will decrease the point number down to 0).

Year	Total streamflow (inches)	Base flow (inches)	Percentage of streamflow as base flow	Surface runoff (inches)	Percentage of streamflow as surface runoff
1990	32.33	14.48	45%	17.85	55%
1991	18.19	11.17	61%	7.02	39%
1992	19.01	8.29	44%	10.73	56%
1993	4.55	3.96	87%	0.59	13%
1999	7.19	5.96	83%	1.23	17%
2000	40.89	27.92	68%	12.97	32%

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

12/12/90 - 12/31/90



NEW DATA

PRINT

Time Base

Month	
Year	1990
Month	1
Between	01/01/00 03/31/00
Last days	

Results

MIN	[illegible]
AVERAGE	1 [illegible]
MAX	2 1
MAX FLOW	2
DISTANCE	1 1

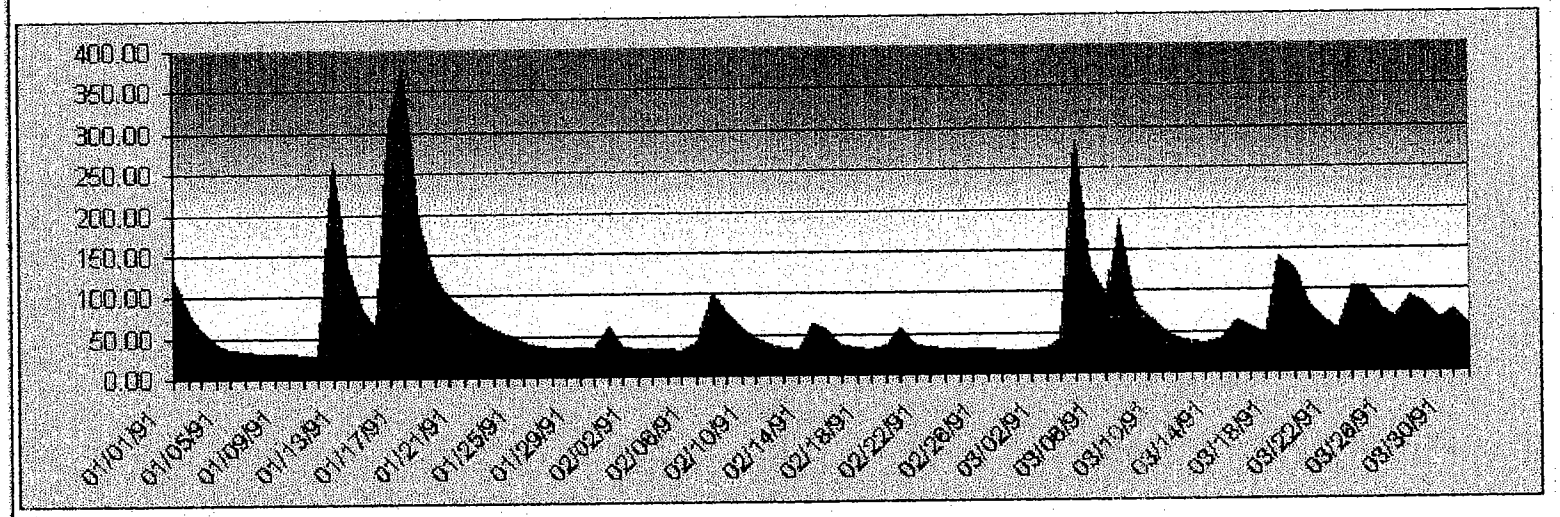
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

1/1/91 - 3/31/91



NEW DATA

PRINT

Time Base

Year	1990
Month	1
Day	01/01/91 03/31/91

Results

MIN	0
AVERAGE	3
MAX	1
BASEFLOW	3
RUNOFF	3
RUNOFF	3

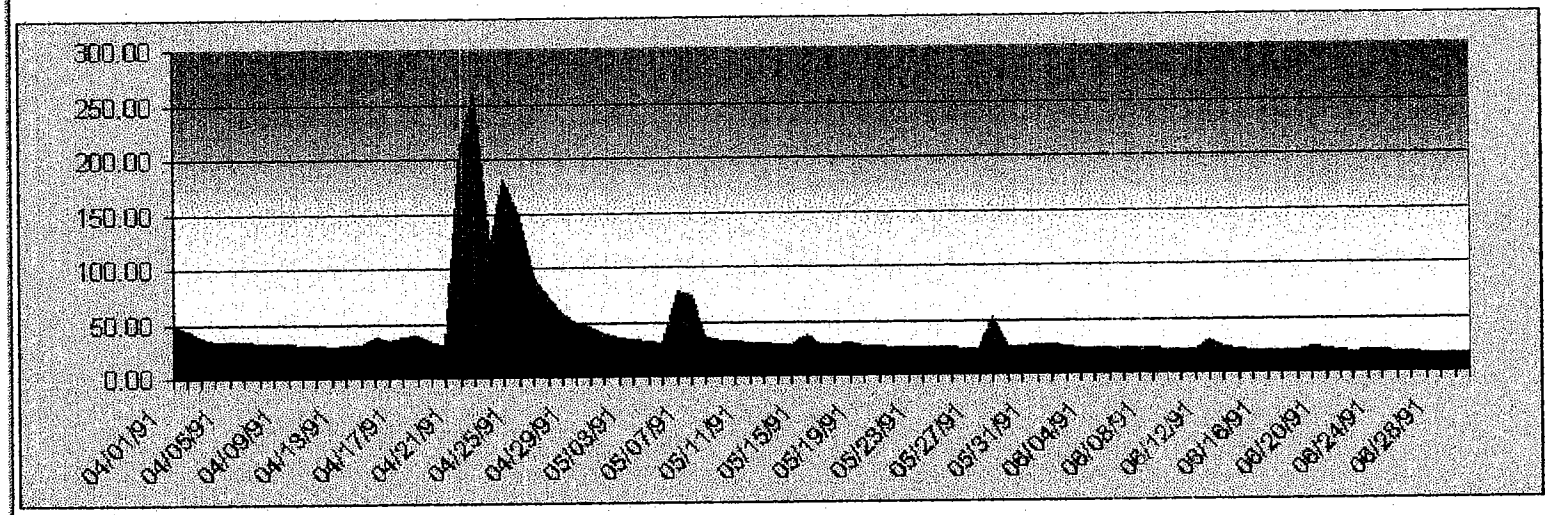
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

4/1/91 - 6/30/91



NEW DATA

PRINT

Time Base

1990	
1	
04/01/91	06/30/91

Results

MIN

AVERAGE

MAX

BASE FLOW

RUNOFF

RATIO

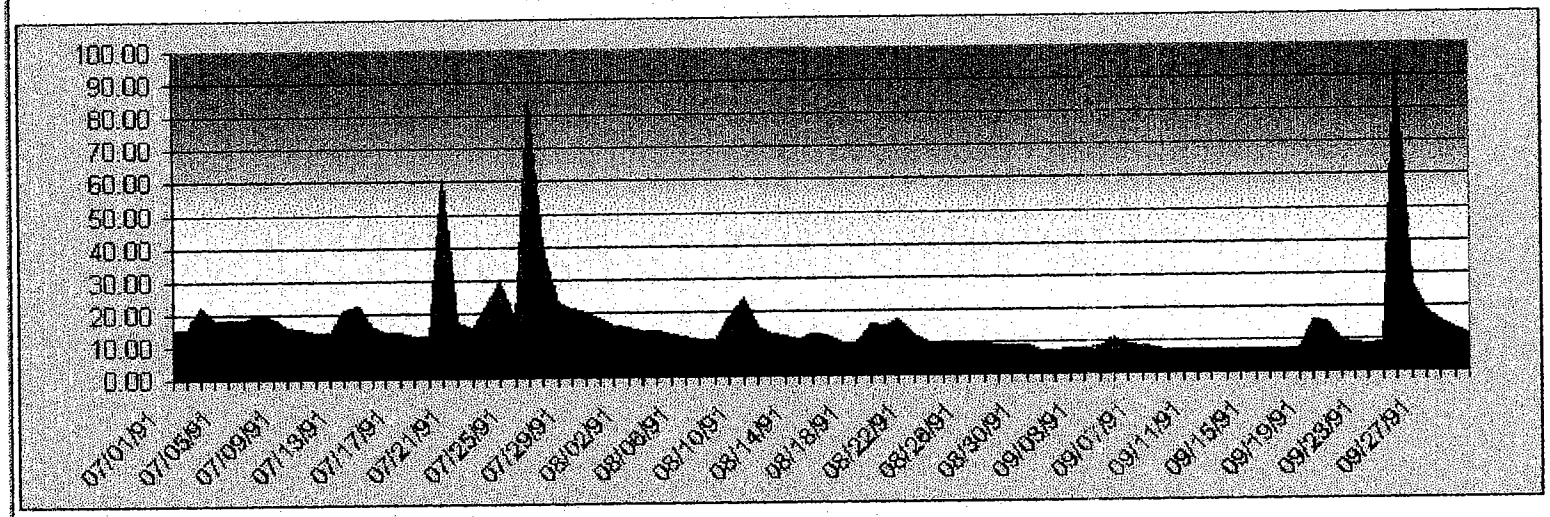
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

7/1/91 - 9/30/91



NEW DATA

PRINT

Time Base

1990	
1	
07/01/91	09/30/91

Results

MIN	7.1
AVERAGE	5.1
MAX	5.1
DAYS EXCEEDED	0
DATE	1.1

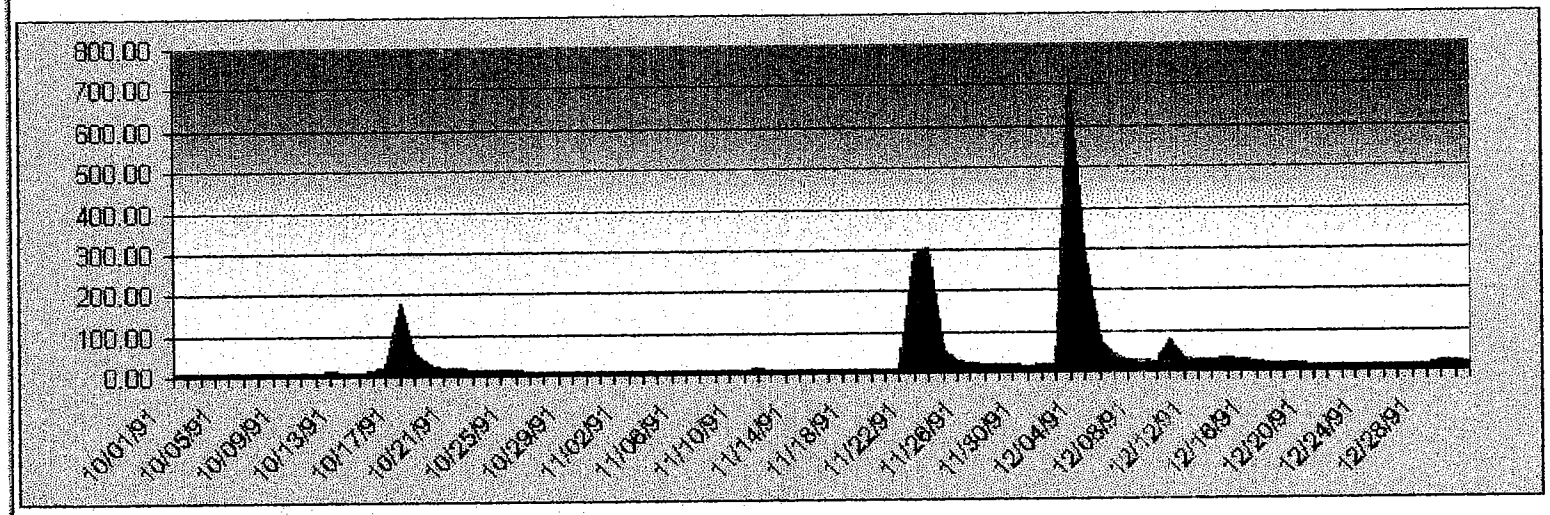
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

10/1/91 - 12/31/91



NEW DATA

PRINT

Time Base

1990	
1	
10/01/91	12/31/91

Results

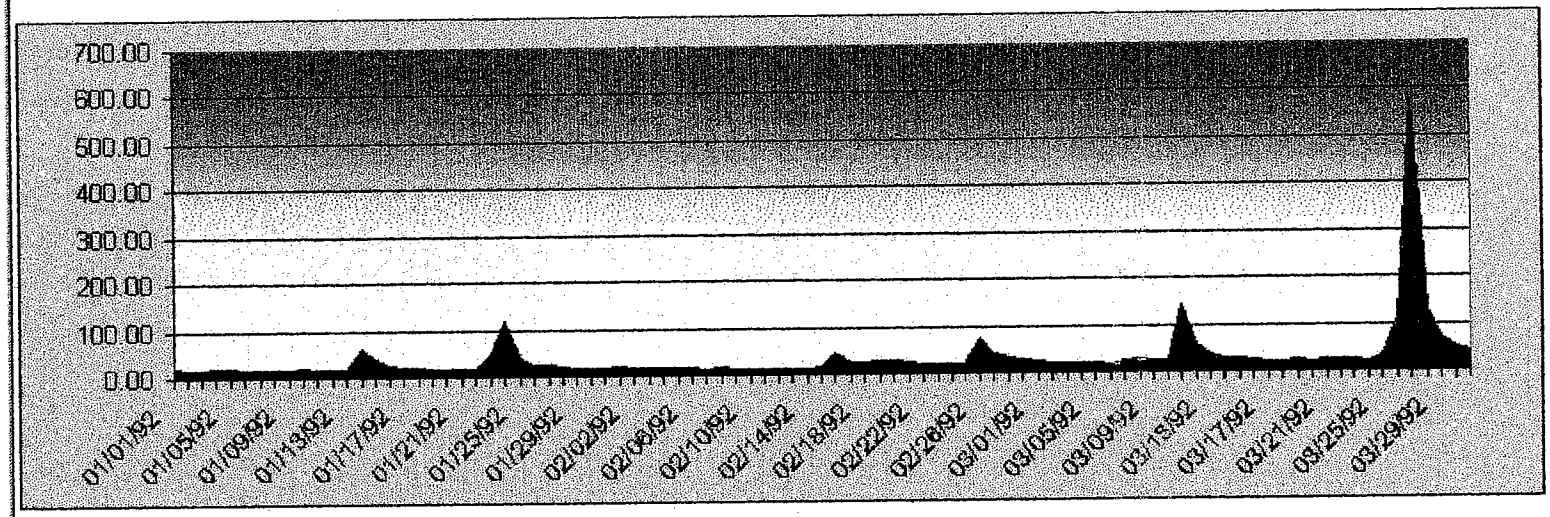
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

1/1/92 - 3/31/92



NEW DATA

PRINT

Time Base

1990	
1	
01/01/92	03/31/92

Results

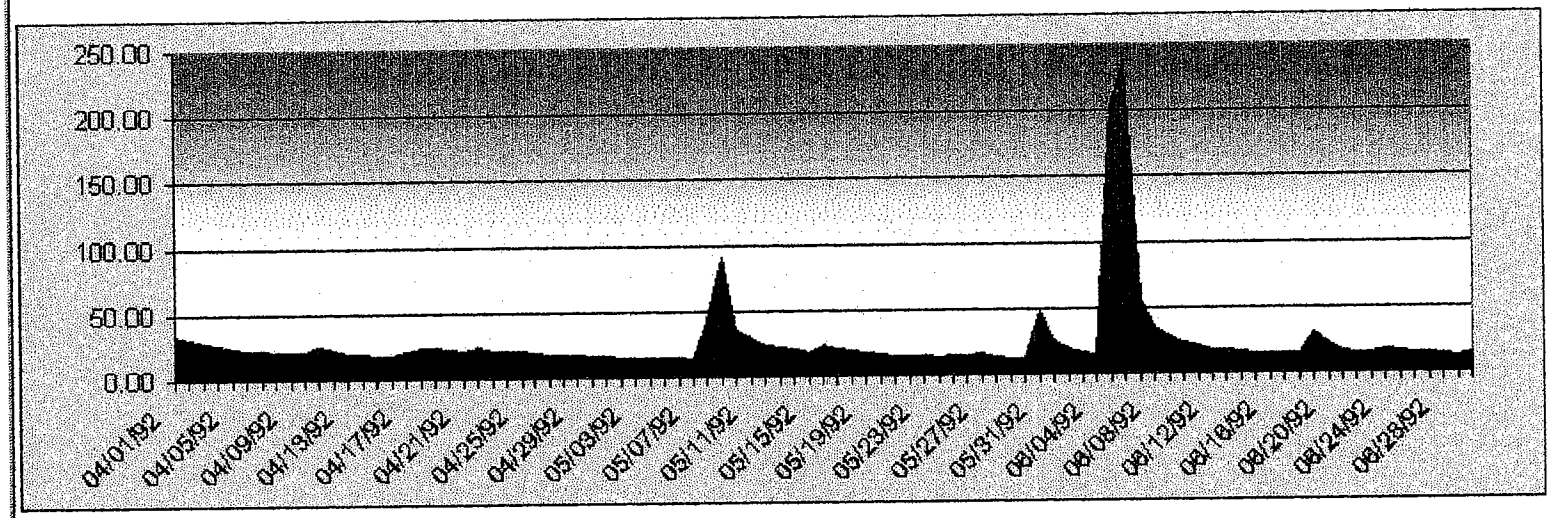
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

4/1/92 - 6/30/92



NEW DATA

PRINT

Time Base

All data		
Annual	1990	
Monthly	1	
Between	04/01/92	06/30/92
Last downloaded		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DIS. RATIO	
0.25-0.75	

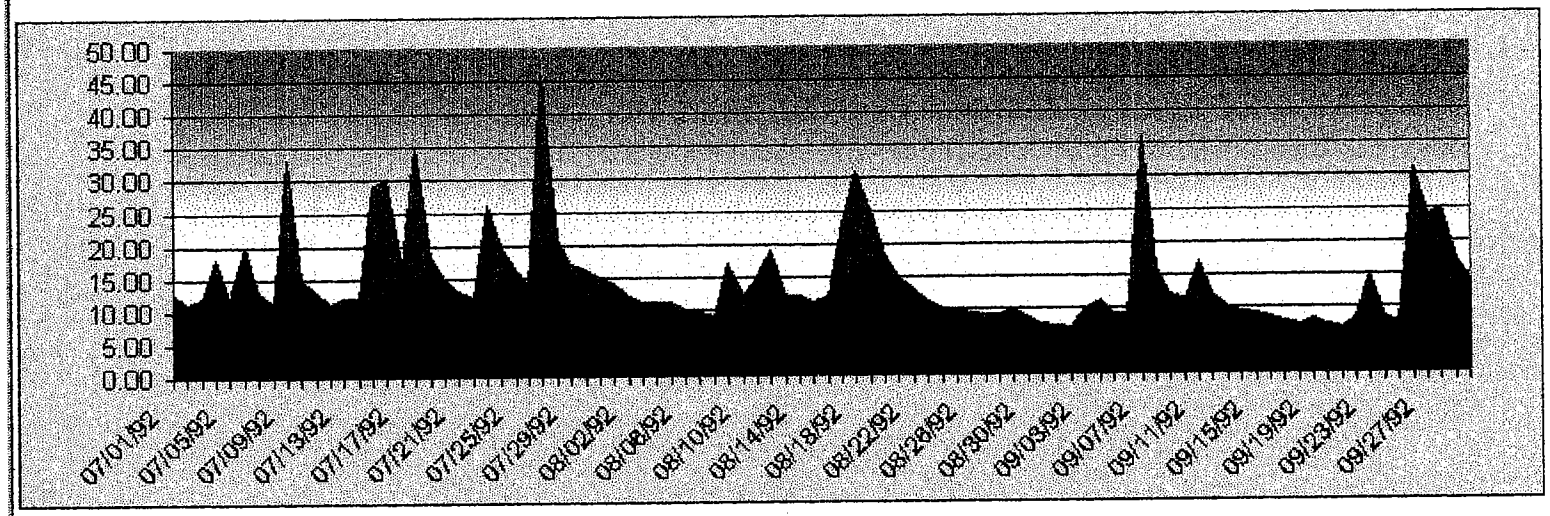
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

7/1/92 - 9/30/92



NEW DATA

PRINT

Time Base

All data		
Drive	1990	
Month	1	
Between	07/01/92	09/30/92
Last drive		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DIS RATIO	
02/07/5	

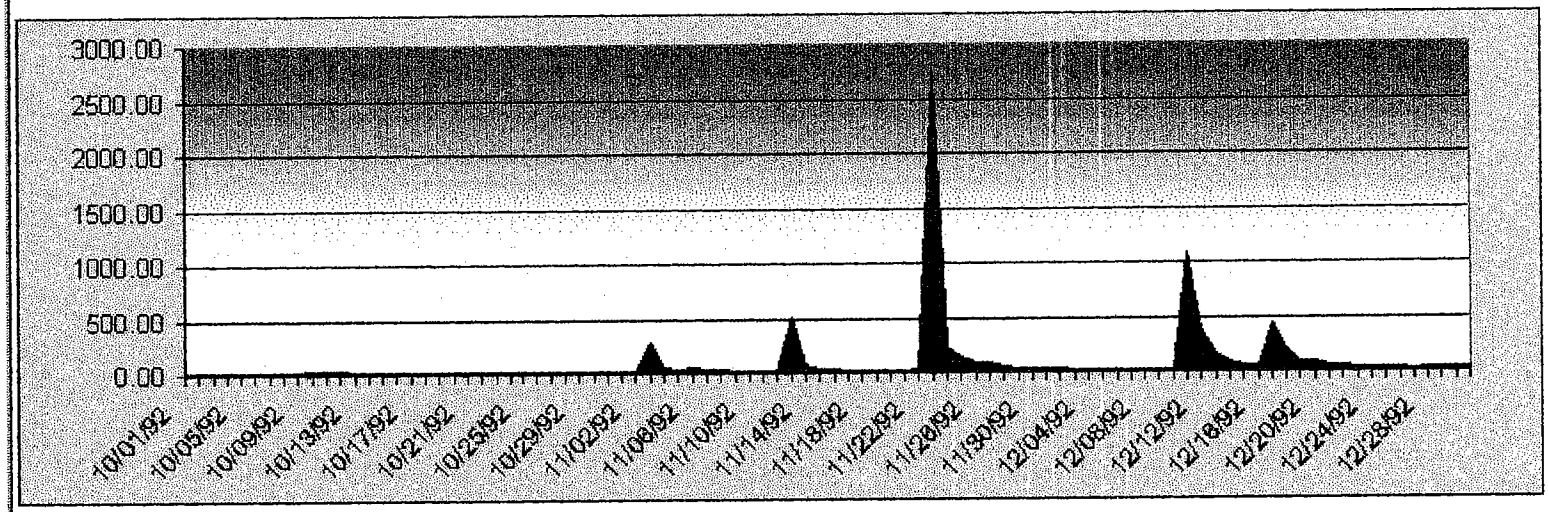
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

10/1/92 - 12/31/92



NEW DATA

PRINT

Time Base

All data		
Annual	1990	
Monthly	1	
Between	10/01/92	12/31/92
Last download		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DIS. RATIO	
0.25 DIS	

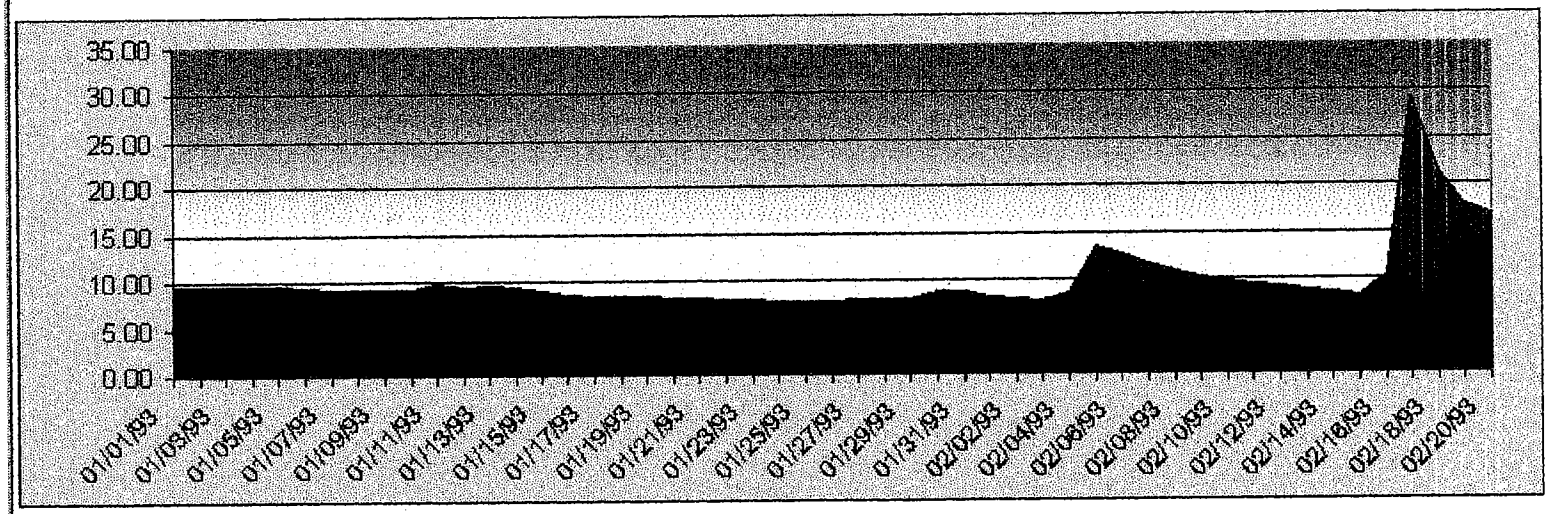
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

1/1/93 - 2/20/93



NEW DATA

PRINT

Time Base

All data		
Annual	1993	
Monthly	1	
Between	10/01/92	12/31/92
Last days		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DIS. RATIO	

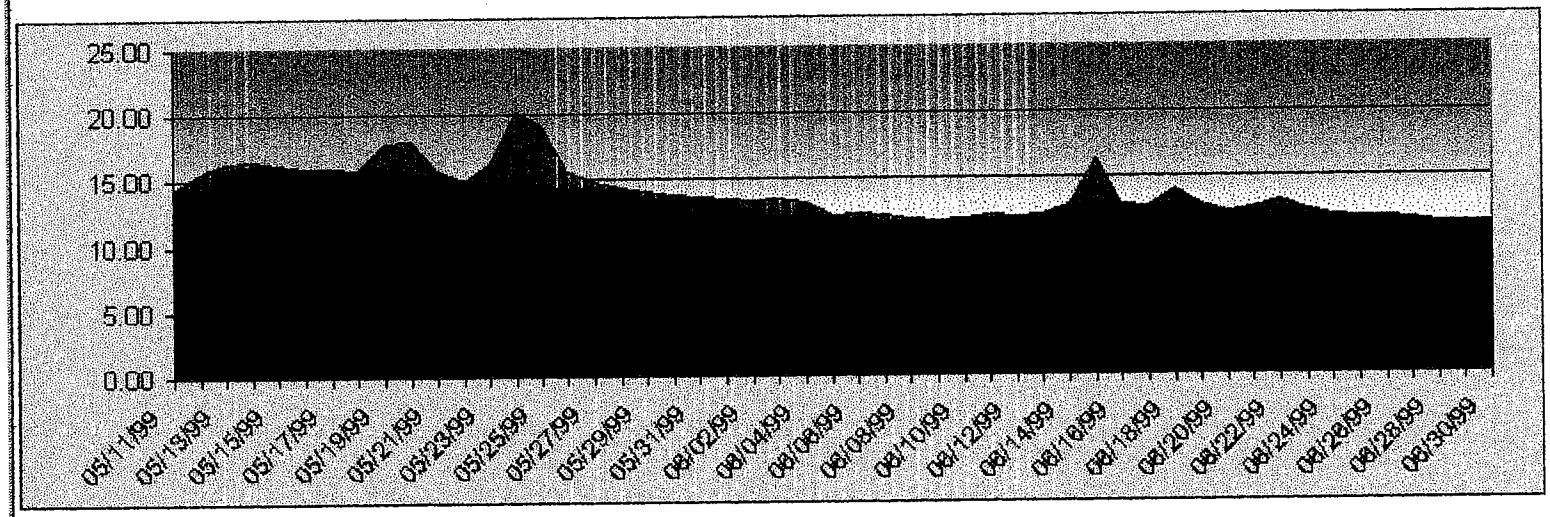
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

5/11/99 - 6/30/99



NEW DATA

PRINT

Time Base

All data		
Annual	1993	
Monthly	1	
Between	04/01/99	06/30/99
Last download		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
BIG RATIO	
@25/0/6	

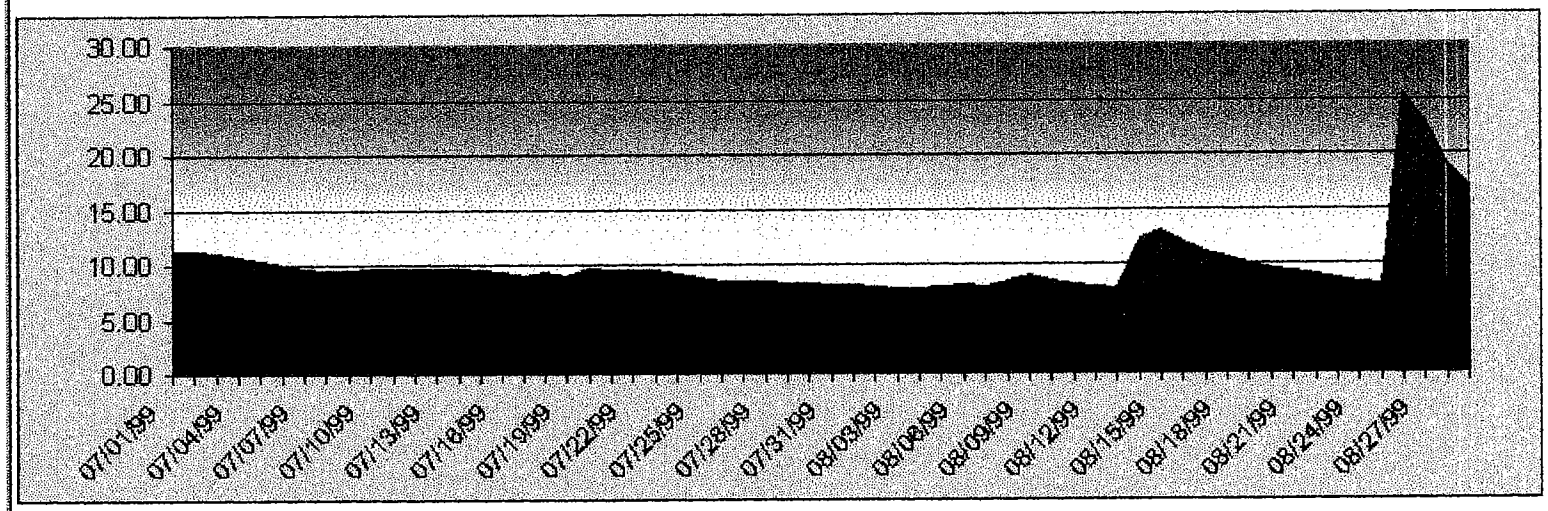
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

7/1/99 - 8/29/99



NEW DATA

PRINT

Time Base

All data		
Annual	1993	
Monthly	1	
Between	07/01/99	09/30/99
Last month		

Results

MIN	
AVERAGE	
MAX	
BASELOAD	
DISTRIB	
STDDEV	

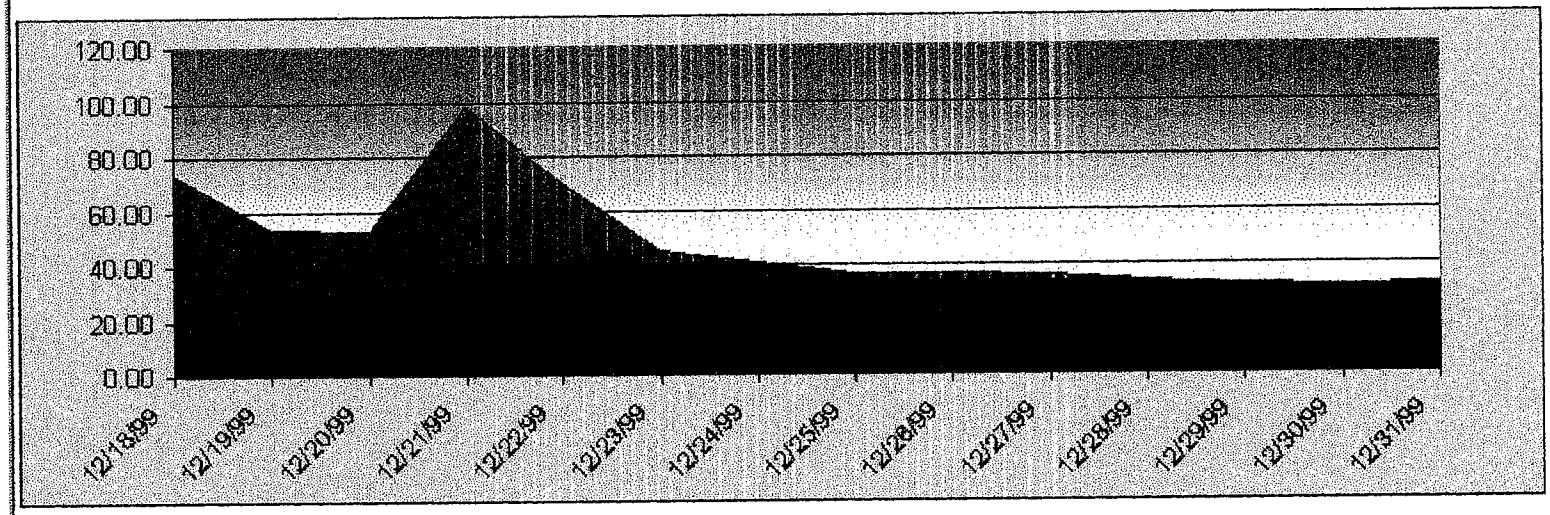
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

12/18/99 - 12/31/99



NEW DATA

PRINT

Time Base

Minutes		
Annual	1993	
Monthly	1	
Between	10/01/99	12/31/99
Last Decade		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DB RATIO	
6250/5	

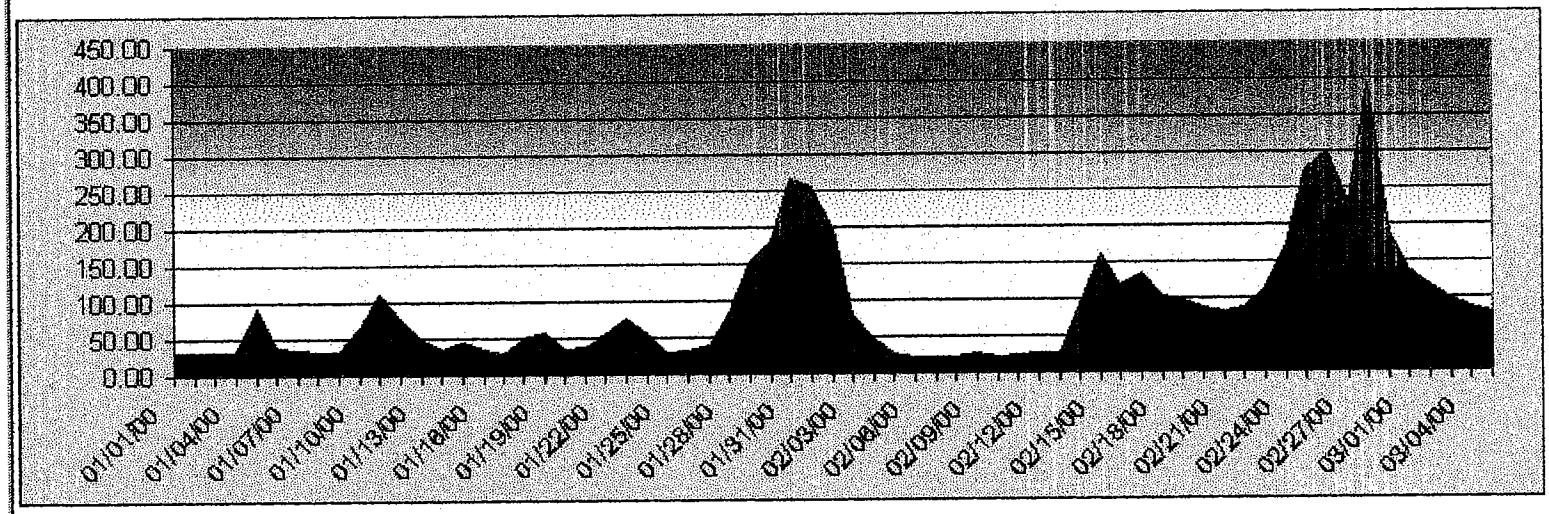
CALIBRATE

CALCULATE

File Edit View Insert Format Tools Data Window Help

COOKS CREEK STREAM ANALYSIS

1/1/00 - 3/5/00



NEW DATA

PRINT

Time Base

All data		
Annual	1993	
Monthly	1	
Between	01/01/00	03/31/00
Last days		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DR. RATIO	
DAYS	

CALIBRATE

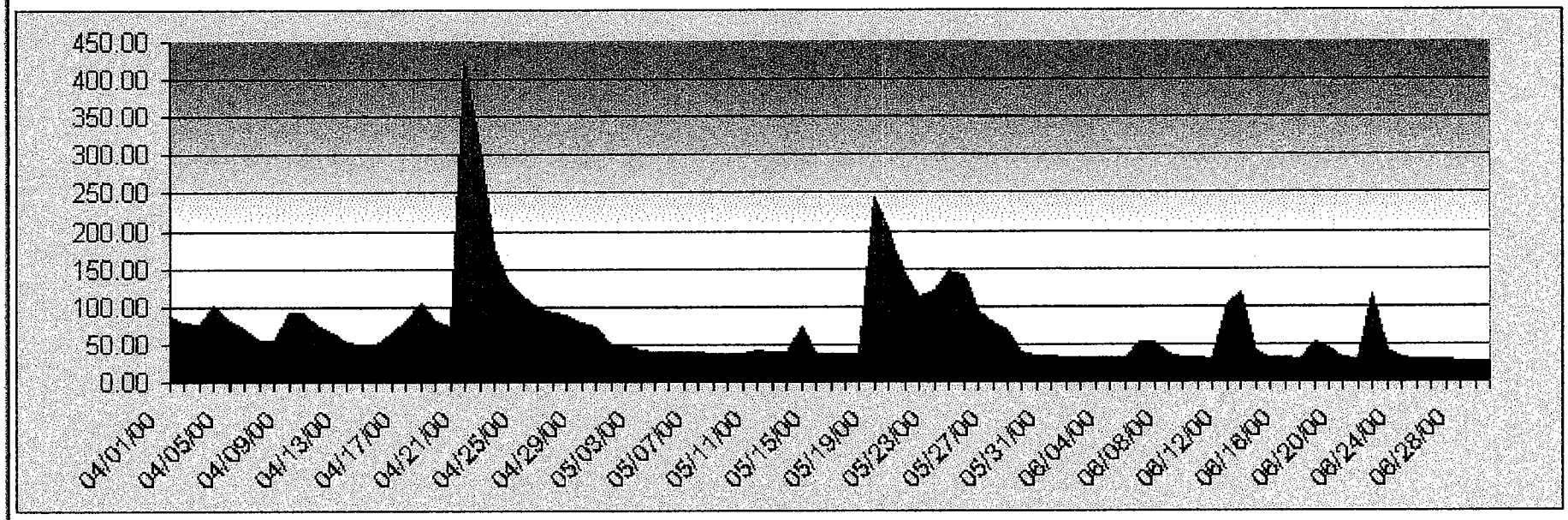
CALCULATE

File Edit View Insert Format Tools Data Window Help Send

Favorites Go C:\Projects\00-0023-DurhamRivers\Wamos\WAMOS 2.1R-F-06300

COOKS CREEK STREAM ANALYSIS

4/1/00 - 6/30/00



NEW DATA

PRINT

Time Base

All data		
Annual	2000	
Monthly	9	
Between	04/01/00	06/30/00
Last downlo		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DIS. RATIO Q25/Q75	

CALIBRATE

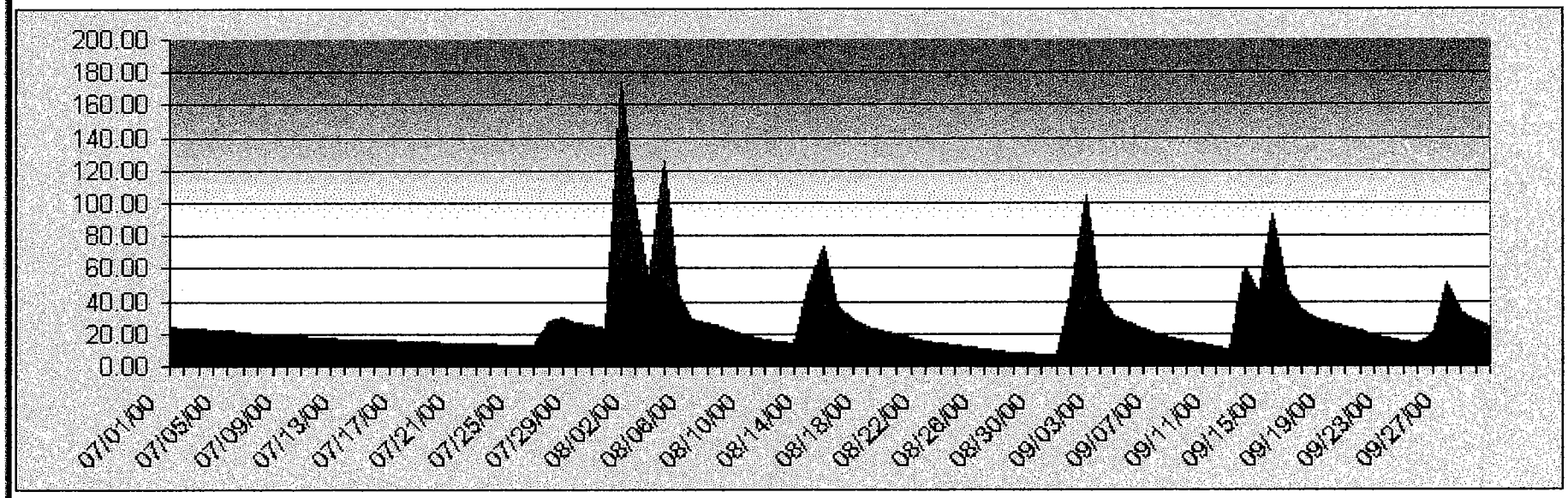
CALCULATE

File Edit View Insert Format Tools Data Window Help Send

Favorites Go C:\Projects\00-0023-DurhamRivers\Wamos\WAMOS 2.1R-F-06300

COOKS CREEK STREAM ANALYSIS

7/1/00 - 9/30/00



NEW DATA

PRINT

Time Base

All data		
Annual	2000	
Monthly	9	
Between	07/01/00	09/30/00
Last downloa		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DIS. RATIO Q25/Q75	

CALIBRATE

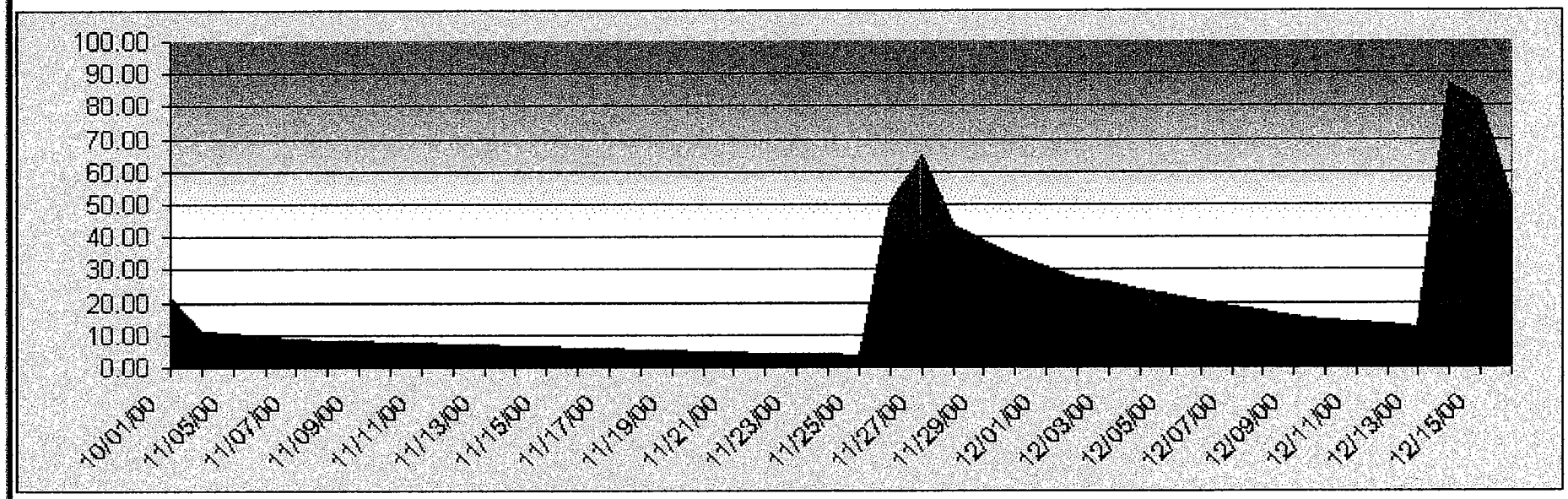
CALCULATE

File Edit View Insert Format Tools Data Window Help Send

Favorites Go C:\Projects\00-0023-DurhamRivers\Wamos\WAMOS 2.1R-F-06300

COOKS CREEK STREAM ANALYSIS

10/1/00 - 12/16/00



NEW DATA

PRINT

Time Base

All data		
Annual	2000	
Monthly	9	
Between	10/01/00	12/16/00
Last downlo		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DIS. RATIO Q25/Q75	

Category Axis

CALIBRATE

CALCULATE

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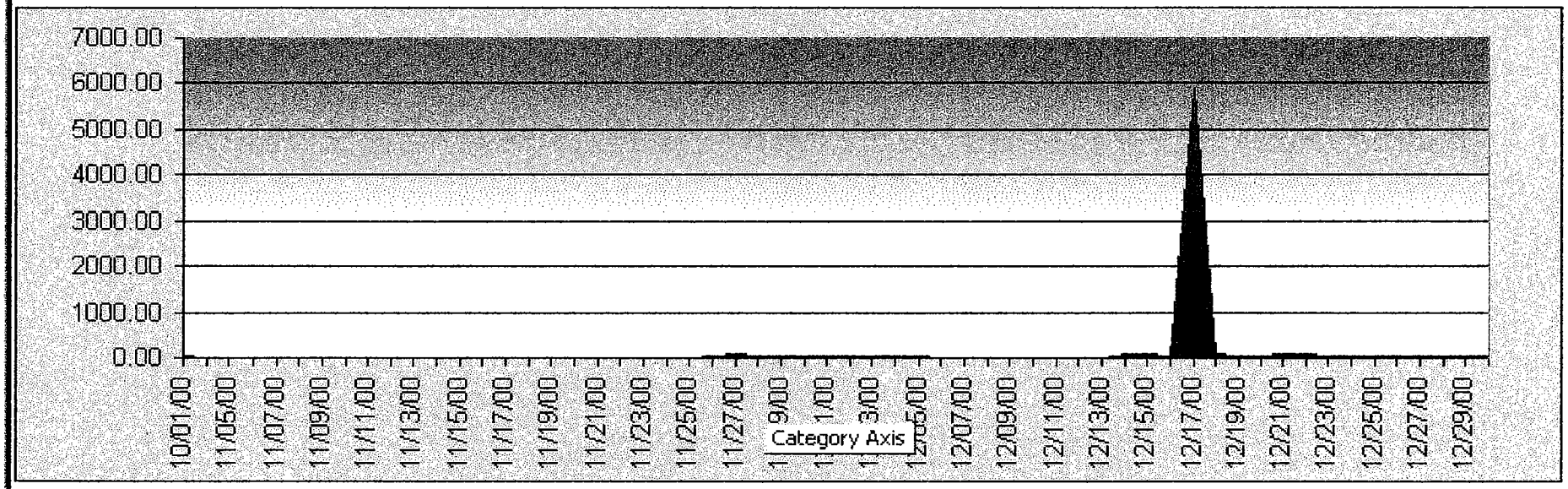
Favorites Go C:\Projects\00-0023-DurhamRivers\Wamos\WAMOS 2.1R-F-06300

COOKS CREEK STREAM ANALYSIS

10/1/00 - 12/30/00



NEW DATA

PRINT

Time Base

All data		
Annual	2000	
Monthly	9	
Between	10/01/00	12/30/00
Last downlo		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DIS. RATIO 025/075	

CALIBRATE

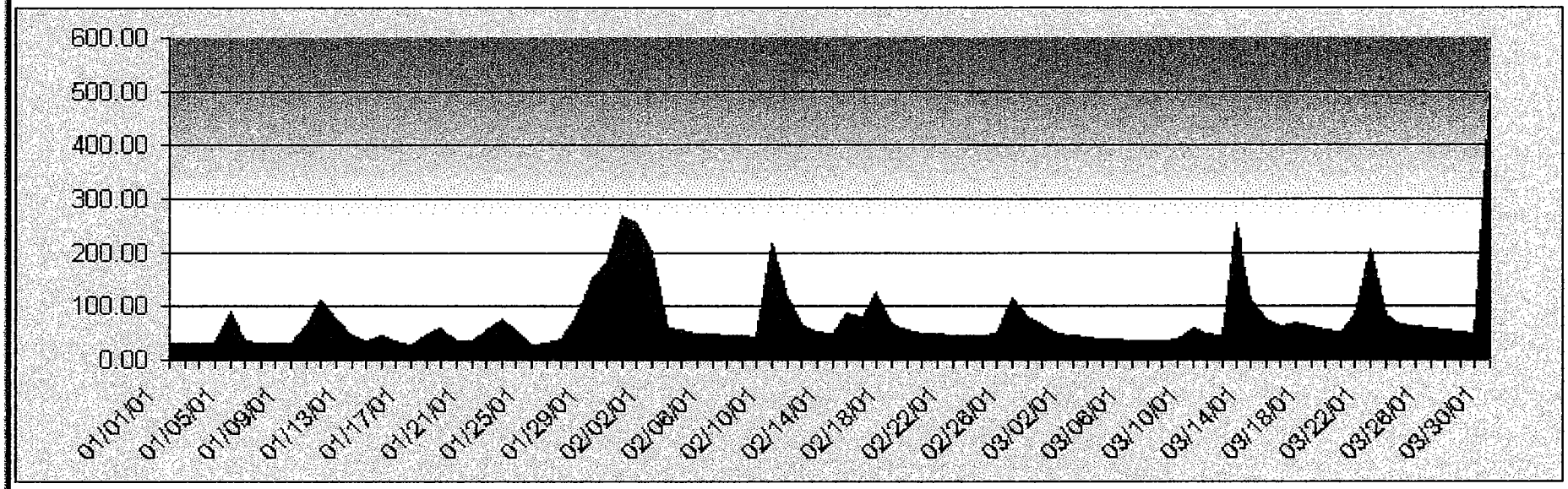
CALCULATE

File Edit View Insert Format Tools Data Window Help Send

Favorites Go C:\Projects\00-0023-DurhamRivers\Wamos\WAMOS 2.1R-F-06300

COOKS CREEK STREAM ANALYSIS

1/1/01 - 3/30/01



NEW DATA

PRINT

Time Base

All data		
Annual	2000	
Monthly	9	
Between	01/01/01	03/30/01
Last downloa		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DIS. RATIO Q25/Q75	

CALIBRATE

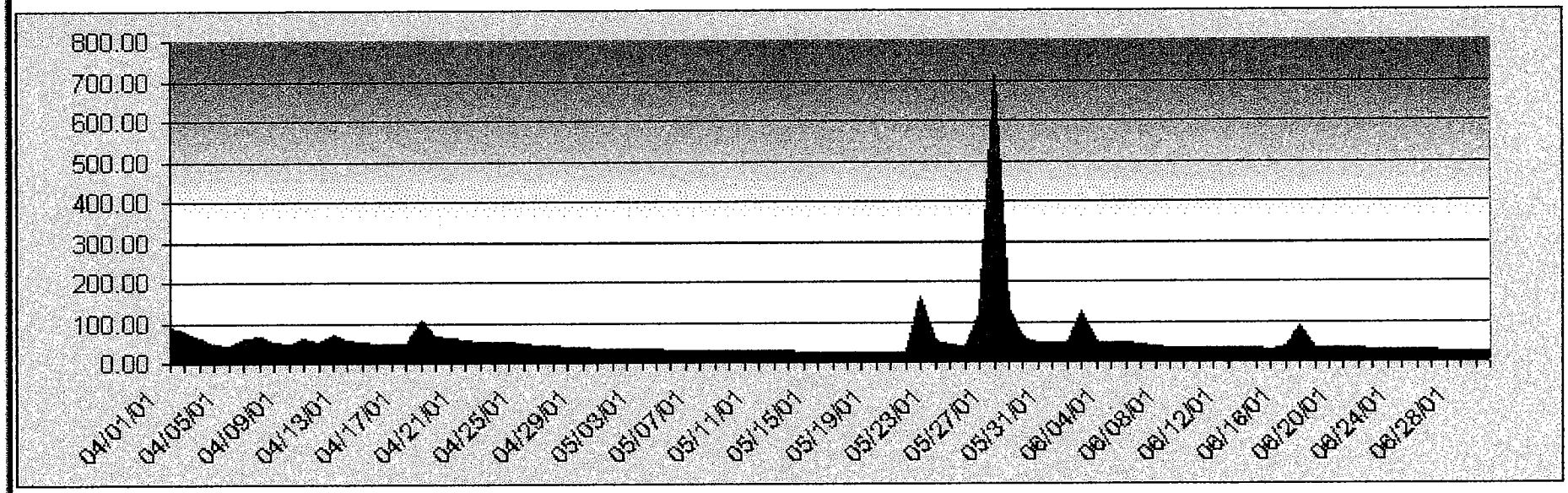
CALCULATE

File Edit View Insert Format Tools Data Window Help Send

Favorites Go C:\Projects\00-0023-DurhamRivers\Wamos\WAMOS 2.1R-F-06300

COOKS CREEK STREAM ANALYSIS

4/1/01 - 6/30/01



NEW DATA

PRINT

Time Base

All data		
Annual	2000	
Monthly	9	
Between	04/01/01	06/30/01
Last downlo		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DIS. RATIO 0.25/0.75	

CALIBRATE

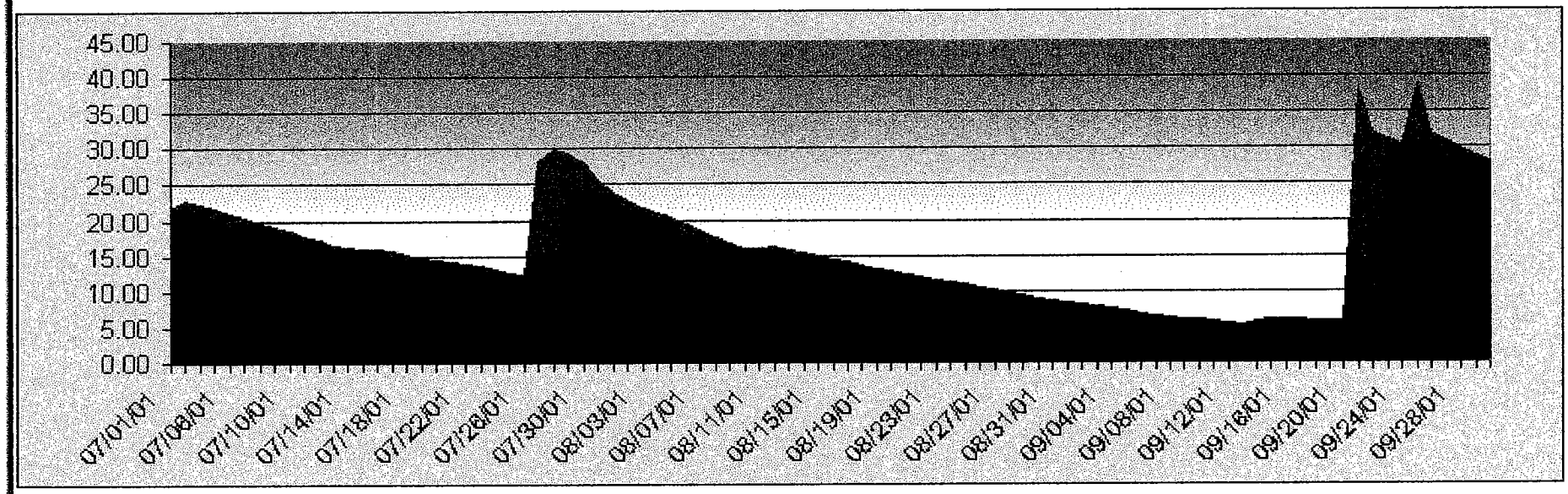
CALCULATE

File Edit View Insert Format Tools Data Window Help Send

Favorites Go C:\Projects\00-0023-DurhamRivers\Wamos\WAMOS 2.1R-F-06300

COOKS CREEK STREAM ANALYSIS

7/1/01 - 9/30/01



NEW DATA

PRINT

Time Base

All data		
Annual	2000	
Monthly	9	
Between	07/01/01	09/30/01
Last download		

Results

MIN	
AVERAGE	
MAX	
BASEFLOW	
DIS. RATIO Q25/Q75	

CALIBRATE

CALCULATE

Date	Flow
12/12/90	25
12/13/90	25
12/14/90	23
12/15/90	27
12/16/90	58
12/17/90	31
12/18/90	69
12/19/90	69
12/20/90	38
12/21/90	49
12/22/90	66
12/23/90	65
12/24/90	254
12/25/90	103
12/26/90	61
12/27/90	41
12/28/90	31
12/29/90	27
12/30/90	55
12/31/90	312
01/01/91	125
01/02/91	83
01/03/91	60
01/04/91	43
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01/06/91	33
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01/08/91	30
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01/11/91	29
01/12/91	265
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01/14/91	82
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01/20/91	99
01/21/91	82
01/22/91	69
01/23/91	59
01/24/91	51
01/25/91	42
01/26/91	38
01/27/91	35

Date	Flow
01/28/91	36
01/29/91	34
01/30/91	36
01/31/91	60
02/01/91	35
02/02/91	33
02/03/91	32
02/04/91	32
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02/23/91	31
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03/10/91	54
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03/12/91	37
03/13/91	35
03/14/91	40
03/15/91	62

Date	Flow
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03/17/91	44
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03/19/91	125
03/20/91	81
03/21/91	62
03/22/91	52
03/23/91	102
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04/27/91	72
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09/16/91	7.2
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Date	Flow
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12/17/90	31
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12/23/90	65
12/24/90	254
12/25/90	103
12/26/90	61
12/27/90	41
12/28/90	31
12/29/90	27
12/30/90	55
12/31/90	312
01/01/91	125
01/02/91	83
01/03/91	60
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01/22/91	69
01/23/91	59
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01/25/91	42
01/26/91	38
01/27/91	35

Date	Flow
01/28/91	36
01/29/91	34
01/30/91	36
01/31/91	60
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Date	Flow
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09/22/91	8.5

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01/26/00	32.580
01/27/00	38.825
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02/05/00	25.806
02/06/00	21.840
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02/17/00	134.886
02/18/00	102.505
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07/28/00	29.76
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08/24/00	12.73
08/25/00	11.64
08/26/00	10.59
08/27/00	9.55
08/28/00	8.66
08/29/00	8.03
08/30/00	7.30
08/31/00	6.75
09/01/00	44.39
09/02/00	104.48
09/03/00	42.61
09/04/00	31.37
09/05/00	27.00
09/06/00	23.29
09/07/00	20.10
09/08/00	17.55
09/09/00	14.99
09/10/00	13.72
09/11/00	12.15
09/12/00	10.79
09/13/00	60.54
09/14/00	43.76
09/15/00	92.95
09/16/00	46.84
09/17/00	34.58
09/18/00	29.33
09/19/00	26.26
09/20/00	23.93
09/21/00	21.59
09/22/00	19.13
09/23/00	17.01
09/24/00	15.51
09/25/00	14.11
09/26/00	20.13

09/27/00	50.69
09/28/00	33.40
09/29/00	27.60
09/30/00	23.94
10/01/00	21.64
11/04/00	10.81
11/05/00	10.22
11/06/00	9.50
11/07/00	8.89
11/08/00	8.36
11/09/00	7.97
11/10/00	7.80
11/11/00	7.70
11/12/00	7.23
11/13/00	6.82
11/14/00	6.48
11/15/00	6.22
11/16/00	5.92
11/17/00	5.63
11/18/00	5.30
11/19/00	5.03
11/20/00	4.79
11/21/00	4.55
11/22/00	4.33
11/23/00	4.10
11/24/00	3.90
11/25/00	3.74
11/26/00	50.46
11/27/00	64.95
11/28/00	43.77
11/29/00	38.85
11/30/00	34.23
12/01/00	30.63
12/02/00	27.51
12/03/00	26.11
12/04/00	23.92
12/05/00	22.07
12/06/00	20.38
12/07/00	18.77
12/08/00	17.37
12/09/00	15.98
12/10/00	14.79
12/11/00	13.97
12/12/00	13.19
12/13/00	12.12
12/14/00	87.47
12/15/00	81.64
12/16/00	51.98

12/17/00	5900.25
12/18/00	73.73
12/19/00	53.58
12/20/00	52.50
12/21/00	98.34
12/22/00	70.50
12/23/00	44.90
12/24/00	40.49
12/25/00	36.59
12/26/00	36.37
12/27/00	35.81
12/28/00	33.54
12/29/00	32.41
12/30/00	31.50
12/31/00	32.38
01/01/01	31.50
01/02/01	31.25
01/03/01	32.25
01/04/01	32.16
01/05/01	90.91
01/06/01	36.27
01/07/01	33.12
01/08/01	32.36
01/09/01	31.86
01/10/01	65.90
01/11/01	110.58
01/12/01	75.62
01/13/01	46.55
01/14/01	33.67
01/15/01	43.74
01/16/01	33.63
01/17/01	28.94
01/18/01	49.17
01/19/01	57.64
01/20/01	34.56
01/21/01	35.62
01/22/01	54.38
01/23/01	77.08
01/24/01	56.15
01/25/01	29.27
01/26/01	32.58
01/27/01	38.82
01/28/01	82.25
01/29/01	153.73
01/30/01	181.11
01/31/01	267.00
02/01/01	254.88
02/02/01	197.25

02/03/01	61.03
02/04/01	54.13
02/05/01	49.03
02/06/01	47.29
02/07/01	45.85
02/08/01	44.06
02/09/01	42.83
02/10/01	217.90
02/11/01	116.13
02/12/01	64.81
02/13/01	53.58
02/14/01	49.10
02/15/01	86.26
02/16/01	81.82
02/17/01	125.72
02/18/01	67.66
02/19/01	55.22
02/20/01	50.34
02/21/01	47.79
02/22/01	46.24
02/23/01	45.35
02/24/01	44.11
02/25/01	47.63
02/26/01	116.69
02/27/01	81.00
02/28/01	65.41
03/01/01	49.58
03/02/01	44.53
03/03/01	41.96
03/04/01	39.95
03/05/01	38.20
03/06/01	36.33
03/07/01	34.70
03/08/01	34.51
03/09/01	37.96
03/10/01	60.25
03/11/01	47.67
03/12/01	44.30
03/13/01	255.33
03/14/01	113.29
03/15/01	75.99
03/16/01	64.18
03/17/01	68.81
03/18/01	62.72
03/19/01	56.20
03/20/01	52.44
03/21/01	84.89
03/22/01	206.00

03/23/01	84.78
03/24/01	67.24
03/25/01	61.50
03/26/01	57.59
03/27/01	54.21
03/28/01	51.51
03/29/01	49.23
03/30/01	495.41
03/31/01	164.49
04/01/01	90.41
04/02/01	77.07
04/03/01	60.62
04/04/01	47.67
04/05/01	43.82
04/06/01	59.22
04/07/01	62.96
04/08/01	50.68
04/09/01	46.98
04/10/01	62.04
04/11/01	52.19
04/12/01	70.97
04/13/01	57.55
04/14/01	50.24
04/15/01	47.13
04/16/01	47.74
04/17/01	47.68
04/18/01	106.25
04/19/01	65.22
04/20/01	59.72
04/21/01	56.11
04/22/01	53.20
04/23/01	51.01
04/24/01	49.28
04/25/01	47.15
04/26/01	43.74
04/27/01	40.27
04/28/01	38.45
04/29/01	35.92
04/30/01	33.88
05/01/01	32.19
05/02/01	31.42
05/03/01	30.74
05/04/01	30.25
05/05/01	29.66
05/06/01	28.84
05/07/01	28.25
05/08/01	27.78
05/09/01	27.37

05/10/01	27.02
05/11/01	26.62
05/12/01	26.23
05/13/01	25.78
05/14/01	25.29
05/15/01	24.94
05/16/01	24.51
05/17/01	24.10
05/18/01	23.76
05/19/01	23.55
05/20/01	23.09
05/21/01	22.87
05/22/01	164.96
05/23/01	51.55
05/24/01	41.05
05/25/01	37.43
05/26/01	122.54
05/27/01	713.61
05/28/01	133.86
05/29/01	61.32
05/30/01	47.40
05/31/01	45.55
06/01/01	44.21
06/02/01	126.59
06/03/01	48.46
06/04/01	46.71
06/05/01	45.13
06/06/01	41.28
06/07/01	37.13
06/08/01	34.47
06/09/01	32.58
06/10/01	31.78
06/11/01	31.01
06/12/01	30.36
06/13/01	30.82
06/14/01	30.49
06/15/01	29.61
06/16/01	37.72
06/17/01	89.36
06/18/01	34.36
06/19/01	31.79
06/20/01	31.10
06/21/01	30.36
06/22/01	29.72
06/23/01	29.01
06/24/01	28.28
06/25/01	27.30
06/26/01	26.10

06/27/01	25.06
06/28/01	24.10
06/29/01	23.14
06/30/01	22.29
07/01/01	21.73
07/03/01	22.82
07/04/01	22.29
07/05/01	21.72
07/06/01	20.99
07/07/01	20.31
07/08/01	19.62
07/09/01	18.98
07/10/01	18.47
07/11/01	17.87
07/12/01	17.15
07/13/01	16.54
07/14/01	16.20
07/15/01	16.05
07/16/01	15.92
07/17/01	15.69
07/18/01	15.24
07/19/01	14.68
07/20/01	14.44
07/21/01	14.01
07/22/01	13.89
07/23/01	13.56
07/24/01	13.04
07/25/01	12.61
07/26/01	12.23
07/27/01	28.36
07/28/01	29.76
07/29/01	29.42
07/30/01	27.92
07/31/01	25.72
08/01/01	23.81
08/02/01	22.63
08/03/01	21.71
08/04/01	20.94
08/05/01	20.36
08/06/01	19.44
08/07/01	18.48
08/08/01	17.54
08/09/01	16.76
08/10/01	16.09
08/11/01	15.89
08/12/01	16.12
08/13/01	15.76
08/14/01	15.33

08/15/01	14.85
08/16/01	14.41
08/17/01	14.02
08/18/01	13.61
08/19/01	13.18
08/20/01	12.80
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08/23/01	11.52
08/24/01	11.24
08/25/01	10.86
08/26/01	10.49
08/27/01	10.13
08/28/01	9.77
08/29/01	9.34
08/30/01	8.99

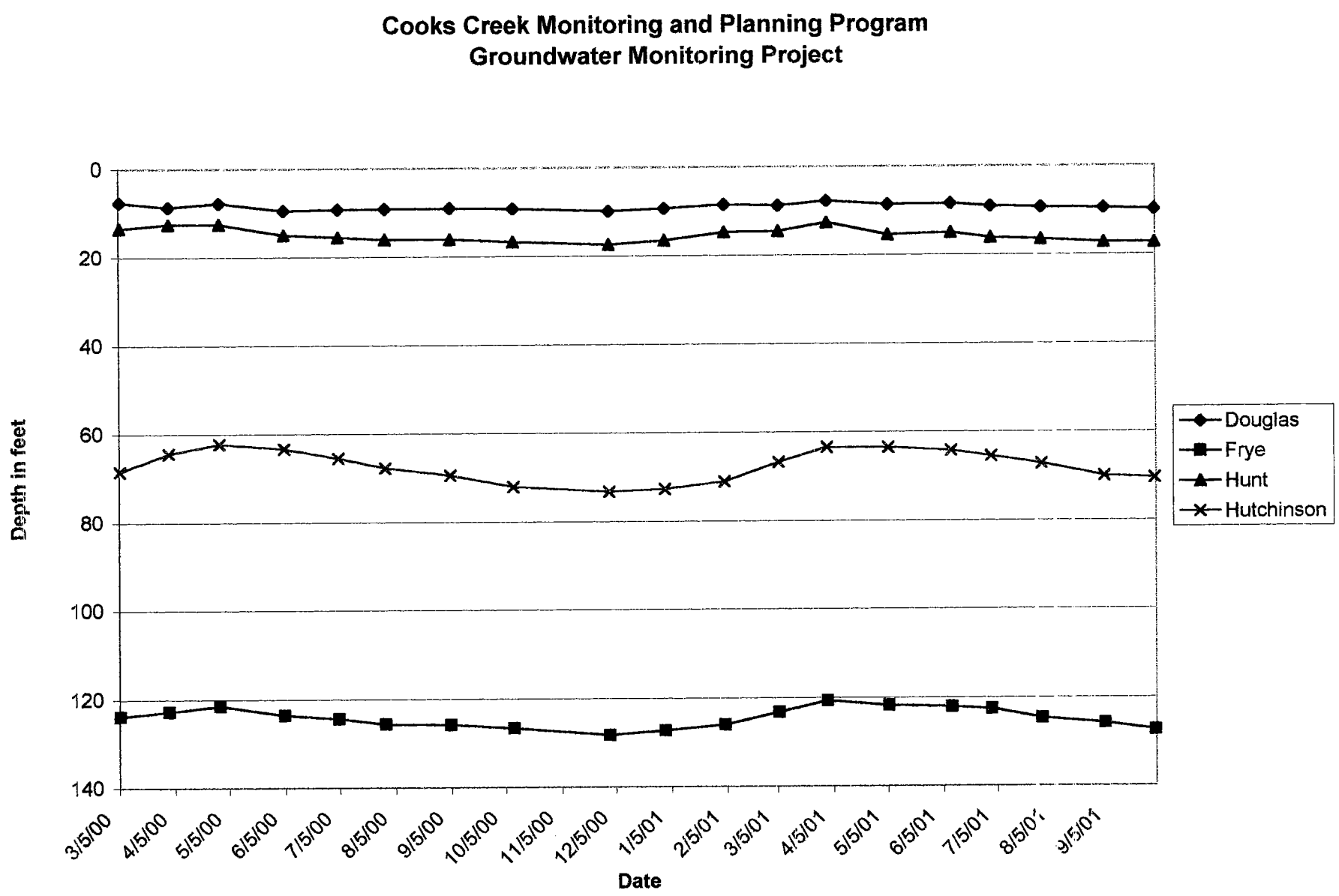
08/31/01	8.68
09/01/01	8.45
09/02/01	8.05
09/03/01	7.79
09/04/01	7.51
09/05/01	7.25
09/06/01	6.93
09/07/01	6.62
09/08/01	6.34
09/09/01	6.09
09/10/01	5.90
09/11/01	5.73
09/12/01	5.49
09/13/01	5.26
09/14/01	5.63
09/15/01	6.13

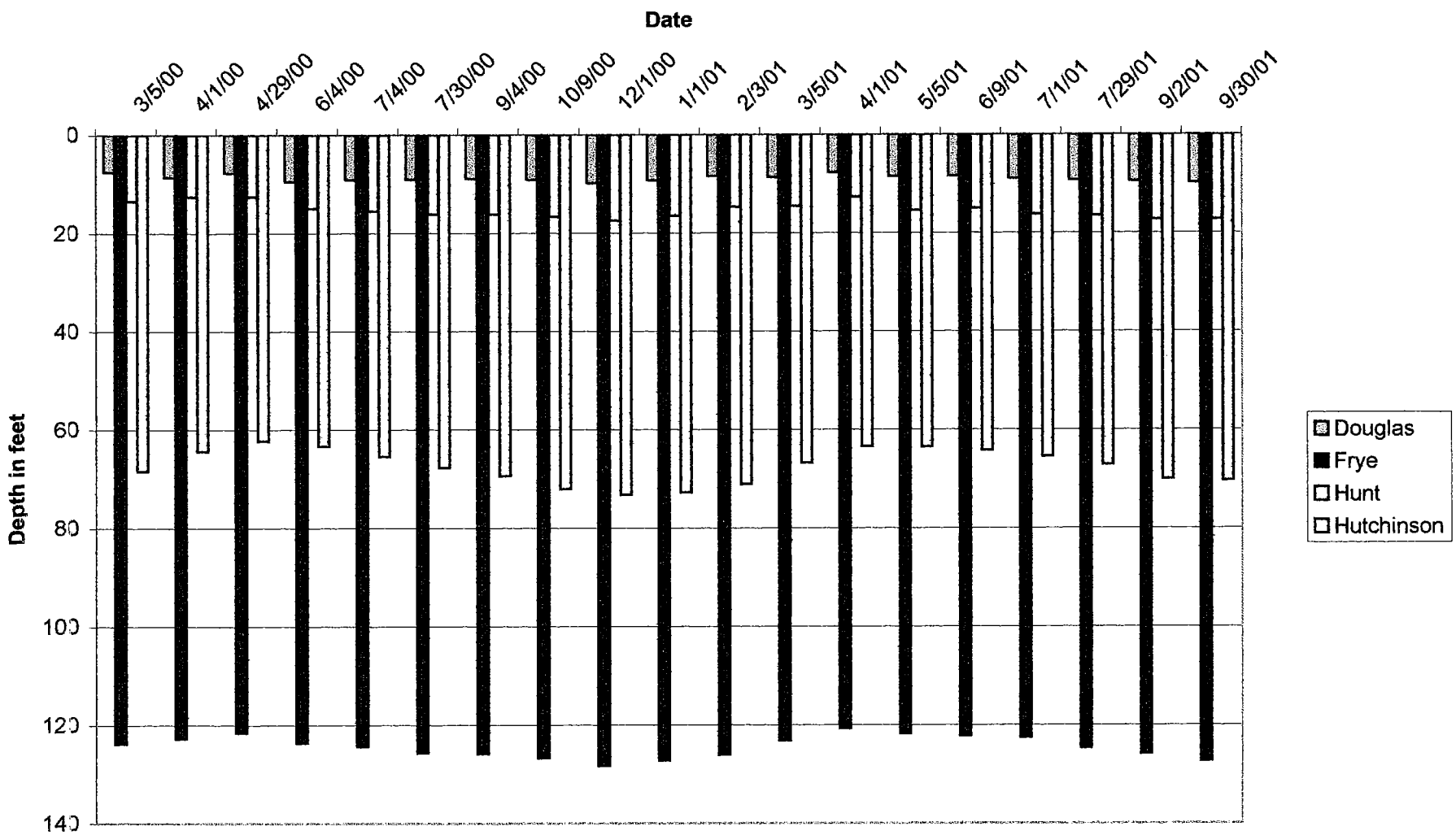
09/16/01	6.06
09/17/01	5.91
09/18/01	5.81
09/19/01	5.72
09/20/01	5.66
09/21/01	37.98
09/22/01	32.15
09/23/01	31.22
09/24/01	30.28
09/25/01	38.63
09/26/01	31.94
09/27/01	30.76
09/28/01	29.78
09/29/01	28.76
09/30/01	27.92

	Date	Douglas			Frye		
		Depth To Water (feet)	Change in Level (feet)	Change in Level (inches)	Depth To Water (feet)	Change in Level (feet)	Change in Level (inches)
November	11/13/99	7.50			127.83		
December			-0.03	-0.36		1.23	14.76
January			-0.03	-0.36		1.23	14.76
February	3/5/00	7.58	-0.03	-0.32	123.83	1.33	16.00
March	4/1/00	8.67	-1.09	-13.08	122.75	1.08	12.96
April	4/29/00	7.75	0.92	11.04	121.50	1.25	15.00
May	6/4/00	9.50	-1.75	-21.00	123.58	-2.08	-24.96
June	7/4/00	9.17	0.33	3.96	124.33	-0.75	-9.00
July	7/30/00	9.08	0.09	1.08	125.67	-1.34	-16.08
August	9/4/00	9.00	0.08	0.96	125.83	-0.16	-1.92
September	10/9/00	9.17	-0.17	-2.04	126.67	-0.84	-10.08
October	12/1/00	9.83	-0.33	-3.96	128.25	-0.79	-9.48
November	12/1/00	9.83	-0.33	-3.96	128.25	-0.79	-9.48
December	1/1/01	9.33	0.50	6.00	127.25	1.00	12.00
January	2/3/01	8.50	0.83	9.96	126.00	1.25	15.00
February	3/5/01	8.75	-0.25	-3.00	123.16	2.84	34.08
March	4/1/01	7.75	1.00	12.00	120.67	2.49	29.88
April	5/5/01	8.58	-0.83	-9.96	121.75	-1.08	-12.96
May	6/9/01	8.42	0.16	1.92	122.16	-0.41	-4.92
June	7/1/01	9.00	-0.58	-6.96	122.58	-0.42	-5.04
July	7/29/01	9.33	-0.33	-3.96	124.67	-2.09	-25.08
August	9/2/01	9.50	-0.17	-2.04	125.83	-1.16	-13.92
September	9/30/01	9.83	-0.33	-3.96	127.33	-1.50	-18.00

	Date	Hunt			Hutchinson		
		Depth To Water (feet)	Change in Level (feet)	Change in Level (inches)	Depth To Water (feet)	Change in Level (feet)	Change in Level (inches)
November	11/13/99	17.00			71.17		
December			1.17	14.04		0.92	11.04
January			1.17	14.04		0.92	11.04
February	3/5/00	13.50	1.17	14.00	68.42	0.92	11.00
March	4/1/00	12.58	0.92	11.04	64.42	4.00	48.00
April	4/29/00	12.58	0.00	0.00	62.25	2.17	26.04
May	6/4/00	15.00	-2.42	-29.04	63.33	-1.08	-12.96
June	7/4/00	15.50	-0.50	-6.00	65.50	-2.17	-26.04
July	7/30/00	16.08	-0.58	-6.96	67.75	-2.25	-27.00
August	9/4/00	16.08	0.00	0.00	69.42	-1.67	-20.04
September	10/9/00	16.67	-0.59	-7.08	72.08	-2.66	-31.92
October	12/1/00	17.42	-0.67	-8.04	73.25	-1.92	-22.98
November	12/1/00	17.42	-0.38	-4.50	73.25	-0.59	-7.02
December	1/1/01	16.50	0.92	11.04	72.75	0.50	6.00

January	2/3/01	14.75	1.75	21.00	71.08	1.67	20.04
February	3/5/01	14.50	0.25	3.00	66.75	4.33	51.96
March	4/1/01	12.67	1.83	21.96	63.42	3.33	39.96
April	5/5/01	15.42	-2.75	-33.00	63.50	-0.08	-0.96
May	6/9/01	15.00	0.42	5.04	64.25	-0.75	-9.00
June	7/1/01	16.17	-1.17	-14.04	65.50	-1.25	-15.00
July	7/29/01	16.50	-0.33	-3.96	67.17	-1.67	-20.04
August	9/2/01	17.25	-0.75	-9.00	70.00	-2.83	-33.96
September	9/30/01	17.25	0.00	0.00	70.42	-0.42	-5.04


Cooks Creek Monitoring and Planning Program
Groundwater Monitoring Project
Depth in feet
0
20
40
60
80
100
120
140
3/5/00
4/5/00
5/5/00
6/5/00
7/5/00
8/5/00
9/5/00
10/5/00
11/5/00
12/5/00
1/5/01
2/5/01
3/5/01
4/5/01
5/5/01
6/5/01
7/5/01
Date
Douglas
Frye
Hunt
Hutchinson


Cooks Creek Monitoring and Planning Program
Groundwater Monitoring Project
Date
3/5/00
4/1/00
4/29/00
6/4/00
7/4/00
7/30/00
9/4/00
10/9/00
12/1/00
1/1/01
2/3/01
3/5/01
4/1/01
5/5/01
6/9/01
7/1/01
7/29/01
9/2/01
9/30/01
Depth in feet
0
20
40
60
80
100
120
140
Douglas
Frye
Hunt
Hutchinson

APPENDIX E

Best Management Practices

Equation (4) provides an estimate of monthly "potential" evapotranspiration (PET) that represents the evaporating power of the atmosphere observed on the ground in a plant-covered area where there is at all times sufficient water in the soil for the needs of the vegetation. If there were a shortage of water, the actual evapotranspiration (AET) would be a function of the PET and the quantity of available water.

As a first approximation, one imagines that the upper layer of the soil constitutes a reservoir, the maximum capacity of which is estimated (St). In this reservoir, evapotranspiration may occur freely at the potential evapotranspiration (PET) rate. When it is empty, the evapotranspiration can only feed on the precipitation of the given month. When it is full, the excess moisture generates infiltration towards the aquifer. During a given month, one calculates the balance of the rainfall, the PET and the soil moisture storage (St), which makes it possible to compute the AE and the moisture surplus (N), that water available for runoff and/or groundwater recharge.

The attached table, Table 7-2, gives the results for the climatological station located at the Doylestown using the Thornthwaite formula to calculate PET. Thus we can estimate, as a first approximation, that the moisture surplus in 1999 ranged between –2.67 inches (deficit), August 1999, and 5.45 inches, September 1999. In 2000 the moisture surplus ranged between –1.18 inches (deficit), June 2000, and 3.56 inches, March 1999.

7.2 Water Balance

The concept of a groundwater regime is based on the fact that the occurrence and distribution of groundwater is not merely a product of chance, but the consequence of a finite combination of climatic, hydrologic, geologic, topographic, ecologic and soil-forming factors that together form an integrated dynamic system. These factors are interrelated in such a way that each provides some insight into the functioning of the total system and thus serves as an indicator of local conditions of groundwater occurrence. It is possible, therefore, to evaluate the general potential of an area for groundwater development by appraising as many of the factors listed above as practical and then by interpreting the local regime on the basis of known relationships among the factors and their effect on the groundwater regime.

Most important among the preceding relationships are the physical characteristics of the framework in which the groundwater system occurs, the balance between groundwater recharge and discharge and the consequent hydrologic and lithologic implications that may be drawn, and the relationship among the factors affecting the movement of groundwater from the point of recharge to the point of discharge.

Obviously the groundwater regime must be viewed as a dynamic system in which water is absorbed at the land surface and eventually recycled back to that surface. Groundwater may be visualized as occurring in a subsurface reservoir, the boundaries of which are formed by adjacent less permeable or impermeable geological materials. The reservoir may be open everywhere to the

land surface (unconfined), or it may be capped in large part by impermeable or relatively impermeable geological materials (confined).

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

In developing an estimate of balance between recharge to, and discharge from, a groundwater regime the general manner in which that regime functions must be identified. The potential for recharge to the groundwater regime in an area depends on the amount and pattern of annual precipitation in relation to the potential for evaporation and to the occurrence of any surface or subsurface inflow from adjacent areas. Most of this potential recharge is commonly intercepted by the soil veneer and eventually returned to the atmosphere through processes of evapotranspiration or dissipated as surface runoff.

The GIS tools were used to create areal coverages of drainage basin divides, bedrock geology, and boundaries for the Cooks Creek Basin. Drainage basin divides were digitized from USGS 1:24,000 scale 7 ½ minute topographic quadrangle maps. The Cooks Creek Basin, including the mainstem lower section, was divided into 40 basins or subbasins so that the basin or subbasin areas were determined their local geology. The mainstem Cooks Creek, lower section subbasin (area CC1), has a drainage area of 3.79 mi^2 (Figure 24-2 and Figure 25-2). The drainage basin coverages will be used in determining ground water contributions to base flow for the basins or subbasins on the basis of geology. Assigned basin and subbasin names, and drainage areas are listed in Table 7-3

Bedrock geologic contact lines were transferred on the subbasins maps and the refined geologic coverages on the basis of basin/subbasins areas will be used to calculate the percentage of each geologic unit in each subbasin. The geologic units of the entire watershed were grouped into four geologic categories, (1) Brunswick Group and Lockatong Formation, (2) the diabase, (3) carbonate rocks, and (4) crystaline rocks, that will be used in determining ground water contributions to base flow for the basins or subbasins. Figures 25-1 through 25-7 present the geology for the entire local area, areas 1 through 7, while Figures 24-1a through 24-7a present the geologc composition of subbasins areas grouped by the designation of subbasins, such as first-order and second order.

For a small scale analysis the subbasins were grouped into seven areas determined of the dominant local geology and of the subbasin type .

One statistic available to define the critical base flow condition is the Q7-10, the lowest 7-consecutive-day average flow with a probability of occurring no more than once in 10 years. The recorded data for Cooks Creek streamflow-measurements station (12/12/1990 – 02/20/93, 05/11/199 – 08/29/1999, and 12/18/1999 – to present date) provided a Q7 = 222 GPD/acre (between 09/11/1991 and 09/18/1991 the average stream flow was 7.14 cfs). The average stream flow for 1991 was 40.20 cfs which yields a Q365 = 1255 GPD/acre.

Having the limited stream gage data collected for Cooks Creek, yield ratios for the various rocks aquifers were estimated from annual base flow for the 2-,5-, 10-, 25-, and 50-year recurrence intervals at streamflow-measurements station of Brandywine Creek and Neshaminy Creek Basins (USGS Water-Resources Investigations Report 96-4127). The discharges (yields) and ratios of them to the average value recorded are calculated and shown in tables 7-4 and 7-5.

The technical analysis of land and water resources within the study area begins with a careful measurement of both, making use of the Geographic Information System (GIS) files created for this purpose and which cover the full study area. The delineation of first order streams and larger catchments within Cooks Creek basin was required for analysis, as discussed previously. As was shown in Figures 24 and repeated here as Figure 13-1 through Figure 13-6, the watershed has been divided into 40 sub-basins. These areas vary significantly in size, but average about 609 acres for the 40 sub-basins.

We have included in the Figure 13-1 through Figure 13-6 the locations of those wells that were found in dcnr database, Pennsylvania Ground water Information System Database (Pa GWIS). When available the maximum recorded yield is shown on the maps. The hydrogeological formation where their open interval is located are specified and shown on the maps too.

Analyzing the existing and potential future hydrologic balance in each of these sub-basins required the application of what is referred to here as the Water Balance Model (WBM). On a conceptual basis, the model considers the dynamics of water movement from incident rainfall through the soil into the groundwater reservoir, with gradual discharge as stream base flow. It is the stream base flow which is taken as the net result of all intervening processes, including evaporation, transpiration and human intervention, so that existing uses and conditions are all reflected in this statistic. The model can consider base flow variability by each geological structural element, surface yield and subsurface withdrawals, with hydrologic analysis for wet, dry and average years. The WBM can be thought of as a bookkeeping process which accounts for the dynamics of the water cycle by considering each catchment under stress conditions which test the specific resource impact; drought periods of base flow for water supply (Q7-10 = 222 GPD/acre), dry years cycles (Q365-10 = 1255 GPD/acre) for groundwater contaminants such as Nitrate (1 Nb3), and storm periods (based on annual runoff) for estimates of potential pollutant runoff from future urbanized lands.

Of course any such fixed analysis of the hydrologic cycle ignores the dynamic nature of the process, with the water in constant movement. All elements of the cycle vary with time and seasonal change. Patterns of incident rainfall, as documented by the climatological record in terms of seasonal variability and event probability, changes in the evaporative and transpirational losses as a function of temperature and vegetative land cover, changes in the net withdrawals from the aquifers by wells and additions by wastewater effluent of on-site systems, and the resultant impact on storm and dry weather stream flows which are produced by land surface alteration, all contribute to the dynamic nature of this process. The VBM has been applied and aggregated to reflect the total watershed, balance and variability within each basin for planning purposes, and to allow us to identify potential stress conditions in the system so that we may prevent or intervene to protect the resource.

Water Use Based on Existing Conditions

Each of the 40 sub-basins experience some amount of water use at present, primarily based on residential use or the equivalent use of other land activities expressed in "equivalent dwelling units" (EDUs) The demands of agriculture are not included in this estimate, since the future land use scenarios all assume that the lands zoned agricultural and used as such at present will provide the developable lands (excluding those parcels under permanent easements or protective covenants). For a more accurate estimate, the individual agricultural parcels could be evaluated and a current demand estimated, but this level of data gathering was not considered necessary for this study of future impacts.

Based on a set of assumptions with respect to the number of dwelling units in each sub-basin (as estimated from the existing GIS database of population and households for 1990 census) and the water use per dwelling unit (300 GPD/DU), the existing water use is summarized in Table 8 by sub-basins. The estimated water demand is based on assumptions as to an approximate number of dwelling units, which exist in a given sub-basin. Of course, where a current count of actual dwelling units can be made, it is a more accurate statistic, and as the individual sub-basins are studied in greater detail, that value will replace this estimate. Also the average value of Q7-10 = 222 GPD/acre (7.14 cfs/29.7 square miles) is based on only 3.5 years stream flow recording and could overestimate the aquifer contribution during a drought period. However other streamflow measurements for similar settings (streamflow-measurements station of Brandywine Creek and Neshaminy Creek Basins for 10 consecutive years) yielded close statistic value of Q7-10 (i.e. 192 GPD/acre).

For example, in sub-basin CC1, the 2,643 acres should yield 222 GPD/acre in a drought, and setting a consumptive loss limit at 50% of this base flow means that 305,852 GPD can be evaporated. The 409 existing dwelling units in the sub-basin at present, all of which are assumed to use on-site wastewater systems, will lose about 24,540 GPD, or only 4 % of the Q 7-10 flow, and so the answer to the limit question is no (2).

For those sub-basins where public water is provided throughout most of the drainage, such as SC1, SC2a, SC3a, and a very small area from CC, the water supply is not imported from other sub-basins and the resultant effluent is returned to the same system. Development still has an impact of water resources, but in the form of potential lost groundwater recharge and increased runoff with NPS pollution, from new (and existing) impervious surfaces.

For the most sub-basins both individual wells and on-site systems are utilized, the impact of consumptive loss on base flow is not the only issue. The Nitrate loading to the groundwater with land application of effluent raises the issue of increased Nitrate in the aquifer above the standard of 10 mg/1. The Nitrate loading estimated in the last column of Table 8 is evaluated in terms of the annual dry year groundwater volume available to dilute this addition, assuming an existing background concentration of 2 mg/1 in the groundwater. If this Nitrate limit (based on an annual groundwater volume of 1,255 GPD/Acre for 1991 as dry year) would be less than the present loading in sub-basins, which are supplied from individual wells, could be concern as to potential

water quality constraints. Our calculation doesn't show any concern since for all drainages the Nitrate limit is much higher than Nitrate Load.

"Futures" Analysis

For the potential impact of future growth on the regional water resources, it is useful to consider exactly how the resource capacity is estimated. As stated previously, the groundwater yield as stream base flow is used as the surrogate for system capacity, rather than the entire volume of water that may be contained in an aquifer at any given moment. This interrelationship between groundwater storage and surface water flow is frequently neglected in water resource studies, where the total discharge or stream flow (including both wet and dry periods) from a drainage area is the primary focus of analysis. The terms "safe yield" and "water budget" have been frequently mis-applied to suggest that a given amount of water can be withdrawn from an aquifer per unit area without impact. While such concepts have been used as the basis for regulation, the reality is that any withdrawal of a water resource, without recycling or compensation, has some given quantitative (and qualitative) effect elsewhere in the water system. This interconnection between ground and surface flows is an assumption that drives much of the analysis developed in the WBM. The projected impacts of both existing and future development, are driven by this' estimated limit of system capability.

Simulating different "future" outcomes or scenarios should be based initially on two basic sets of conditions. In the initial analysis, the question is what will be the water resources impacts of continuation of "baseline" or "business as usual" policies and programs (i.e., the existing management system), basically a build out of existing zoning. The second alternative future considers following the Landscapes Plan as the pattern of future land development. In both instances, the process begins with an estimate of potentially developable lands, derived as the vacant parcels and unrestricted agricultural parcels in the study area, as shown in Figure 22.

On the other hand multiple, alternative methods of estimating ground water discharge and recharge should be used (e.g. ground water flow modeling) because of the uncertainty associated with any one technique. Estimates of recession index from stream-discharge hydrographs, ground water hydrographs, and hydraulic diffusivity were performed by testing aquifers in basins throughout the eastern United States. Reliable identification of the recession index and so Q7-10 may require recession periods in excess of 200 days that were not influenced by hydrologic phenomena other than ground awter discharge to surface water features(Ground Water Journal, vol 38, No. 3, pp. 331-342, May-June 2000).

7.3 Drinking Water Well Management

Keeping your well water free of harmful contaminants is a top priority - for your health a I Id for the environment. This chapter helps

amin e how you manage your well, and how activities on or near your property may affect well water quality The Mowing topics are covered:

- Well Location -- How dose is your well to potential pollution sources? How might your soil type af- water quality?
- Well Construction and Maintenance -- Do you know how old your well is and what type of well it is? Is your well casing properly sealed?
- Water Testing and Unused Wells -- Have tests of your well water revealed any problems? Are abandoned wells protected against contamination?

Why Should You Be Concerned?

About 95% of rural residents use private wells to supply drinking water. These wells, which tap into local groundwater, are designed to provide clean, safe drinking water. However, improperly constructed or poorly maintained wells can create a pathway for fertilizer bacteria, pesticides, or other materials to enter the water supply Once in groundwater, contaminants can flow from your property to a neighbor's well, or from a neighbor's property to your well.

Contaminants often have no odor or color and therefore are hard to detect. They can put your health at risk and it is difficult and expensive to remove them. Once your water becomes contaminated, the only options may be to treat your water after pumping, drill a new well, or get your water from another source.

A. Well Location

The location in relation to other features on or near your property will determine some pollution risks. The nearness of your well to sources of pollution and the direction of groundwater flow between the pollution sources and your well are the primary concerns.

What pollution sources might reach your well?

Whether groundwater in your area is just below the surface or hundreds of feet down, the location of your well on the land surface is very important. Installing a well in a safe place takes careful planning and consideration. Where the well is located in relation to potential pollution sources is a critical factor.

When possible, locate a well where surface water (stormwater runoff, for example) drains away from it. If a well is downhill from a leaking fuel storage tank, septic system, or overfertilized farm field, it runs a greater risk of becoming contaminated than a well on the uphill side of these pollution sources. In areas where the water table is near the surface, groundwater often flows in the same direction as surface water Surface slope, however, is not always an indicator of groundwater flow.

Changing the location or depth of the well may protect your water supply, but not the groundwater itself. Any condition likely to cause groundwater contamination should be eliminated, even if your well is far removed from the potential source.

Provide as much separation as possible between your well and any potential pollution source - at least 100 feet. Separating your well from a pollution source may reduce the chance of contamination, but it does not guarantee that the well will be safe.

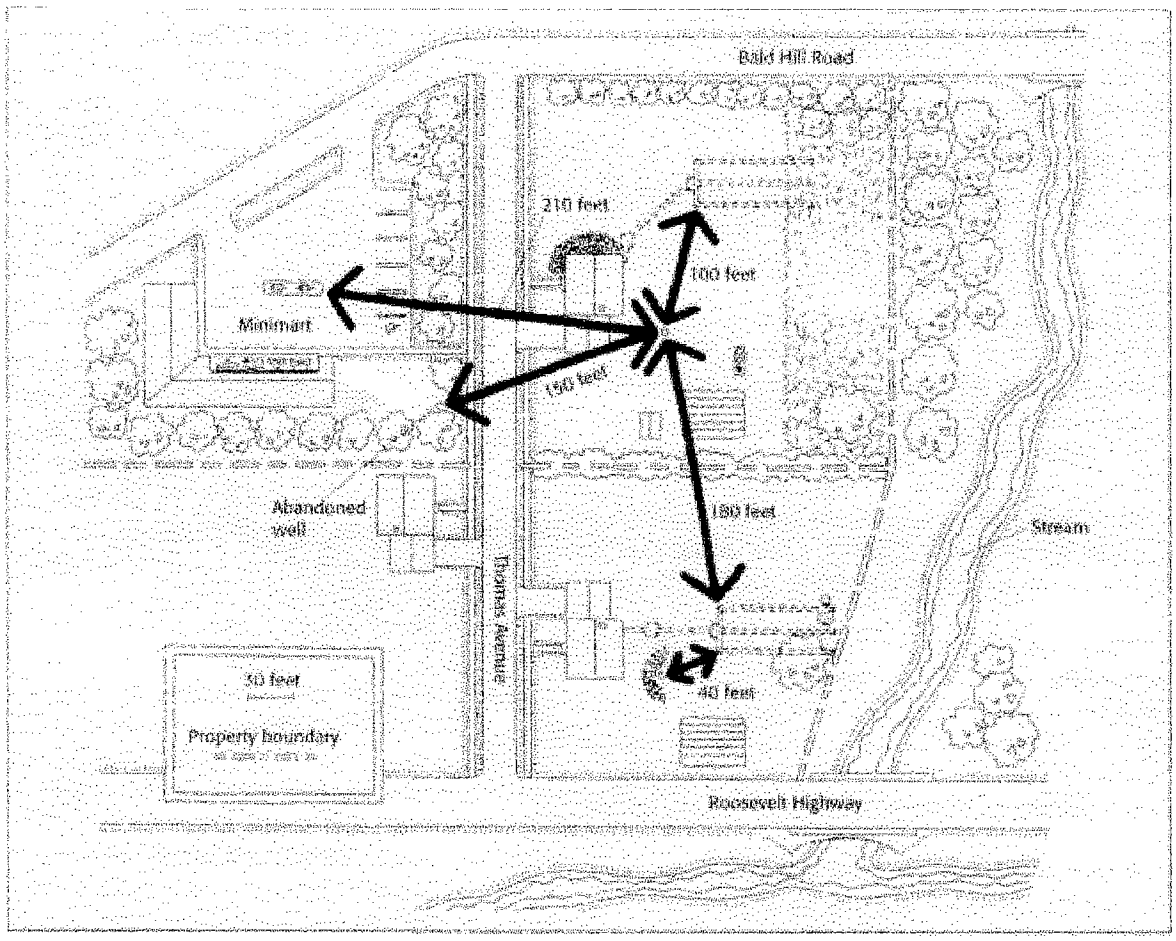


Figure 7-9 Map of Homesite showing distances of pollution sources from well.

Pollution risks are greater when the water table is near the surface, because contaminants do not have far to travel. Groundwater contamination is more likely if soils are shallow (a few feet above bedrock) or if they are highly porous (sandy or gravelly). If bedrock below the soil is fractured - that is, if it has many cracks that allow water to seep down rapidly - then groundwater contamination is more likely. See Figures 20b through 20h for the type of soils are on that property and if it is feasible for on-site wastewater treatment.

Assessment - Well Location

	LOW RISK	MEDIUM RISK	HIGH RISK
Position of well in relation to pollution sources	Well is uphill from all pollution sources. Surface water doesn't reach well or is diverted.	Well is level with or uphill from most pollution sources. Some surface water runoff may reach well.	Well is downhill from pollution sources or in a pit or depression. Surface water runoff reaches well.
Separation distances between well and pollution sources*	Distances from Potential pollution sources meet or exceed all state minimum requirements.	Some but not all distances from potential pollution sources meet state minimum requirements.	Distances from most or all potential pollution sources do not meet state minimum requirements.
Soil type	Soil is fine-textured like clay loams or silty clay.	Soil is medium-textured like silt or loam.	Soil is coarse-textured like sand, sandy loam, or gravel.
Subsurface conditions	The water table or fractured bedrock are deeper than 20 feet.	The water table or fractured bedrock are deeper than 20 feet.	The water table or fractured bedrock are shallower than 20 feet.

B. Well Construction and Maintenance

Old or poorly designed wells increase the risk of groundwater contamination by allowing rain or snowmelt to reach the water table without being filtered through soil. If a well is located in a depression or pit or is not properly sealed and capped, surface water carrying nitrates, bacteria, pesticides, and other pollutants may easily contaminate drinking water.

You wouldn't let a car go too long without a tune-up or oil change. Your well deserves the same attention. Good maintenance means keeping the well area clean and accessible, keeping pollutants as far away as possible, and having a qualified well driller or pump installer check the well periodically or when problems are suspected.

How old is your well

Well age is an important factor in predicting the likelihood of contamination. Wells constructed more than fifty years ago axe likely to be shallow and poorly constructed. Older well pumps are more likely to leak lubricating offs, which can get into the water. Older wells are also more likely to have thinner casings that may be cracked or corroded. Even wells with modem casings that am thirty to forty years old are subject to corrosion and perforation. If you have an older well, you may want to have it inspected by a qualified well driller. If you don't know how old your well is, assume it needs an- inspection.

Are your well casing and well cap protecting your water?

Well drillers install a steel or plastic pipe "casing" to prevent collapse of the well hole during drilling The space between the casing and sides of the hole is a direct channel for surface water- and pollutants-to reach the water table (figure 3.3 on the following page). To seal off that channel, drillers fill the space with grout (cement or a type of clay called bentonite).

You should visually inspect the condition of your well casing for holes or cracks. Examine the part that extends up out of the ground. Remove the cap and inspect inside the casing using a flashlight. If you can move the casing around by pushing it, you may have a problem with your well casing's ability to keep out contaminants. Sometimes damaged casings can be detected by listening for water running down into the well when the pump is not running. If you hear water, there might be a crack in the casing, or the casing may not reach the water table. Either situation is risky.

The depth of casing required for your well depends on the depth to groundwater and the nature of the soils and bedrock below. In sand and gravel soils, well casings should extend to a depth of at least 20 feet and should reach the water table. For wells in bedrock, the casing should extend through the weathered zone and into at least 10 feet of bedrock. A minimum of 20 feet of casing should be used for all wells.

The casing should extend at least 12 inches above the ground surface. If there are occasional floods in your area, the casing should extend 1 to 2 feet above the highest flood level recorded for the site. The ground around the casing should slope away from the wellhead in all directions to prevent water from pooling around the casing.

The well cap should be firmly attached to the casing, with a vent that allows only air to enter. If your well has a vent, be sure that it faces the ground, is tightly connected to the well cap or seal, and is properly screened to keep insects out. Wiring for the pump should be secured in an electric conduit pipe.

Is the well shallow or deep?

As rain and surface water soak into the soil, they may carry pollutants down to the water table. Local geologic conditions determine how long this takes. In some places, the process happens

quickly - in weeks, days, or even hours. Shallow wells, which draw from groundwater nearest the land surface, are most likely to be affected by local sources of contamination.

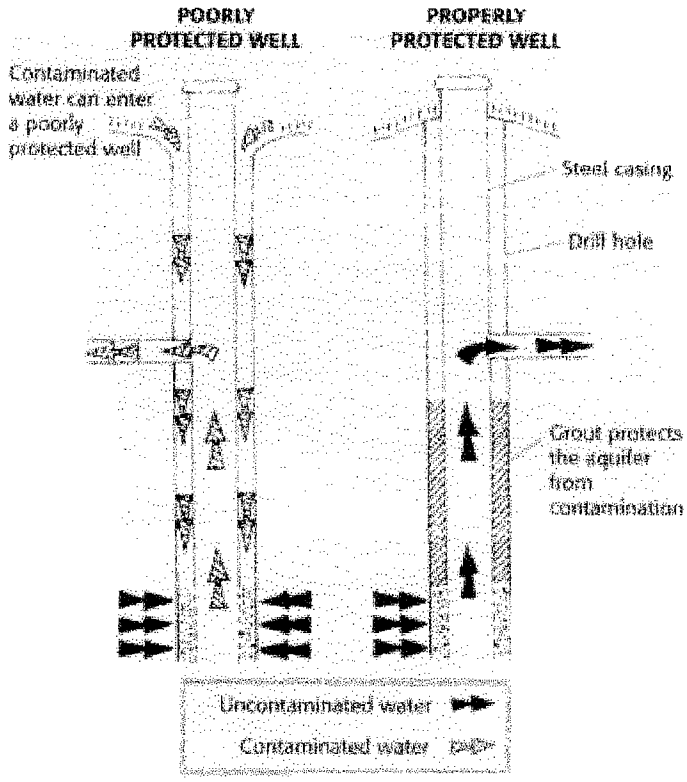


Figure 3.3 A poorly protected well versus a properly protected well.

Do you take measures to prevent backflow?

Backflow of contaminated water into your water supply can occur if your system undergoes sudden pressure loss. Pressure loss can occur if the well fails or, if you are on a public water system, if there is a line break in the system. The simplest way to guard against backflow is to leave an air gap between the water supply line and any reservoir of "dirty" water. For example, if you are filling a swimming pool with a hose, make sure that you leave an air gap between the hose and the water in the pool. Toilets and washing machines have built-in air gaps.

Where an air gap cannot be maintained, a backflow prevention device such a check valve or vacuum breaker should be installed on the water supply line. For example, if you are using a pesticide sprayer that attaches directly to a hose, a check valve should be installed on the faucet to which the hose is connected.

C. Water Testing and Unused Wells

Water testing helps monitor water quality and identify potential risks to the health. Contaminants enter drinking water from many sources. Many contaminants can only be detected through a water test.

Abandoned wells, if improperly sealed, can provide a direct route for contaminants to enter groundwater. It is important to identify old or abandoned wells and determine appropriate action.

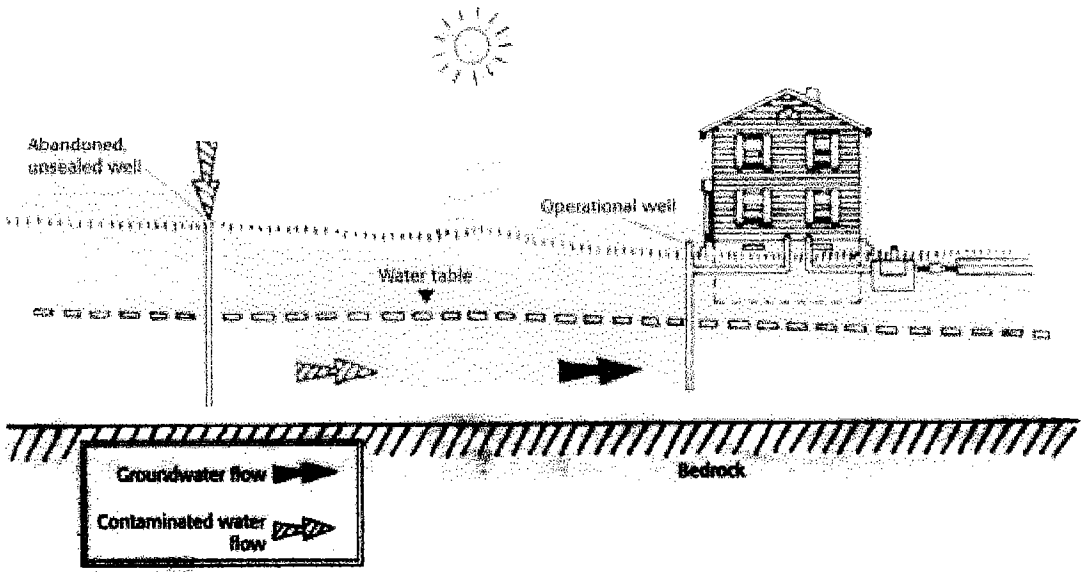


Figure 3.4 Abandoned wells that are not properly sealed provide a pathway for contaminants to reach groundwater.

Many properties have wells that are no longer used. Sites with older homes often have an abandoned shallow well that was installed when the house was first built. If not properly filled and sealed, these wells can provide a direct channel for waterborne pollutants to reach groundwater (figure 3-4). A licensed, registered well driller or pump installer should be hired to dose these wells. Effective well plugging calls for experience with well construction materials and methods, as well as knowledge of the geology of the site. The cost to close a well will vary with well depth, well diameter, and soil/rock type. The money spent sealing a well will be a bargain compared to the potential costs of cleanup or the loss of property value if contamination occurs.

When was the water last tested?

At a minimum, the water should be tested every year for the four most common indicators of trouble: bacteria, nitrates, pH, and total dissolved solids (TDS). If you haven't had a full-spectrum, comprehensive water test, then you don't know the characteristics of your water. For the general procedure for taking water sample always follow lab instructions.

A more complete water analysis for a private well will tell you about its hardness; corrosivity; and iron, sodium, and chloride content. In addition, you may choose to obtain a broad-scan test of your water for other contaminants such as pesticides. A good source of information on well water quality may be your neighbors. Ask them what their tests have revealed.

What contaminants should you look for?

Test for the contaminants that might be found at your location. For example, if you have lead pipes, soldered copper joints, or brass parts in the pump, test for the presence of lead. Test for volatile organic chemicals (VOCs) if there has been a nearby use or spill of oil, liquid fuels, or solvents.

Pesticide tests, though expensive, may be justified if your well has high nitrate levels - more than 10 milligrams per liter (mg/l) of nitrate-nitrogen (NO3-N) or 45 mg/l of nitrate (NO3). Tests are also warranted if a pesticide spill has occurred near the well. Pesticides are more likely to be a problem if your well is shallow, has less than 15 feet of casing below the water table, or is located in sandy soil and is downslope from irrigated lands such as farms or golf courses where pesticides are used.

You can seek further advice on testing from your local Cooperative Extension office or health department. You should test your water more than once a year if (1) someone in your household is pregnant or nursing; (2) there are unexplained illnesses in the family, (3) your neighbors find a dangerous contaminant in their water; (4) you note a change in water taste, odor, color, or clarity; or (5) you have a spill or backsiphonage of chemicals or fuels into or near your well. Water can be tested by both public and private laboratories. Once tested, keep a record of your results with your records on well construction and maintenance. This will allow you to monitor water quality over time.

7.4 Septic Systems

Why should you be concerne?

Wastewater treatment systems help protect your health and the environment. Household wastewater from sinks, toilets, washing machines, and showers carries dirt, soap, food, grease, and bodily wastes "down the drain" and out of your house. Wastewater also carries disease-causing bacteria, viruses, and other pathogens as well as nutrients like nitrogen, phosphorus, and organic

wastes. Such nutrients promote weed growth and lower oxygen levels in surface water and thus affect fishing and recreational use of rivers and lakes.

Wastewater treatment systems are designed to remove or break down these contaminants before they enter groundwater - the source of drinking water via wells or nearby lakes, streams, or wetlands.

Wastewater treatment is often out-of-sight and out of-mind until problems occur. Knowing the basics about your household system and taking simple precautions can prevent problems. It's a wise investment to keep your system working well. Replacing a failed system can cost thousands of dollars.

General suitability of soils for on-site sewage is regulated in Pennsylvania by DER Title 25, Rules and Regulations, chapter 73, Standards For Sewage Disposal Facility, USA Department of Agriculture, Soil Survey of Bucks and Philadelphia Counties, July 1975. Bucks County Planning Commission refers to the following soil classification for on-site sewage disposal system suitability:

1. Soils feasible for conventional systems;

2. Soils feasible for alternate systems;

3. Soils not feasible for any type of on site system;

4. Carbonate derived soils, not feasible in Bucks County for any on-site system; and,

5. Soils subject to flooding; not feasible for any on-site sytems.

Maps with location of soils types grouped by their suitability for on-site sewage were prepared for the entire Cooks Creek watershed area by use of the GIS database. These maps are presented in Figures 20c through 20h.

The soil must be of a suitable type and deep enough to treat wastewater before it reaches groundwater. The soil filters out larger particles and pathogens, which eventually die off in the inhospitable soil environment. Under suitable conditions, beneficial soil microbes and natural chemical processes break down or remove most of the contaminants in the effluent. Hazardous synthetic chemicals such as solvents and fuels are not easily degraded in wastewater treatment systems. These chemicals can contaminate sludge in the septic tank, kill the beneficial bacteria that digest wastes, and travel into groundwater.

The existing soil type on a property determines which type of on-site sewage disposal system should be used on that property. A typical septic system consists of a septic tank and drainfield, which is also known as a soil absorption field, leach field, or tile field. It is important to maintain your wastewater treatment system and use it wisely whether you have a holding tank or septic tank followed by a mound, sand filter, or other alternative on-site treatment system.

Conventional Septic Systems

Soils vary in their ability to absorb and treat wastewater. Well-drained, medium-textured soils such as loam are best. Coarse gravel or sandy soils allow wastewater to flow too quickly for treatment. In fine clay or compacted soils, water moves too slowly. Soil microbes need oxygen to digest wastes quickly. If the air spaces between soil particles remain filled with water, the lack of oxygen prevents the rapid breakdown of wastes by aerobic (oxygen-requiring) soil microbes.

Anaerobic soil microbes (those that live in the absence of oxygen) digest wastes slowly and give off putrid, smelly gases characteristic of a failing septic system. Anaerobic conditions occur when soils are poorly drained, groundwater levels are high, surface runoff saturates the drainfield, or excessive amounts of water are used in your household.

Good wastewater treatment depends on good dispersal of wastewater over the drainfield. In a conventional, gravity-fed distribution system, the distribution pipes are often laid out in a fork-shaped pattern joined by a distribution box (Figure 7-9). Leveling devices on the distribution box help ensure an even flow of wastewater to every trench. Often, however, certain trenches or low points in the distribution system receive more effluent than others.

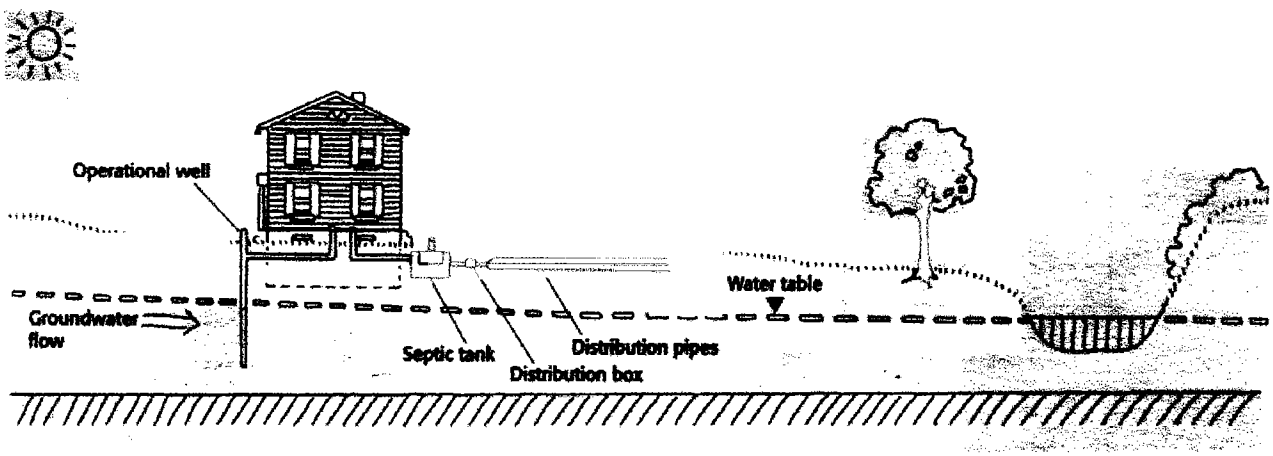


Figure 7- 9 Cross section of a septic system showing the septic tank an distribution System.

A dosing or enhanced-flow system has a pump or siphon to improve the distribution of effluent. Periodically pumping a certain volume of effluent to wet the entire drainfield area and then allowing the soil to drain between doses provides a period of aeration, which helps microorganisms in the soil digest the wastes.

In a pressure distribution system, effluent is pumped directly through small-diameter pipes, not sent through a distribution box. Wastewater is evenly distributed throughout the entire drainfield, promoting better treatment of wastewater and system longevity.

Alternative Septic Systems

If soil or site conditions are not suitable for a conventional drainfield, an alternative system might be used. In a mound system, the drainfield is elevated to provide additional soil depth for treatment before the effluent reaches groundwater. A sand filter consists of layers of sand and gravel in which the wastewater is treated before it is distributed into the soil. Other types of filters use small foam pieces or peat as a filter medium.

With suitable climate and soil conditions, other alternative systems such as evapotranspiration systems, constructed wetlands, spray irrigation, lagoons, or mechanically aerated systems for household wastewater treatment are approved in some localities. Descriptions of these systems are beyond the scope of this report.

Aerobic treatment units operate much like a municipal sewage treatment plant, where wastewater is mixed with air, promoting bacterial digestion of organic wastes and pathogens. The biological breakdown of wastes in a septic tank's anaerobic (oxygen-deprived) conditions is relatively slow. Aerobic units are more expensive and require significantly more maintenance than conventional septic tanks. However, they provide good wastewater treatment on homesites that are otherwise unsuitable for development because the soil type, depth, or area is inadequate for an on-site treatment system. The effluent from an aerobic unit can be discharged into a soil absorption system or may be treated with chlorine, ozone, or other disinfectant before surface discharge if state and local regulations permit.

Disposal of toilet wastes does not have to mean flushing away great volumes of water. Composting toilets use microbes to aerobically digest toilet wastes; they work well only if the right temperature, moisture level, oxygen level, and nutrient mixture is maintained. Other types of waterless toilets include incinerating toilets, recirculating oil-flush toilets, and chemical disinfecting toilets. Without the blackwater (water carrying human body waste) from toilets, greywater (wastewater other than sewage) from sinks, tubs, and washing machines can be treated in a household wastewater system sized to handle about half the volume of a standard wastewater system.

There is controversy over the safe use and disposal of greywater (wastewater other than sewage, from sinks, tubs, and washing machines): state health regulations covering if and how greywater can be used vary. Many states strictly prohibit any surface disposal of greywater but permit its use in subsurface irrigation systems for watering plants. However, caution is advised because greywater may contain infectious bacteria and viruses (for example, from soiled diapers or clothing worn by someone with an infectious disease). Direct contact with greywater must be prevented. Beware that certain detergents, bleach, and salts may damage the health of plants and soils.

In areas with limited water resources, particularly during drought periods, water use must be reduced. Water conservation methods are encouraged, along with unrestricted uses of clear water (for example, flushing toilets with shower warm-up water).

Septic System Location, How close is too close?

To prevent contamination of water supplies, the drainfield must be at least 100 feet from any wetland, shoreline, stream bed, or drinking water well (see figure 4.6; state and local regulations regarding separation distances may vary). The greater the distance, the lower the chance of contaminating the water supply. If your system is downhill from a well, the well will be better protected. You should test your well water more often for nitrates and bacteria if your system is closer to your well than recommended.

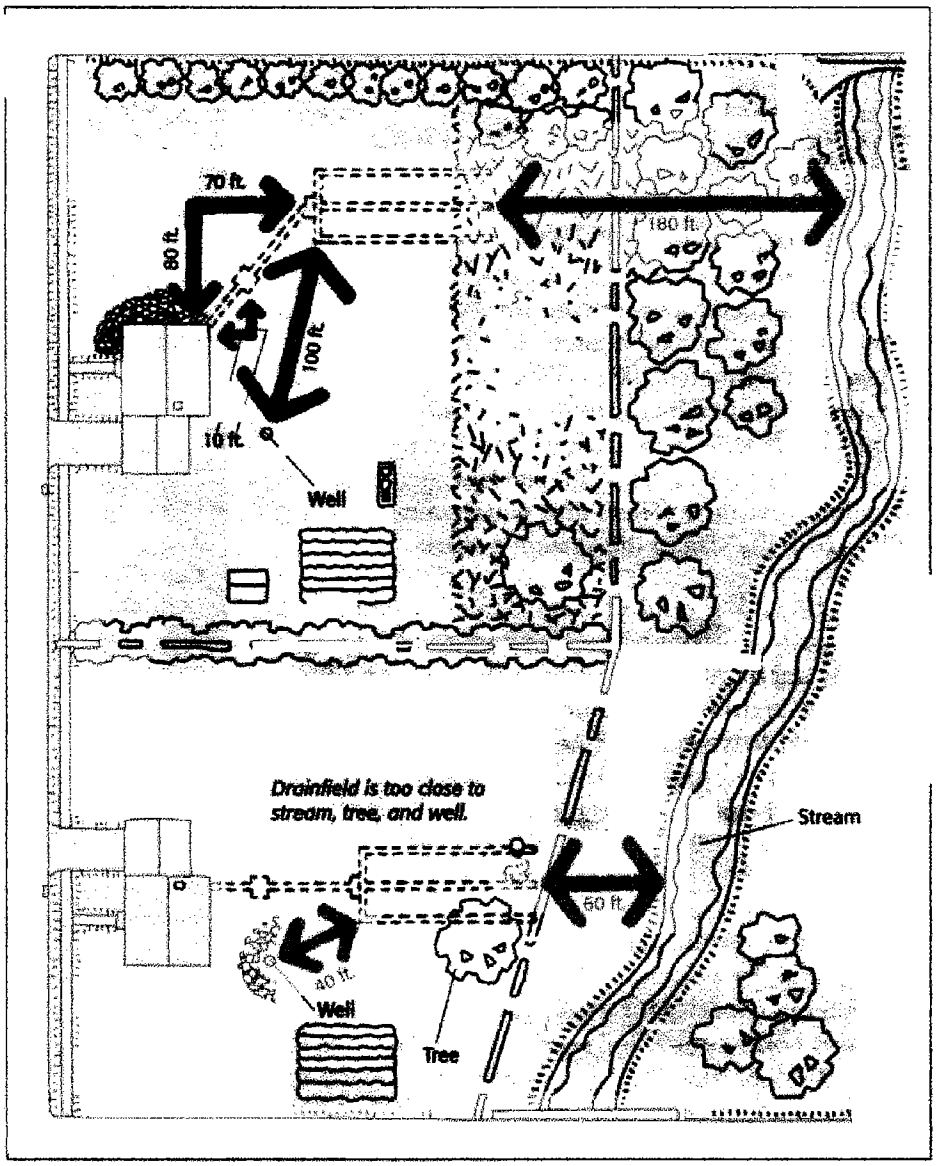


Figure 7-10 Homesite Map showing location of septic system.

7.5 Effects of Confined Animal Feeding Operations on Aquatic Ecosystems

A Research Overview of the Effects of Confined Animal Feeding Operations on Aquatic Ecosystems Thomas A. Muir 1 , Franceska D. Wilde 2 , James W. Preacher 3 , and Lawrence R. DeWeese.

Confined animal feeding operations are a rapidly growing sector of the United States agricultural economy. The U.S. Geological Survey (USGS) is actively involved in research efforts to assess the effects of Animal Feeding Operations (AFOs) on aquatic ecosystems and on the chemical quality of ground-water and surface-water resources.

USGS scientists are applying diverse and interdisciplinary approaches to ecosystem research, in particular with respect to understanding contaminant transport and assimilation processes. Questions being addressed through research and on-site monitoring involve the occurrence and magnitude of nutrients, pharmaceuticals, and pathogens that could be entering streams and ground-water systems and that originate from concentrated sources of animal feed and waste products. The results of these studies are germane to public concerns that industrial-scale livestock, dairy, swine, poultry, and aquaculture operations could have acute, long-term, and cumulative effects on riparian, surface-water and ground-water resources.

A summary of some of the major categories of USGS research and investigations related to concentrated animal feeding operations follows:

- PHARMACEUTICALS (antibiotics and endocrine disruptors): Reconnaissance sampling of 100 streams across the United States is underway to provide baseline data on the occurrence of antibiotics in streams. Occurrences of antibiotics will be compared with predominant animal types for respective watersheds.

- PATHOGENS (viruses, bacteria, and protozoa): Streams and ground water adjacent to high-density animal production facilities are being sampled for pathogens in five States.

- NUTRIENTS (nitrates, ammonia, phosphorus): Monitoring the water quality of springs in a region of northern Arkansas populated with poultry AFOs is ongoing to determine the nonpoint source of nutrient contamination.

- METALS, TRACE ELEMENTS, AND PESTICIDES: The fate and transport of these contaminants in runoff from dairy operations in California is being investigated.

- TECHNOLOGY AND METHODS DEVELOPMENT: Analytical methods to detect low concentrations of some of the most prevalent classes of pharmaceutical compounds are being developed and validated. DNA testing is being conducted to determine the source (poultry or cattle) of fecal-coliform contamination in Missouri streams. RNA ribotyping techniques are

being developed and applied to track the source of microorganisms in Virginia streams and ground water near AFOs. Age dating and nitrogen isotope ratio analyses are being applied to ground-water samples in Colorado to determine the origin of elevated nitrate and ammonia. Computer models, such as SPARROW, are being developed and adapted to assist water-resource managers in their decision-making.

7.6 Stream Visual assessment

Visual assessment (cover instream, fine sediments, flow pattern, bank conditions, pressures (riparian), width of riparian zone, litter, overall assessment) performed at 27 locations pointed out a few stream segments that have qualifiers "marginal" and "poor" for overall assessment conditions (see Figure 33).

The following table shows the DRBC concept of the visual assessment of small streams.

Table 7-3. Visual assessment of small (wadeable) streams, the creek and surrounding area for 50 yds. upstream and 50 yds. downstream of the sampling site.

ASSESSMENT FACTOR	RESPONSE			
	EXCELLENT	GOOD	MARGINAL	POOR
1. Instream cover (habitat for fish & aquatic organisms)	The stream contains lots of boulders (over 10"), cobble (2-10"), submerged logs, undercut banks or other stable habitat	There is adequate habitat of both rock & wood for maintenance of diverse populations of fish & bugs	Some rock and wood or other stable habitat, but much less than desirable	Not much stable habitat; lack of habitat is obvious
2. Fine particle sediments (sand, silt, mud)	The rocks in the stream are not surrounded by fine sediments; I see very little sand, silt, or mud on the bottom	Rocks are partly surrounded by fine sediments; I could easily flip over the rocks on the bottom	Rocks are more than half surrounded by fine sediments; rocks are firmly stuck into sediments	Rocks are deeply stuck into fine sediments; bottom is mostly sand, silt, or mud

3. "Flow patterns": How many does the stream have?	All 4 of these velocity/depth patterns are present within 50 yards upstream or downstream of this site: **slow/deep, slow/shallow, fast/deep, fast/shallow**	Only 3 of 4 regimes (flow patterns) are present	Only 2 of the 4 regimes present	Dominated by 1 velocity/depth regime
4. Condition of banks & coverage? (If the two banks are very different, assess the worse side, if possible)	The banks are stable; no evidence of erosion or bank failure; the whole bank is covered with vegetation or rock	Moderately stable; some small areas of erosion mostly healed over; most of the bank is covered by vegetation or rock	Largely unstable; almost half of the bank has areas of erosion or is NOT covered by vegetation or rock	Unstable; eroded areas; "raw" areas occur frequently; less than half of the bank is covered by vegetation or rock
5. Disruptive pressures to the "riparian" area? (If the two banks are very different, assess the worse side, if possible)	Trees, shrubs, or grasses have not been disturbed through forestry, grazing or mowing; almost all plants are growing naturally; mature trees, understory, and vegetation are present	Some disruption, but not affecting full plant growth potential to any great extent; trees, woody plants, and soft green plants are dominant	Disruption is obvious; some patches of bare soil, cultivated fields or closely cropped vegetation are the norm	There is not much natural vegetation left or it has been removed to 3 inches or less in average stubble height
6. Riparian vegetative zone width (If the two banks are very different, assess the worse side, if possible)	Riparian zone is more than 35 yards wide; human activities (parking lots, roads, learcuts, lawns, or crops) have not impacted zone	Riparian zone 12-35 yards wide; human activities have impacted zone only minimally	Width of riparian zone 6-12 yards; human activities impacting zone are commonly evident	Width of riparian zone is less than 6 yards; lots of nearby human activities

7. Litter	There is no litter in the area	There is very little litter in the area; probably some degradable paper accidentally dropped by fishermen or hikers	Litter is fairly common and includes metal or plastic, obviously purposely dropped.	Area is a candidate for a clean-up project; lots of litter, dumping, tires, or barrels present
8. Overall I rate the VISUAL ASSESSMENT of this site ...	EXCELLENT	GOOD	MARGINAL	POOR

DEFINITIONS:
Riparian zone - The land connected with or immediately adjacent to the banks of a stream or other body of water.
Disruptive pressure - Any activities, which interfere with the natural unity of a system. In the case of riparian assessment, this usually refers to land use practices such as mowing, grazing, logging, paving, building construction, heavily worn paths, etc.
Habitat - The "places" where a plant or animal normally lives and grows throughout all the phases of its life cycle.
Stable Habitat - The condition in which places used for hiding, resting, reproducing, living, and growing are not undergoing rapid or constant change. In the case of stream assessment, this is usually referring to large rocks, logs, and undercut banks which are more or less permanently in place.

As noted in the Tabel 7-7, marginal and poor stream condition (cover instream, bank conditions and riparian pressures) was assessed throughout the watershed. However most of them are crossing roads. These locations are: SW8, SW11, SW14, SW15, SW16, SW17, SW21, SW22, SW23, and SW25. For location of visual assessment station see Figure 2.

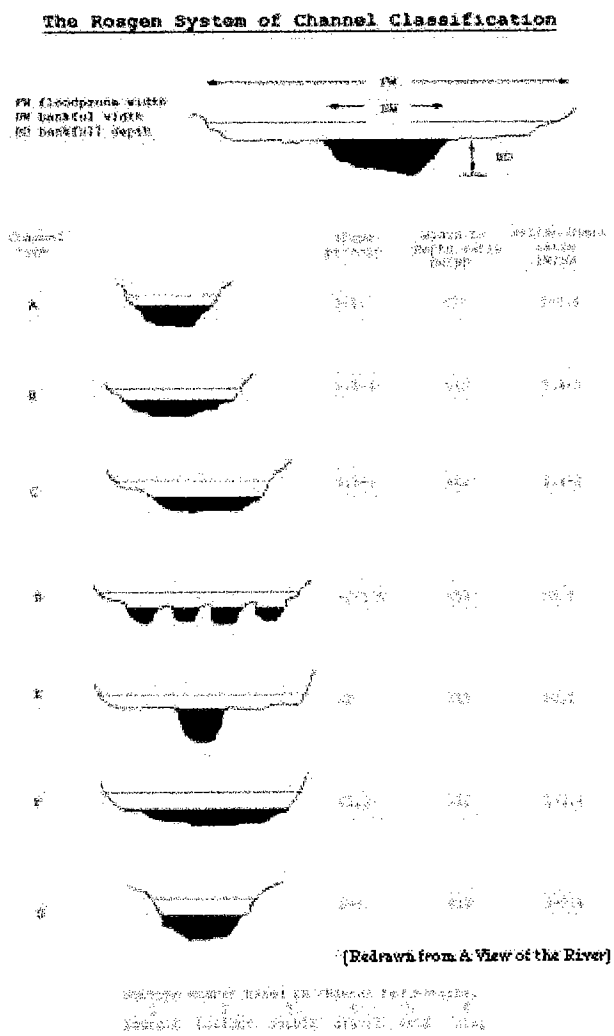
7.7 Stream Morphology Stability

The most widely accepted method of describing channel morphology has been proposed by David L. Rosgen. Basically, the Rosgen system of channel classification is modeled after parameters of form and pattern. Of importance is its ability to elucidate channel behavior, which can be important to restoration efforts and provide clues of deviation from normal river conditions.

Under the Rosgen system of classification, river types are the result of a combination of channel slope, substrate (bed) material, width to depth ratio, sinuosity (meandering), and the degree of lateral constraint and confinement. The Rosgen Classification System has seven types ranging

from A to G and various subclasses that describe the size and coarseness of parent material. Generally, most channel types are in the A to D range with subclasses between 2 and 6.

The morphology survey completed for Cooks Creek shows significant longitudinal (upstream or downstream) change in character and class under natural conditions as a result of varying substrate material, entrance of tributaries, or change in landscape. Summaries of field morphology survey are presented in Table 7-8 and Table 7-9.



In Natural Stability Concept natural stream channel stability is achieved by allowing the stream to develop a stable dimension, pattern, and profile such that, over time, channel features are maintained and the stream system neither aggrades nor degrades Finally, stream observation data is to be used to understand past treatments and responses to the following questions:

- What caused the problem?

- How did the stream respond?
- What was the consequence of the stream response?
- How can we remedy the problem?
- How can we prevent the problem?

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.