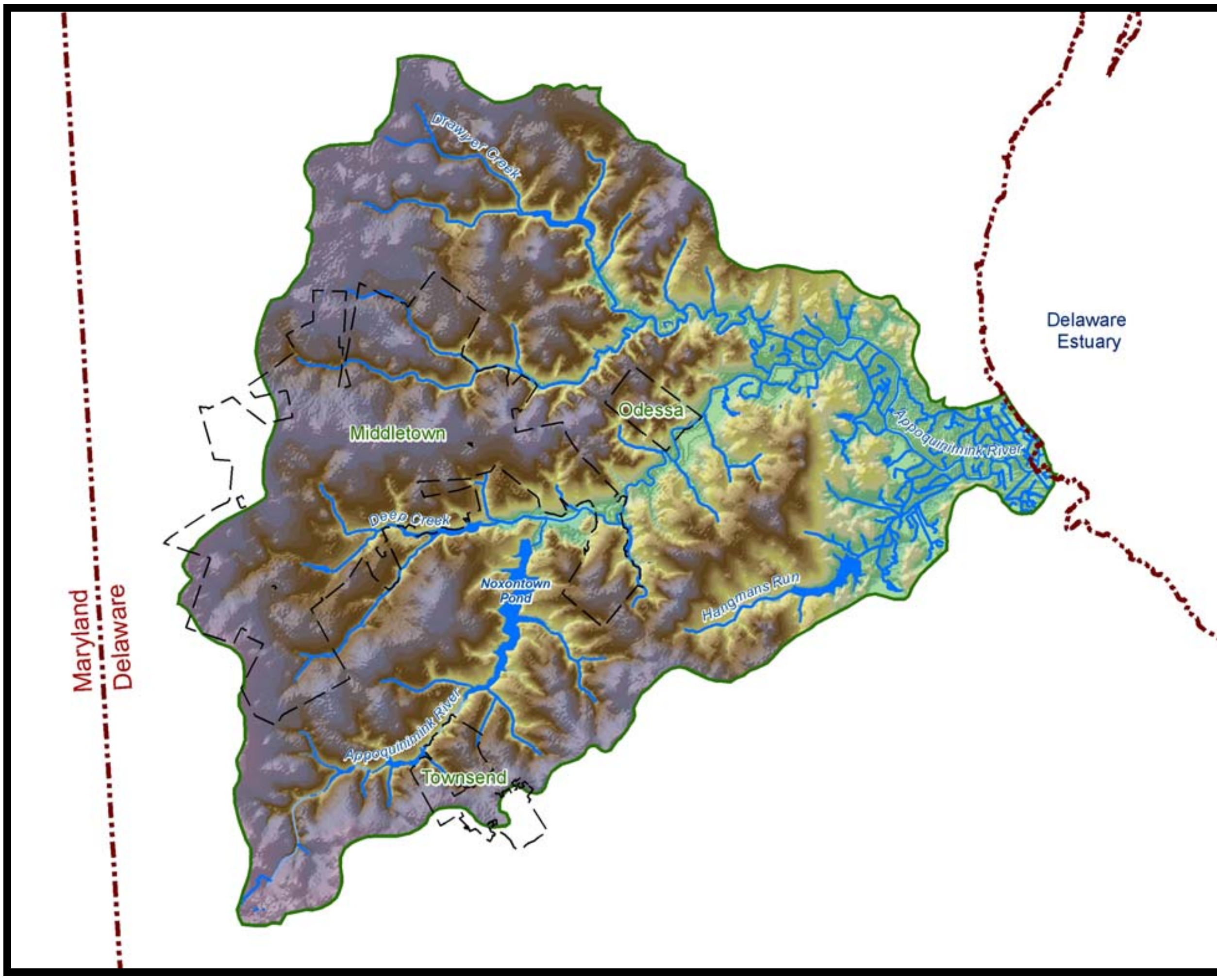
APPOQUINIMINK RIVER WATERSHED STORMWATER MANAGEMENT PLAN



NEW CASTLE COUNTY, DELAWARE

FINAL

May 14, 2010

BL PROJECT NO. 2006-2013-01

APPOQUINIMINK RIVER WATERSHED STORMWATER MANAGEMENT PLAN

NEW CASTLE COUNTY, DELAWARE

VOLUME I - EXECUTIVE SUMMARY

FINAL

May 14, 2010

BL PROJECT NO. 2006-2013-01

PREPARED FOR:

DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL
Division of Soil and Water Conservation
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VOLUME I - EXECUTIVE SUMMARY

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PLAN FORMAT

The format of the Appoquinimink River Watershed Stormwater Management Plan consists of Volume I, the Executive Summary, Volume II, the Plan Report, and Volume III, the Background Technical Materials.

Volume I provides an overview of the why the Plan was needed and a summary of the standards and criteria developed for the watershed. Volume II, the Plan Report, provides an overview of stormwater management, purpose of the study, data collection, all GIS maps, present conditions, projected land development patterns, calculation methodology, and implementation discussion. Volume III provides supporting data, watershed modeling parameters and modeling runs, peak flows, release rates, the existing municipal ordinance matrix, and obstructions inventory. Due to large volumes of data, one copy of Volume III will be on file at DNREC office and one at the New Castle Conservation District office. Large-scale copies of the figures are at the DNREC office and at the New Castle Conservation District office.

A. Introduction

This Plan was developed for the Appoquinimink River watershed in New Castle County, Delaware to partially comply with the requirements of § 4001, Chapter 40, Title 7, of the Delaware Code. The amendment to Chapter 40, Title 7 provides for the establishment of a statewide comprehensive and coordinated erosion and sediment control and stormwater management program to conserve and protect land, water, and other resources of the state. This program is to take into consideration both the quantity and quality of water resources within the state. The Department of Natural Resources and Environmental Control, (DNREC) is required to develop a State Stormwater Management Program in conjunction with appropriate state and federal agencies, conservation districts, other governmental subdivisions of the state, and the regulated community. The code imposes duties, and confers power to the Department of Natural Resources and Environmental Control, conservation districts, municipalities, and counties, and provides for enforcement and appropriations. The amendment gives the DNREC the authority to develop and publish guidelines and criteria for delegation of stormwater program requirements, and the authority to review the implementation of all components and review and approve designated watersheds. The Act requires DNREC to establish criteria for approval of designated watersheds and develop guidelines for stormwater management standards and criteria for application within those designated watersheds.

This Plan was compiled to record the findings of the Appoquinimink Watershed Study and document the rationale used to develop standards and criteria for the watershed that are necessary to implement the Plan. The primary focus of the Plan is on engineering and municipal topics which are directly and indirectly related to stormwater. A thorough understanding of these interrelated stormwater issues is necessary to form the basis of the Plan which will be adopted by each municipality within the watershed. Upon approval of this Designated Watershed Plan, all proposed projects within the Appoquinimink River watershed will have stormwater requirements placed upon them that are consistent with the Plan.

B. Watershed Description

The Appoquinimink River watershed is located in the southern portion of New Castle County, Delaware. It is one of the first major watersheds located to the south of the Chesapeake and Delaware Canal. The watershed encompasses the towns of Middletown, Odessa, and Townsend. The remainder of the watershed is located within New Castle County. Of the three urban centers located within the watershed, Middletown covers the largest geographic area and is located in the western portion of the watershed. Odessa is the second largest urban area and is located in the center of the watershed with Townsend situated on the southwestern border of the watershed.

C. Drainage Area

The Appoquinimink River watershed has a total drainage area of approximately 46.6 square miles. There are many tributaries that contribute flow to the river. Major tributaries of the Appoquinimink River include: Appoquinimink River Main Stem, Doves Nest Branch, Drawyer Creek, Deep Creek, Noxontown Pond and Hangmans Run. The main stem of the Appoquinimink is approximately 16 miles long and originates about 2 miles west of Townsend in the southwest part of the watershed. The main stem of the river travels in a northeast direction towards the Town of Odessa, then changes direction about 2 miles east of Odessa, where it flows in a southeast direction until it discharges into the Delaware River Estuary. Large portions of the eastern half of the watershed area comprised of tidal marshes and wetlands and there are several sizeable ponds or lakes located throughout the watershed (Shallcross Lake, Silver Lake, Wiggins Mill Pond, Noxontown Pond and an unnamed pond on Hangmans Run).

D. Methodology

The Plan was developed from data collected on the physical features of the watershed, such as soils, wetlands, topography, floodplains, dams and reservoirs, stream dimensions, and obstructions. Information on existing problem areas was solicited from the Steering Committee which consisted of representatives from DNREC, the municipalities within the watershed, as well as other interested parties including the New Castle County Conservation District, Appoquinimink River Association, Delaware Department of Transportation and others. Although the Plan is not geared solely toward solving existing problems, knowing where and why they exist aided the engineer in developing the sub-watersheds, identifying points of interests, and understanding the hydrologic flow of the watershed as a whole. Information on existing land use and zoning was also collected. This helped the engineer to determine where and to what extent future development would take place. All of this data was compiled into a geographic information system (GIS) database.

The computer model used for the project was the US Army Corps of Engineers Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS). This model was chosen for the project because it can be easily adapted to an urban and/or rural area, it has the ability to analyze reservoir or detention basin-routing effects, and it is accepted by most state and federal agencies. To gain a realistic picture of how stormwater is generated in the Appoquinimink River watershed and moves through the watershed, the model, which was created using the Delmarva Unit Hydrograph, was calibrated using target flows developed from regression models and data obtained from the Federal Emergency Management Administration (FEMA).

The process of determining how stormwater runoff flows through the watershed is a complex one. The hydrologic model of the Appoquinimink River watershed was developed with sixty-nine (69) subareas, ranging in size from nine (9) to fourteen hundred (1,400) acres. Using the calibrated hydrologic model the hydrographs of each of these subareas was evaluated at four (4) separate points of interest to understand how watershed timing impacts the flow in different parts of the Appoquinimink River. This analysis was then used to establish management districts for the watershed to better manage post construction stormwater runoff. For this study, the 2-, 10-, 25-, 50-, and 100-year storms were modeled.

A precipitation and annual runoff analysis was conducted for the watershed in which the model was used to determine the amount of rainfall that is equivalent to 90% of the annual runoff volume from the watershed. This analysis determined that 90% of the annual runoff occurs from events that provide precipitation depths equivalent to approximately the 1-year storm. In addition to the aforementioned hydrologic modeling efforts, the Plan also identified and performed a cursory evaluation of significant obstructions and problem areas within the watershed. This was completed in order to help the municipalities to prioritize, plan and program needed infrastructure improvements within the watershed.

E. Standards and Criteria

All of the modeling efforts completed for this study were conducted in order to better understand the watershed and establish standards and criteria for the management of stormwater within the watershed. Therefore, all regulated activities not otherwise exempt from the standards and criteria set forth in this Plan are required to implement stormwater management controls defined by this Plan. Generally, they are as follows:

1. *Groundwater Recharge Volume is equivalent to the difference between the volume of stormwater runoff for the 2-year post-construction runoff and the 2-year, 24-hour existing condition. The NRCS Runoff Equation shall be used to calculate the existing and post-construction stormwater runoff volumes. To compensate for the large amount of agricultural land cover in the Appoquinimink River watershed, the existing conditions stormwater runoff volume shall be calculated with a composite curve number that is based upon a minimum of no less than twenty-five (25) percent of the existing non-forest, non-meadow land cover calculated as meadow.*

   Unless it can be conclusively demonstrated with on-site testing that physical site constraints preclude the use of infiltration practices, the recharge volume shall be permanently removed from the stormwater runoff leaving any development site. In the event that site conditions limit but do not preclude the use of infiltration practices, BMPs shall be installed to promote as much infiltration as reasonably practicable based upon the constraints established from on-site testing.

2. *Water Quality Volume shall be equal to the first one (1) inch of excess stormwater runoff flowing off the disturbed area proposed for construction. The Water Quality Volume shall be treated as follows:*

   i. *The water quality volume shall be detained on site and released over a period of not less than 24 hours.*

   ii. *The water quality volume shall not be discharged from the site until it has been conveyed through or treated by no less than two stormwater BMPs. These BMPs may consist of any combination of nonstructural and structural BMPs. Nonstructural BMPs such as disconnection of impervious surface, filter strips, revegetation, reduced impervious surface, level spreaders shall precede structural BMPs such as detention basins, wet ponds and infiltration trenches/basins.*

   iii. *All excess stormwater produced from proposed disturbed areas on the site associated with proposed construction shall be treated as part of the water quality volume. It shall be unacceptable to only manage a portion of the disturbed area and allow other disturbed areas proposed for construction to flow off of the site untreated by a BMP. In cases where it can be* *demonstrated that achieving this standard may require significantly more disturbance to the environment than not implementing this standard, this criteria may be waived upon approval from DNREC.*

iv. *If the Groundwater Recharge Volume is greater than the Water Quality Volume and it can be demonstrated that the full groundwater recharge volume is recharged on-site, the water quality requirements shall be considered satisfied.*

v. *If the fraction of the Groundwater Recharge Volume that is recharged on-site is greater than the Water Quality Volume then water quality requirements shall be considered satisfied.*

3. *Streambank Erosion within the Appoquinimink River watershed shall be managed by reducing the post-construction rate of release of stormwater flow for the 2-year, 24-hour design storm from sites within the watershed to rates that are no greater than fifty (50) percent of the existing condition discharge rate from the sites. To achieve this standard, all points of concentrated discharge from development sites shall be maintained as close as reasonably practical to existing points of discharge.*

   No less than twenty-five (25) percent of the existing non-forested, non-meadow land cover shall be considered as meadow when determining the streambank erosion target flows.

   The 2-year, 24-hour design discharge at any given point of concentrated discharge whose entire drainage area has not been disturbed but only contains a fraction of the entire drainage area which is disturbed as a result of a change in the existing land cover shall be reduced in proportion to the amount that the disturbed area contributes to the 2-year, 24-hour peak rate of discharge.

4. *Tidal Marsh Habitat - A vegetated buffer shall be established around the perimeter of all marshes within Appoquinimink River watershed which shall be measured at a distance of no less than one-hundred-fifty (150) feet from the mean daily high water level of the marshes within the Appoquinimink River watershed. The vegetated buffer shall be maintained in a natural condition with dense vegetation and without disturbance. Properly stabilized outfalls may be constructed within the vegetated buffer as long as all earth disturbance necessary to construct or maintain the facility is immediately revegetated with native plant species after constructing the outfall or performing maintenance. No development including stormwater management facilities shall be permitted within the buffer area adjacent to a tidal marsh.*

5. *Overbank Events and Extreme Events - The peak rate of post-construction discharge to manage overbank events from a development site or a site in which a change to the existing land cover is proposed shall not exceed the peak rate of release as identified on the Management District Map, Map V-1. No less than twenty-five (25) percent of existing non-forested, non meadow land cover shall be considered as meadow when determining release rates.*

F. Implementation

All municipalities within the watershed that administer their own Subdivision/Land Development ordinances will be required to adopt the standards and criteria set forth Appoquinimink River Watershed Stormwater Management Plan. The standards and criteria contained in this Plan will apply only to those portions of the municipality that are located within the boundaries of the Appoquinimink River watershed. The areas outside of the watershed will still be regulated by the municipality's Subdivision/Land Development Ordinance unless otherwise written so as to apply to other areas of the municipality.

APPOQUINIMINK RIVER WATERSHED STORMWATER MANAGEMENT PLAN

NEW CASTLE COUNTY, DELAWARE

VOLUME II - PLAN CONTENTS

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APPOQUINIMINK RIVER WATERSHED DESIGNATED STEERING COMITTEE (SC) MEMBERS
As of May 14, 2010

Organization	SC Designee
New Castle County Department of Land Use	John Gysling Engineer
New Castle County Department of Special Services	Mike Harris Environmental Program Manager
Appoquinimink River Association Delaware and Department of Natural Resources & Environmental Control,	Sara Wozniak Watershed Coordinator
New Castle County, Town of Middletown	Morris Deputy Town Manager
Delaware Department of Natural Resources & Environmental Control	David Twing State Dam Safety Engineer
Delaware Department of Natural Resources & Environmental Control	Elaine Webb Engineer
Delaware Department of Natural Resources & Environmental Control	Randell Greer Engineer
Delaware Department of Natural Resources & Environmental Control	Jennifer Walls Principal Planner
Delaware Department of Natural Resources & Environmental Control	Frank Piorko Administrator, Drainage & Stormwater Section
A.D. Marble & Company	Andrew Parker Senior Environmental Scientist
Delaware Department of Transportation	Marianne Walch, Ph.D. Environmental Scientist
Delaware Department of Transportation	Randall Cole Environmental Program Manager

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SECTION I

INTRODUCTION

A. Introduction

This Plan has been developed for the Appoquinimink River watershed in New Castle County, Delaware to partially comply with the requirements of § 4001, Chapter 40, Title 7, of the Delaware Code. The amendment to Chapter 40, Title 7 provides for the establishment of a statewide comprehensive and coordinated erosion and sediment control and stormwater management program to conserve and protect land, water, and other resources of the state. This program is to take into consideration both the quantity and quality of water resources within the state. The Department of Natural Resources and Environmental Control, (DNREC) is required to develop a State Stormwater Management Program in conjunction with appropriate state and federal agencies, conservation districts, other governmental subdivisions of the state, and the regulated community. The code imposes duties, and confers power to the Department of Natural Resources and Environmental Control, conservation districts, municipalities, and counties, and provides for enforcement and appropriations. The amendment gives the DNREC the authority to develop and publish guidelines and criteria for delegation of stormwater program requirements, and the authority to review the implementation of all components and review and approve designated watersheds. The Act requires DNREC to establish criteria for approval of designated watersheds and develop guidelines for stormwater management standards and criteria for application within those designated watersheds.

The Appoquinimink River watershed is part of the Delaware Estuary basin, and drains approximately 46.6 square miles to the Appoquinimink River. The Appoquinimink River flows through agricultural lands in the headwaters to wetlands and tidal marshes that extend from the central portions of the watershed to the confluence with the Delaware River. The Appoquinimink River watershed is located predominantly in southern New Castle County and it is one of the first major watersheds located to the south of the Chesapeake and Delaware Canal.

This Plan was compiled to record the findings of the Appoquinimink Watershed Study and document the rationale used to develop standards and criteria for the watershed that are necessary to implement the Plan. The primary focus of the Plan is on engineering and municipal topics which are directly and indirectly related to stormwater. A thorough understanding of these interrelated stormwater issues is necessary to form the basis of the Plan which will be adopted by each municipality within the watershed. Upon approval of this designated watershed Plan, all proposed projects within the Appoquinimink River watershed will have stormwater requirements placed upon them that are consistent with the Plan.

B. Stormwater Control and Management

According to § 4001, Chapter 40, Title 7, of the Delaware Code, the General Assembly has noted that erosion and sedimentation from uncontrolled stormwater runoff continues to be a serious problem and a detriment to the environment. Problems with improper stormwater management affect not only habitat within the state but domestic, agricultural, industrial and recreational uses of water resources as well. These problems are partially attributable to changes in stormwater runoff rate, volume, velocity and quality. Effective stormwater management requires managing all aspects of surface runoff, caused by precipitation events.

Historically, stormwater management was only applied on a site-specific basis. However, in recent years, perspectives and policies on effective stormwater management have changed. It is now widely recognized and accepted that effective stormwater management can only be achieved through comprehensive evaluation and control of stormwater runoff and its effects upon all water resources within a watershed, both on the surface and below the ground. (i.e., impacts a development in a watershed's headwaters upon downstream flooding). Truly effective stormwater management controls flooding, prevents soil and streambank erosion, reduces sedimentation, maintains groundwater and improves the overall quality of the receiving streams.

C. Purpose of the Study

Typically, development in a watershed causes an increase in stormwater runoff and a reduction in groundwater recharge. A number of negative effects result from uncontrolled stormwater runoff including streambank erosion, sedimentation, reduced baseflow, depleted groundwater levels, downstream flooding, diminished aquatic habitat and poor water quality. These problems manifest themselves locally and are typically magnified in the downstream reaches of the watershed as the problems compound and accumulate to the point where large, complex problems are created in downstream segments of the watershed. For example, increased flows due to development can cause erosion of stream banks resulting from accelerated stormwater velocities in streams. The sediment that is eroded in the upstream segments of the watershed can be deposited in downstream segments of streams, alter geometric configurations of natural channels, which in turn can cause flooding. Large scale flooding can create potential safety issues and result in property damage, which requires large sums of money to mitigate and restore damaged areas. The same is possible with water quality issues. Increased development often results in stormwater runoff raising the temperature of the streams, and reducing dissolved oxygen levels which in turn impair the aquatic food chain. Reduced baseflow of streams can further impair aquatic life during the drier summer months. Industries and recreational activities that depend on this aquatic life are then indirectly affected by ineffective stormwater management.

There is an increased statewide as well as local recognition that a sound and effective stormwater management plan requires a diversified multi-faceted approach. Comprehensive management plans for water resources should address the full range of hydrologic consequences resulting from development. This can only be accomplished by considering a range of impacts to water resources brought on by development and its effect upon runoff volume, streamflow, baseflow, water quality and habitat rather than simply focusing on controlling peak rate of flow from a single site.

Managing stormwater runoff on a site-specific basis does not meet the precepts of watershed based planning. This is because what may appear acceptable as a management practice for a specific site may not necessarily be beneficial for the watershed as a whole. Understanding how one portion of the watershed interacts with another is essential to creating a watershed-based management plan. Watershed timing is an important aspect of the interaction of one portion of the watershed with another. Timing greatly effects streamflow within a watershed and contributes significantly to the flooding potential for a particular storm. For example, detaining and slowly releasing stormwater from lower sections of a watershed can potentially increase the peak flow in downstream sections of the watershed by delaying the peak and allowing it to combine with peaks from other upstream portions of the watershed. Thus, it is important that each stormwater management facility within a watershed be developed by understanding the relationship of the individual facility and management strategy with respect to the entire watershed.

The Appoquinimink River Watershed Stormwater Management Plan provides standards and criteria for development activities within the watershed to better manage stormwater runoff and protect the health, safety and welfare of the public. Policies, regulations and laws from the federal, state, county and municipal level, are incorporated into this Plan's hydrologic analysis to develop a watershed-wide stormwater management plan for the Appoquinimink River. Once fully implemented, the Plan will aid in reducing future costs associated with inadequately or poorly managed water resources. The Plan will help municipalities and developers become more aware of comprehensive planning of stormwater and will help maintain the quality of the Appoquinimink River and its tributaries.

SECTION II

GENERAL DESCRIPTION OF WATERSHED

The Appoquinimink River watershed is located in the southern portion of New Castle County, Delaware. It is one of the first major watersheds located to the south of the Chesapeake and Delaware Canal. The watershed encompasses the towns of Middletown, Odessa, and Townsend, as illustrated in Table II-1 below and in Map II-1, the Base Map. The remainder of the watershed is located within New Castle County. Of the three urban centers located within the watershed, Middletown covers the largest geographic area and is located in the western portion of the watershed. Odessa is the second largest urban area and is located in the center of the watershed with Townsend situated on the southwest border of the watershed.

TABLE II-1
Appoquinimink River Watershed – Municipalities

New Castle County
Town of Middletown
Town of Odessa
Town of Townsend

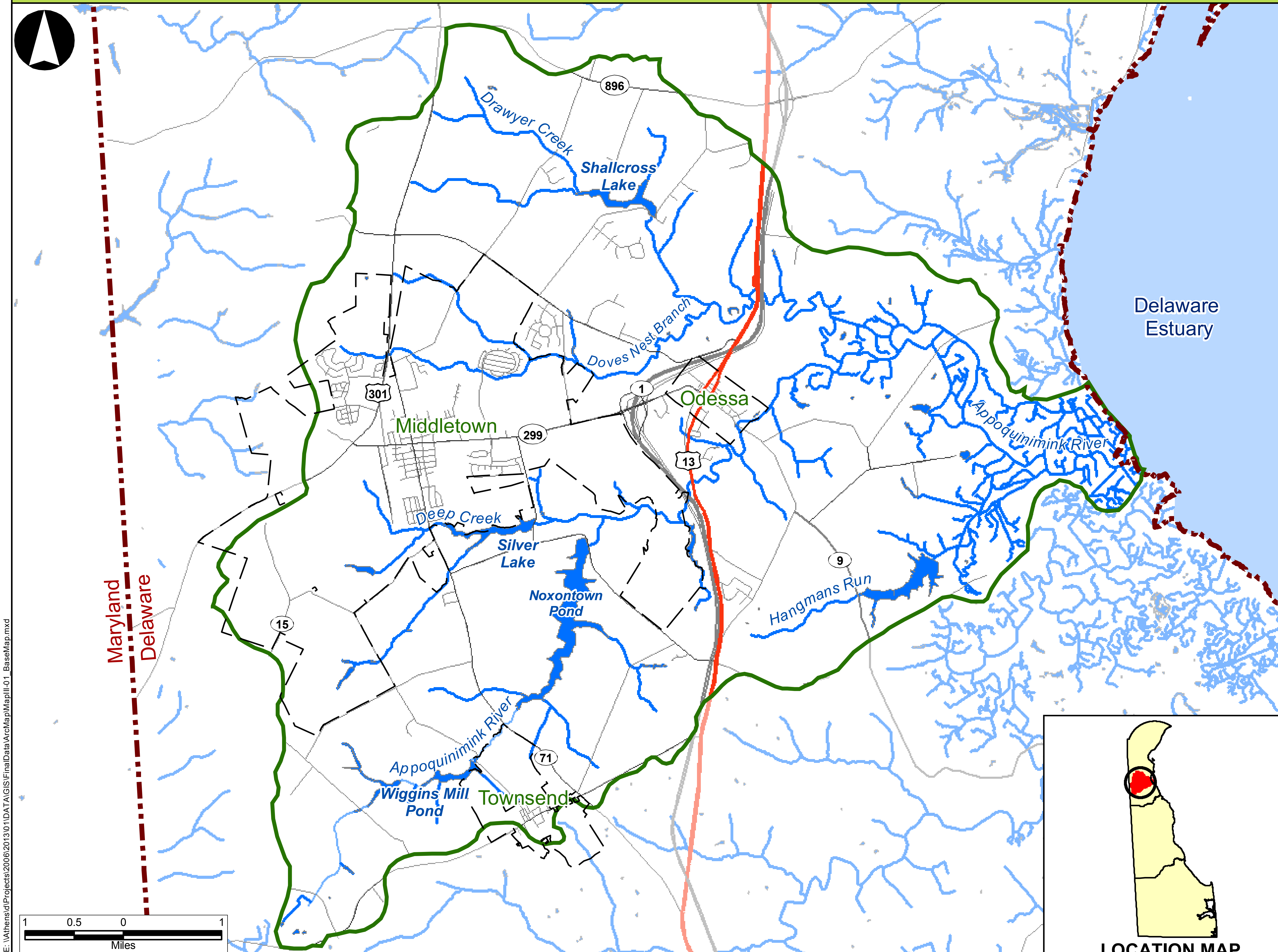
A. Drainage Area

The Appoquinimink River watershed has a total drainage area of approximately 46.6 square miles. There are many tributaries that contribute flow to the river. Major tributaries of the Appoquinimink River include: Appoquinimink River Main Stem, Doves Nest Branch, Drawyer Creek, Deep Creek, Noxontown Pond and Hangmans Run. The main stem of the Appoquinimink is approximately 16 miles long and originates about 2 miles west of Townsend in the southwest part of the watershed. The main stem of the river travels in a northeast direction towards the Town of Odessa, then changes direction about 2 miles east of Odessa, where it flows in a southeast direction until it discharges into the Delaware River Estuary. Large portions of the eastern half of the watershed area are comprised of tidal marshes and wetlands and there are several sizeable ponds or lakes located throughout the watershed (Shallcross Lake, Silver Lake, Wiggins Mill Pond, Noxontown Pond and an unnamed pond on Hangmans Run).

The major traffic routes in the Appoquinimink River watershed include U.S. Routes 13 and 301 and Delaware State Routes 1, 9, 15, 71, and 299. U.S. Route 13 is aligned in a north-south direction for approximately 11 miles through the center of the watershed and generally divides the watershed into east and west sections. The highway appears to be the former major north-south thoroughfare through this portion of the state and passes directly through the Town of Odessa located in the center of the watershed. State Route 1 essentially parallels U.S. route 13 through the center of the watershed and appears to be a modern highway designed to reduce the amount of through traffic using Route 1 to pass through this portion of the state. Given the large amounts of traffic volume using these thoroughfares, the U.S. Route 13 and Delaware Route 1 corridor are considered to have high development potential. U.S. Route 301 and Delaware State Route 71 cross the western portion of the watershed and are aligned in a north/south direction.

APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN

MAP II-1: BASE MAP



Legend

- State Boundaries
- Municipal Boundaries
- Watershed Boundary
- Water Bodies
- Estuary
- Appoquinimink River
- Artificial Paths
- Perennial Streams
- Intermittent Streams
- U.S. Highways
- State Highways
- Other Roads

Prepared For:
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NOTES:
Portions of this map were generated from the existing data sources noted below. Certain elements of the base map such as municipal boundaries, railroad locations, stream alignments and road networks are provided primarily for reference purposes only and were not directly used for hydrologic computations. In the development of the mapping Borton-Lawson has noted some inconsistencies in the data used for the map. Where obvious inconsistencies in the geographic data were observed the data was adjusted, as needed, to prepare a reasonably accurate map. Although the geographic data was adjusted to compensate for these inconsistencies it is not part of the work plan for this project to correct mapping inconsistencies. Therefore, some geographic inconsistencies may remain on the map.

DATA SOURCES:
Watershed Boundary - DNREC (Modified by BLE)
Roads - DelDOT
Counties - DelDOT
Municipalities - DelDOT
Streams - U.S. Geological Survey, and U.S. EPA
Water Bodies - DNREC

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DATE: 1/12/2010
CHECKED BY: SJD
PROJECT NO.: 2006-2013-01

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State Route 301 enters the watershed in the northwest section of the watershed and exits the watershed to the west of Middletown. State Route 71 intersects U.S. Route 301 north of Middletown and exits the watershed near Townsend. Route 9 crosses over Hangmans Run in the southeastern portion of the watershed. A small segment of State Route 15, approximately 1.5 miles, crosses the western portion of the watershed. Route 15 travels for approximately 1.5 miles in a north-south direction through the western portion of the watershed. Route 299 runs in an east-west direction for about 5.7 miles and passes through the towns of Middletown and Odessa.

B. Data Collection for Physical Feature of the Watershed

In order to evaluate the hydrologic response of the watershed, data was collected on the physical features of the watershed and mapped using GIS as follows:

1. **Base Map:** The watershed boundary and water body GIS data was received from the Delaware Department of Natural Resources and Environmental Conservation (DNREC) and the road, municipal boundary, and county boundary data are from the Delaware Department of Transportation (DelDOT). Stream data was obtained from the U.S. Geological Survey.

   The Appoquinimink River watershed boundary was overlaid on USGS topographic maps to ascertain accuracy. Minor adjustments to the boundary were made based on the USGS topographic maps.

2. **Elevation Data:** A Digital Elevation Model (DEM) for the Appoquinimink River watershed was developed from DEM data obtained from the USGS. Subwatersheds or subareas used in the watershed modeling process were derived from the DEM. Subareas, drainage courses, land slopes and lengths, and drainage element lengths and slopes could all be determined from the DEM.

3. **Soils:** Soil mapping data developed by the Natural Resource Conservation Service was obtained from the Delaware Department of Natural Resources and Environmental Control (DNREC).

4. **Geology:** The digital geology coverage for New Castle County was obtained from the Delaware Geological Survey at the University of Delaware.

5. **Land Cover:** Land cover data was created in 2002 by EarthData International of Maryland for the Delaware State Geographic Data Committee. The existing land cover map was generated by overlaying the year 2002 land cover data on year 2006 aerial photographs and then using parcel data and heads up digitizing to update the land cover data and improve the spatial accuracy.

6. **Wetlands:** Wetlands were obtained from the United States Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) in digital format and incorporated into GIS for the project. NWI maps are compiled from photo interpreted aerial photography from the National Aerial Photography Program (NAPP) 1:40,000 Scale, and the National

High Altitude Photography Program (NHAP) 1:58,000 or 1:80,000 Scale. Source dates range from the 1970's to the present. The wetlands data is provided for reference and illustrative purposes only. It is possible that there are additional wetland areas that exist in the watershed that are not depicted on NWI maps.

C. Topography

The topography of the watershed is relatively flat with the highest elevation in the watershed only about 89 feet above sea level. The highest elevation in the watershed is situated on the watershed boundary about a half mile north of the southwest tip of the watershed. The lowest elevation, approximately 3 feet below sea level, is found at the western part of Silver Lake, with much of the area adjacent to the main stem of the river and east of U.S. Route 13, near the confluence of the Appoquinimink River and the Delaware Estuary at sea level. The Digital Elevation Model (DEM) for the watershed is provided in Map II-2. The low flat topography of the eastern portion of the watershed makes much of the area susceptible to tidal influences and as a result there are many tidal marshes adjacent to the main stem of the Appoquinimink River and its tributaries. As the terrain is relatively flat throughout the watershed, the slope of the river is also relatively flat with the average slope of the main stem of the river at 0.0008ft/ft.

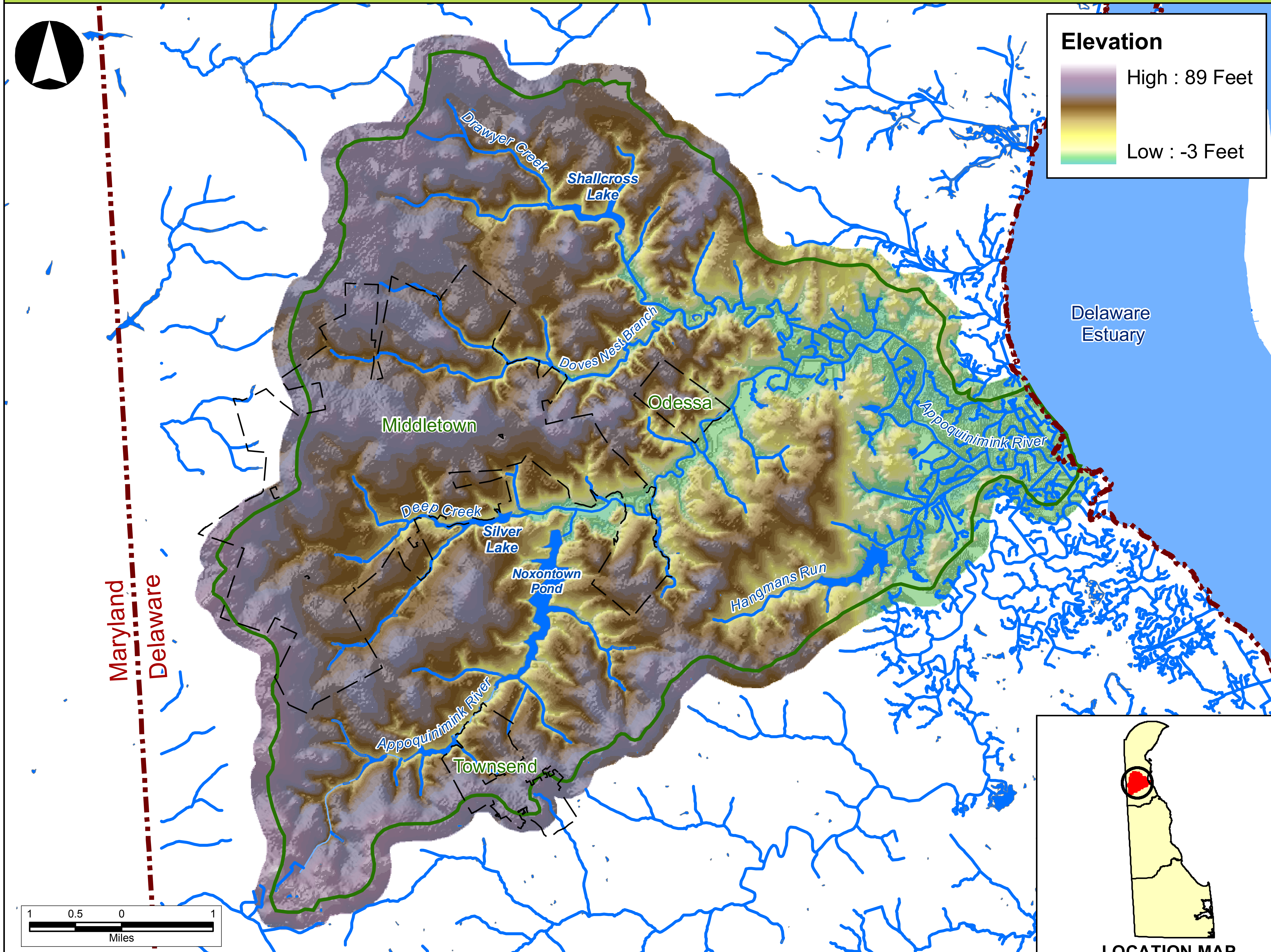
D. Soils

The spatial distribution of permeable soils within the Appoquinimink River watershed are shown in Map II-3 and the common soils series located within the watershed are listed in Table II-2. Permeability of these soils varies based upon soil characteristics such as soil structure, porosity, gradient and texture. Each of these characteristics influences the downward movement of water through the soil and the ability of the soil to infiltrate a portion of the stormwater flow across and through it. Soil permeability is measured at rates in inches per hour and is classified as follows: *very slow* (less than 0.06 inches/hr); *slow* (0.06 to 0.20 inches/hr); *moderately slow* (0.20 to 0.60 inches/hr); *moderate* (0.60 to 2.0 inches/hr); *moderately rapid* (2.0 to 6.0 inches/hr); *rapid* (6.0 to 20.0 inches/hr); and *very rapid* (more than 20.0 inches/hr) (NRCS USDA). These rates vary based upon soil layer, or depth below the surface.

Map II-4 shows erodible soils in the watershed. The map, with information provided by DNREC, shows the erodibility hazard indicating the level of erosion controls necessary when disturbing soils. The erodibility hazard is divided into four classifications ranging from slight to severe, which is indicative of the degree of major soil limitations within the series that must be considered when developing management strategies for earth disturbance. A slight rating indicates that the risk of soil erosion is low, rating of moderate indicates that erosion control are necessary during earth disturbance activities, and a rating of severe indicates that erosion potential is a severe hazard when disturbing these soils. Approximately 49% of the area within the Appoquinimink River watershed is classified as moderately erodible soils and about 38% is considered slightly erodible. Small pockets of moderately to severe and severely erodible soils (about 10%) are found along the Appoquinimink River and its tributaries. Approximately 0.15% of the area in the watershed is classified as Urban Land/Made Land, which does not have an erodibility classification.

APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN

MAP II-2: DIGITAL ELEVATION MODEL (DEM)



Legend

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- Municipal Boundaries
- Watershed Boundary
- Water Bodies
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- Perennial Streams
- Intermittent Streams

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DATA SOURCES:
Watershed Boundary - DNREC (Modified by BLE)
States - DelDOT
Streams - U.S. Geological Survey, and U.S. EPA
Water Bodies - DNREC
DEM - USGS

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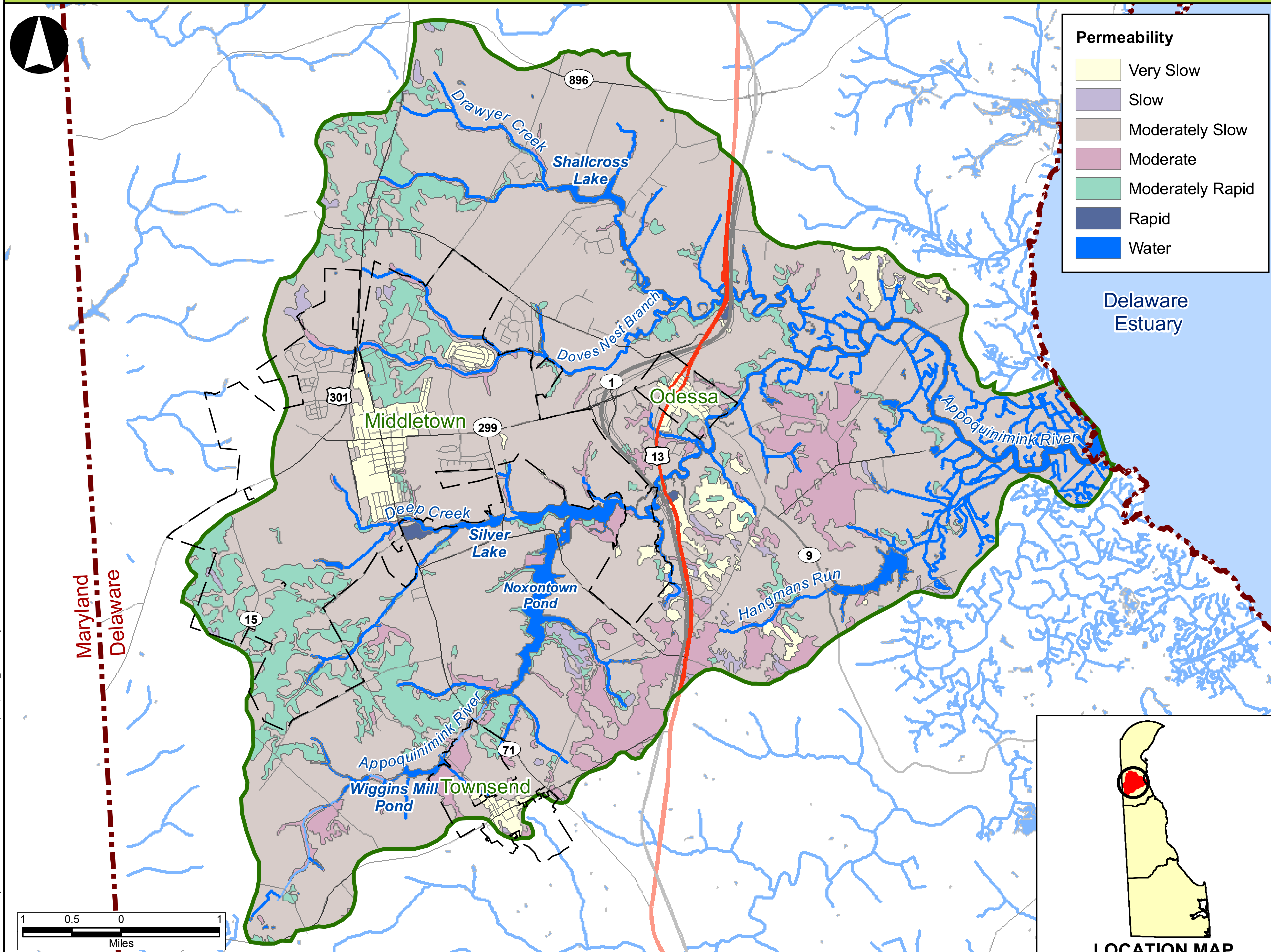
PROJECT NO.: 2006-2013-01



APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN

MAP II-3: PERMEABILITY

Legend

- State Boundaries
- Municipal Boundaries
- Watershed Boundary
- Water Bodies
- Estuary
- Appoquinimink River
- Artificial Paths
- Perennial Streams
- Intermittent Streams
- U.S. Highways
- State Highways
- Other Roads

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Roads - DelDOT
Counties - DelDOT
Municipalities - DelDOT
Streams - U.S. Geological Survey, and U.S. EPA
Water Bodies - DNREC
Soils - DNREC

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PROJECT NO.: 2006-2013-01

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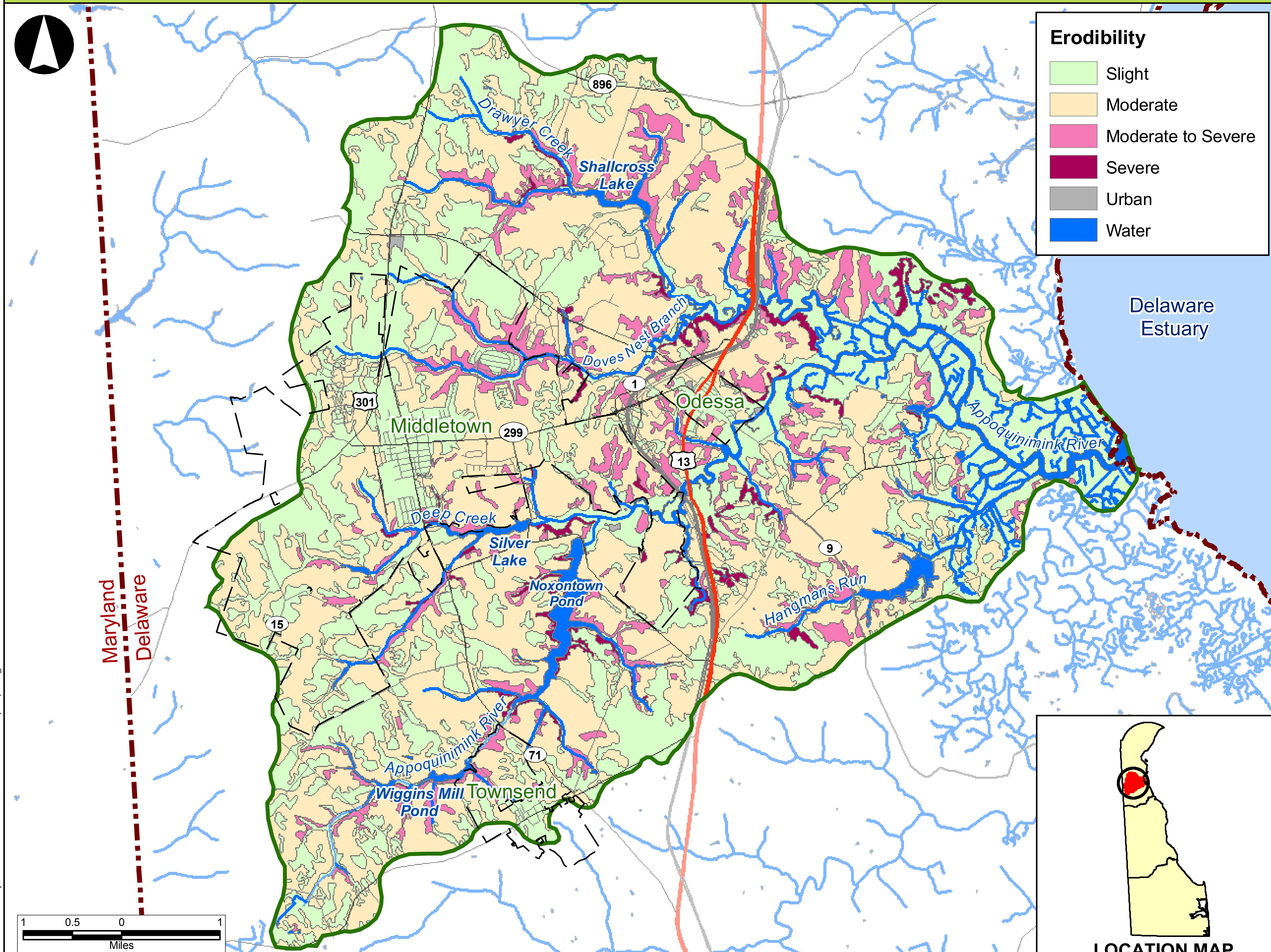

APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN

MAP II-4: ERODIBLE SOILS

Legend

- State Boundaries
- Municipal Boundaries
- Watershed Boundary
- Water Bodies
- Estuary
- Appoquinimink River
- Artificial Paths
- Perennial Streams
- Intermittent Streams
- U.S. Highways
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Streams - U.S. Geological Survey, and U.S. EPA
Water Bodies - DNREC
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TABLE II-2
Appoquinimink River Watershed Soils

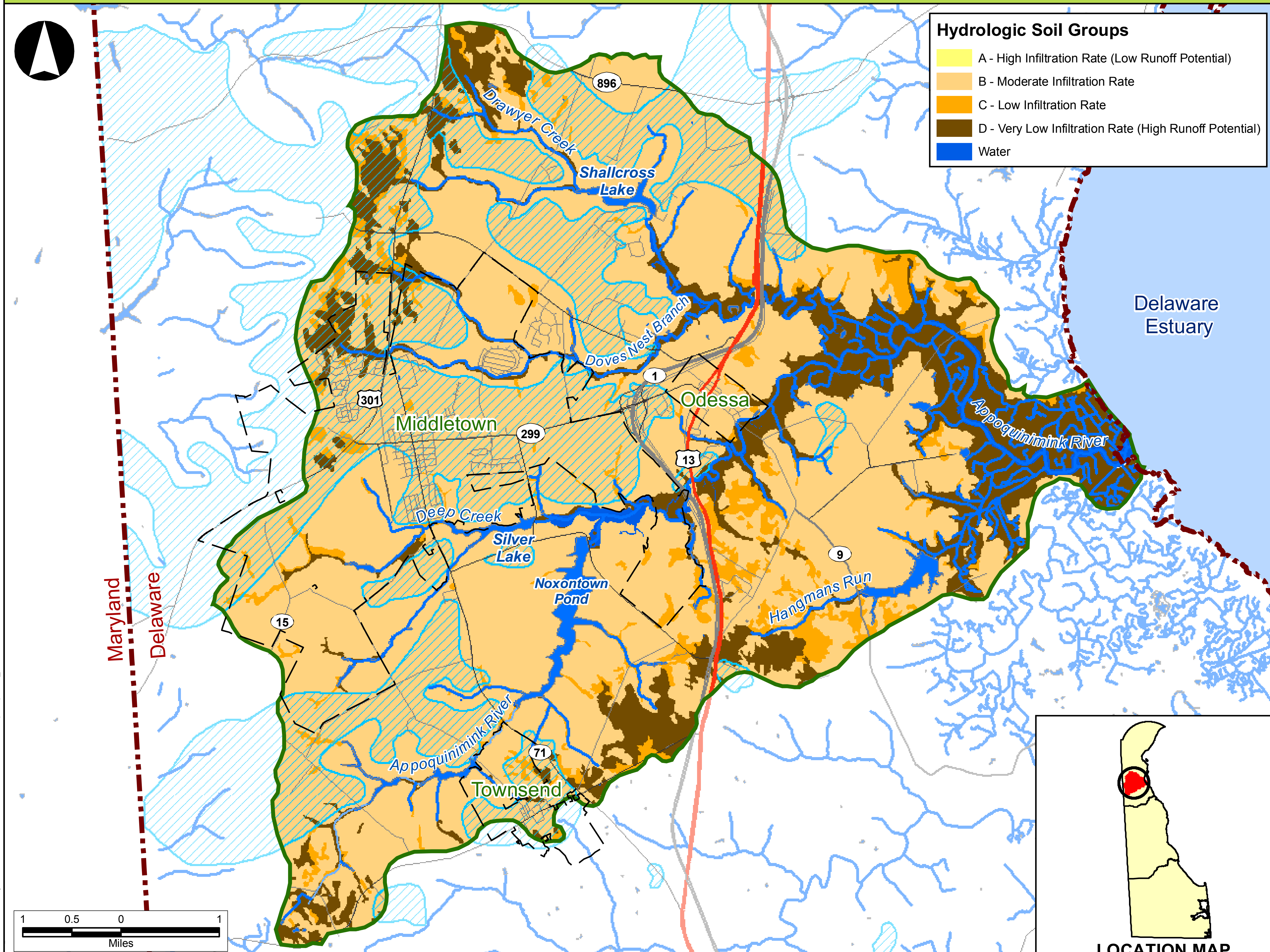
Soil Series	Drainage Classification	Permeability	Hydrologic Soil Group
Collington	Well Drained	Moderate to Moderately Slow	B
Downer	Well Drained	Moderately Rapid to Moderate	B
Fallsington	Poorly Drained	Moderate to Moderately Slow	B/D
Hambrook	Well Drained	Rapid to Slow, depending on horizon	B
Hammonton	Moderately Well Drained	Moderately Rapid to Moderate	B
Keyport	Moderately Well Draindded	Slow to Very Slow	C
Lenni	Poorly Drained	Rapid to slow depending on horizon	C/D
Othello	Poorly Drained	Moderately Slow	C/D
Reybold-Hambrook	Well Drained	Moderate	B
Reybold-Sassafras	Well Drained	Moderate to Moderately Slow	B
Sassafrass	Well Drained	Moderate to Moderately Slow	B
Udorthents	Variable	Variable	Variable
Woodstown	Moderately Well Drainded	Moderate	C

The soil properties influence the amount of surface runoff produced by any given precipitation event. The United States Department of Agriculture Natural Resource Conservation Service (NRCS) established a criterion to estimate the hydrologic response of soils to precipitation by dividing the soils into one of four different hydrologic soil groups (A, B, C, and D). The hydrologic soil groups for the Appoquinimink River watershed are shown in Map II-5.

There are no A soils, which have a high infiltration rate and low runoff potential within the Appoquinimink River watershed. The majority of soils within the watershed are within group B. Group B is characterized as having moderate infiltration rates, and consists primarily of moderately deep to deep, moderately well to well drained soils that exhibit a moderate rate of water transmission. Group C soils, found sporadically throughout the watershed, have slow infiltration rates when thoroughly wetted and contain fragipans, a layer that impedes downward movement of water and produces a slow rate of water transmission. D soils are tight, low permeable soils, with low transmission rates through the soil strata. Group D soils are located primarily in the Tidal Marshes of the watershed, along the main stem of the river and its tributaries and at the mouth of the watershed. There are also some sporadic areas of D soils along the southern and western boundaries of the watershed.

APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN

MAP II-5: HYDROLOGIC SOIL GROUPS



Legend

- State Boundaries
- Municipal Boundaries
- Watershed Boundary
- Water Bodies
- Estuary
- Recharge Areas
- Appoquinimink River
- Artificial Paths
- Perennial Streams
- Intermittent Streams
- U.S. Highways
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Municipalities - DelDOT
Water Bodies - DNREC
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Streams - U.S. Geological Survey, and U.S. EPA
Soils - DNREC
Recharge Areas - DNREC

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Runoff potential is the ability of a certain soil or land cover to produce stormwater runoff, which ultimately influences both the rate and volume of stormwater runoff. Typically, Group A soils present the lowest runoff potential, or have the least capacity to produce runoff for a given amount of precipitation. Conversely, Group D soils have the highest runoff potential or the capacity to yield the greatest amount of runoff in a given event. In stormwater management it is also important to consider groundwater recharge. Recharge is the replacement of groundwater by the infiltration of surface water. With Group A soils having the least runoff potential, these soils have the greatest ability to recharge groundwater supplies because of their high permeability. Conversely, as Group D soils have the greatest runoff potential, these soils typically have low permeabilites and as such have low groundwater recharge capacities. Therefore, it is generally considered better to develop areas that naturally produce more runoff, such as Group C and D soils, than it is to develop in areas that naturally produce less runoff such as Group A and B soils. The rationale behind this statement is that as areas become more developed they become more impervious and less capable of infiltrating surface water. Thus, covering a soil that has a low runoff potential with impervious surface will generate more runoff than covering a soil with higher runoff potential with the same amount of impervious surface. By covering the soil with a low runoff potential with impervious surface, the water resources within the area are essentially experiencing a double impact. Not only is there more runoff being generated, potentially causing more flooding and more erosion problems in the streams, the areas capable of recharging the greatest amount surface water to the groundwater supplies are no longer available, thus depleting groundwater levels and ultimately impacting baseflow to streams.

Map II-5 also shows groundwater recharge areas within the watershed. Groundwater recharge areas were identified by Delaware Geological Survey and the Delaware Water Resources Agency in 2002 and updated in 2006. These areas, characterized by their abilities to infiltrate water from land surfaces into underlying soil and rock, were identified based on a methodology developed in Delaware Geological Survey Open Files Report No. 34. Field work, laboratory and GIS data were reviewed for wells, test borings and single-well aquifer tests to develop recharge potential areas to a depth of 20 feet for New Castle County and across the state. Most of the recharge areas are located west of U.S. Route 13, in the western part of the watershed. It is very important that creation of impervious surface and compaction of the soils in these recharge areas be limited and that the areas are maintained with pervious surfaces as much as possible to reduce surface runoff and maintain groundwater levels in the watershed.

Another factor related to soils and groundwater recharge that influences stormwater resources is depth to groundwater. Many areas in the eastern half of the watershed have high groundwater elevations. In these areas, the soils are not capable of infiltrating significant amounts of groundwater because they are limited by the proximity of the groundwater to the surface of the ground. As the movement of groundwater from one area to another can be very slow, the ability of the ground to infiltrate surface water is reduced in these high groundwater areas. Typically, it is best to have a separation distance between the bottom of a stormwater management facility and the groundwater table to provide infiltration storage volume and facilitate the trapping and removing of nonpoint source pollutants transported by stormwater by the soil. Without this buffer, nonpoint source pollutants can be directly conveyed to the groundwater supplies.

E. Geology

Geology plays a direct role in surface runoff in Appoquinimink River watershed because it affects the type of soil within the watershed. It is through the weathering and breakdown of the geologic formations in the watershed that the various types of soils are created. The geologic formations are important to water resources within the watershed as the voids and fractures within the rock are capable of either holding or transmitting water. A geologic formation that is capable of either holding or transmitting water is called an aquifer. Formations that have significant interconnected fractures act as the best aquifers. Conversely, geologic formations with few interconnected fractures or voids are not good aquifers. As a watershed becomes more developed and more impervious there is less area available to help recharge the aquifers below the soil and, as such, the groundwater supply is more quickly diminished and is more sensitive to drought conditions. The geologic formations found in the Appoquinimink River watershed are shown on Map II-6. A description of geologic formations in the watershed is provided below.

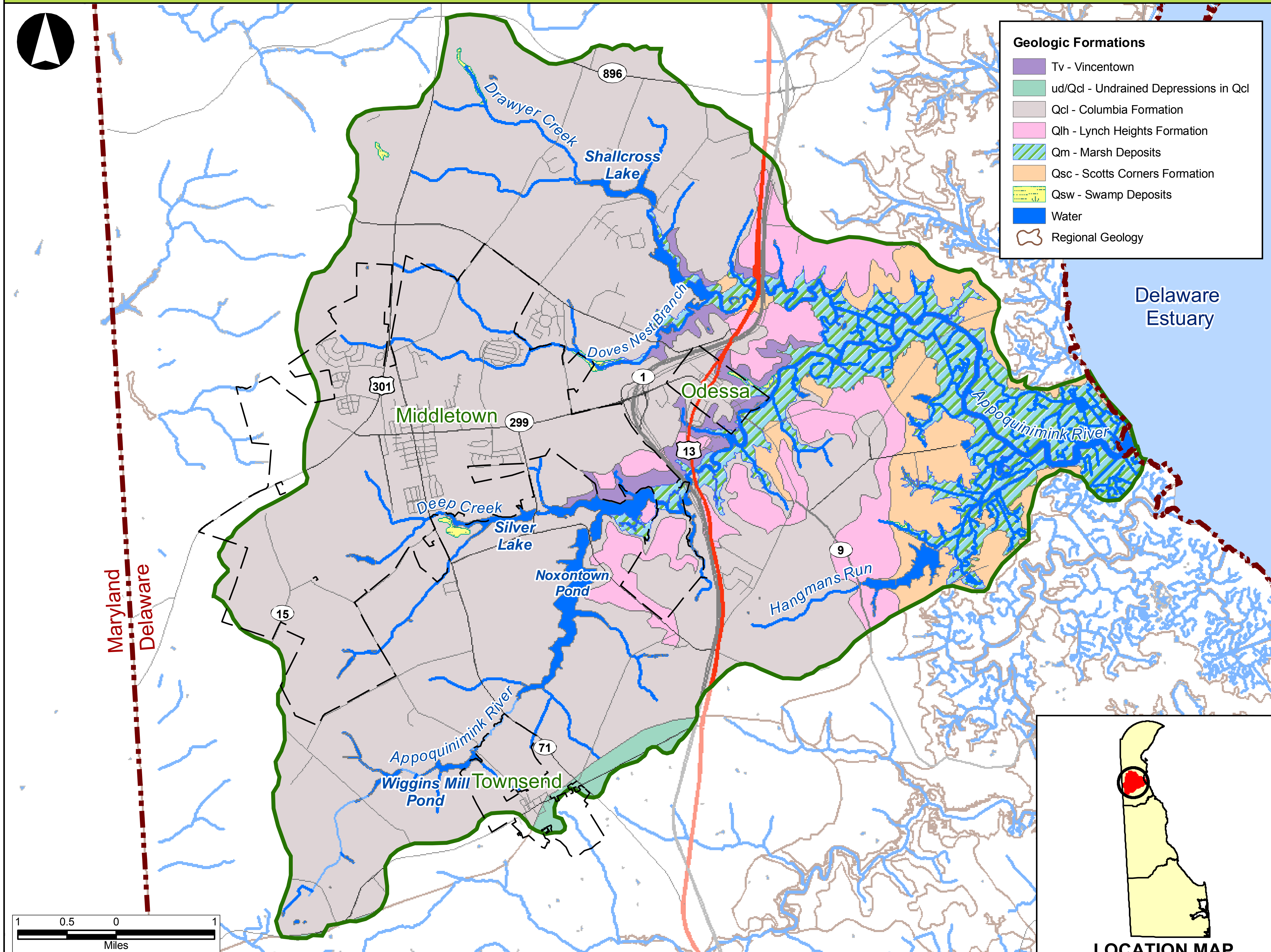
1. **Qcl – Columbia Formation (middle Pleistocene):** Yellowish to reddish-brown, fine to coarse, feldspathic quartz sand with varying amounts of gravel. Typically cross-bedded with cross-sets ranging from a few inches to over three feet in thickness. Scattered beds of tan to reddish-gray clayey silt are common. In places, the upper 5 to 25 feet is a grayish to reddish-brown silt to very fine sand overlying medium to coarse sand. Near the base of the unit, clasts of cobble to small boulder size features are found in a gravel bed ranging from a few inches to three feet thick. Gravel fraction consists primarily of quartz with lesser amounts of chert. Clasts of sandstone, siltstone, and shale from the Valley and Ridge Province, and pegmatite, micaceous schist, and amphibolite from the Piedmont are present. The Columbia fills an eroded surface and ranges from less than 10 feet thick to over 100 feet. Primarily a body of glacial outwash sediment (Jordan, 1964; Ramsey, 1997). Pollen indicates deposition in a cold climate during middle Pleistocene (Greet and Jordan, 1999).

2. **Qlh – Lynch Heights Formation (upper Pleistocene):** A heterogeneous unit of light-gray to brown to light yellowish brown, medium to fine sand with discontinuous beds of coarse sand, gravel, silt, fine to very fine sand, and organic-rich clayey silt to silty sand. Upper part of unit commonly consists of fine, well-sorted sand. Small-scale cross-bedding within the sands is common. Some interbedded clayey silts and sands are burrowed. Beds of shell rarely encountered. Sands are quartzose, slightly feldspathic, and typically micaceous where very fine to fine grained. Unit underlies a terrace parallel to present Delaware River that has elevations between 50 and 30 feet. Interpreted to be a fluvial to estuarine unit of fluvial channel, tidal flat, tidal channel, beach, and bay deposits (Ramsey, 1997). Overall thickness rarely exceeds 20 feet.

3. **Qm – Marsh Deposits (Holocene):** Structureless to finely laminated, black to dark-gray, organic-rich silty clay to clayey silt with discontinuous beds of peat and rare shells (Ramsey, 1997). In-place or transported fragments of marsh grasses such as Spartina are common. Includes some clayey silts of estuarine channel origin. Map area delineated on the distribution of salt-tolerant marsh grasses. Thickness ranges between 1 and 40 feet.

APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN

MAP II-6: GEOLOGY



Legend

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Water Bodies - DNREC
Geology - Delaware Geological Survey, University of Delaware

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4. **<u>Qsc - Scotts Corner Formation (upper Pleistocene):</u>** A heterogeneous unit of light-gray to brown to light-yellowish-brown, coarse to fine sand, gravelly sand and pebble gravel with rare discontinuous beds of organic-rich clayey silt, clayey silt, and pebble gravel. Sands are quartzose with some feldspar and muscovite. Commonly capped by one to two feet of silt to fine sandy silt. Laminae of opaque heavy minerals common. Unit underlies a terrace parallel to the present Delaware River that has elevations less than 25 feet. Interpreted to be a transgressive unit consisting of swamp, marsh, estuarine channel, beach, and bay deposits. Climate during deposition was temperate to warm temperate as interpreted from fossil pollen (Ramsey, 1997). Overall thickness rarely exceeds 15 feet.

5. **<u>Qsw – Swamp Deposits (Holocene):</u>** Structureless, black to brown, organic-rich, silty and clayey, fine to coarse quartz sand with thin interbeds of medium to coarse quartz sand. Organic particles consist of leaves, twigs, and larger fragments of deciduous plants in stream valleys. In stream valleys, swamp deposits fine upward and grade laterally with salt marsh deposits toward the Delaware River. Defined primarily on the presence of deciduous vegetation in stream valleys (Ramsey, 1997). On uplands, consist of dark to light-gray clayey silt and very fine to coarse sand. Characterized by areas of seasonally standing water, internal drainage, and hydrophyllic trees. From 1 to 20 feet thick.

6. **<u>Tv – Vincentown Formation (Paleocene):</u>** Glauconitic sand that ranges from slightly silty to moderately silty and slightly to moderately clayey. Dominant constituent is subrounded to subangular clear quartz sand that ranges from medium to fine grained. Fine-grained glauconite is a secondary constituent, which ranges from 5 percent in the clayey zones to 15 percent where cleaner. Towards bottom of unit, glauconite percentages increase to about 50 percent of the sand fraction. Silty and clayey zones are thin to thick laminae ranging from 0.01 to 0.5 feet thick. Olive gray to dark-yellowish-brown in zones where iron cement is present. Interpreted to be marine in origin. Rarely occurs in outcrop and is covered by colluvium along the stream valley bluffs where shown on the map. Ranges from 50 to 100 feet in thickness in the subsurface and less than 50 feet thick where it is cut by younger deposits updip.

7. **<u>ud/Qcl – Undrained Depression Deposits (upper Pleistocene to lower Holocene):</u>** A belt of upland depressions that stretches across southern New Castle County. Sometimes referred to as Delmarva Bays, are irregular in shape and have internal drainage not integrated with any stream network. Filled with organic-rich woody silts to gray medium to coarse quartz sand (Webb, 1990). Some have a sandy rim at their margins. During wet periods, many are filled with water. Because of the abundance and relative small size (<500 foot diameter), individual basins are not mapped; rather, a pattern indicates the extent of these units where they overlie the Columbia Formation. Largest depressions appear as areas of swamp. Radiocarbon dates (Webb, 1990) indicate ages from 11,000 B.P. to Recent.

F. Streambank Erosion Inventory

A.D. Marble & Company conducted an assessment of streambank erosion and stability within the Appoquinimink River watershed in conjunction with the development of this watershed Plan. The study focused on fifteen data points that were previously studied by the Center for

Watershed Protection in 2005. As part of the analysis a Severe Erosion Form, Bank Erosion Hazard Index and Near Bank Stress were completed for each site. Standardized forms examining various geomophological characteristics of the watershed's streambanks were collected to continue to monitor the degradation of the streambanks and channels of the watershed in order to provide metrics pertaining to the degradation. The survey showed increased runoff from agriculture and residential development has lead to increased bed and bank erosion at the previously studied sites since the time of the original study in 2005. The study further indicated that the sediment deposited within the watershed's tributaries and streams has the potential to adversely impact aquatic habitat. For additional information on the Streambank Inventory, see the A.D. Marble Report entitled, *Appoquinimink Watershed Assessment Streambank Erosion Inventory and Tidal Marsh Assessment Summary Report*, dated May 2009.

G. Tidal Marsh Impairment Assessment

A.D. Marble & Company conducted a study in which they assessed tidal marsh impairment at four sites within the Appoquinimink River watershed. The purpose of the study was to compare "pristine" sections of tidal marsh and tidal streams with impacted areas to determine if any indicators of stress could be observed and measured in the watershed's waters. The ultimate objective was to identify factors that could be used as possible metrics to monitor the health of the tidal marshes and streams. As this was primarily a qualitative assessment of only two marshes and two stream segments, no key indicators impairment were identified by the study. Three possible reasons for the absence of readily identifiable indicators of the health of the marshes and streams examined were offered by the conclusion of the study.

1. The "pristine" wetlands sued as the reference sites in the study may be as equally impaired as the impaired sites studied.
2. The methodologies used to complete the qualitative analysis may not be robust enough to identify differences between the pristine sites and the impaired sites.
3. The sample size examined by the study: four sited; two impaired sites and two "pristine" sites; may have been too small a sample size to identify an indicator.

For additional information on the Tidal Marsh Assessment, see the A.D. Marble Report entitled, *Appoquinimink Watershed Assessment Streambank Erosion Inventory and Tidal Marsh Assessment Summary Report*, dated May 2009.

H. Climate

The Appoquinimink River watershed is located in lower middle portion of the New Castle County. According to the FIS, the climate of New Castle County is characterized by warm summers, when the temperatures can rise above 85 degrees Fahrenheit (°F), and cool winters, when the temperature can fall below 20 °F. In winter, the average temperature is 34.3 °F and the average daily minimum temperature is 26.1 °F. The average annual total precipitation is about 42.0 inches with the major portion of the precipitation occurring in the late spring.

I. Land Cover

The landscapes of the Appoquinimink River watershed vary from rural to densely suburban. Map

II-7 displays the existing land cover of the watershed based on 2002 land use data that was adjusted for existing conditions based on 2006 aerial photography. Table II-3 identifies the major land cover types within the Appoquinimink River watershed by category.

TABLE II-3
Land Cover Status by Category

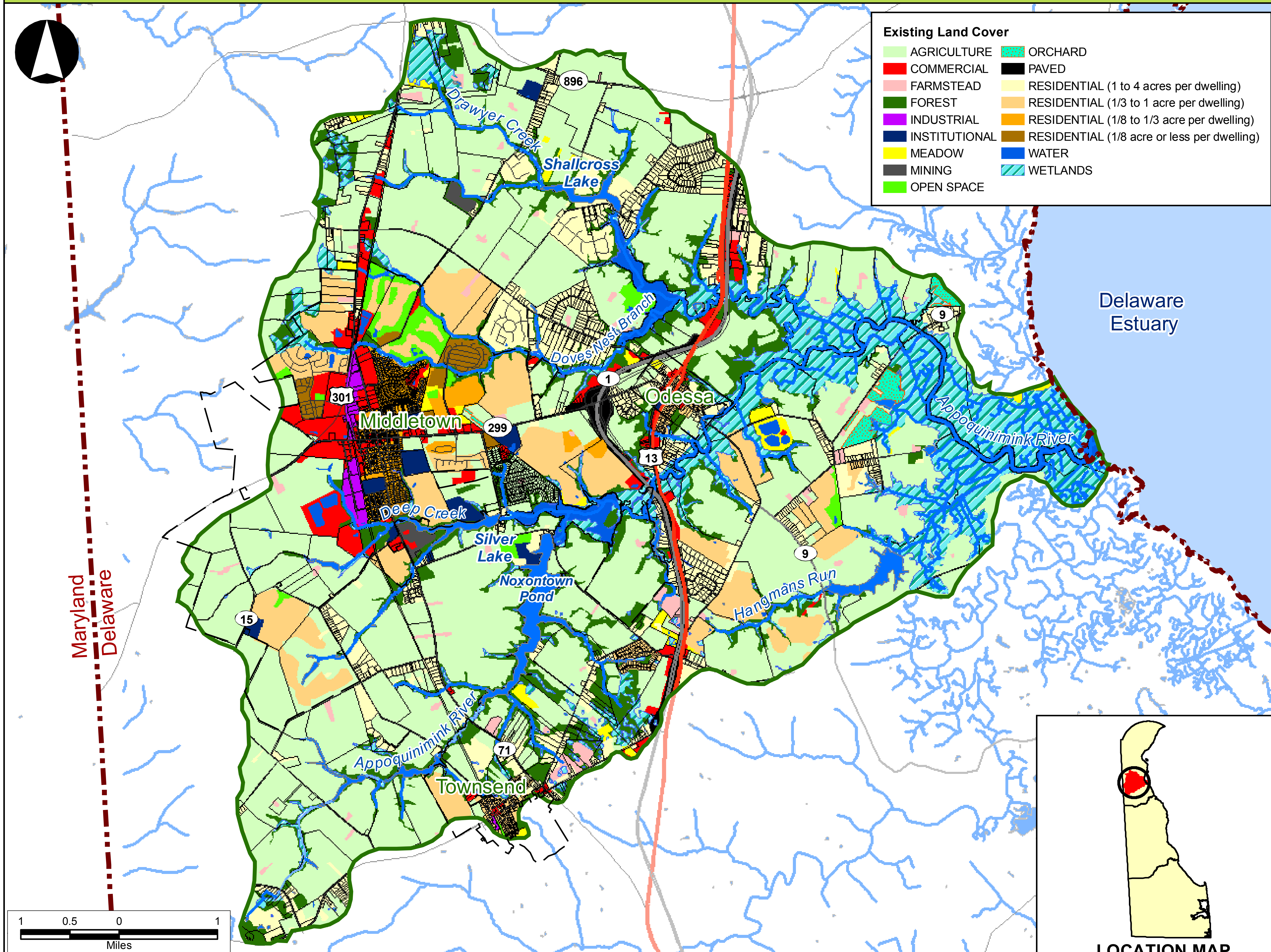
LAND COVER	SQUARE_MILES	ACRES	PERCENT_AREA
Agricultural	20.9	13,368	44.8
Commercial	1.5	949	3.2
Farmstead	0.5	347	1.1
Forest	3.8	2,450	8.2
Industrial	0.2	141	0.5
Institutional	0.4	240	0.8
Meadow	0.4	239	0.8
Mining	0.1	70	0.2
Open Space	0.5	332	1.1
Orchard	0.2	137	0.5
Paved	0.6	409	1.4
Residential (1 - 4 acre lots size)	4.5	2,868	9.6
Residential (1/3 – 1 acre lot size)	4.0	2,501	8.4
Residential (1/8 – 1/3 acre lot size)	0.8	517	1.7
Residential (1/8 acre or less lot size)	0.4	229	0.8
Water	2.0	1,308	4.4
Wetlands	5.8	3,728	12.5
TOTAL	**46.6**	**29,840**	**100%**

While the majority of the watershed is undeveloped, low-density residential areas are dispersed throughout the watershed and higher-density development is found in the western portion of the watershed in and around the towns of Middletown and Odessa. The predominant land use in the watershed is classified as agricultural (44.8%) with the next highest land cover classifications categorized as low density residential (1-4 acre lot size) and wetlands. Approximately 20.5% of the watershed is residential land and wetlands account for 12.5% of the land cover.

Land cover is very important to and integrally related to stormwater runoff. Typically as a watershed becomes more developed, the pervious surface is covered by more impervious surface, (i.e., pavement, buildings) allowing less infiltration to occur into the ground and resulting in increased surface water runoff (both rate and volume). Furthermore, as the watershed becomes more developed, the watershed becomes more interconnected, thus reducing the time it takes water to flow through the watershed and increasing the peak rate of runoff. This manifests itself in larger flows in the streams and more frequent flooding. It also creates streambank erosion problems, causing bank instability and the deposition of sediment into the watershed's streams, which affects the aquatic habitat. For more information on land use and its impact upon the watershed, see the study, *Southern New Castle County Priority Watershed Strategy*, prepared by the Institute of Public Administration at Delaware University.

APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN

MAP II-7: EXISTING LAND COVER



Legend

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- Municipal Boundaries
- Parcel Boundaries
- Watershed Boundary
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Land Cover - Delaware State Office of State Planning Coordination Modified by BLE)

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J. Pre-Existing Land Cover

The pre-existing land cover of the Appoquinimink River watershed was developed for the watershed in order to assess how land cover within the watershed has changed over the years and to understand how surface runoff has changed over the same timeframe. Pre-existing land cover was established using heads up digitizing to 1937 Orthophotography of the watershed. Heads up digitizing is a process that visually assigns land cover classifications by examining aerial photography and grouping land into similar classes based upon the appearance of the aerial photographs. The Orthophotograpy used in the heads up digitizing process was created in 1937 by the Delaware Geological Survey and obtained from the internet-based data clearing house Delaware DataMIL.

The landscape of the Appoquinimink River watershed in 1937 was predominantly agricultural with 69.4% of the watershed used for farming. In 1937, the watershed consisted of approximately 12.5% wetlands, 7.1% forest, 4.0% water, 2.3% meadow, 1.6% residential, and 1.3 % farmstead, with the remaining land cover types consisting of less than 1% of the total watershed area. Comparing the 1937 land cover data to the existing land cover data shown in Table II-3, indicates that the major change has occurred with the transfer of large portions of the watershed from agriculture to residential and other land cover categories indicative of development.

The significance of this shift in land cover from agriculture to developed land cover classifications and its implication on stormwater runoff is further emphasized when considering that agricultural land management practices of 1937 were plausibly different than today. In 1937, most farms in the watershed contained dairy cows that would have required permanent pasture and/or hayland to sustain the livestock. DNREC estimates that agricultural lands in 1937 may have consisted of a mixture of 25% permanent pasture, 25% hayland and 50% cropland. This change in farming practices between 1937 and today results in a higher runoff potential for agricultural lands of today than those of 1937.

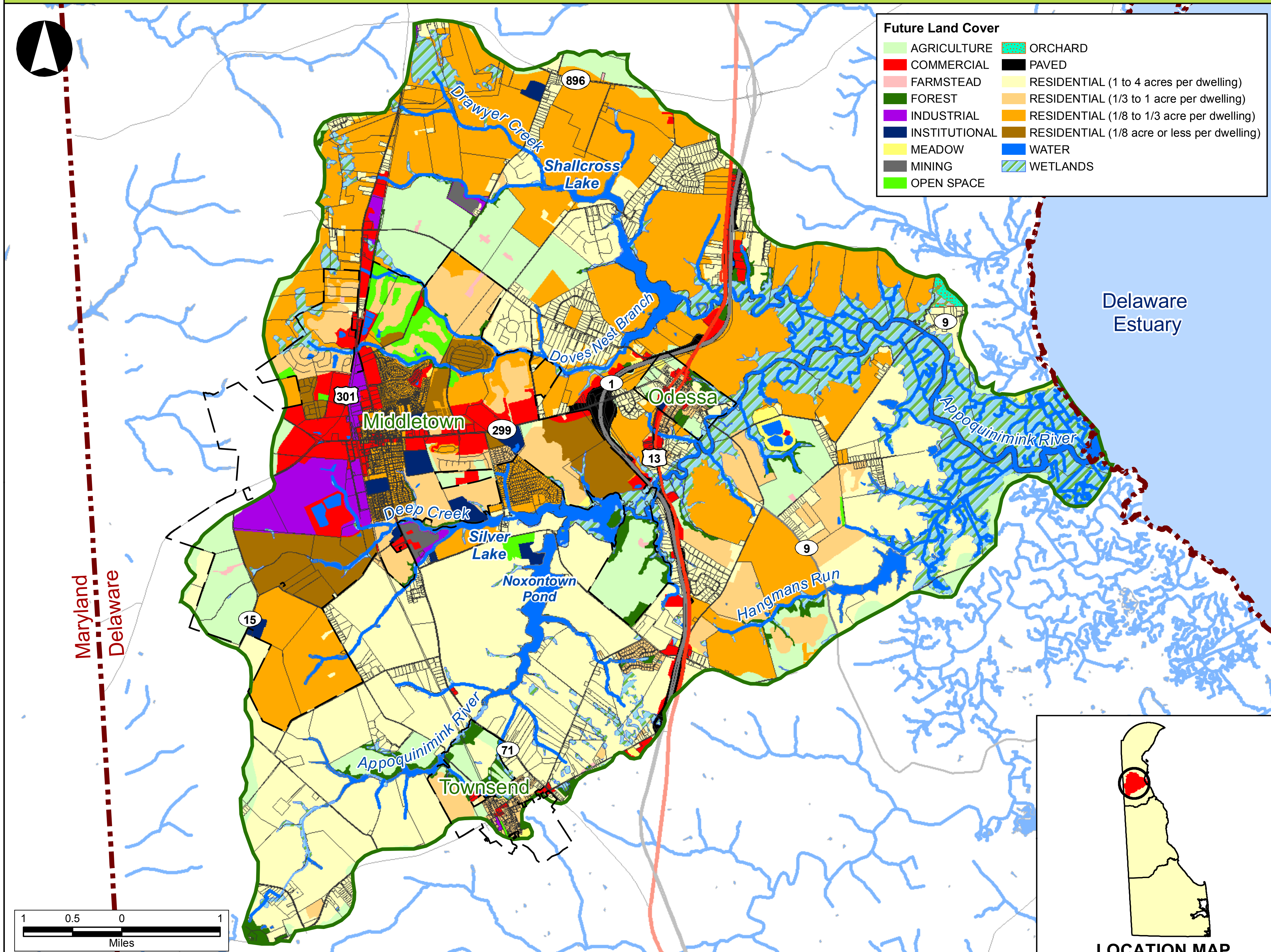
K. Land Development Patterns

Presently, there is an abundant amount of undeveloped land available for development throughout the Appoquinimink River watershed. In order to understand the implication of development upon stormwater runoff within the watershed it is important to assess future land development patterns. To complete this analysis, GIS data identifying developable parcels and existing zoning information was obtained from the Center for Watershed Protection. From this data, potential projected future land cover was created by overlaying parcel data on top of the existing land cover data and modifying the attributes of the existing land cover to correspond with the zoning attributes of the parcels.

It is important to understand that the future land cover, as described in this section, is based upon a hypothetical total build-out scenario for the watershed based on existing zoning and is not meant to identify a particular year in which the total build-out will occur. If and when a total build-out would occur is contingent upon many variables including regulations, such as zoning and socio-economic factors. Although the future build-out condition may be many years or decades to eventual realization, the future land development patterns provide an indication of what the watershed may look like at some point in the future.

APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN

MAP II-8: FUTURE LAND COVER



Legend

- State Boundaries
- Municipal Boundaries
- Parcel Boundaries
- Watershed Boundary
- Water Bodies
- Estuary
- Appoquinimink River
- Artificial Paths
- Perennial Streams
- Intermittent Streams
- U.S. Highways
- State Highways
- Other Roads

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NOTES:
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DATA SOURCES:
Roads - DelDOT
Water Bodies - DNREC
Counties - DelDOT
Municipalities - DelDOT
Watershed Boundary - DNREC (Modified by BLE)
Streams - U.S. Geological Survey, and U.S. EPA
Land Cover - Delaware State Office of State Planning Coordination (Modified by BLE)

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DATE: 1/13/2010
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PROJECT NO.: 2006-2013-01

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Table II-4 provides an overview of projected land development patterns in the Appoquinimink River watershed with future land cover depicted in Map II-8. The future land development analysis identified that the majority (approximately 49%) of new development within the Appoquinimink River watershed is expected to be in the form of smaller residential developments, (1/8 to 1/3 acre lot). This type of development is expected to occur throughout the watershed, except in the southern portion. The second largest form of development (approximately 42%) is expected to be single family dwellings with lot sizes greater than one acre. Low density residential development of this type is anticipated to occur predominately in the southern portion of the watershed. Industrial development, which accounts for approximately 3% of future development, is expected to occur in the area in and around Middletown. Commercial development, which is projected to be 2% of future development, is expected to occur primarily along S.R. 299. The only land cover type corresponding to development which exhibited a decrease in the total area covered between the existing and future condition was residential, with lots of the size 1/3 to 1 acre. This may be indicative of infill development, where area which is presently classified as 1/3 to 1 acre, moves from the larger lot size to one of the smaller lot sizes such as the 1/8 to 1/3 acre size, which exhibits a significant increase in land coverage in the future condition.

TABLE II-4
Existing and Future Development in the Appoquinimink River Watershed

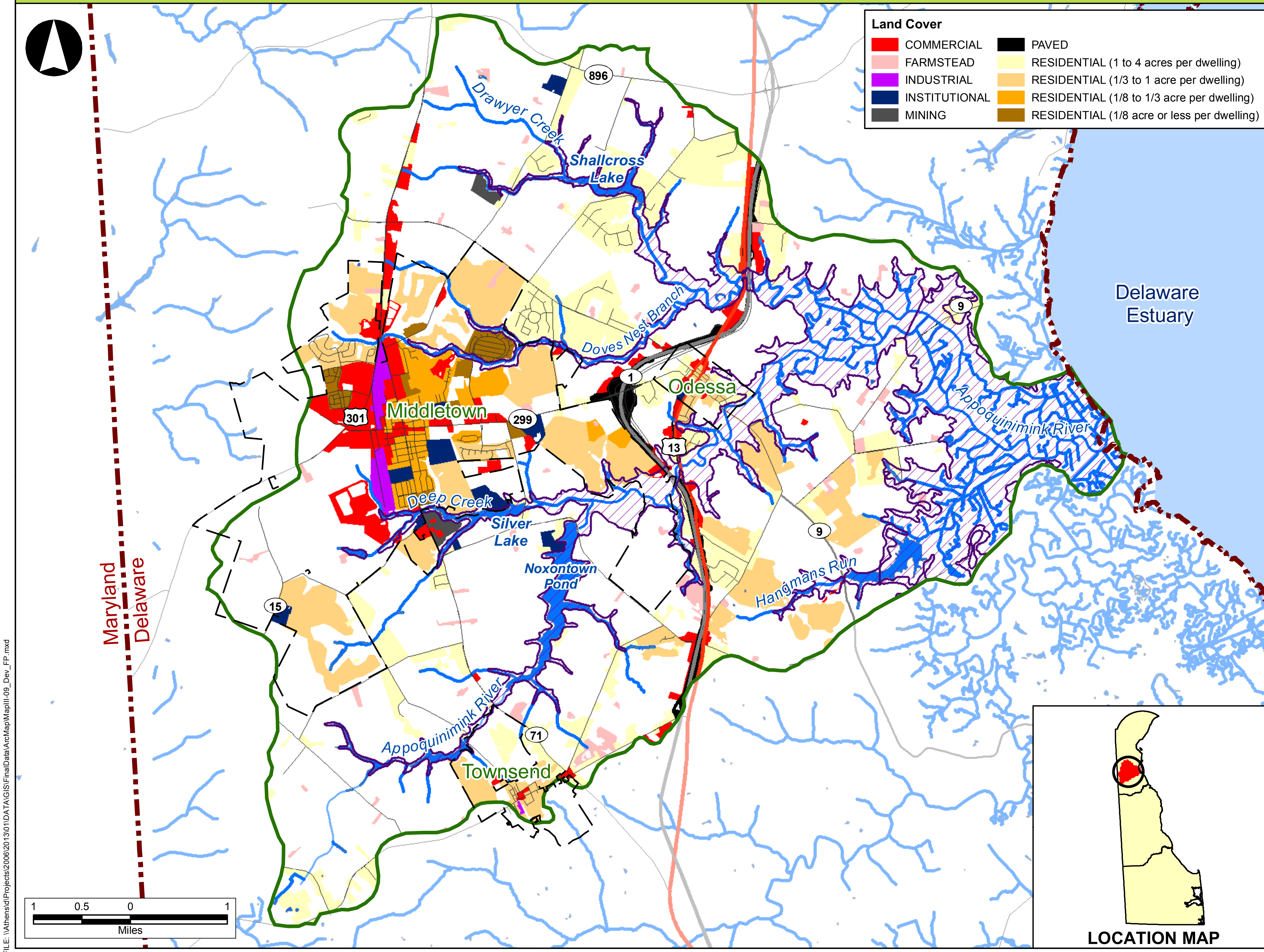
Development Type	Existing Development Area (Acres)	Future Development Area (Acres)	Future Development Increase (Acres)	Percent Increase in Future Development
Commercial	949	1,168	219	2%
Industrial	141	532	391	3%
Institutional	241	242	1	<0%
Paved	409	411	2	<0%
Residential (1 - 4 acres)	2,869	8,541	5,672	42%
Residential (1/3 – 1 acres)	2,501	2,217	-284	-2%
Residential (1/8 – 1/3 acres)	517	7,061	6,544	49%
Residential (1/8 acre or less)	230	993	763	6%
Total:	**7,857 Acres**	**21,165 Acres**	**13,308 Acres**	**100%**

L. Present (Existing) and Projected Development in the Flood Hazard Areas

For this analysis, encroachments of the residential, industrial, and commercial land covers were identified by overlaying the existing land cover on the floodplain using GIS. Map II-9 shows the 100-year floodplains and existing developable areas within the Appoquinimink River watershed and Table II-5 provides a summary of the amount of existing and future development within the floodplain. Approximately 5,203 acres (17.4%) of the watershed is located within identified floodplains. Of these 5,203 acres, about 162 acres are currently developed. The remainder of the identified floodplain consists of agriculture, forest, meadow, open space, orchard, water, or wetland land cover types.

APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN

MAP II-9: DEVELOPMENT IN FLOODPLAINS



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Municipalities - DelDOT
Counties - DelDOT
Watershed Boundary - DNREC (Modified by BLE)
Streams - U.S. Geological Survey, and U.S. EPA
Floodplains - FEMA
Land Cover - Delaware State Office of State Planning Coordination (Modified by BLE)

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PROJECT NO.: 2006-2013-01

Combining the floodplain information with the future land cover for the ultimate build-out scenario discussed in Section II-K, indicates that without effective floodplain management implemented throughout the watershed, in the hypothetical full build-out scenario approximately 883 acres of flood hazard areas will consist of developed land cover. This is more than a fourfold increase in development within flood hazard areas and represents a significant potential problem subjecting homes, business and industry to future high water events within the watershed. Without effective stormwater management and floodplain management regulations applied within the watershed, development will cause an increase in the magnitude and frequency of flood flows in the Appoquinimink River and its tributaries. The harmful effects of poorly managed stormwater and floodplain hazard areas will be compounded by the placement of structures within the floodplain, which may act as obstructions, and will be subject to damage from flooding.

TABLE II-5
Summary of the Total Amount of Developed Floodplain Area

Land Cover	Existing Development in Floodplain (Acres)	Future Development in Floodplain (Acres)
Commercial	14.9	13.5
Farmstead	7.2	0.1
Industrial	0.4	10.0
Institutional	6.0	6.0
Mining	1.9	1.9
Paved	5.9	6.0
R1	95.0	544.4
R2	25.6	28.9
R3	0.3	236.4
R4	4.8	36.2
TOTAL	**162.0**	**883.4**

Therefore, effective stormwater management planning is critical in areas both affected and currently unaffected by stormwater problems in the Appoquinimink River watershed. In areas currently experiencing stormwater problems associated with flooding, the problems mainly occur during larger storm events. The Appoquinimink River Watershed Stormwater Management Plan can help minimize future problems associated with flooding by better managing runoff from developing areas so that the magnitude and frequency of such events will not become larger or more frequent. This Plan shall provide communities within the watershed with a preliminary engineering assessment essential in evaluating and upgrading current undersized stormwater systems as indicated in Section III-J. For areas currently unaffected by stormwater problems, the Plan shall provide controls on future development to aid in preventing future stormwater runoff problems.

One of the biggest problems in floodplain management is the increase in peak flow caused by development in the watershed. Recognizing this, the Natural Flood Insurance Program (NFIP) has developed a Community Rating System (CRS) to give communities credit for floodplain management activities that exceed the minimum requirements. As part of this rating system, credit points can be awarded to communities if they implement the following:

1. regulatory language (ordinance) requiring peak rate of runoff from development to be no greater than the predevelopment runoff;
2. stormwater master plan (such as this Plan);
3. state review of the stormwater management plan;
4. regulations requiring a building's lowest floor to be elevated above flood levels;
5. erosion and sediment control regulations;
6. water quality regulations.

With the CRS, the more credits a community accumulates, the less its residents will have to pay for flood insurance. For further information on the community rating system, see the publication *"CRS Credit for Stormwater Management,"* July 1996, published by FEMA.

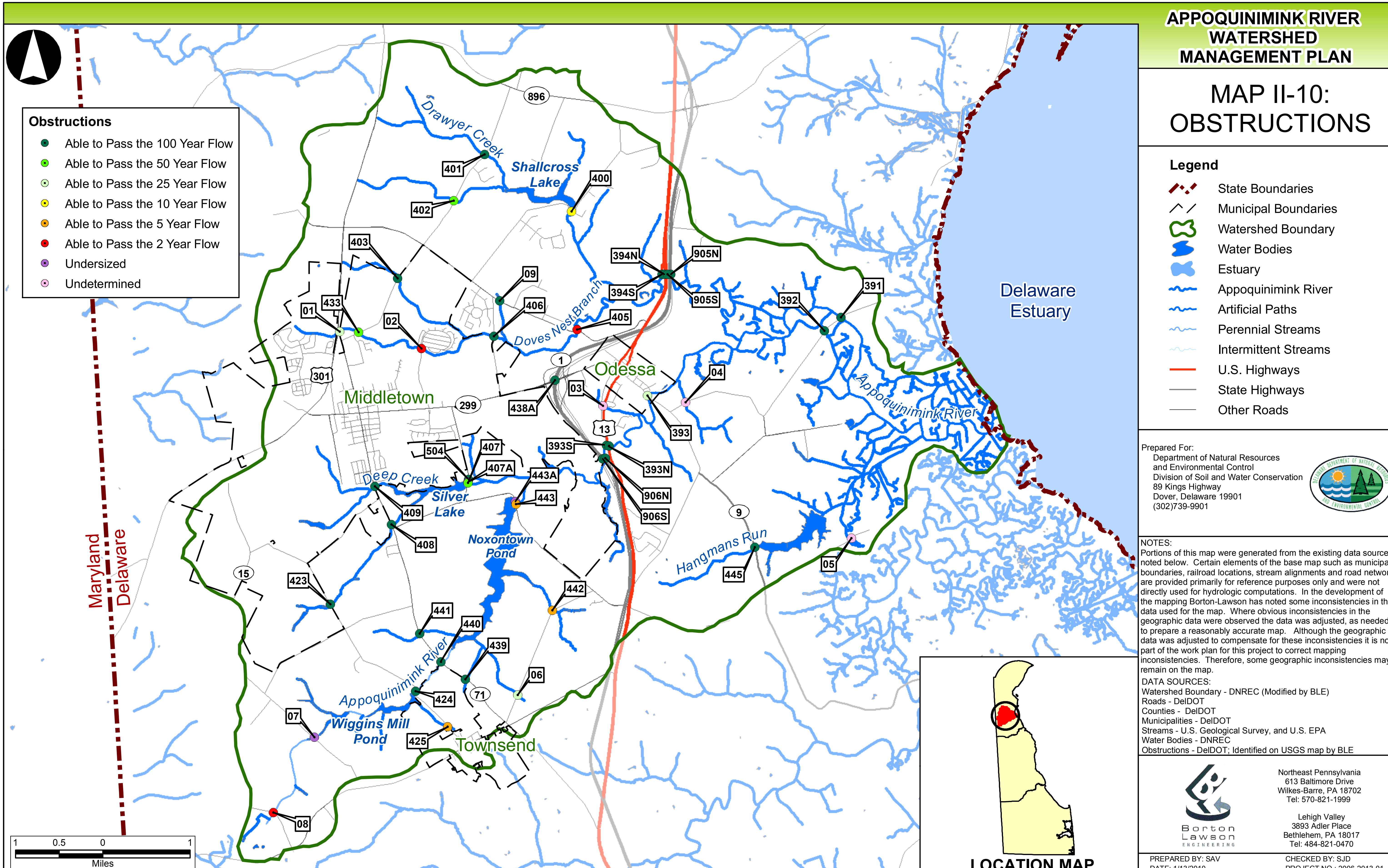
M. Obstructions

The locations of significant waterway obstructions (i.e., culverts, bridges, etc.) in the Appoquinimink River watershed were obtained from the Delaware Department of Transportation (DelDOT). Additional obstructions were identified by examining the United States Geologic Survey's (USGS) topographic mapping for select locations where the topographic maps suggest that water collects and are conveyed under, around or through potential obstructions in the watershed waterways and flow paths. Geometric data for these obstructions was obtained from DelDOT and field measurements performed by Borton-Lawson.

Design flows to each of these obstructions were determined for a series of return intervals and the culvert capacity was calculated based on the geometric configuration of the obstructions. The obstruction flow capacities were then compared to the peak design flows. The obstructions were then classified into seven categories as follows:

1. Obstructions capable of passing the 100-year, 24-hour storm without obstructing the flow.
2. Obstructions capable of passing the 50-year, 24-hour storm without obstructing the flow.
3. Obstructions capable of passing the 25-year, 24-hour storm without obstructing the flow.
4. Obstructions capable of passing the 10-year, 24-hour storm without obstructing the flow.
5. Obstructions capable of passing the 5-year, 24-hour storm without obstructing the flow.
6. Obstructions capable of passing the 2-year, 24-hour storm without obstructing the flow.
7. Obstructions which are <u>NOT</u> capable of passing the 2-year, 24-hour storm without obstructing the flow.

The locations of all significant obstructions identified by this study, including those that fall into the seven categories above, are shown in Map II-10. This map shows fewer than ten obstructions that are either undersized or not able to pass the 10-year storm without overtopping the obstruction. It is important to note that this analysis is only a preliminary engineering assessment using limited geometric data and is based on inlet control assumption. Therefore, the actual performance of the culvert may vary from this assessment when field survey data is obtained and examined.



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The purpose of this assessment is to provide communities with a preliminary assessment to identify potential problems culverts and help communities set priorities for which obstructions should be considered for replacement. The geometric data for the significant obstructions identified by this study and the flow capacities used in the analysis are compiled in Volume III of this Plan, the Technical Appendix.

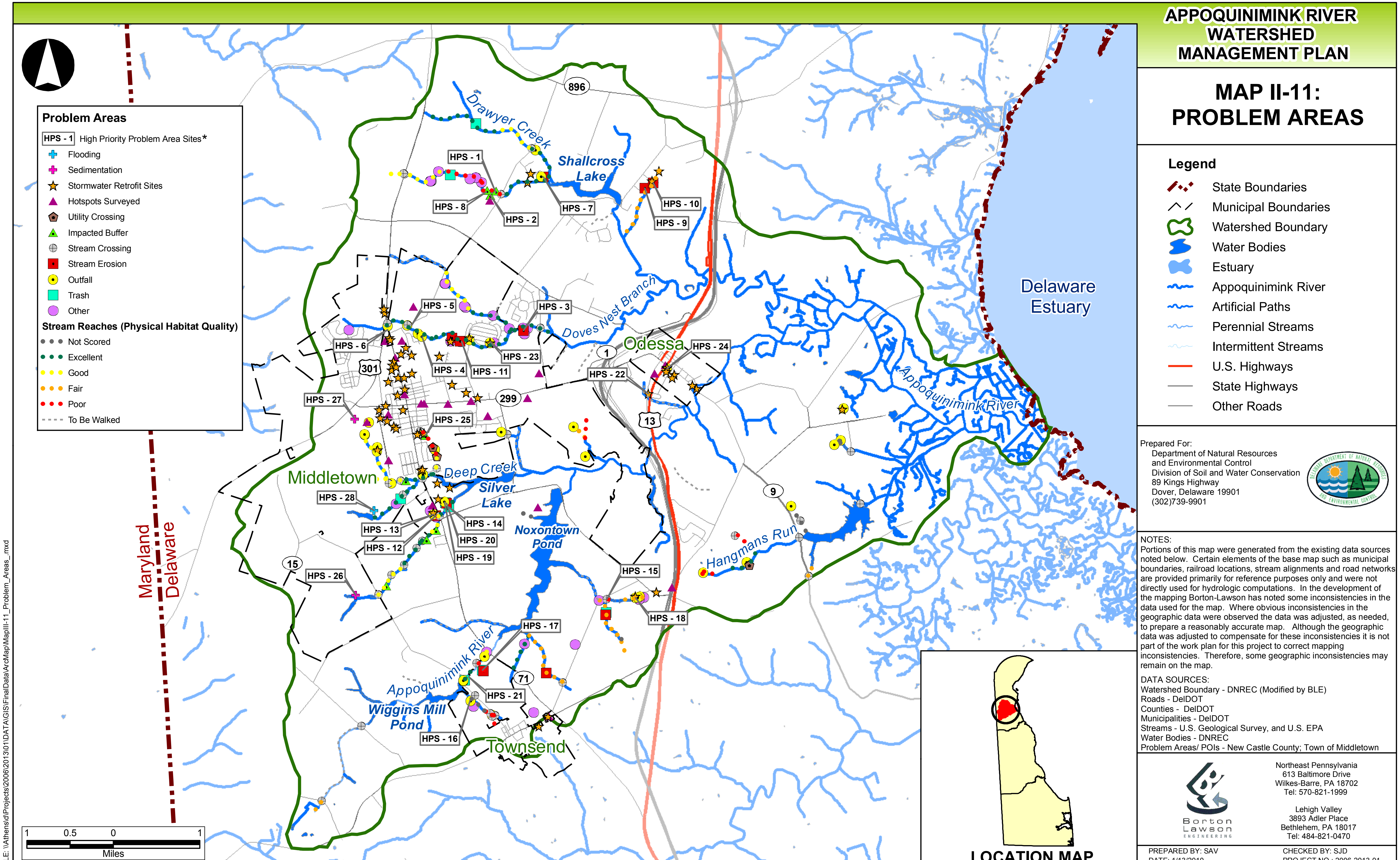
N. Existing Drainage Problems

Information on drainage problems within the Appoquinimink River watershed was obtained from DNREC and the Town of Middletown. The data provided by DNREC was obtained from the 2005 Appoquinimink Watershed Implementation Plan prepared by the Center for Watershed Protection (CWP). The focus of this report was mainly on water quality problems and not water quantity. As such, many of the sites listed within this report do not have a substantial impact upon issues typically associated with the rate or volume stormwater runoff. Of those sites identified by the study, only the eleven (11) erosion sites, three (3) utility crossings, thirty-seven (37) outfall locations, and thirty-five (35) stream crossing locations were considered to be related to rate or volume issues associated with stormwater runoff. All other sites documented in the Appoquinimink River Watershed Implementation Plan were potential water quality problem areas.

The majority of problems reported by CWP are situated in the most urbanized areas of the watershed. A total of fifteen (15) hotspots were identified in Middletown; with most of these sites located in the central portion of Middletown near more developed areas of the town. One (1) area prone to flooding and two (2) areas prone to sedimentation were identified in along tributaries to the Deep Creek. Four (4) locations subject to streambank erosion as well as two (2) impacted buffers were identified along several of the tributaries in the town. Eighteen (18) stormwater outfalls were reported along the streams in Middletown. The Town of Townsend also reportedly experiences a number of problem areas. One (1) area prone to erosion, three (3) outfalls and five (5) crossings were identified by the study along the Appoquinimink River, while five (5) outfalls were identified along a tributary to the river in Townsend. According to the CWP study, the Town of Odessa contains two (2) hotspots situated in close proximity to Route 13 and seven (7) potential retrofit sites. Problem areas are shown graphically in the Problem Area Map, Map II-11.

Of the problems listed in the CWP study provided by DNREC, nine (9) problems were denoted as significant problems. Eight (8) of the significant problems are classified as severe erosion sites and are listed by the study as high priority restoration sites by the Center for Watershed Protection. The additional point significant problem site was a flooding problem situated in the Town of Middletown. Each of these significant problem sites represents an important location or a point of interest where quantifying the amount of flow is essential to better managing stormwater runoff in the watershed.

In addition to the CWP report, forms were distributed as part of this study to municipalities within the watershed to help the communities identify and locate problem areas, stormwater facilities, and flood control measures. Only Middletown responded to this request for information. Three (3) problems areas were identified Middletown using the survey form, one (1) flooding site and two (2) sedimentation sites.


APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN
MAP II-11: PROBLEM AREAS
Problem Areas
HPS - 1 High Priority Problem Area Sites*
Flooding
Sedimentation
Stormwater Retrofit Sites
Hotspots Surveyed
Utility Crossing
Impacted Buffer
Stream Crossing
Stream Erosion
Outfall
Trash
Other
Stream Reaches (Physical Habitat Quality)
Not Scored
Excellent
Good
Fair
Poor
To Be Walked
Legend
State Boundaries
Municipal Boundaries
Watershed Boundary
Water Bodies
Estuary
Appoquinimink River
Artificial Paths
Perennial Streams
Intermittent Streams
U.S. Highways
State Highways
Other Roads
Drawyer Creek
Shallcross Lake
Doves Nest Branch
Odessa
Middletown
Deep Creek
Silver Lake
Noxontown Pond
Hangmans Run
Appoquinimink River
Wiggins Mill Pond
Townsend
Delaware Estuary
Maryland
Delaware
896
301
299
1
13
9
15
71
HPS - 1
HPS - 2
HPS - 3
HPS - 4
HPS - 5
HPS - 6
HPS - 7
HPS - 8
HPS - 9
HPS - 10
HPS - 11
HPS - 12
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HPS - 18
HPS - 19
HPS - 20
HPS - 21
HPS - 22
HPS - 23
HPS - 24
HPS - 25
HPS - 26
HPS - 27
HPS - 28
1 0.5 0 1
Miles
LOCATION MAP
Prepared For:
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Division of Soil and Water Conservation
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Watershed Boundary - DNREC (Modified by BLE)
Roads - DelDOT
Counties - DelDOT
Municipalities - DelDOT
Streams - U.S. Geological Survey, and U.S. EPA
Water Bodies - DNREC
Problem Areas/ POIs - New Castle County; Town of Middletown
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FILE: \\Athens\d\Projects\2006\201301\DATA\GIS\FinalData\ArcMap\MapII-11_Problem_Areas_.mxd

O. Existing and Proposed Stormwater Collection Systems

Based on information obtained in the municipal stormwater survey forms, stormwater collection systems in the Appoquinimink River watershed are located throughout the Town of Middletown. As no data was received from Odessa or Townsend, the extent of existing and proposed stormwater collection systems within these municipalities was not determined by this study. All storm sewers within the watershed are dedicated for only stormwater conveyance. This conclusion was confirmed by DNREC, which indicated there are no combined sewers located in New Castle County within the limits of the Appoquinimink River watershed. Combined sewers are sewers that carry both wastewater and stormwater. In low-flow conditions, the combined sewer water in combined systems is typically conveyed to treatment plants for treatment. However, in large storm events, such systems often surcharge into streams and represent a significant stormwater quality problem.

P. Existing and Proposed State, Federal and Local Flood Control Projects

There are no existing or proposed flood control projects located within Appoquinimink River watershed identified by the FEMA FIS. The absence of these facilities within the watershed was verified DNREC's Division of Dam Safety.

Q. Existing and Proposed Stormwater Control Facilities

Based on data supplied by New Castle County and the Town of Middletown, there are a number of stormwater control facilities within the Appoquinimink River watershed. The types and operations of these facilities vary, but typically include both dry and wet ponds, otherwise known as detention basins and retention ponds. In New Castle County there are a total of fifty-three (53) identified stormwater control facilities located within the Appoquinimink River watershed. Most of these facilities are located in Middletown, which has twenty-seven (27) retention ponds. Several new stormwater management facilities are proposed for construction within the watershed. All these proposed stormwater facilities are scheduled to be retention ponds proposed for Middletown. The Town of Middletown was unable to confirm if any of the proposed facilities were financed or scheduled for construction. The locations of these facilities are shown on Map II-12.

R. Best Management Practices

According to information obtained from New Castle County, there are several best management practices (BMPs) installed within the Appoquinimink River watershed. Stormwater BMPs are stormwater management facilities designed to better manage stormwater runoff. It is the design intent of these facilities to create a stormwater management control that addresses not only local rate controls and drainage problems but to create a system that addresses water quality problems, stormwater volume problems and groundwater recharge. There are a total of six (6) reported biofiltration facilities located just south of the Town of Odessa and one bioretention facility situated in close proximity to the northern portion of Noxontown Pond. The locations of these BMPs are shown on Map II-12.

S. Repetitive Loss Structures

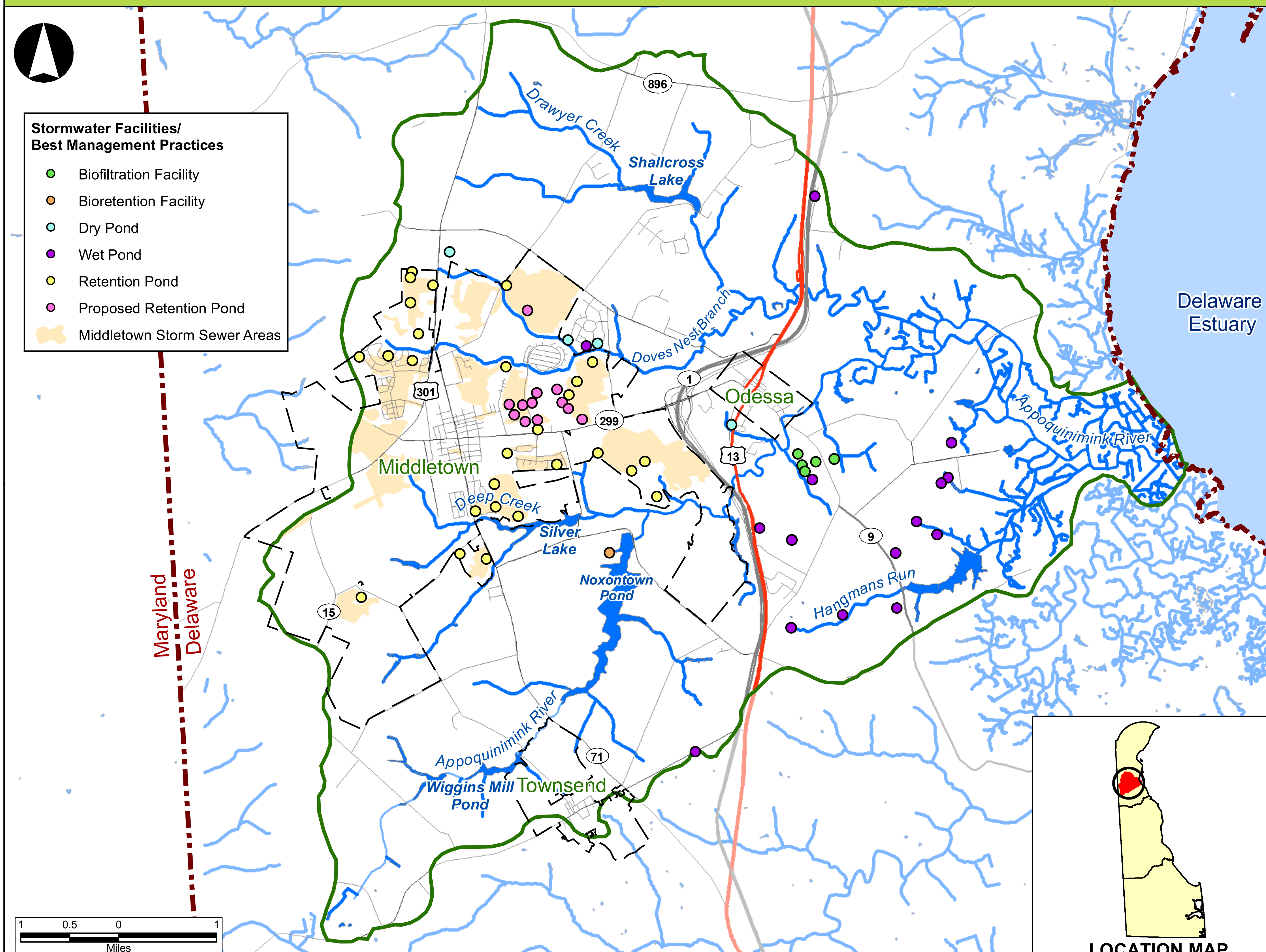
Repetitive loss structures are buildings that have filed at least two (2) claims of more than $1,000 in flood damages to the National Flood Insurance Program (NFIP) within a ten year period. According to FEMA, there are five (5) repetitive loss structures with Middletown mailing addresses. However, FEMA was unable to provide the address of the repetitive loss structures due to privacy and confidentiality issues. FEMA indicated that four (4) of the structures were located on North New Street, which is outside the watershed. Information about the location of the last structure could not be obtained from FEMA. However, DNREC's Division of Soil and Water Conservation indicated that the last structure was not within the Appoquinimink River watershed. This information was also verified by New Castle County's Department of Land Use.

T. Wetlands

The location of wetlands within the watershed were obtained from the National Wetlands Inventory Maps in digital format and incorporated into the overall GIS mapping for the project. Map II-13 shows the location of wetlands in the watershed. Most wetlands within the watershed are found along the Appoquinimink River and its tributaries with many of these wetlands, especially in the eastern portion of the watershed, influenced by tidal effects. Wetlands play an important part in flood flow attenuation, pollutant filtering, aquatic habitat, watershed aesthetics, terrestrial habitat, groundwater recharge and baseflow augmentation. With wetlands playing such a vital role in stormwater management and having a strong impact upon the environment, it is essential that these areas be preserved in order to protect the Appoquinimink River watershed. For more information on wetlands see the Work Plan for Wetlands Program Development, Southern New Castle County, DE.

APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN

MAP II-12: STORMWATER FACILITIES / BMPS



Legend

- State Boundaries
- Municipal Boundaries
- Watershed Boundary
- Water Bodies
- Estuary
- Appoquinimink River
- Artificial Paths
- Perennial Streams
- Intermittent Streams
- U.S. Highways
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Municipalities - DelDOT
Streams - U.S. Geological Survey, and U.S. EPA
Water Bodies - DNREC
Stormwater Facilities -

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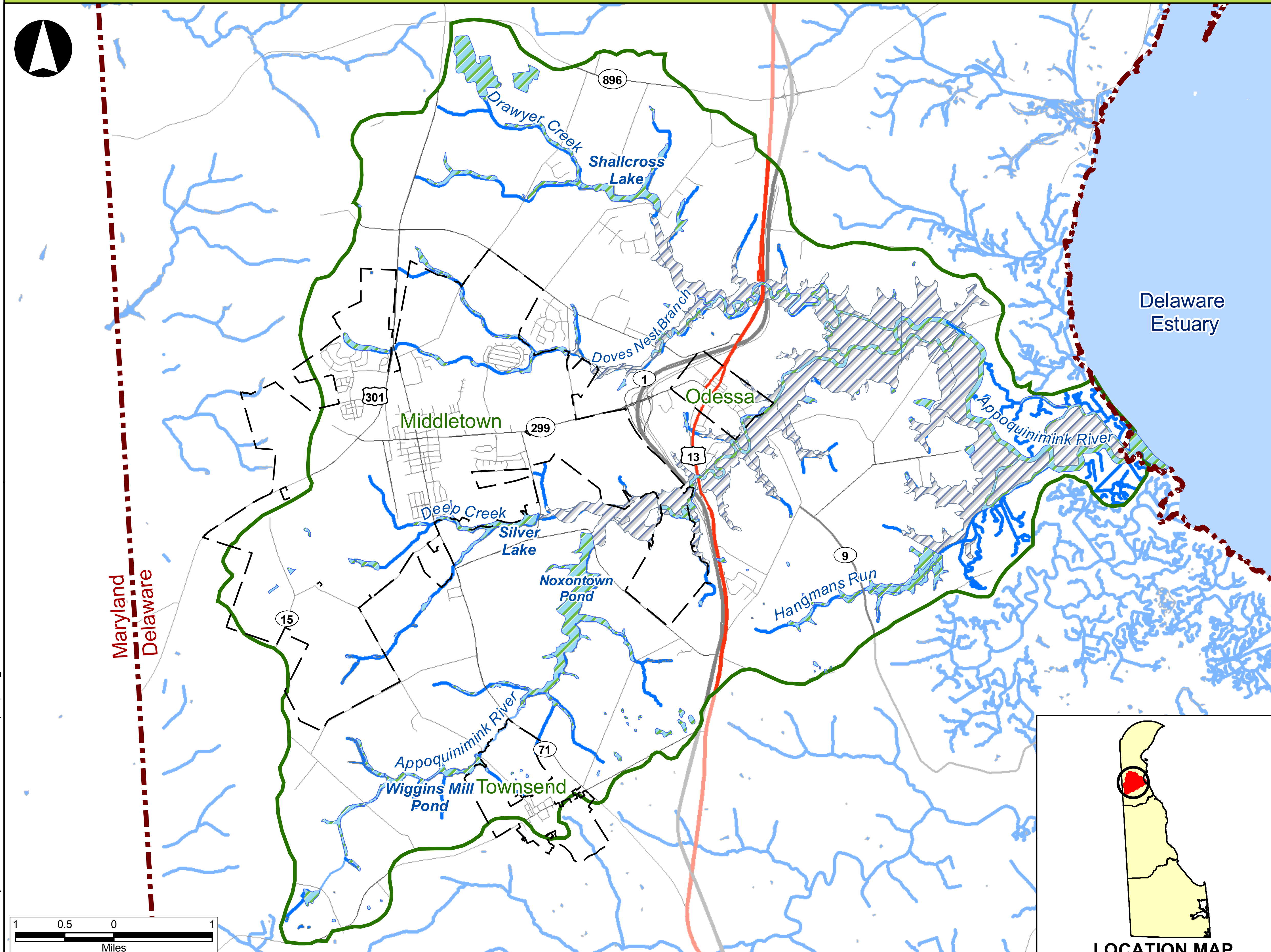

APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN

MAP II-13: WETLANDS

Legend

- State Boundaries
- Municipal Boundaries
- Tidal Wetlands
- Non-tidal Wetlands
- Watershed Boundary
- Water Bodies
- Estuary
- Appoquinimink River
- Artificial Paths
- Perennial Streams
- Intermittent Streams
- U.S. Highways
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Counties - DelDOT
Water Bodies - DNREC
Roads - DelDOT
Watershed Boundary - DNREC (Modified by BLE)
Streams - U.S. Geological Survey, and U.S. EPA
Wetlands - U.S. Fish and Wildlife Service National Wetlands Inventory

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SECTION III

REVIEW OF EXISTING PLANS/STUDIES/REPORTS/PROGRAMS

A. Overview

An initial step in the preparation of this Stormwater Management Plan was to complete a comprehensive review of existing stormwater management publications and regulations pertaining to the Appoquinimink River watershed from federal, state, county, municipal, and educational institution sources. This review focused on the availability of information pertaining to the following key topics:

1. Stormwater Quantity concerns and existing control measures within the watershed.
2. Stormwater Quality concerns and existing control measures within the watershed.
3. Groundwater Protection within the watershed.
4. Environmental Impacts affecting the watershed.
5. Existing Regulations pertaining to the watershed.

Review of each source focused on the items listed above. The sources were also reviewed for consistency and applicability to the development of a watershed-wide stormwater management plan. Review of the information collected through the municipal data questionnaire process was also completed.

B. Water Supply and Wellhead Protection Plans

In 1999, the U.S. Environmental Protection Agency (EPA) endorsed the Delaware Comprehensive State Ground Water Protection Program (CSGWPP). The CSGWPP provides a description of groundwater resource protection and assessment throughout Delaware. It also provides a framework for better focus and coordination across multiple groundwater protection programs.

Delaware’s approach to source water assessment is outlined and described in the Delaware Source Water Assessment Plan (SWAP) (October 1999) that was endorsed by the U.S. EPA. The Delaware Wellhead Protection Plan (WHPP) was approved by EPA in 1990. The WHPP provides for delineation of wellhead protection areas around public water supplies.

New Castle County revised their Unified Development Code (UDC) in 1991 allowing for increased coverage of their Water Protection Area Ordinance and Wellhead Protection Plan (WPP) by restricting development activities within the delineated boundaries. Our research found that each of the municipalities within the Appoquinimink River watershed currently has a Wellhead Protection Ordinance.

C. Flood Mitigation Plans

The State of Delaware has a model Flood Damage Reduction Ordinance which municipalities within the state can modify and incorporate. Sections of this ordinance have been incorporated into the New Castle County Code and ordinances for all three Municipalities within the

Appoquinimink River watershed, Middletown, Odessa, and Townsend. Examination of these Codes and Ordinances will be covered in Section F.

D. Municipal Wastewater Management Plans

Construction and operation of Publically Owned Wastewater Treatment facilities (POTS's) are regulated under Title 7, Natural Resources and Environmental Control, Section 7200, Surface Water Discharges Section of the Delaware Administrative Code. These regulations apply to all municipal water pollution control facilities and govern the design, construction, installation, replacement, modification and operation of any facility which has the potential to discharge a pollutant to a surface water. Permitting and certification requirements are also addressed in these regulations.

Construction and operation of on-site wastewater facilities are regulated under Title 7, Natural Resources and Environmental Control, Section 7101, *Regulations Governing the Design, Installation and Operation of On-Site Wastewater Treatment and Disposal Systems*. Regulations for licensing of persons completing soil testing, facility design, facility construction and monitoring/inspection of existing systems are also found here.

E. Municipal Flood Insurance Studies (various), Federal Emergency Management Agency

The Federal Emergency Management Agency (FEMA) has undertaken various Flood Insurance Studies (FIS) for the state of Delaware. These studies are typically completed on a county-wide basis and provide a delineation of the floodplain associated with a 100-year storm flowing through the subject watercourse. This delineation can be generated using "detailed" computer modeling of the watercourse and associated watershed or generated using "approximate" methods which provide less accurate results. The current delineation for the Appoquinimink was generated using the "approximate" method; however, a detailed study is currently being completed.

F. State, County and Municipal Regulations/Ordinances

<u>Delaware Sediment & Stormwater Regulations</u>

Sediment and Stormwater regulations are found in Title 7, Natural Resources and Environmental Control, Section 5101 Sediment and Stormwater, of Delaware's Administrative Code. These regulations include the following:

1. Direct Sediment and Stormwater regulations be delegated to Conservation Districts, Local Governments or other State Agencies.

2. Establish minimum standards and criteria for Sediment and Stormwater regulation including minimum standards and specifications for both temporary and permanent stabilization, and permanent stormwater management.

3. Establish plan approval fees, maintenance fees and performance bonds.

4. Provide criteria for implementing a stormwater utility.

5. Establish application and approval process for Sediment and Stormwater plans including required certification of persons completing the work and allowable review time frames.

6. Provide criteria for a Designated Watershed and procedures for establishing a Designated Watershed or Subwatershed. Process includes identifying water quality or quantity (flooding) concerns and provides a framework for what is required in studies.

7. Provides requirements for certified review of certain projects.

8. Provides for contractor certification program which is required for all persons involved in the construction project.

9. Provides construction review and enforcement requirements, including when construction inspections are required and procedures to be followed if violations are found.

10. Provides requirements for binding and perpetual maintenance agreements of stormwater management facilities.

A Municipal Ordinance Matrix providing a comprehensive list of Municipal regulations related to stormwater management for each of the Municipalities within the watershed is found in Volume III.

New Castle County Code

The New Castle County Code is a model ordinance for municipalities within the County. Chapters 12 and 40 of the Code provide stormwater management regulations. Chapter 12, Drainage Code, addresses control of stormwater runoff and Chapter 40, Unified Development Code, land development activities.

Specific topics addressed in the Drainage Code include:

1. Standards for compliance.
2. Grading to promote adequate drainage.
3. Conveyance systems design.
4. Stormwater management facility and watercourse maintenance.
5. Drainage improvements by New Castle County.
6. Prohibitions, enforcements and penalties.

Specific topics related to stormwater management addressed in the Unified Development Code include:

1. FEMA floodplain delineation and permitting criteria for activities within the floodplain.
2. Riparian buffer standards.
3. Drainageway requirements.

4. Utilization of Green Technology Stormwater Best Management Practices (GTBMP), including stormwater filtration and infiltration. Maintaining non-erosive velocities and disconnecting impervious surfaces are also identified as GTBMP's.

Middletown Unified Development Code

The Middletown Unified Development Code provides requirements addressing activities in the floodplain. Sections 78-1 though 78-18 regulate development within the floodplain and define what activities are permitted. The Delaware State regulations for water quality, water quantity, infiltration (recharge), and streambank protection apply in Middletown. A detailed list of Middletown regulations is provided in the Municipal Ordinance Matrix found in the Appendix of this report.

Odessa Unified Development Code

The Odessa Unified Development Code includes regulations for development in wellhead/water recharge protection areas. Specific regulations include:

1. Underground storage tanks containing petroleum or any hazardous substances listed in 40 CFR 116 in an aggregate quantity equal to or greater than a reportable quantity as defined in 40 CFR 117 shall not be permitted in Recharge Water Resource Protection Areas.

2. At least twenty-five percent (25%) of the gross area designated within a subject parcel as a Recharge Water Resource Protection Area shall be maintained as Open Space. Permitted uses within Open Space in a Recharge Water Resource Protection Area shall include Open Areas as defined in this ordinance and other Open Space uses as permitted in the zoning district containing the subject parcel. Open Spaces uses in a Water Resource Protection Area should contain no impervious surfaces.

3. The Development code states that no new development may be constructed within floodplain water resource protection areas. This is in agreement with the Zoning Ordinance.

The Delaware State regulations for water quality, water quantity, infiltration (recharge), and streambank protection apply in Odessa.

A detailed list of Odessa regulations is provided in the Municipal Ordinance Matrix found in the Appendix of this report.

Townsend Unified Development Code

The Townsend Unified Development Code includes regulations for development in wellhead/water recharge protection areas and development within the floodplain. Specific regulations include:

1. **Water Quality (Section 1110) –** This section includes regulations for wellhead protection areas, including the following:

a. Areas within three hundred (300) feet of the well shall be one hundred (100) percent open space.

b. The protection area around the well may be reduced to a one hundred and fifty (150) foot radius provided a hydrogeological report certifying that (1) the minimum 60-day time of travel from a point to the public water supply well is maintained and (2) the well draws from a confined aquifer.

c. The natural runoff flowing into wellhead areas shall be allowed and all new stormwater runoff shall be diverted around the wellhead protection areas wherever practical.

d. The stormwater system's discharge to wellhead WRPAs shall be by sheet through a grassland or discharge from a stormwater management facility having a wetland or aquatic bench. Stormwater runoff from all parking areas shall be directed to a stormwater management facility before it is discharged into a wellhead WRPA.

e. Within the wellhead area, impervious surfaces shall be limited to the buildings and access associated with the well and distribution and treatment facilities and their maintenance.

f. The minimum lot area for a proposed public water supply well and related facility drawing from a confined aquifer shall be 1 acre and the minimum lot area for a public well drawing from an unconfined aquifer shall be 2 acres.

g. This only applies to wellheads constructed after August 2001. All existing wellheads constructed prior to this date are considered "grandfathered" and the regulations of the section do not apply.

2. **Floodplain (Section 1103) –** This section details the requirements, allowable disturbances, and permitted construction practices within floodplains and floodways and includes the following:

   a. No structure shall intrude into the floodway or floodplain except for piers needed to support bridges, erosion control structures, dams for flood control or water supply, and utility crossings.
   b. No filling is permitted in floodways or floodplains.
   c. No structures designed for human habitation are permitted.

   In addition, where a conflict between a mapped boundary and actual field conditions is identified, a determination of the exact boundary of the area subject to inundation by the one hundred (100) year flood elevation shall be completed. Elevation information provided in the Flood Insurance Study (FIS) is to be used for this determination. For the floodway portion of the floodplain, the exact boundaries shall be determined by scaling the distances shown on the floodway map and by utilizing the data in the applicable (FIS) for the area. Where the boundary of the floodplain is disputed, the burden of proof shall be on the Applicant.

The Delaware State regulations for water quality, water quantity, infiltration (recharge), and streambank protection apply in Townsend.

A detailed list of Townsend regulations is provided in the Municipal Ordinance Matrix found in the Appendix of this report.

Floodplain Ordinance Recommendations

Both New Castle County and the Town of Middletown have comprehensible ordinances. No further recommendations are necessary for these municipalities. However, the towns of Odessa and Townsend both have floodplain ordinances that do not cover an entire array of situations. For example under the New Castle County Code, no new residential lots shall be created in the floodplain without sufficient buildable area outside of the floodplain. This means that new lots can be created in the floodplain as long as any structures placed within that lot are located sufficiently out of the floodplain. Regulations such as these are missing from the Town of Odessa and Town of Townsend ordinances. As such, these municipalities should update their ordinances and model their floodplain regulations after those in the New Castle County ordinances.

G. Imperviousness: A Performance Measure of a Delaware Water Resource Protection Area Ordinance (Kauffman, 2002)

This document is a case study to evaluate the performance of the New Castle County WRPA Ordinance. New Castle County Unified Development Code Section 40.10.380 Water Resource Protection Area (WRPA), as amended on September 26, 2006, states that no development shall be permitted to have more than twenty (20) percent impervious surface ratio in recharge, wellhead, reservoir watershed, and limestone aquifer areas to protect the County's water resources from contamination and pollution and to insure adequate water quantity for future needs. The research evaluates the effectiveness of the WRPA ordinance in limiting new development to less than 20% impervious cover. The report concluded that the overall the WRPAs protected by New Castle County ordinance are reasonably healthy at 15% impervious, which is less than the 20% threshold set on new development by code. It also noted that there are wellhead areas with greater than 20% impervious areas where water quality is impacted.

H. Appoquinimink River Watershed Baseline Assessment & the Appoquinimink River Watershed Implementation Plan (Center For Watershed Protection, 2005)

These documents focused on the water quality of the Appoquinimink River watershed. The first document, the Baseline Assessment, examined various physical parameters of the watershed such as; land use, stream conditions, upland conditions, regulatory protection ordinances, and subwatershed characterization. This document compiles this information in one place and also identifies potential water quality restoration opportunities.

An Implementation Plan was also written, and includes an in-depth water quality assessment of the major waterways within the Appoquinimink River watershed. The scope of this document focused on the impacts that development would have on water quality problems caused by erosion, outfalls, hotspots, and crossings.

Several stream reaches are reported as "severely eroded." Additional details regarding these locations are provided in the A.D. Marble report entitled *Appoquinimink Watershed Assessment Streambank Erosion Inventory and Tidal Marsh Assessment Summary Report*, dated May 2009. Also, flow calculations for these specific problem areas are provided in Section IV of this report.

I. University of Delaware Mosquito Breeding in Basins Study

A 2004 study completed by Jack B. Gingrich at the University of Delaware involved the study of mosquito breeding in stormwater management sites. The primary objective was to further evaluate and compare mosquito vector production and larval abundance at 5 different types of BMP's or wetlands.

The article reports that detention ponds appear to be a preferred breeding ground for mosquitoes which contributes to the most prevalent mosquito being a floodwater mosquito. Detention ponds were the preferred location because of their design of holding water for several days directly coincides with mosquitoes' larval cycle. The article reports that basins were holding water for up to 2 weeks even though most stormwater regulations require basins to empty completely within 72 hours.

Several measures which could help minimize mosquito breeding within detention basins were identified and include the establishment of artificial wetlands within a basin, adjusting basin geometry, and creative BMP placement within the basin. These measures helped provide deeper ponds with steeper side slopes which generally had less mosquitoes detected.

It is also recommended that existing detention basins be inspected and maintained as needed to ensure their intended function. Detention basins should not have standing water for greater than 72 hours unless designed as a retention/wet pond which should include appropriate plantings to provide a habitat for mosquito predators.

J. Other Studies Discovered During the Planning Process

1. Bennett, Andrea, *Source Water and Wellhead Protection in USEPA Region III*, MD State-County Ground Water Symposium, September 20, 2006.
2. *Delaware Source Water Assessment Plan* (SWAP), Section F.
3. Delaware Department of Natural Resources and Environmental Control, *Delaware Bay and Estuary Environmental Profile*.
4. Town of Middletown Comprehensive Plan (2005).
5. Draft of Middletown Water Resource Protection Ordinance (2009).
6. Town of Odessa Comprehensive Plan (2006).
7. Delaware Regulation Governing the Control of Water Pollution (2006).
8. *Delineation of Ground-Water Recharge Resource Protection Areas in the Coastal Plain of New Castle County, Delaware*, dated January 1993, revised May 2001.

SECTION IV

WATERSHED TECHNICAL ANALYSIS

A. Selection of Computational Model

An initial step in the preparation of the Appoquinimink River Watershed Stormwater Management Plan was the selection of a simulation model to examine the hydrologic response of the watershed to precipitation and help develop an understanding of how the stormwater moves through the watershed. To aid in the analysis, it was necessary to select a computational model which was:

1. Capable of modeling design storms of various durations and frequencies,
2. Adaptable to the size of the subareas used in this study,
3. Easy to manipulate and evaluate the characteristics of the rainfall-runoff generation process,
4. Capable of producing reliable results without excessive amounts of input data,
5. Able to model the flow attenuation effects of dams, lakes and/or reservoirs.

The computational model selected for this study was the U. S. Army Corps of Engineers, Hydrologic Engineering Center, Hydrologic Modeling System (HEC-HMS). In addition to the aforementioned items, this computational model was selected for the following reasons:

1. It was developed by the Hydrologic Engineering Center specifically for the analysis of the timing of surface flow contributions to peak rates of runoff at various locations in a modeled watershed.
2. Although originally developed as an urban runoff simulation model, the data requirements and flexibility of the software makes it readily adaptable to a rural situation.
3. The model contains many different variables and parameters which can be simply adjusted to complete the calibration process.
4. The model is fully accepted by the Federal Emergency Management Agency (FEMA) and Delaware Department of Natural Resources and Environmental Control (DNREC).

Although other models, such as those that appear in Table IV-1, may provide similar results as HEC-HMS, HMS's ability to compute flows at various points throughout the watershed using many different hydrologic parameters and numerical methods make it both flexible and well suited for the hydrologic modeling of the Appoquinimink River watershed. Another benefit of the software is the model's ability to summarize the results of the hydrologic computations in predefined, easy to understand tables and graphs. The watershed data, both input and output, as well as precipitation and runoff data can be easily presented by individual subarea, reach, or the watershed as a whole. The flexibility of the model to complete the computations using different hydrologic methods and present the results in different formats makes the program a valuable and powerful tool in the process of understanding how the watershed responds to precipitation and stormwater runoff.

TABLE IV-1
Acceptable Computational Methodologies for Stormwater Management Plans

METHOD	DEVELOPED BY	APPLICABILITY
TR-20 (or commercial computer package based on TR-20)	USDA NRCS	Applicable where use of full hydrology computer model is desirable or necessary.
TR-55 (or commercial computer package based on TR-55)	USDA NRCS	Applicable for land development plans where limitations described in TR-55.
HEC-1/ HEC-HMS	US Army Corps of Engineers	Applicable where use of a full hydrologic computer is desirable or necessary.
Rational Method (or commercial computer package based on Rational Method)	Emil Kuichling (1889)	For sites up to five (5) acres or as approved by DNREC.

B. Modeling Process

The HEC-HMS model works by applying precipitation parameters to the individual portions of the watershed called subareas and then generates stormwater runoff for selected subareas based upon the hydrologic variables that are reflective of the characteristics of these subareas.

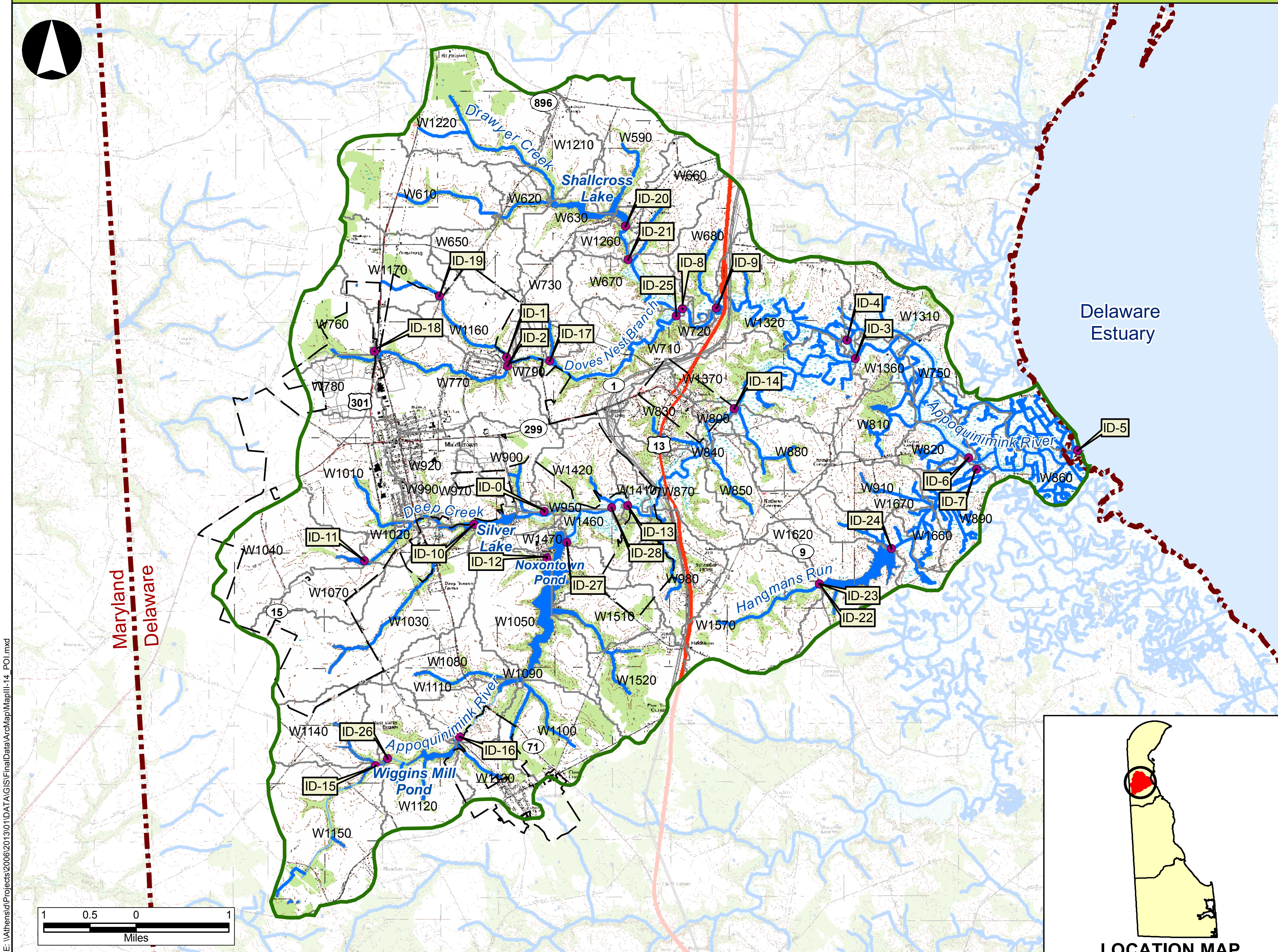
After delineating the Appoquinimink River watershed on the USGS 3-foot DEM, the watershed was divided into subareas. The main consideration in the development of subareas for the watershed model was grouping of areas of the watershed that exhibit similar hydrologic characteristics. This division of the watershed into subareas was completed while keeping mindful of the location of obstructions, significant problem areas, and tributary confluences. The subarea development process for the Appoquinimink River watershed resulted in the creation of 69 subareas ranging in size between 9 and 1,400 acres.

The subareas are shown in Map IV-1. Map IV-1 also shows points of interest for the watershed. A point of interest is any location where it is beneficial to quantify the amount of runoff and gain an understanding of how the runoff is produced. Points of interest are typically located at stream gages, major confluences, sites with important infrastructure, problem areas, flood control structures, major storage facilities, and the mouth of the watershed.

The amount of runoff generated from each subarea is a function of its slope, soil type, and land cover. The land cover is indicative of the amount of development and vegetative cover within any given portion of the watershed. For this analysis, the SCS soil loss equations were used to convert the precipitation to excess stormwater runoff through the assignment of curve numbers.

APPOQUINIMINK RIVER WATERSHED MANAGEMENT PLAN

MAP IV-1 SUBAREA MAP



Legend

- Points of Interest
- Watershed Boundary
- State Boundaries
- Municipal Boundaries
- Subbasin DA
- U.S. Highways
- State Highways
- Other Roads
- Water Bodies
- Estuary
- Appoquinimink River
- Artificial Paths
- Perennial Streams
- Intermittent Streams

Prepared For:
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NOTES:
Portions of this map were generated from the existing data sources noted below. Certain elements of the base map such as municipal boundaries, railroad locations, stream alignments and road networks are provided primarily for reference purposes only and were not directly used for hydrologic computations. In the development of the mapping Borton-Lawson has noted some inconsistencies in the data used for the map. Where obvious inconsistencies in the geographic data were observed the data was adjusted, as needed, to prepare a reasonably accurate map. Although the geographic data was adjusted to compensate for these inconsistencies it is not part of the work plan for this project to correct mapping inconsistencies. Therefore, some geographic inconsistencies may remain on the map.

DATA SOURCES:
Watershed Boundary - DNREC (Modified by BLE)
Roads - DelDOT
Counties - DelDOT
Municipalities - DelDOT
Streams - U.S. Geological Survey, and U.S. EPA
Water Bodies - DNREC
Points of Interest - Borton-Lawson

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Lehigh Valley
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DATE: 1/13/2010

CHECKED BY: EXY
PROJECT NO.: 2006-2013-01

Composite curve numbers were generated for the watershed by overlaying land use data with subarea and hydrologic soil group data within GIS. The composite curve numbers developed using GIS were used as input into the HEC-HMS model of the watershed. Using the curve numbers and other hydrologic parameters developed with GIS, such as lag times and storage variables, the model is able to produce a stormwater runoff hydrograph (a plot of the rate of flow versus time) from small predefined sections of the watershed which exhibit similar runoff characteristics. A hydrograph of excess stormwater for each section of the Appoquinimink River watershed was created with the model by applying a predefined relationship of stormwater runoff to peak runoff rate and hydrograph shape based on the drainage area and lag time (length of time between the middle of the precipitation event and the peak of the runoff hydrograph) of the drainage area. The predefined relationship used to develop stormwater runoff hydrographs for the Appoquinimink River watershed was the 24-hour Delmarva Unit Hydrograph.

After creating stormwater runoff hydrographs for the subareas, the model combines hydrographs from subareas to create regional hydrographs. The regional hydrographs are combined by the model to form hydrographs for individual tributaries of the river and eventually the entire watershed. In the process of combining the stormwater runoff hydrographs, the model also routes the flows through storage areas thereby adjusting the hydrograph volume (area under the hydrograph curve) and altering the shape of the hydrograph, typically delaying and reducing the peak rate of runoff. The model also accounts for the effects of storage and attenuation upon the stream and river hydrographs by the floodplain and stream channels in a similar fashion by applying the Muskingham channel routing equation.

It is important to understand that the model completes all computations with respect to time. This relationship of time to peak runoff and hydrograph shape is essential in understanding how one portion of the watershed interacts with another portion of the watershed. For instance, although a subarea may peak quickly if it is separated by a large distance from another subarea, the peaks may not combine and may not result in flooding or stormwater problems. However, if several smaller subareas are in close proximity to each other, their peaks may combine and create a peak that is much higher than any individual peak alone. In addition to the importance of the peak of the stormwater runoff hydrograph, the shape of the hydrograph is important as well. If the portion of the hydrograph after the peak is slow to recede, then in certain cases the receding limb of the hydrograph is available to combine with other hydrographs and create a new combined peak that is higher than any individual subarea peak.

In summary, the modeling process addresses:

1. runoff contributions of individual subareas;
2. time to peak of stormwater runoff;
3. combination of hydrographs from subareas with respect to time;
4. peak discharge values at various locations throughout the watershed and its tributaries;
5. changes in hydrograph shape for reservoir and floodplain storage;
6. overall watershed timing.

Hydrologic models of the watershed were created for the 1-, 2-, 5-, 10-, 25-, 50-, 100- and 500-year, 24-hour, storm events to determine the hydrologic response of the watershed to design events of different magnitudes. The input and output from the hydrologic models are compiled in Volume III, Technical Appendix for this Plan.

C. Calibration

The value of a model is established by its ability to simulate what occurs in real world. A model that does not reflect what actually occurs is of little value. Conversely, a model that simulates closely what actually occurs in the world is an invaluable tool that can be used to test various design scenarios and identify likely ramifications of such scenarios. To accurately simulate storm flows for the watershed with confidence that the modeled flows reflect what actually occurs in the watershed, the computer model must be calibrated. Calibration is a tuning process used to adjust the model to provide the most accurate representation of the actual runoff and timing conditions of the watershed. The model calibration process involves the adjustment of input parameters, within an acceptable range of values, so that the model is able to calculate flows that are similar to actual flows that occur in the watershed. Variables available to calibrate the model include curve number, initial abstraction, lag time, channel routing coefficients and reach travel time. It is very important that any adjustment made in the calibration parameters be logical and reflective of actual conditions within the watershed. Adjusting the model using parameters that are not representative of watershed conditions is not part of the calibration process but merely an improper adjustment to the model to achieve a desired outcome. To create the most accurate calibration it understandable that localized events, snowmelt, and unique conditions are typically not used for calibration because their unique circumstances causes a hydrologic response that diverges from norm.

Typically, it is preferable to calibrate the hydrologic model to actual measurements of streamflow from stream gauges located within the subject watershed. To accomplish this, it is best to have a large continuous set of streamflow measurements from multiple stream gauges. In this scenario, a statistical analysis can be completed on the streamflow measurements to identify peak flows for an array of design events at several points throughout the watershed. A search of the USGS Surface Water website identified six USGS stream gauges within the Appoquinimink River watershed. Table IV-2 lists the gauge number, location and years of record available for those six stream gauges. As shown in Table IV-2, the Appoquinimink River does not have sufficient gauge data or years of record to facilitate calibration of the model with actual storms, or the development or design flows for an array events using a statistical analysis of stream measurements. For instance, Gauge No. 01483153, Noxontown Lake Outlet near Middletown, has only 6 years of recorded data within the ten year period of record and Gauge No. 01483170, Doves Nest Branch near Odessa, contains only 3 peak flow events. The other gauges have either little or no data available.

In the absence of streamflow measurements to complete the calibration of the model, another method of calculating target flows was needed to adjust the model to better represent the watershed flows. Consideration of other potential methods of calibrating the model concluded that the regression equations contained in USGS Scientific Investigation Report (SIR) 2006-5146, *Magnitude and Frequency of Floods on Nontidal Streams in Delaware*, were the next best method available for calculating target flows to calibrate the Appoquinimink hydrologic model.

TABLE IV-2
Appoquinimink Creek USGS Stream Gauges

USGS Gauge No.	Location	Years of Record
01483153	Noxontown Lake Outlet Near Middletown, DE	1993-2003[1]
01483155	Silver Lake Tributary at Middletown, DE	2001-2006
01483160	Drawyer Creek Near Mount Pleasant, DE	N/A
01483165	Spring Mill Branch Near Armstrong, DE	2001-2004
01483170	Doves Nest Branch Near Odessa, DE	1979-2004[2]
01483175	Drawyer Creek at Odessa, DE	N/A

N/A-No online data was available for site
1 Peak discharge at gage affected by diversion or regulation of streamflow. Only 6 peak streamflow measurements available for period of record
2 Only 3 peak streamflow measurements available for period of record

USGS, in conjunction with DelDOT and the Delaware Geological Survey, developed the regression equations for calculating various design flows (2- through 500-year) using streamflow measurements from stream gauges throughout the state of Delaware. The equations were developed by grouping gauges into regions and examining the relationship of various watershed parameters that affect hydrology such as drainage area, forest cover, impervious area, basin storage, housing density, soil type and mean basin slope to obtain an equations that can estimate a design peak flow from the aforementioned variables.

StreamStats, an internet-based USGS application which uses the regression equations presented in SIR 2006-5146, was used to calculate target peak flows at several calibration points throughout the Appoquinimink River watershed. The reason multiple points were selected to calibrate the model was so that the model would be capable of calculating accurate streamflows throughout the watershed and not just at a single point in the watershed, such as the mouth of the river. Table IV-3 lists the calibration points used for the Appoquinimink River watershed hydrologic model.

The calibration process used for the Appoquinimink River watershed was an iterative process that used 10 calibration points dispersed throughout the watershed. The calibration process was initiated in the upper reaches of the watershed and worked its way through the watershed to the lower reaches. Thus, once the downstream end of the model was calibrated, the entire watershed was capable of yielding accurate flows. Prior to initiating the calibration process, a sensitivity analysis was conducted on the model to determine how the model responds to adjustments in the calibrations parameters. From these runs, it was determined that the initial rainfall abstraction and subarea travel time were the most sensitive parameters available to adjust the Appoquinimink River watershed model.

The hydrologic response of most watersheds is dissimilar for small events and large events. Therefore, it is insufficient to complete just one calibration. Modeling experiences has demonstrated that most watershed models can be fully calibrated by completing one calibration for small events, and another calibration for large events. Therefore, two calibrations were completed for the Appoquinimink River watershed, one for the 5-year event and the other for the 100-year event. The calibration parameters for 1-, 2-, and 10- year events are identical to those used for the 5-year event and the calibration parameters for the 25- and 50-year event are identical to the calibration parameters for the 100-year event.

TABLE IV-3
Appoquinimink Calibration Points

Point	HEC-HMS ID	Tributary Name	Description of Location	Drainage Area (s.m.)
1	Deep Creek	Reservoir-Silver Lake	Downstream of Silver Lake Dam	6.46
2	Appoquinimink River	UserPoint 6	Upstream of Drawyer Creek confluence with Appoquinimink. River	23.13
3	Drawyer Creek	UserPoint 5	Mouth of Drawyer Creek (junction with Appoquinimink River)	15.78
4	Appoquinimink River	Outlet F	Mouth of Appoquinimink River	46.16
5	Appoquinimink River	J271	Upstream of confluence of Hangmans Run with Appoquinimink River	45.47
6	Drawyer Creek	UserPoint 14	Upstream of Drawyer Creek's confluence with Doves Nest Branch	7.27
7	Appoquinimink River	UserPoint 7	Approximately 5,000 ft Downstream of Noxontown Pond	17.90
8	Doves Nest Branch	UserPoint 13	Upstream of Doves Nest Branch confluence with Drawyer Creek	6.40
9	Appoquinimink River	UserPoint 8	Downstream of Noxontown Pond	9.53
10	Deep Creek	J252	Downstream of Silver Lake	7.19

A tabulation of the final calibrated hydrologic variables used in the Appoquinimink River watershed model, for both the 5-year and 100-year events is provided in Volume III, the Technical Appendix of the Plan Report.

A comparison of the target flows developed from the regression equations contained in SIR 2006-5146 and flows computed using the calibrated HEC-HMS model of the Appoquinimink River watershed for the 2- through 100-year, 24-hour, design events are shown in Figures IV-1 through IV-5. This comparison of the calibrated model flows to the target flows indicates that the model is able to provide an accurate determination of flows throughout the watershed for a variety of events. Table IV-3 lists the peak flows for various Points of Interest (POIs), for different storm frequencies as obtained from the model.

D. Verification

After the calibration is complete, the hydrologic model is typically verified. The verification process involves comparing the model flows with flows from historical events. To complete the verification process, two types of data are required. The first set of data required is hourly precipitation data, which defines the rainfall distribution for a series of given events. As the amount of precipitation can vary greatly from one region to another, it is important that recorded precipitation data be from gauges within close proximity to the watershed. The second data set required is hourly streamflow data, which corresponds to the recorded rainfall measurements.

Figure IV-1
2-Year Calibrated Model Comparison

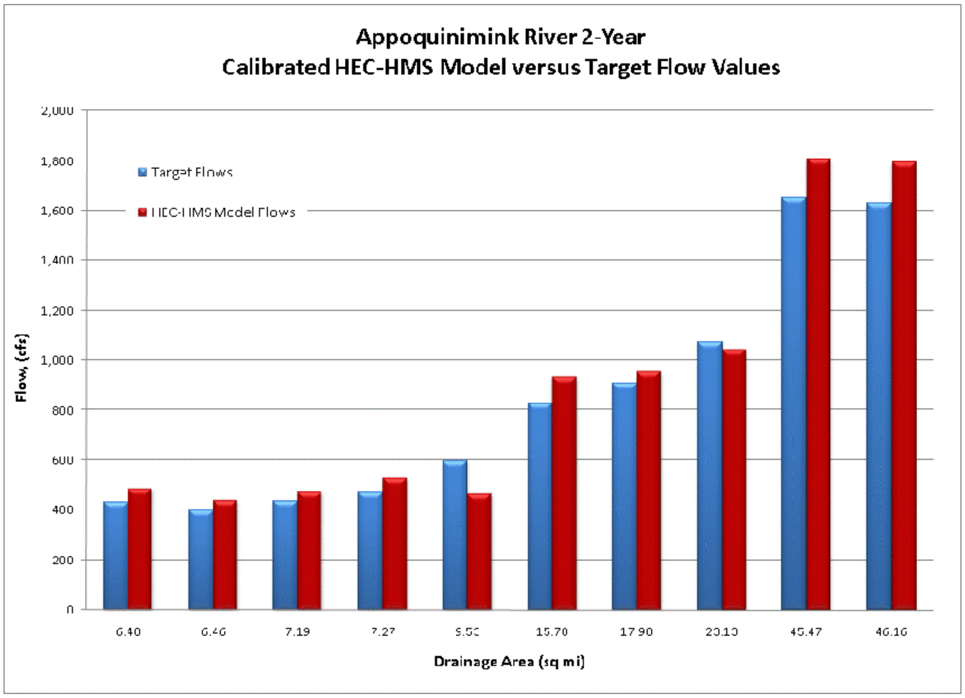


Figure IV-2
10-Year Calibrated Model Comparison

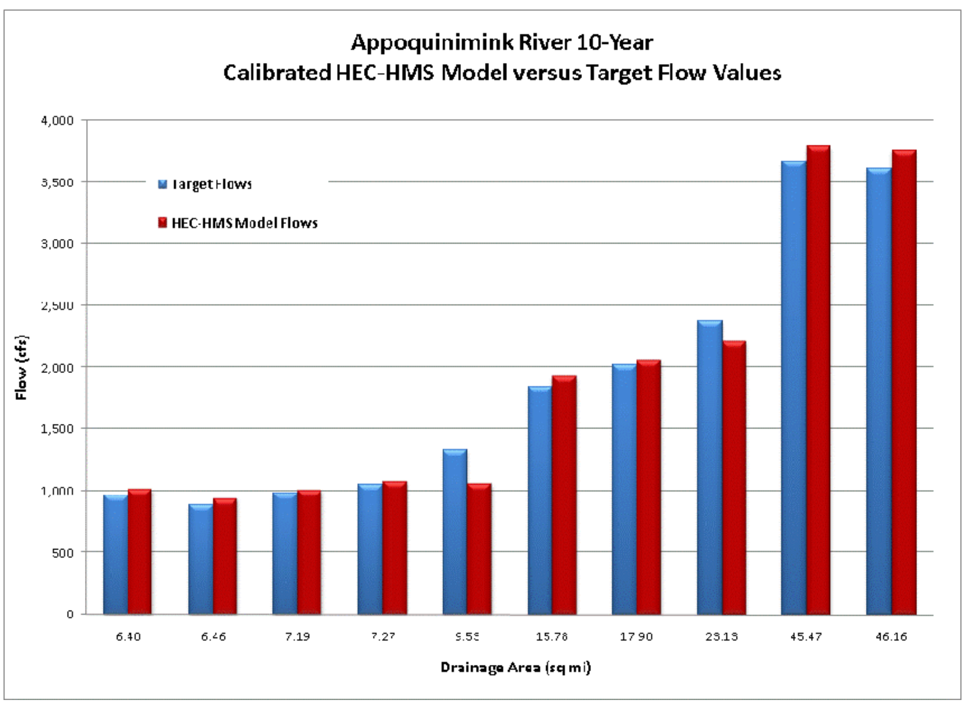


Figure IV-3
25-Year Calibrated Model Comparison

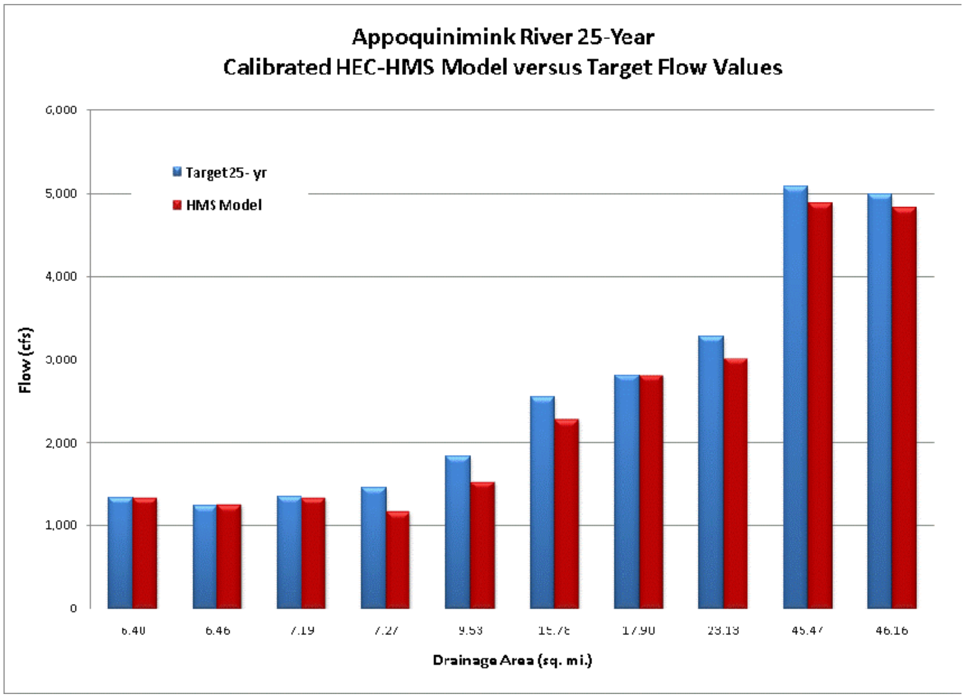


Figure IV-4
50-Year Calibrated Model Comparison

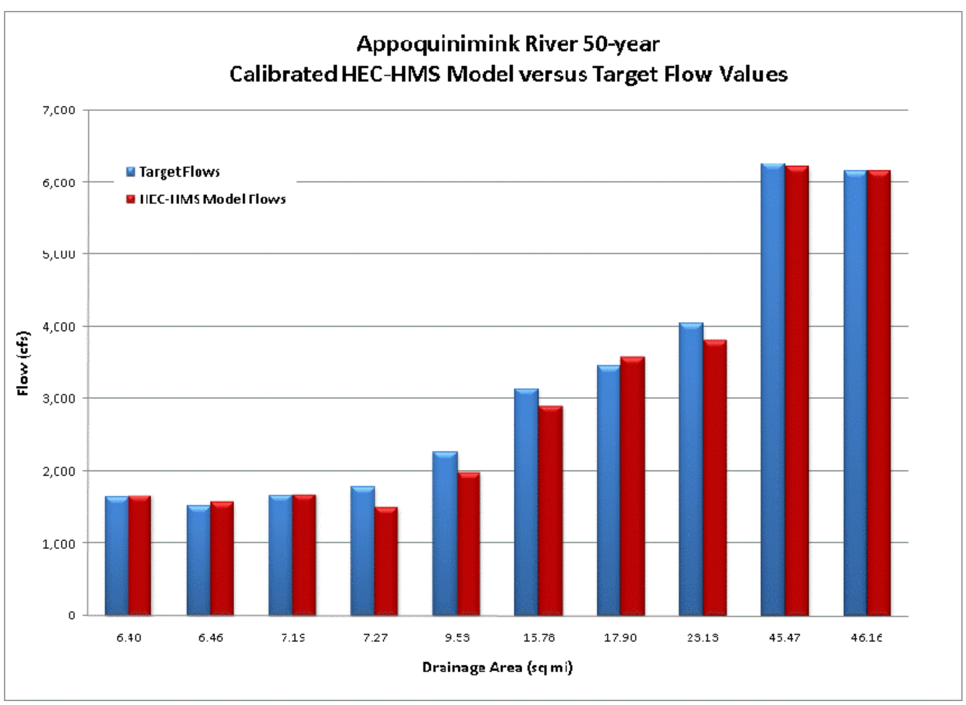
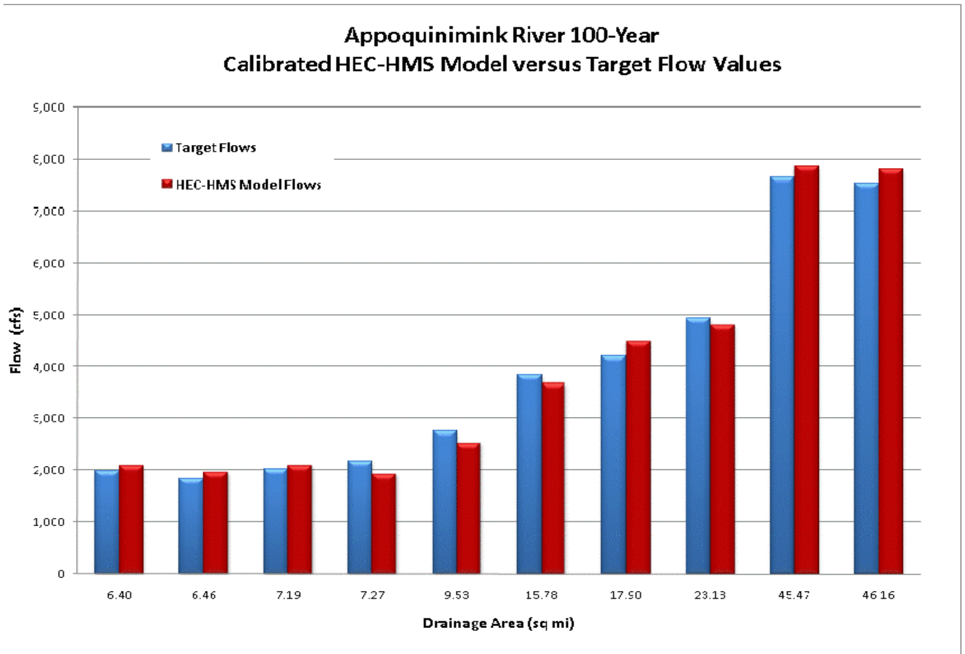


Figure IV-5
100-Year Calibrated Model Comparison



Ideally, it is best when there are multiple gauges, both precipitation and streamflow, located throughout the watershed, with a long history of streamflow data to calibrate against. However, the ideal situation regarding precipitation and stream gauges is rarely realized and such is the case with the Appoquinimink River watershed. As discussed in the previous section, there are several USGS stream gauges within the watershed. However, these gauges are located in the headwaters of the Appoquinimink River watershed and contain a limited set of data that can be used in the verification. Furthermore, a search of the National Oceanic and Atmospheric Administration database of precipitations gauges within or near the watershed found only one precipitation gauge within the watershed (Middletown 3 E, COOPID 075852). This gauge contained rainfall data for the period from 1952-1988. However, this data did not coincide with available stream gauge data. The next closest precipitation gauge (Wilmington DE, COOPID 079595) is 15 miles outside of the watershed. This distance makes the data unusable for verification process. Given the lack of sufficient precipitation and stream data, verification of the model with historical streamflow and precipitation measurements could not be completed.

Problems with verifying the Appoquinimink hydrologic model can be better understood when looking at an individual event such as the June 2006 event. This event created flooding in various areas of the mid-Atlantic and northeastern United States. In the Appoquinimink River watershed, both hourly precipitation data and stream gauge data are available for this event. In the case of streamflow, recorded hourly measurements of flows are available for this event at a USGS stream gauge located on the Silver Lake tributary (01483155) of the Appoquinimink River. However, according to USGS National Water Information System, this stream gauge has a drainage area of only 2 square miles and is located in the upper portion of the watershed. Comparing the location of the stream gauge with the basin files contained in the Appoquinimink hydrologic model indicates that this gauge is located near the outlet of subarea W1030.

TABLE IV-4
Peak Flows at Various Points of Interest
from the Appoquinimink Watershed HEC-HMS Model

Map ID	Peak Flow, (cfs)						
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
0	412	667	885	1167	1485	1868	2921
1	95	142	180	234	288	356	537
2	245	360	453	592	721	880	1302
3	1120	1673	2222	3087	3937	4989	7848
4	872	1362	1792	2341	2908	3647	5601
5	1821	2885	3807	5132	6479	8180	12829
6	1830	2898	3825	5157	6511	8219	12895
7	347	474	574	738	867	1023	1431
8	522	835	1107	1446	1805	2283	3528
9	840	1318	1737	2269	2822	3545	5454
10	444	668	854	1103	1364	1690	2572
11	147	230	300	385	487	616	970
12	552	872	1151	1635	2058	2603	4094
13	872	1423	1910	2669	3417	4335	6880
14	976	1585	2121	2953	3772	4782	7544
15	302	448	570	777	951	1169	1762
16	366	586	779	1114	1409	1791	2765
17	431	645	822	1064	1311	1620	2452
18	254	373	470	615	748	913	1352
19	98	147	187	243	300	370	560
20	483	777	1029	1341	1675	2122	3287
21	513	826	1094	1427	1783	2260	3501
22	272	417	537	698	869	1083	1659
23	272	417	537	698	869	1083	1659
24	409	621	798	1039	1289	1601	2440
25	565	852	1090	1407	1741	2159	3291
26	434	646	823	1123	1375	1692	2555
27	407	671	910	1336	1721	2190	3522
28	450	727	964	1271	1616	2032	3176

This subarea includes only 2.14 square miles of the overall 46.6 square miles of the Appoquinimink River watershed. Simulation of the 2006 event with this limited data will only provide verification for one subarea, or 4.5% of the watershed.

Even though the model could not be verified with historical data, confidence can still be placed in the analyses completed with the Appoquinimink model because the model was calibrated using target flows generated from the regression equations contained in USGS SIR 2006-5146. As indicated in the previous section, the regression equations developed in the USGS report are based on actual stream gauge measurements for streams in Delaware. Since the model's design events are closely calibrated to target flows calculated from regression equations developed specifically for various regions in Delaware, the model is considered acceptable for study of the hydrologic response of the watershed to precipitation. It is important to note that even though the hydrologic model could not be verified with historic data, the model can be easily verified in the future if the required data becomes available. Therefore, future verification when the necessary data becomes available is recommended, and if deemed necessary, further adjustments can be made to the calibration at that time.

E. Comparison to FEMA Flow

The effective FEMA Flood Insurance Study (FIS) of New Castle County, Delaware (January 2007) contains limited data quantifying the magnitude of the 100-year design storm in the Appoquinimink River watershed. The only information contained in the existing study is the elevation of the 1-percent-annual occurrence (100-year) flood at Shallcross Lake. No flows were available in the flood insurance study to compare to the HEC-HMS hydrologic model of the watershed.

In addition to the FIS, the area around Shallcross Lake has been the subject of two Letters of Map Revision (LOMR). One LOMR was approved August 2004 and the other was approved October 2007. Both LOMRs quantified the 1-percent-annual occurrence design flow for tributaries west of the Lake only. A comparison of the drainage areas and 100-year peak design flows from the FEMA approved LOMRs, and from the Appoquinimink HEC-HMS hydrologic model developed for this study, is provided in Table IV-4. Table IV-4 shows several substantial differences between the peak discharges calculated by the HEC-HMS model and the values reported by the LOMRs. Closer inspection of the hydrologic data used in the development of the LOMR applications identified significant differences in the drainage areas, and modeling parameters, such as lag time, used in the TR-20 hydrologic analysis for the LOMRs. Upon closer inspection of the inconsistencies in flows and the cause of these discrepancies, it was decided that because the HEC-HMS modeled flows were based on a thorough hydrologic analysis using more detailed and complete hydrologic methods, that the HEC-HMS modeled flows represent a better estimate of design flows for the watershed than the flows developed in the LOMR applications.

Discrepancies between the HEC-HMS modeled flows and the LOMR flows were noted in a report entitled, *Flood Map Modernization Program Hydrology Report Appoquinimink Watershed New Castle County, Delaware,* dated January 30, 2009, which was prepared by Borton-Lawson and submitted to DNREC and FEMA for review and approval. After reviewing the report, FEMA concurred with the findings of the report that the flows from the Appoquinimink HEC-HMS hydrologic model are the most appropriate for the watershed.

TABLE IV-5
Discharge Comparison Table

Flooding Source and Location HMS Model vs. Effective FIS	HEC-HMS Model / *Effective New Castle County, DE FIS (2007)* Drainage Area (sq. miles)	HEC-HMS Model / *Effective New Castle County, DE FIS (2007)* 100-year Peak Discharges (cfs)
Shallcross Lake Branch No. 1 at confluence with Shallcross Lake	1.4 / *1.9*	1,063 / *2,200*
Shallcross Lake Branch No. 5 at confluence with Shallcross Lake	1.0 / *1.20*	750 / *1,200*
Spring Mill Branch at the confluence with Shallcross Lake	1.98 / *0.41*	785 / *449*

F. Alternate Land Cover and Its Affect on Stormwater Runoff

The primary land use of Appoquinimink River watershed has been and continues to be agricultural. In Section II of this report, the existing land cover of the watershed was compared to a historical assessment of the land cover in the watershed based upon 1937 aerial photographs. Although in both conditions the land cover is primarily agriculture, the agricultural practices of 1937 are considered to be different from those of today. In 1937, most farms in the watershed contained dairy cows that would have required permanent pasture and/or hayland to sustain the livestock. DNREC estimates that agricultural lands in 1937 may have consisted of a mixture of 25% permanent pasture, 25% hayland and 50% cropland. This change in farming practices between 1937 and today results in a higher runoff potential for agricultural lands of today than those of 1937. To determine the ramification of changes in land cover in the watershed on stormwater runoff, the existing conditions hydrologic model was adjusted to create a historical model of the watershed. Using the 1937 land cover, a revised composite curve number was calculated for each subwatershed to estimate the flow for the 100-year storm event. For this model, all of the hydrologic variables used in the existing conditions 100-year calibration were carried over to create the historic model. Table IV-5 lists the peak discharge at the calibration points throughout the watershed and organized in the table by drainage area. As expected, the modeled peak flows for the 1937 historical conditions are less than existing conditions, with the existing conditions 2% to 26% larger than the peak 100-year flows of 1937. The 100-year flow for the existing condition, at the mouth of the watershed, is 19% larger than the 1937 flow.

TABLE IV-6
Comparison of 100-Year Peak Discharges at Calibration Points

Point Number / Tributary	Location	Drainage Area (square miles)	Peak Discharge (cfs)				
			1937 Historical Condition	Existing Condition	Difference Historical to Existing (%)	Future Build-Out	Difference Existing to Future Build-Out (%)
8 Doves Nest Branch	Upstream of Doves Nest Branch's confluence with Drawyer Creek	6.40	1,712	2,159	26.1	2,248	4.0
1 Deep Creek	Downstream of Silver Lake Dam	6.46	1,552	1,868	20.3	2,038	8.3
10 Deep Creek	Downstream of Silver Lake	7.19	1,669	2,032	21.8	2,221	8.5
6 Drawyer Creek	Upstream of Drawyer Creek's confluence with Doves Nest Branch	7.27	2,070	2,283	10.2	2,432	6.2
9 Appoquinimink River	Downstream of Noxontown Pond	9.53	2,085	2,190	5.0	2,091	-4.7
3 Drawyer Creek	Mouth of Drawyer Creek's (confluence with Appoquinimink River)	15.78	3,566	3,647	2.3	3,854	5.4
7 Appoquinimink River	Approximately 5,000 feet Downstream of Noxontown Pond	17.90	3,850	4,335	12.6	4,229	2.1
2 Appoquinimink River	Upstream of Drawyer Creek's confluence with Appoquinimink. River	23.13	4,137	4,989	20.6	5,107	2.3
5 Appoquinimink River	Upstream of Hangmans Run's confluence with Appoquinimink River	45.47	6,921	8,219	18.8	8,528	3.6
4 Appoquinimink River	Mouth of Appoquinimink River	46.16	6,860	8,180	19.2	8,487	3.5

The largest increases in the 100-year flows appear to logically coincide with areas experiencing the greatest amount of development over the last 70 years and those experiencing the smallest increase in flow appear to correspond with portions of the watershed that remain primarily agricultural. Areas experiencing the greatest increases in flows are in the central and western-central parts of the watershed. HEC-HMS output from the historic model and the existing condition model is provided in Volume III of this Plan.

A similar analysis was completed for the future hypothetical full build-out of the watershed, discussed in Section II of this report. This model was based on composite curve numbers of the subareas developed from zoning classifications, without respect or consideration of the existing land cover or existing curve numbers. This condition is strictly theoretical, and is not intended to imply an actual future condition in the watershed, but provide an indication of where the peak 100-year stormwater runoff could potentially be if development is not regulated and stormwater management is not effectively controlled. As shown in Table IV-5, this analysis indicates that the increase in the 100-year peak stormwater runoff for the hypothetical build-out condition will range between -5% and 9%.

Given the hypothetical full build-out of the watershed, the increase in flow between the existing condition and the full build-out is considered to be somewhat underestimated. The reason for this underestimate of the potential increases in flows is because the curve number methodology assigns a lower curve number, or runoff potential, to low-density residential areas than it does to agricultural areas. With a large portion of the existing land cover in the watershed consisting of agriculture and then shifting to low density residential in the full build-out condition, the future conditions model in these areas will have a lower curve number than the existing condition. This effect can be clearly observed at Point 9 where the conversion of large portions of agriculture to low-density residential land cover results in a decrease in the future build-out flows. To compensate for this condition, many municipalities require a portion of sites, typically 20%, that are to be converted from agricultural land to low-density residential areas be considered as meadow in good condition for the existing condition stormwater runoff analysis. This adjustment in the existing condition curve number compensates better for the interconnection of impervious surfaces in low-density residential areas, resulting from the installment of swales, storm sewer, channels, downspouts, driveways and gutter. Using this procedure to evaluate existing land cover for the development of low-density residential areas from agriculture lands ensures that some form of stormwater management will be applied to the land with the new development.

Although the increase in flows in the future conditions analysis is not exceptional, the model does confirm an increase in future flows will occur in most subareas throughout the watershed. In other words, the model confirms that with development there will be more frequent problems and more extensive problems, thus underscoring the need for application of effective stormwater management practices in the watershed to alleviate existing problems and avoid potential future problems.

G. High Intensity Low Duration Event

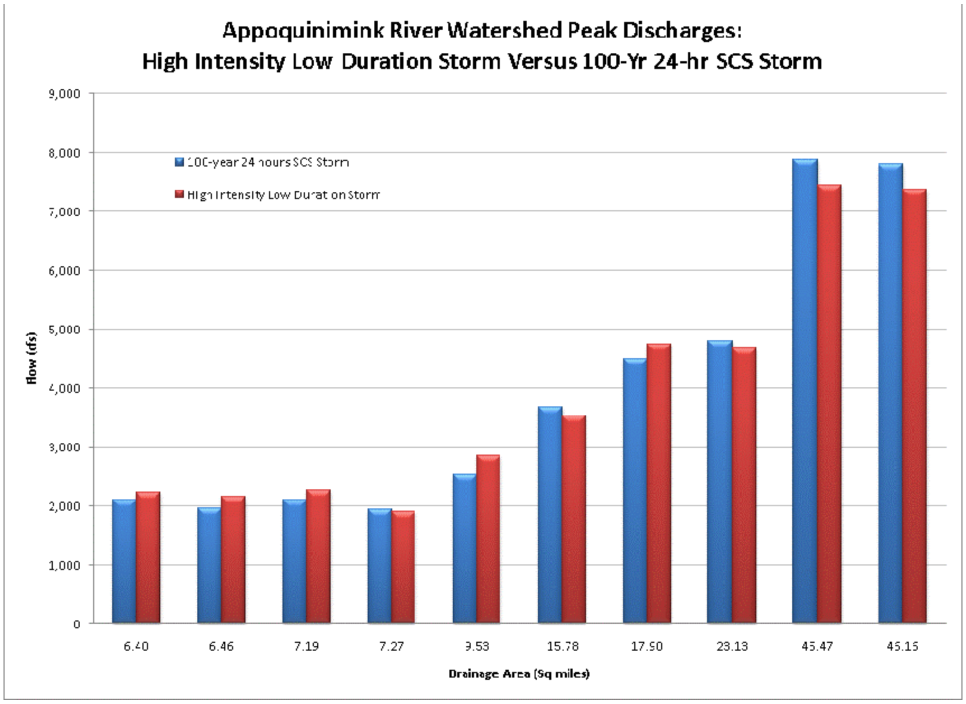
The hydrologic model of the existing conditions for the Appoquinimink River watershed is based on a 100-year, 24-hour SCS Type II storm distribution using the Delmarva unit hydrograph to transform the excess precipitation into a stormwater runoff hydrograph. As the model is based on the 24-hour design event, the question was posed: how would the peak runoff change if the distribution of the precipitation was altered such that the same amount of rain as occurred during the 100-year, 24-hour event was altered to occur over a shorter period? To answer this question, a hypothetical high intensity, low duration storm event was simulated using the calibrated Appoquinimink 100-year hydrologic model. For this analysis, the 100-year return frequency, with 8 inches of precipitation, was altered such that all of the precipitation was input into the model over a 6-hour period instead of 24 hours. Figure IV-1 shows, graphically, the results of this analysis comparing the 24-hour flows with those of the high intensity, short duration event.

The data appears to indicate that the low intensity, short duration event typically yields higher peak flows than the normal 24-hour duration in areas with smaller tributary areas but lower peak flows in areas with larger drainages areas. The response of the model appears logical when considering how the size of a subarea affects the stormwater hydrograph shape and size. Typically, smaller subareas have a smaller time base taking the hydrograph a shorter length of time to peak and then recede. The opposite is true as the tributary area becomes larger. Furthermore, when applying the unit hydrograph to the excess stormwater runoff, the peak runoff is inversely proportionate to the lag time (length of time between the middle of the precipitation event and the peak of the runoff). So as the lag time decreases the peak runoff rate also increases. By shortening the length of the rainfall from 24 hours to 6 hours, the peak rate of runoff is increased in the smaller subareas of the watershed.

This explains why the peak rate of runoff for the small subareas gets larger but why does the relationship change in the lower sections of the watershed with the larger drainage areas exhibiting smaller peaks in the shorter duration events? There are two plausible explanations for this. First, as indicated previously, the duration of the storm impacts the shape of the runoff hydrograph. With a decrease in storm duration, the time base or length of time for the individual subarea hydrographs is reduced. Thinking of the stormwater runoff hydrograph as a triangle, runoff from short duration events would be taller and have a smaller base than their 24-hour counterparts that have longer storm duration. When combining subareas, as the runoff moves downstream through the watershed, the shorter time base of the hydrographs would mean less subareas would interact with one another, resulting in lower peaks in the downstream segments of the watershed.

The second reason the peaks in the downstream area of the watershed are smaller in the short duration event concerns floodplain storage. In the high intensity, short duration event, the overall hydrograph consists of many smaller peaks that combine into a lower peak that is sustained for a longer period of time. In the 24-hour design event, peak is higher and lasts for a shorter period of time. However, because of the wide base of the 24-hour downstream hydrograph, the floodplain storage is filled when the peak comes through the downstream reaches of the watershed and the floodplain is able to provide less attenuation. Therefore, the floodplain storage in the lower portions of the watershed along the Appoquinimink River is able to attenuate the many smaller peaks from the subareas of the high intensity event and thereby reduce the overall peak better than it is able to reduce the larger peak in the 24-hour design event.

Figure IV-6
100-Year Calibrated Model Comparison



H. Detention Basin Analysis

As noted in Section II, there are numerous existing stormwater management facilities located primarily around the urban centers of the watershed such as Middletown, Odessa and Townsend. A common question that often arises with respect to these facilities is: what impact do existing stormwater management facilities have upon the watershed? The answer is that any one individual detention or retention basin has very little impact upon the rate of flow in the watershed unless the proportion of the available storage to the proportion of overall runoff volume in any given subarea or the watershed as a whole is large, which is rarely the case. Typically, most basins are relatively small and are only designed to manage flow from an individual site that is relatively small in comparison to the subarea or watershed as a whole. Therefore, the rate of flow in the stream near the facility may be controlled by an individual facility but the impact of the device upon the flow in the tributary is lessened as additional drainage area contributes flow to the tributary. Hydrologic modeling experience has demonstrated that since existing management facilities are rarely large enough to impact flows throughout the watershed or control a significant portion of the watershed they are typically not of value to incorporate into the model.

It is plausible that many facilities located throughout the watershed could have a beneficial effect upon the flows within the watershed. However, this is typically not the case in watersheds that do not have a watershed-based management strategy. In many of these watersheds, post-development stormwater is controlled to not exceed existing conditions. Although not immediately apparent, this approach to stormwater management has complications because it does not consider how one area of the watershed interacts with another area of the watershed. Typically, as an area is developed it becomes more impervious and more interconnected, thus producing more runoff volume, a higher peak, and a shorter time to peak. Installment of detention facilities to control post development stormwater runoff to peak existing conditions results in a peak rate of release that is near the existing condition, but because there is more volume of runoff, the peak rate of runoff is extended longer than in the existing predevelopment condition. This extension of the peak rate of release allows more opportunity for the post construction stormwater hydrograph to interact with hydrographs from other areas of the watershed and may in fact make watershed flows higher than if no management facility is in place. Further discussion on this topic is presented in Section V.

One of the strengths of the HEC-HMS hydrologic model of the Appoquinimink River watershed is that it has the ability to evaluate individual flows in various parts of the watershed with respect to event timing. Therefore, the hydrologic model is fully capable of evaluating hydrographs from individual sites or facilities within the subareas. However, since there was insufficient data pertaining to individual drainage area size, curve number, time of concentration, storage volume and outlet control data for the individual facilities within the watershed, no individual control facilities were placed into the model. Should the data for any individual facility or multiple facilities become available in the future, the hydrologic model can easily be adjusted to evaluate the precise effect of these facilities upon the flows at any point in the watershed.

I. 90% Precipitation Depth and 90% Stormwater Runoff Volume

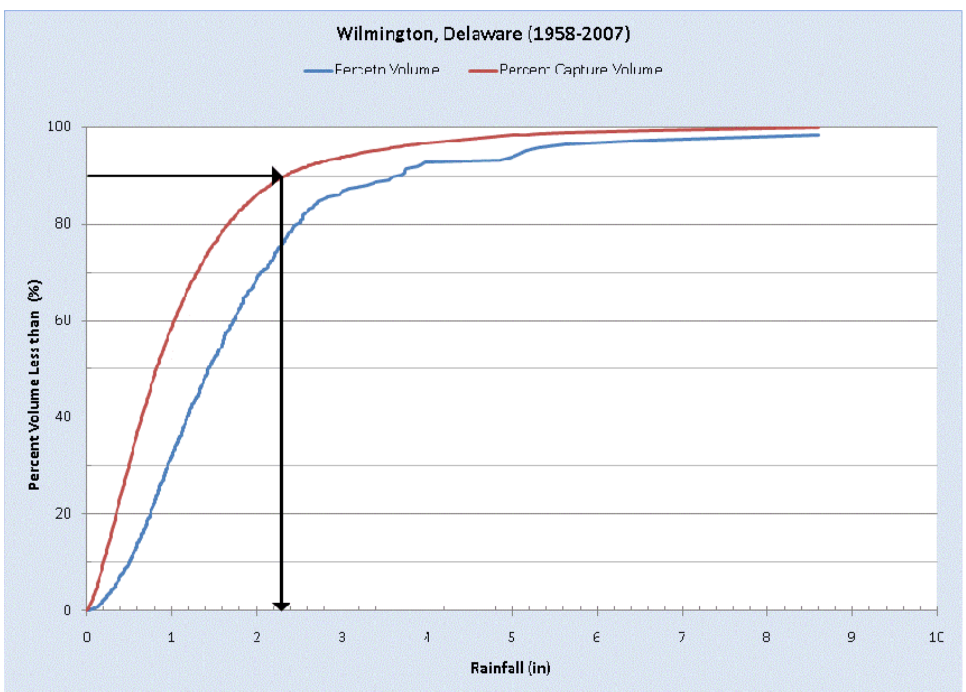
To better understand the relationship between precipitation and stormwater runoff in the Appoquinimink River watershed, an analysis of precipitation data was completed as part of the hydrologic study of the watershed. In the absence of a significant rainfall data from a precipitation gauge within the watershed, hourly precipitation data from the NOAA station at Wilmington New Castle County, Delaware (COOPID 079595) was used for this analysis. The Wilmington gauge is located about 15-20 miles to the north of the Appoquinimink River watershed and has the longest period of recorded hourly precipitation data (back to 1948) for the state. Given the distance of the gauge from the watershed, the precipitation data is not useful for the verification of the hydrologic model, where distribution and spatial variability of the precipitation could be significant. However, the gauge is a good source of data for an analysis of annual precipitation and correlation to annual stormwater runoff from the Appoquinimink River watershed.

The hourly precipitation data was grouped into individual precipitation events by examining the data for gaps in the records when the gauge indicated that no precipitation occurred. Successive records with measurements greater than zero inches were summed to determine the depth of rainfall for any given event. The individual records were then ranked from smallest to largest and added together to create a running total and determine the total depth of rainfall that fell over the period of record. The total rainfall depth for the period record was multiplied by 0.9 to determine annual depth of rainfall that is equivalent to 90% of the rainfall depth in the watershed. This analysis determined that 90% of the rainfall occurs in events with depths that are less than 1.4 inches.

Although ninety percent of rainfall occurs in depths equivalent to 1.4 inches or less, this depth is not equivalent to 90% of the runoff volume from the watershed. This is because smaller events generate less runoff than larger events. To convert the rainfall to excess precipitation and to determine the rainfall depth that is equivalent to 90% of the runoff, the SCS curve number, initial abstraction, and subarea drainage area was used to calculate the amount of runoff, using the SCS loss equation, for the respective amounts of precipitation. The total stormwater runoff for all events was totaled and using a similar process as used with the precipitation analysis the 90% of runoff volume was determined to be equivalent to 3.9 inches of rain. Therefore, if all of the rainfall for events up to and including 3.9 inches of rainfall were captured and controlled while all events greater than 3.9 inches of rainfall were allowed to runoff freely then 90% of the annual runoff would be controlled.

It is difficult to control only those events up to a certain depth of precipitation. Typically most controls are applied to all events, not just events larger than 3.9 inches of rain, and as such the controls are available to capture some percentage of stormwater runoff, even from the largest storms. Taking into consideration that controls will impact all events, both large and small, the depth of rainfall equivalent to 90% of the annual stormwater runoff is reduced from 3.9 to 2.6 inches. Figure IV-2 contains a plot of runoff volume and rainfall depth which graphically demonstrates the relationship of the total volume and the capture volume. Data used in the precipitation analysis and runoff analysis is provided in Volume III, Technical Appendix.

Figure IV-7
Rainfall Depth and 90% Annual Runoff Volume



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SECTION V

STANDARDS AND CRITERIA FOR STORMWATER CONTROL

A. Watershed Level Control Philosophy

Historically, stormwater management standards and criteria have been developed and applied on a local basis, focusing on individual sites instead of the watershed as a whole. With this approach, sites are managed as individual entities without regard to how one site interacts with another. Following this management strategy, it is possible that an individual site could meet its management objectives but because of sustained stormwater runoff rates, the watershed as a whole could be subject to increased flows and stormwater-related complications. The reason sustained post-construction runoff occurs is because typically, development results in the creation of more impervious land cover. With peak post-construction rates of release typically capped at existing conditions, a longer period of sustained peak flow is required in the post-construction condition to release all of the stormwater out of the control facility. This extended peak flow allows peak flows from adjoining areas to overlap and potentially exceed natural conditions. Hence, the following common problems can occur in both unmanaged watersheds and those managed with site management strategies:

1. Flooding
2. Streambank erosion
3. Drainage problems
4. Water quality problems
5. Thermal problems
6. Groundwater depletion
7. Baseflow reduction
8. Habitat degradation
9. Sedimentation
10. Loss of Habitat

The primary goal of truly effective stormwater management is to manage post-construction stormwater runoff so that it mimics natural stormwater runoff conditions in the entire watershed and not just locally at an individual site. The ultimate objective with respect to stormwater management is to not change the quantitative characteristics of stormwater runoff, both rate and volume; and the qualitative characteristics of the stormwater runoff, both chemical and thermal. As such, the watershed level control philosophy of stormwater management was developed. This stormwater management philosophy seeks to better manage increases in post-construction runoff volumes by applying management standards and criteria to individual sites that were developed while considering the entire watershed and the impact of one area of the watershed upon another.

B. Standards and Criteria

The State of Delaware enacted Senate Bill 359 in order to amend Chapter 40, Title 7, of the Delaware Code. The Bill authorized the development of a comprehensive stormwater management program in which watersheds or subwatersheds approved as Designated Watersheds or Subwatersheds by DNREC shall have the regulatory requirements to manage stormwater specified in a watershed plan. In order to be declared a Designated Watershed, the watershed must have a management plan that contains the following elements:

1. Stormwater quantity or quality problem identification
2. The overall needs of the watershed, not just the additional impacts of new development activities
3. Alternative approaches to address the existing and future problems
4. A defined approach which includes the overall costs and benefits
5. A schedule for implementation
6. Funding sources and amounts
7. A public hearing process prior to departmental approval

It is the intent of the stakeholders overseeing the development of the Appoquinimink River Stormwater Management Plan that this document facilitates the declaration of the Appoquinimink River watershed as a Designated Watershed.

Maintaining the existing hydrologic regime for newly developing areas in the watershed and restoring the natural hydrologic regime in redeveloping areas of the watershed is the best approach to managing stormwater runoff in the watershed. The technical standards and criteria, developed as a part of this Plan, seek to protect the watershed by applying management strategies throughout the watershed on a local individual site basis to protect the entire watershed and not just a single portion of the watershed. The Appoquinimink River's technical standards and criteria focus on six (6) different management objectives to better protect the water resources in the watershed:

1. Maintain groundwater recharge
2. Maintain or improve water quality
3. Prevent streambank erosion
4. Manage overbank flood events
5. Manage extreme flood events
6. Maintain or improve tidal marsh habitat

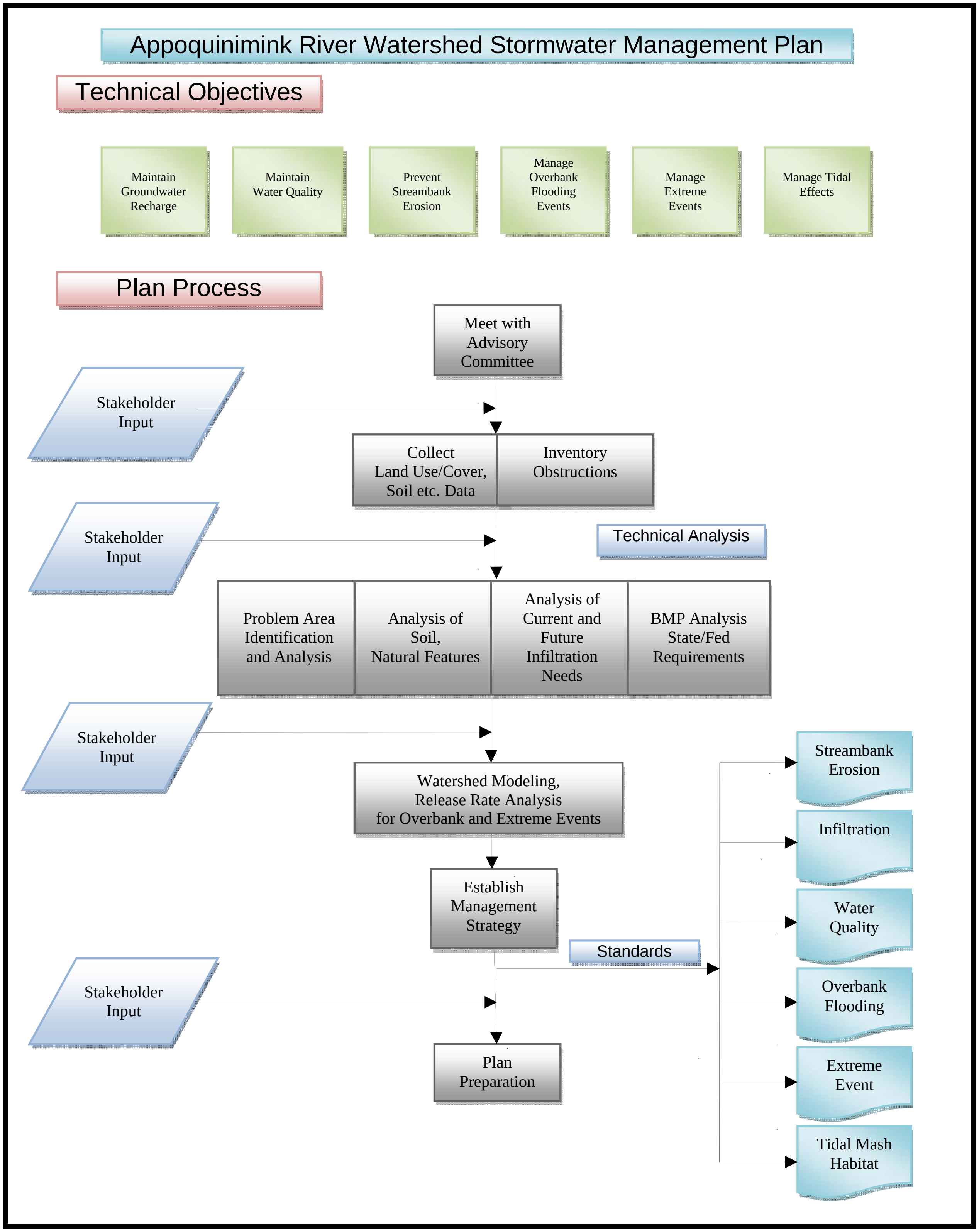
The standards and criteria developed for the Appoquinimink River watershed to address each of these six (6) management objectives were developed using the process depicted in Figure V-1. The six (6) stormwater management objectives are listed at the top of the figure under technical objectives with the Plan and standards development process shown beneath. The process started with a meeting with the project stakeholders; followed by data collection and inventory of watershed obstructions; technical analysis and then the development of a management strategy.

Throughout the planning process and the development of the standards and criteria, several meetings were conducted with the stakeholders in order to develop the following stormwater management standards and criteria for the Appoquinimink River watershed.

1. **Groundwater Recharge**

   Recharging rainfall into the ground replenishes the groundwater supplies and provides baseflow to streams (a process that keeps streams flowing during the drier summer months). As development within a watershed occurs and impervious land cover increases, rainfall reaching the groundwater decreases and stormwater runoff increases.

Figure V-1
Technical Objectives and Plan Process



This produces several negative impacts within the watershed, including lower base flows to streams, reduced groundwater supplies and increases in runoff rates and volumes. In highly developed watersheds, dry stream conditions, depleted groundwater drinking supplies, and streambank erosion are all indicative of reduced groundwater recharge.

Typically, detention basins can attenuate the developed conditions peak runoff rate to the existing conditions peak runoff rate, but they are not able to address the impacts of increased runoff volume or decreased groundwater recharge. Additional measures need to be incorporated into a stormwater management design to address the groundwater recharge and runoff volume impacts.

Stormwater management measures, commonly referred to as Best Management Practices (BMPs), can be designed to promote groundwater recharge. These measures are particularly effective in areas with hydrologic soil groups (HSG) A and B soils but should be utilized wherever feasible and supported by on-site soil testing (Note: there is no HSG A soil in the Appoquinimink River watershed).

Maximizing groundwater recharge potential is an important aspect of achieving and maintaining the natural hydrologic regime of a watershed in areas where development is projected to occur. The groundwater recharge standard for the Appoquinimink River watershed is based upon the precipitation analysis presented in Section IV of this report, which identified that 90% of the annual runoff volume from the watershed is equivalent to the amount of runoff that occurs from the 1-year, 24-hour event, or approximately 2.7 inches of rain. However, this analysis is based upon existing land cover and not the natural undeveloped hydrologic conditions in the watershed. Completing the analysis with a lower composite curve number, which is more representative of natural conditions in the watershed, would effectively increase the amount of precipitation equivalent to the 90% annual runoff. Therefore, in order to obtain a measure of restoration within the watershed, the recharge volume shall be based upon the 2-year, 24-hour volume, or 3.2 inches of precipitation. The recharge volume for the Appoquinimink River watershed shall be defined as follows:

> *The Groundwater Recharge Volume is equivalent to the difference between the volume of stormwater runoff for the 2-year post-construction runoff and the 2-year, 24-hour existing condition. The NRCS Runoff Equation shall be used to calculate the existing and post-construction stormwater runoff volumes. To compensate for the large amount of agricultural land cover in the Appoquinimink River watershed, the existing conditions stormwater runoff volume shall be calculated with a composite curve number that is based upon a minimum of no less than twenty-five (25) percent of the existing non-forest, non-meadow land cover calculated as meadow.*
>
> *Unless it can be conclusively demonstrated with on-site testing that physical site constraints preclude the use of infiltration practices, the recharge volume shall be permanently removed from the stormwater runoff leaving any development site. In the event that site conditions limit but do not preclude the use of infiltration practices, BMPs shall be installed to promote as much infiltration as reasonably practicable based upon the constraints established from on-site testing.*

To achieve the groundwater recharge management criteria, the following management principals shall be applied to development sites within the watershed:

a. Green Technology BMPs (GTBMPs) (i.e. vegetated filter strips, vegetated buffers, bioretention, rain gardens) and other nonstructural practices shall be given preferential treatment ahead of structural infiltration facilities such as infiltration trenches, infiltration basins and subsurface infiltration facilities. Structural infiltration facilities on residential applications shall only be considered after GTBMPs and nonstructural practices have been eliminated from consideration.

b. All stormwater design shall consider the zoning and subdivision requirements of the local municipality before specifying the installation of structural infiltration facilities to ensure that proposed stormwater management facilities conform to local zoning and subdivision requirements (i.e., buffer requirements, isolation distances, setbacks, ownership, maintenance, etc.).

c. Nonstructural infiltration practices shall be applied as close as possible to the point of stormwater runoff origination. Once stormwater begins to concentrate it is difficult to apply nonstructural techniques to achieve sufficient groundwater recharge without structural methods.

d. Certain soils and topographic conditions are not conducive to recharge. Site-specific testing of actual field conditions is needed to determine infiltration feasibility. The general process for designing the infiltration BMP shall be:

   i. Analyze HSGs as well as natural and man-made features within the site to determine general areas of suitability for infiltration practices.

   ii. Provide field tests such as single ring infiltrometer (at the bottom of the proposed infiltration surface) to determine the appropriate hydraulic conductivity rate. Other infiltration testing methods may be acceptable but they must be consistent with current DNREC Policies. Percolation tests are not acceptable for design purposes. Tests must be performed at the hydraulically most restrictive layer 0-3 feet below the bottom of the infiltration surface.

   iii. Design the infiltration facility for the required retention volume based on field determined infiltration capacity at the bottom of the infiltration facility.

   iv. If individual on-lot infiltration structures are proposed by the Applicant's design professional, it must be demonstrated to the municipality that the soils are conducive to infiltration on each lot where such facilities are proposed. When individual on-lot systems are proposed the property owner is responsible for inspection and maintenance of the devices and all appurtenances. Documentation on the performance, location and maintenance of such systems must be provided to all subsequent property owners.

e. Minimum Design Requirements for all Infiltration BMPs:

i. Infiltration BMPs intended to receive runoff from developed areas shall be selected based on suitability of soils and site conditions. A detailed soils investigation of the project site shall be required to determine the suitability of site conditions for proposed recharge facilities. The evaluation shall be performed by a qualified design professional, and at a minimum, determine the soil permeability, depth to bedrock, depth to the seasonal high water table, soil limitations (for all soil types found on the subject parcel), and stability of the subgrade.

ii. Infiltration practices shall not be permitted to be placed in fill soils or conditions.

iii. Infiltration BMPs shall only be constructed on soils that have a minimum depth between the bottom of the facility and the seasonal high water table, bedrock or limiting zone of 36 inches or more.

iv. Infiltration BMPs shall only be constructed on soils that have an infiltration rate of at least 1.02 inches per hour, and are sufficient to accept the additional stormwater loading and drain completely. Methods and calculations used to establish the infiltration rates soils must be consistent with current DNREC Policies.

v. The loading ratio (drainage area to basal area of the infiltration facility) shall not exceed a ratio of 7:1.

vi. The Infiltration BMP shall be capable of completely infiltrating the recharge volume within 2 days (48 hours).

vii. Pretreatment of stormwater runoff shall be provided before entering all infiltration facilities.

viii. Areas draining to infiltration facilities must be stabilized with a dense vegetative cover for the stormwater to be filtered through before entering the infiltration field.

ix. Infiltration practices greater than three feet deep shall be located at least 20 feet from all structures. For the purposes of this section of the plan a structure may be defined as any building, foundation, or other elements of construction that when constructed were not intentionally designed to be regularly inundated by groundwater or stormwater runoff and were not deliberately designed to mitigate the effects of such inundation upon the structure and its surroundings.

x. Infiltration facilities that are designed to handle runoff from impervious parking areas shall be a minimum of 150 feet from any public or private water supply well.

xi. All structural infiltration facilities shall be constructed with overflow capable of creating non-erosive velocities at the outfall of the facility. Acceptable non-erosive velocities vary depending on the materials used and the configuration of the outfall. All outfalls shall be designed in accordance with Hydraulic Engineering Circular Number 14 (latest edition), Hydraulic Design of Energy Dissipators for Culverts and Channels. Other synthetic materials, such as turf reinforcement mats, may be used to stabilize outfalls if it can be demonstrated that the performance of such materials is within the manufacturers recommended limits for both velocity and shear stress for such materials and is consistent with current DNREC policies.

xii. The slope of the bottom of the infiltration practice shall not exceed one (1) percent and shall not create erosive velocities within the structure. Although the bottom of an infiltration may be designed with a small slope it is preferred to design all infiltration facilities with no slope.

xiii. Stormwater flow to infiltration facilities shall be dispersed as best as practical across the bottom of the facility to maximize infiltration.

xiv. An infiltration practice shall not be installed on or atop a slope whose natural angle of incline exceeds 20%.

xv. Whenever possible, safeguards (i.e., spill containment devices, shutoff valves, diversion devices, pretreatment devices, etc.) shall be applied or installed to protect infiltration facilities from potential groundwater contamination created from a mishap or spill. Extreme caution (i.e., selecting an appropriate location that limits exposure of the facilities to risk of contamination, limitation on the type of vehicular access or land use within the drainage area, implementation of emergency spill response program, development of a pollution prevention plan, etc.) shall be exercised where infiltration is proposed in Source Water Protection Areas.

Extreme caution shall be exercised along roadways and road salt storage areas where salt or chloride could act as a potential pollutant. Soils do little to filter these pollutants and salt and chlorides can contaminate groundwater. Where road maintenance materials are used in close proximity to an infiltration facility, a detailed hydrogeologic investigation may be required by the municipality before approving the construction of an infiltration facility. In such a case, a qualified design professional shall evaluate the possibility of groundwater contamination from the proposed infiltration/recharge facility and prepare a hydrogeologic justification if necessary.

Typically, it is best to construct recharge/infiltration facilities in series with other innovative or traditional BMPs, stormwater control facilities, and nonstructural stormwater management alternatives. It is extremely important that strict erosion and sedimentation control measures be applied surrounding infiltration structures during installation to prevent the infiltrative surfaces from becoming clogged.

2. Water Quality

Nonpoint source pollutants typically accumulate on both pervious and impervious surfaces during periods of dry weather between rainfall events. The pollution potential associated with these chemical and physical constituents cannot be attributed to a single source but the aggregate accumulation of these pollutants on the surfaces of the watershed. These pollutants are typically washed off the surface of the watershed during precipitation events. It is the transport of these nonpoint source pollutants from the land surface to streams, rivers and lakes in the watershed that presents a significant potential source of impairment to receiving surface waters. Common nonpoint source pollutants may consist of nitrates and phosphates normally associated with fertilizers; salts and other roadway maintenance materials; suspended solids associated with erosion; and hydrocarbons, oils and heavy metals related to transportation.

Concentrations of these nonpoint source pollutants tend to be the highest at the beginning of the storm event, a phenomenon commonly referred to as the "first flush." Typically, the first flush is associated with the first inch of excess stormwater runoff that flows off of the land surface. With the weighted curve number for the Appoquinimink River watershed roughly equivalent to a Curve Number of 76, the first flush is roughly equivalent to about 3 inches of precipitation or the 2-year, 24-hour design storm. Therefore, the Water Quality Volume for the Appoquinimink River watershed shall be defined as follows:

> *Water Quality Volume shall be equal to the first one (1) inch of excess stormwater runoff flowing off the disturbed area proposed for construction. The Water Quality Volume shall be treated as follows:*
>
> 1. *The water quality volume shall be detained on site and released over a period of not less than 24 hours.*
>
> 2. *The water quality volume shall not be discharged from the site until it has been conveyed through or treated by no less than two stormwater BMPs. These BMPs may consist of any combination of nonstructural and structural BMPs. Nonstructural BMPs such as disconnection of impervious surface, filter strips, revegetation, reduced impervious surface, level spreaders shall precede structural BMPs such as detention basins, wet ponds and infiltration trenches/basins.*
>
> 3. *All excess stormwater produced from proposed disturbed areas on the site associated with proposed construction shall be treated as part of the water quality volume. It shall be unacceptable to only manage a portion of the disturbed area and allow other disturbed areas proposed for construction*

to flow off of the site untreated by a BMP. In cases where it can be demonstrated that achieving this standard may require significantly more disturbance to the environment than not implementing this standard, this criteria may be waived upon approval from DNREC.

4. *If the Groundwater Recharge Volume is greater than the Water Quality Volume and it can be demonstrated that the full groundwater recharge volume is recharged on-site, the water quality requirements shall be considered satisfied.*

5. *If the fraction of the Groundwater Recharge Volume that is recharged on-site is greater than the Water Quality Volume then water quality requirements shall be considered satisfied.*

GTBMPs and Conservation Design practices are the preferred treatment option for water quality. Water quality practices that are not considered GTBMPs or Conservation Design practices shall be considered only after GTBMPs or Conservation Design practices and concepts have been eliminated for engineering or hardship reasons. Specific stormwater quality practices may be required if a receiving water body has been identified as impaired, or designated with a specific pollutant reduction target necessary to meet the EPA TMDL or State of Delaware water quality regulations. Other management options which shall be applied in the Appoquinimink River watershed to treat the water quality volume are as follows:

a. All stormwater runoff generated from developed surfaces shall be treated prior to discharge/release of the stormwater to a receiving water body resource area designated for protection. Water resources designated for special protection can be obtained from the DNREC's website or from DNREC's Division of water Resources, Watershed Assessment Section.

b. All earth disturbance associated with altering the existing land cover characteristics of any portion of the Appoquinimink River watershed shall provide the necessary computations to verify that the Water Quality Volume for each contributing drainage area has been treated by BMPs necessary to meet the applicable water quality regulations. Offsite areas are not required to be included in the water quality computations.

c. Dry detention/retention basins shall not be used for achieving water quality treatment.

d. The Water Quality Volume shall be utilized to size water quality BMPs. Design criteria of these BMPs shall be in accordance with design specifications outlined in Appendix 2 of Chapter 12 of New Castle County Code; the reference "Green Technology: The Delaware Urban Runoff Management Approach (2004)" or other applicable manuals. The following factors shall be considered when evaluating the suitability of BMPs used to control water quality at a given development site:

- Total contributing drainage area
- Permeability and infiltration rate of the site soils
- Slope and depth to bedrock
- Seasonal high water table
- Proximity to building foundations and wellheads
- Erodibility of soils
- Existing land form and topography
- Existing natural resources
- Land availability
- Peak discharge and required volume control
- Location of existing drainage or flooding problems
- Streambank erosion
- Efficiency of the BMPs to mitigate potential water quality problems
- Volume of runoff that will be effectively treated
- Nature of the pollutant being removed
- Potential for stormwater bypass of BMP
- Potential pollutant concentrations
- Presence of stormwater hotspot
- Maintenance requirements
- Creation/protection of aquatic and wildlife habitat
- Recreational value

3. Streambank Erosion

As stormwater runoff increases, velocities in streams also increase, thus creating streambank erosion problems and aggravating existing erosion problems. Normally, the greatest stream velocities and the greatest amount of streambank erosion typically occurs somewhere between mid-bank and bank-full flow events. Typically, these events are not associated with exceptionally large amounts of rainfall where flooding is a problem but with events that typically occur only several times during the course of the year. Mid-bank to bank-full flow in the Appoquinimink River watershed is considered to occur somewhere between the 1- and 2-year storm events. Therefore, in order to control streambank erosion it is necessary to control the rate of stormwater release from development sites within the watershed for these events. Therefore, the streambank erosion criteria established for the Appoquinimink River watershed is as follows:

Streambank Erosion within the Appoquinimink River watershed shall be managed by reducing the post-construction rate of release of stormwater flow for the 2-year, 24-hour design storm from sites within the watershed to rates that are no greater than fifty (50) percent of the existing condition discharge rate from the sites. To achieve this standard, all points of concentrated discharge from development sites shall be maintained as close as reasonably practical to existing points of discharge.

No less than twenty-five (25) percent of the existing non-forested, non-meadow *land cover shall be considered as meadow when determining the streambank erosion target flows.*

The 2-year, 24-hour design discharge at any given point of concentrated discharge whose entire drainage area has not been disturbed but only contains a fraction of the entire drainage area which is disturbed as a result of a change in the existing land cover shall be reduced in proportion to the amount that the disturbed area contributes to the 2-year, 24-hour peak rate of discharge.

Other management strategies which shall be applied in the Appoquinimink River watershed to control streambank erosion shall include:

a. Regardless of their location in the watershed, all stormwater facilities shall be designed and maintained to discharge all concentrated stormwater in a non-erosive manner. In the absence of supporting documentation and/or computations indicating otherwise, the maximum velocity of all stormwater discharge to any natural unstabilized channel shall not exceed a maximum allowable velocity of 2.5 feet per second for the 2-year design storm.

b. Energy dissipation and/or vegetative stabilization practices, designed according to the Delaware Erosion and Sediment Control Handbook (or other accepted engineering manual such as the Federal Highway Administration' Hydraulic Engineering Circulars) shall be constructed at the outlet end of all points of concentrated discharge.

c. All existing and/or proposed swales and channels either conveying or proposed to convey concentrated stormwater shall provide an assessment that demonstrates the sheer stress of the post-development stormwater flow will not exceed the maximum allowable sheer stress of the surface lining. This assessment shall use the Tractive Force Method of HEC-15 Design of Roadside Channel with flexible Linings (also found in Design Guide DG-1 of the Delaware Erosion and Sediment Control Handbook).

d. The minimum horizontal or vertical dimension of an orifice or weir used to control the rate of stormwater discharge from a stormwater BMP is one and one-half (1½) inches. Any orifice outlet control feature with a minimum dimension of less than three (3) inches shall provided with a means of protecting the device (orifice or weir) from clogging. Protection may take the form of a hood, stone filter, perforated vertical riser, or other device capable of preventing frequent clogging of the small opening. If a vertical riser is used to protect the opening of the orifice or weir, protection may take the form of a horizontal plate located inside a perforated vertical riser with a removable cover at the top of the perforated riser to allow cleaning of the orifice when necessary. The minimum acceptable diameter of the perforated riser shall be eight (8) inches in diameter and the total cross-sectional area of the perforations must be at least ten (10) times the cross sectional area of the orifice. The cross-sectional area of a perforation shall not be less than one-half (½) inch in diameter.

e. In “Conditional Direct Discharge Districts” (District C), the objective is to not attenuate stormwater runoff from storms greater than the 2-year recurrence interval. This can be accomplished by configuring the outlet structure not to control the larger storms, or by a bypass channel that diverts only the 2-year stormwater runoff into the basin or conversely, diverts flows in excess of the 2-year storm away from the basin.

4. Tidal Marsh Habitats

A study of tidal marsh areas within the Appoquinimink River watershed was conducted by A.D. Marble in conjunction with the development of this Plan. This study of marshes within the watershed was unable to identify any indicators of marsh health. Therefore, no direct standard or criteria was identified to protect the marshes of the Appoquinimink River watershed. In lieu of creating specific standards and criteria to protect and preserve the tidal marshes within the watershed, this Plan will rely on the other standards and criteria established herein that pertain to the management of stormwater to help protect marshes until an indicator establishing the health of marshes can be established. This approach is considered adequate as better stormwater controls applied to other parts of the watershed will help reduce erosion and sediment, reduce the rate and volume of stormwater runoff, and address the water quality of the stormwater runoff. The only management criteria established by this Plan pertaining to marshes is as follows:

> *A vegetated buffer shall be established around the perimeter of all marshes within Appoquinimink River watershed which shall be measured at a distance of no less than one-hundred-fifty (150) feet from the mean daily high water level of the marshes within the Appoquinimink River watershed. The vegetated buffer shall be maintained in a natural condition with dense vegetation and without disturbance. Properly stabilized outfalls may be constructed within the vegetated buffer as long as all earth disturbance necessary to construct or maintain the facility is immediately revegetated with native plant species after constructing the outfall or performing maintenance. No development including stormwater management facilities shall be permitted within the buffer area adjacent to a tidal marsh.*

The tidal marsh buffer proposed by this Plan will effectively provide the following functions:

a. Protect wildlife habitat (both aquatic and terrestrial)
b. Protect water quality
c. Control flooding
d. Protect marshes from human disturbance
e. Preserve recreational value of coastal areas
f. Maintain aesthetic and natural diversity
g. Preserve recreational value of the natural resource

5. Overbank Events

Flooding and stormwater problems are caused by excess stormwater runoff. Storm events, which result in water exceeding the natural bank of a stream, are termed as "overbank" events and are typically defined as an expected frequency of occurrence. Bankfull events normally occur somewhere between the 1.5- to 2-year event. Therefore, events greater than the 2-year storm typically result in overbank flooding, where water leaves the main channel of natural waterways. These "overbank" events vary in magnitude but typically range between the 2-year and 10-year events. Effective management of these "overbank" events requires a detailed knowledge of the interrelationship of the various portions of the watershed. Analysis of peak runoff, timing of runoff, and duration of runoff from the various areas of a watershed is critical for establishing these criteria.

It must be recognized that there is a difference between the meanings of storm and flood. Although a certain quantity of rain may classify a rainfall event as a 5-year storm, this does not mean that same amount of rain will result in a 5-year flood. For example, if the event would occur during a drought, a 5-year storm may result in only a 2-year flood because of the capacity of the soil and ground to absorb the excess stormwater. However, if the same event occurred at the same point in time as a snow melt, then a 10-year flood may result because of the extra water volume present in the melting snow. Similarly, the term "5-year flood" does not mean that this event will occur once every five years. Nor does it mean that once a 5-year event occurs; it will be another five years until that event may occur again. A 5-year event refers to the probability that the event will occur in any given year, which is the inverse of the frequency event. Therefore, a 5-year event has a 20% probability of occurring in any given year.

To control overbank events in the Appoquinimink River watershed the following management criteria shall apply:

> *The peak rate of post-construction discharge to manage overbank events from a development site or a site in which a change to the existing land cover is proposed shall not exceed the peak rate of release as identified on the Management District Map, Map V-1. No less than twenty-five (25) percent of existing non-forested, non meadow land cover shall be considered as meadow when determining release rates.*

The rate of release is defined as the percentage of the existing condition flow to a point of interest used in the evaluation of stormwater runoff. The release rate shall be applied to only that portion of stormwater runoff produced from the portion of the site proposed for development or a change in the existing land cover. More information on how the management districts for the Appoquinimink River watershed were developed using the watershed's hydrologic model is fully described in a subsequent portion of this section of the Plan.

6. Extreme Events

"Extreme" flooding events are separated from "overbank" flooding events by the severity of damage which is caused by the event. Typically, events such as the 25-, 50- and 100-year events are labeled as "extreme" events. While overbank and extreme flooding events are inevitable, the goal is to control the frequency of occurrence for such events so that the level of overbank flooding is the same over time and damages to existing conditions infrastructure are not exacerbated while allowing for upstream development.

> *The peak rate of post-construction discharge to manage extreme events from a development site or a site in which a change to the existing land cover is proposed shall not exceed the peak rate of release as identified on the Management District Map, Map V-1. No less than twenty-five (25) percent of all existing non-forested, non meadow land cover shall be considered as meadow when determining release rates.*

C. Development of the Appoquinimink River Watershed Management District Concept (for Overbank and Extreme Events)

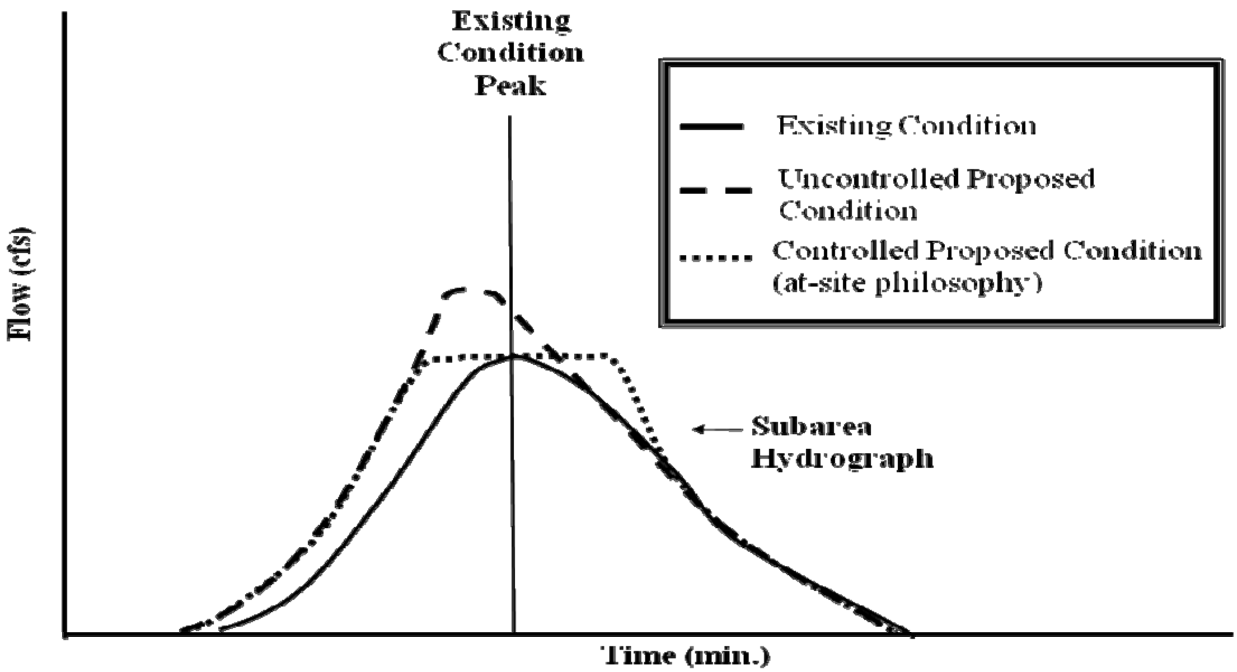
This section of the Plan identifies how the management district performance standards were developed to minimize the adverse effects of increased stormwater runoff caused by development in the watershed. The primary tool used to develop the management districts was the watershed hydrologic model. Development of the hydrologic model of the Appoquinimink River watershed involved dividing the watershed into approximately 69 smaller pieces ranging in size from 9 to about 1,400 acres. These pieces, or subareas, are the building blocks of the watershed's hydrologic model. For each of the subareas, the hydrologic model generates a runoff hydrograph (flow versus time) for a particular design rainfall event. Each of these hydrographs from the subareas represents flow from a given portion of the watershed. To determine the flow in the main channel of the Appoquinimink River at a particular location, each of the subarea hydrographs which contribute flow to a particular point of interest must be shifted or offset by the amount of time it takes for the hydrograph to flow downstream from its point of origin and then added together. The stream channel routing provides the linkage between subarea hydrographs and establishes the timing or relationship of one part of the watershed relative to another. Therefore, the fully developed and calibrated hydrologic model provides the tool for the analysis of how the water moves through the watershed and determination of an appropriate control strategy.

Release Rate Concept

In many circumstances, it is insufficient to control post-development peak runoff to existing levels if the overall goal is not to cause an increase in the peak rate of runoff at any point in the watershed. The reasons this "at-site" control philosophy is incapable of preventing increases in the rate of stormwater runoff throughout the watershed relate to how the various parts of the watershed interact, in time, with one another and the effect of increased volume of runoff typically associated with development. In other words, each of the subareas is not independent of each other and development in upstream subareas, if not managed properly, impacts flows in the downstream portion of the watershed. This concept is better illustrated by examining Figure

V-2. As the watershed becomes more developed, several things occur with respect to post-construction stormwater runoff; stormwater runoff peaks quicker; peaks higher; and because of the added stormwater runoff volume, when at-site controls are applied, the peak will be held for a longer period of time.

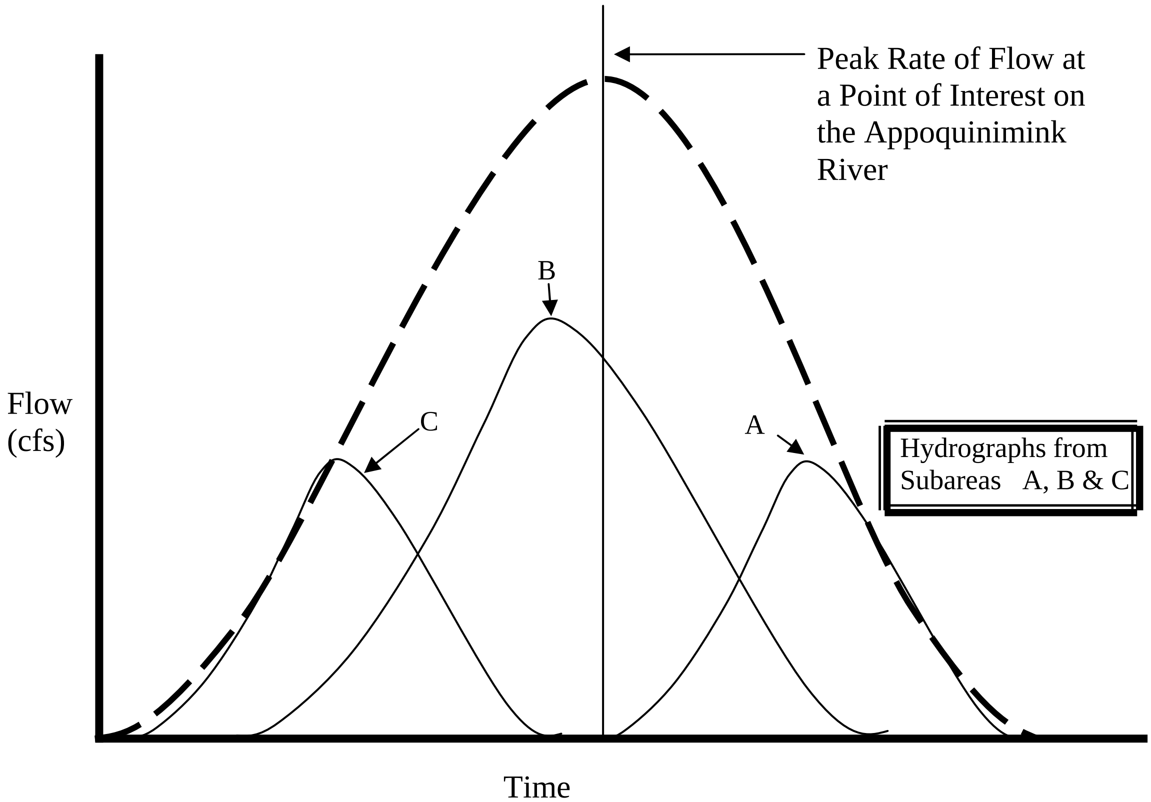
Figure V-2
Effect of Development on Stormwater Runoff Hydrographs



It is the increase in peak flows or extension of the peak flows that causes the problems in the watershed. This is because the Appoquinimink River hydrograph is made up of numerous subarea hydrographs added together. When no stormwater controls are proposed, it is obvious that the added stormwater runoff volume from development will increase the height of the hydrograph. However, what is less obvious is that when at site controls are installed, the peak rate of discharge will be extended, allowing the peak from one subarea to potentially overlap with the peaks from other subareas that do not normally coincide in the existing condition peaks of the watershed timing. When peaks overlap in the post-construction condition this is when stormwater problems occur in the watershed.

Therefore, the critical runoff control criteria for a given site or subarea is not necessarily its own existing condition peak rate of runoff, but the proportion of the existing condition contribution from the site or subarea to the peak rate of flow at a given point of interest in the watershed. This concept is best illustrated through the use of a simplified figure. Figure V-3 shows how the individual runoff contributions from a number of sites or subareas create the total hydrograph at a particular point of interest. A point of interest is a point along a river, stream, or drainage course where flows are analyzed and evaluated. These points of interest are selected based upon their proximity to known problem areas, obstructions, stream gages, or at the confluence of major tributaries within the watershed.

Figure V-3
Point of Interest Hydrograph Analysis



Subareas A through C each have a particular runoff response to a given rainfall event (i.e., each will generate a characteristic hydrograph for a given amount of rainfall). Hydrograph A is a sample hydrograph representative of the flow from sites in the upper portions of the watershed such as Middletown, or possibly the headwaters of the Appoquinimink River in western New Castle County. Stormwater runoff from sites in the central portion of the watershed, around Odessa, are represented by Hydrograph B while Hydrograph C represents flows originating in the downstream portion of the watershed, typically east of the Route 13 corridor. The total flow in the Appoquinimink River at a particular point of interest such as the outlet is shown in Figure V-3 as a dashed line. The configuration of the watershed is such that all areas contribute runoff to the point of interest. However, the three subareas do not contribute flow at the same time. Flows from the headwaters in Middletown, Townsend and western New Castle County have the farthest to travel to get to the point of interest and therefore are located toward the right side of the overall point of interest hydrograph. Whereas flows in the downstream areas, such those areas east of Rout 13 contribute flow immediately to the point of interest and are placed on the left side of the overall point on interest hydrograph. Hence, contribution of each area to the overall Appoquinimink River hydrograph at the point of interest is the individual subarea hydrograph lagged in time by an amount equal to the travel time from the subarea or origin to the point of interest.

It is important to note the location of an individual subarea hydrograph will vary with respect to the peak based on the location of the point of interest. For instance, if a point of interest is selected near Odessa, the subarea C hydrographs would not contribute flow to the point of interest and would be excluded from the summation of subarea flows to obtain the point of interest hydrograph. Another effect of selecting a site near Odessa as a point of interest is that the subarea B hydrograph and the subarea A hydrograph would shift to the right. In this situation, the subarea B hydrograph may take the place of where the subarea C hydrograph is located in Figure V-3 and similarly, the subarea A hydrograph may shift to take the place of the subarea B hydrograph in Figure V-3.

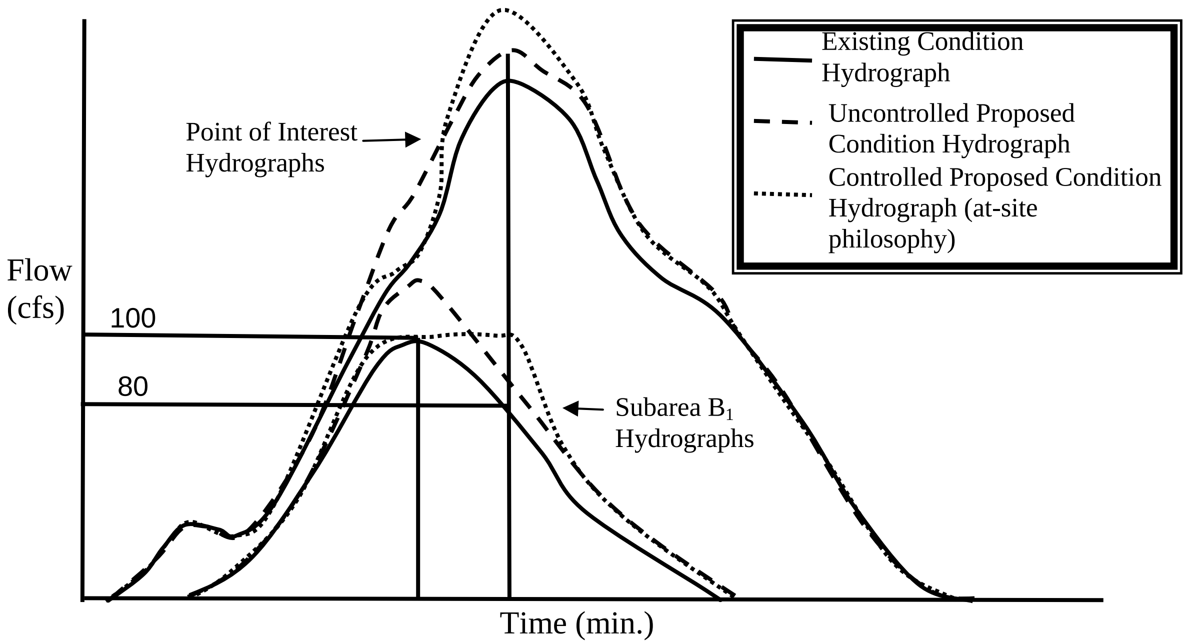
The basic goal of the watershed-level control philosophy is to prevent any increase in the peak rate of runoff throughout the watershed as a result of upstream development. This is achieved by establishing release rates for the subareas in watershed. The release rate concept is perhaps best described by looking at how Hydrograph B, representing sites in the middle of the watershed around Odessa, contribute to the overall hydrograph at the point of interest. Figure V-4 shows the total point of interest hydrograph from Figure V-3 and the hydrograph from subarea B only. Noteworthy facts regarding the two hydrographs are that Hydrograph B peaks before the peak of the total point of interest hydrograph, (the subarea peak flow at the point of interest is 100 cfs) and the subarea hydrograph contributes flow to the peak of the total point of interest hydrograph (Hydrograph B contributes 80 cfs to the peak flow at the point of interest).

Also shown in Figure V-4 are the potential effects of development upon the flow for Hydrograph B. Specifically, the potential changes to the hydrograph assuming development occurs with no stormwater controls and the resultant hydrograph if new development uses at-site philosophy of controlling to pre-development peak levels. Conventional at-site detention philosophy would control post-development peak runoff flows to 100% of pre-development levels. Note that in both cases the flow contribution of Hydrograph B to the peak at the point of interest increases for the “no control” option and for the “at-site” control option). Therefore, the total peak flow at the point of interest for both options increases and neither is an acceptable watershed-based control strategy. The only acceptable control strategy would be to ensure that the contribution of flow from Hydrograph B to the peak flow at the point of interest does not exceed 80 cfs. Note that the 80 cfs represents 80% of the peak subarea flow of 100 cfs from subarea B. Thus, in order to apply the watershed level approach to the point of interest, the peak rate of flow from the subarea must be reduced to a percentage of the existing condition peak flow. Herein lies the basis for the release rate concept.

Mathematically, the release rate is defined as :

$$\text{Release Rate} = \frac{\text{Subarea Flow Contribution to Point of Interest Peak Rate of Flow for Existing Conditions}}{\text{Subarea Peak Rate of Flow}}(100)$$

Figure V-4
Hydrograph Analysis Example
(For Subarea B at the Point of Interest)



Applying the release rate concept used with the watershed based control philosophy to the area representing Hydrograph B the release rate would be 80%, meaning that each individual development site contributing flow to the point of interest hydrograph in this area would have to control post-development peak runoff rates to 80% of existing condition. Based upon this example it can be seen that the watershed level control philosophy and the release rate concept dictates a more stringent level of control than the "at-site" control philosophy, which only limits post-construction peak rate of release to 100% of the existing condition peak. Only with this increased level of control can the point of interest peak flow be managed so that the peak rate of flow at the point of interest is not exceeded in the post-construction condition. In essence, what is being accomplished with the release rate methodology is an exchange. That is an exchange of increased rate control to compensate for the additional volume of stormwater runoff typically generated by development.

The release rate concept was developed using Hydrograph B from Figure V-3 as an example. The two key characteristics of Hydrograph B that make it useful for application of the release rate methodology are that it peaks prior to the point of interest peak and it contributes flow to the point of interest peak flow. Neither Hydrograph A nor Hydrograph C exhibits these characteristics. As such, the appropriate method of runoff control applicable to these areas may differ from the basic release rate control strategy applied to hydrograph from subarea B.

Since Hydrograph A peaks later than the point of interest and does not contribute any runoff to the point of interest peak, it will not affect the peak flow at the point of interest. Therefore, the runoff control strategy adopted for subarea A is nearly inconsequential at the point of interest and could technically be allowed to flow off uncontrolled. However, since multiple points of interest are included in the development of the Appoquinimink River's release rates, the runoff control strategy selected for this area is the 100% release rate.

Conversely, those areas representing hydrograph C peak before the point of interest peak and do not contribute any flow to the point of interest peak. These subareas represent flow from downstream portions of the watershed. In these subareas, the contributing flow from the individual subareas has peaked and passed before the overall point of interest hydrograph peaks. Detention of stormwater runoff in these subareas is a bad idea because detention would extend the subarea peak and potentially allow it to contribute to the flow or even the peak at the point of interest. The appropriate control strategy selected to keep this area's contribution to the point of interest peak at zero, could conceptually be to not control stormwater runoff at all. This control strategy is named a Condition No Detention District. In these districts, no detention is permitted if it can be demonstrated that the unrestricted runoff can be safely conveyed downstream without causing either temporary or permanent damage to the environment, private property and public property; and without endangering the safety, health and welfare of the public.

Appoquinimink River Watershed Release Rates

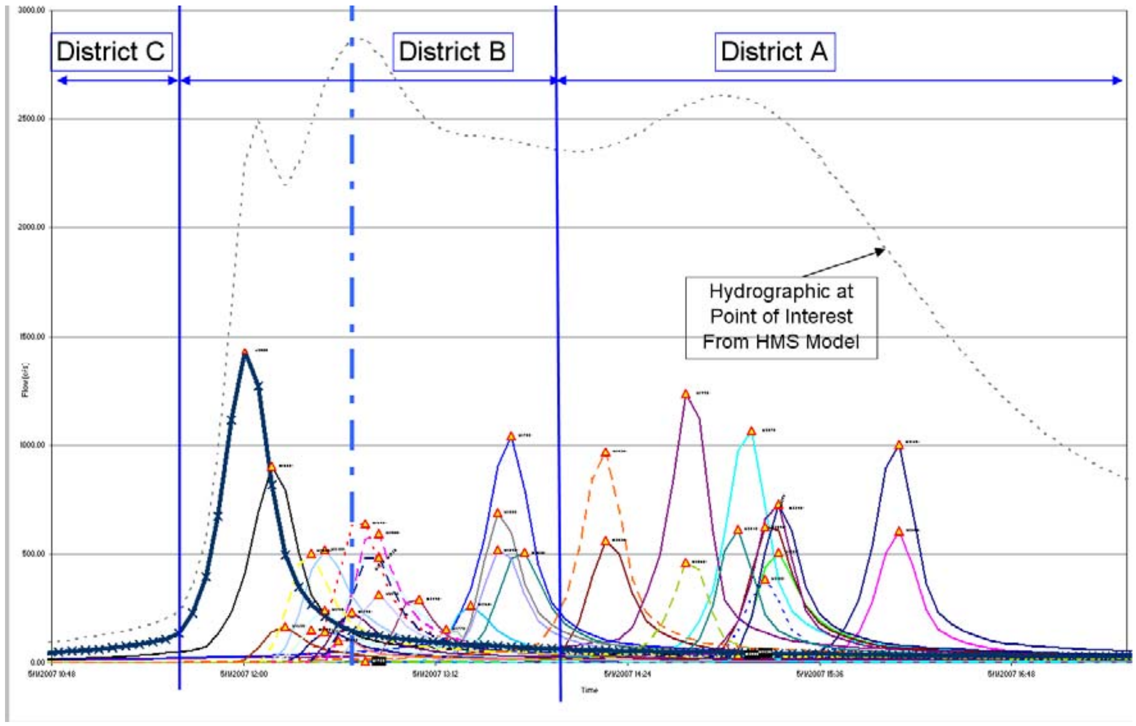
This discussion of the release rate methodology used to develop the peak rate controls for the Appoquinimink River watershed is a simplistic presentation of the process used to develop the management criteria for the watershed. The full analysis looked at many scenarios and numerous hydrographs in order to develop the management district for the Appoquinimink River. Figure V-5 shows two typical plots of the hydrographs at two different points of interest and the many individual subarea hydrographs that contribute flow to the point of interest hydrographs. Each of the plots indicates which subarea hydrographs would be considered as District A, District B and District C.

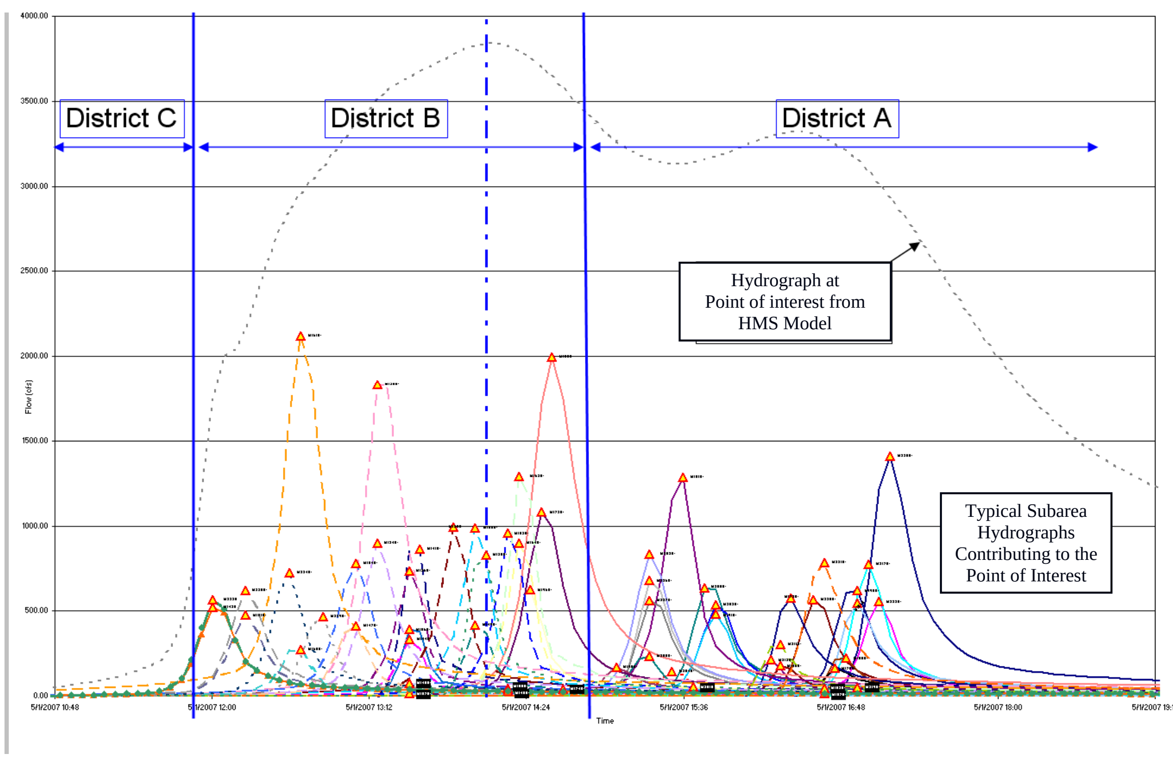
The release rates for the Appoquinimink River were developed using primarily the 100-year design storm at four (4) points of interest:

1. A point located approximately 5,000 feet downstream of Noxontown Pond on the Appoquinimink River.
2. The crossing of Drawyers Creek at State Route 1.
3. A point upstream of the confluence of the Hangmans Run with the Appoquinimink River.
4. The outlet of the Appoquinimink River.

After establishing preliminary management districts with the 100-year design storm, the management scenarios were checked against other storms with more frequent return intervals. The 100-year event was selected for several reasons. First, smaller storms such as the 2-year storm are with the streambank erosion criteria. Second, the downstream portion of the Appoquinimink River does not exhibit significant flooding problems in more frequent storm events because the floodplains along the main stem of the river in the downstream portion of the watershed are relatively open and undeveloped. Lastly, extensive work in other watersheds has shown that most out of bank events from larger storms, such as those greater than the 5-year event, exhibit similar timing and peak flow relationships. Therefore, it was found that using the 100-year event to establish the release rates satisfactorily managed not just the 100-year storm runoff, but the smaller events as well.

Figure V-5
Point of Interest Hydrographs





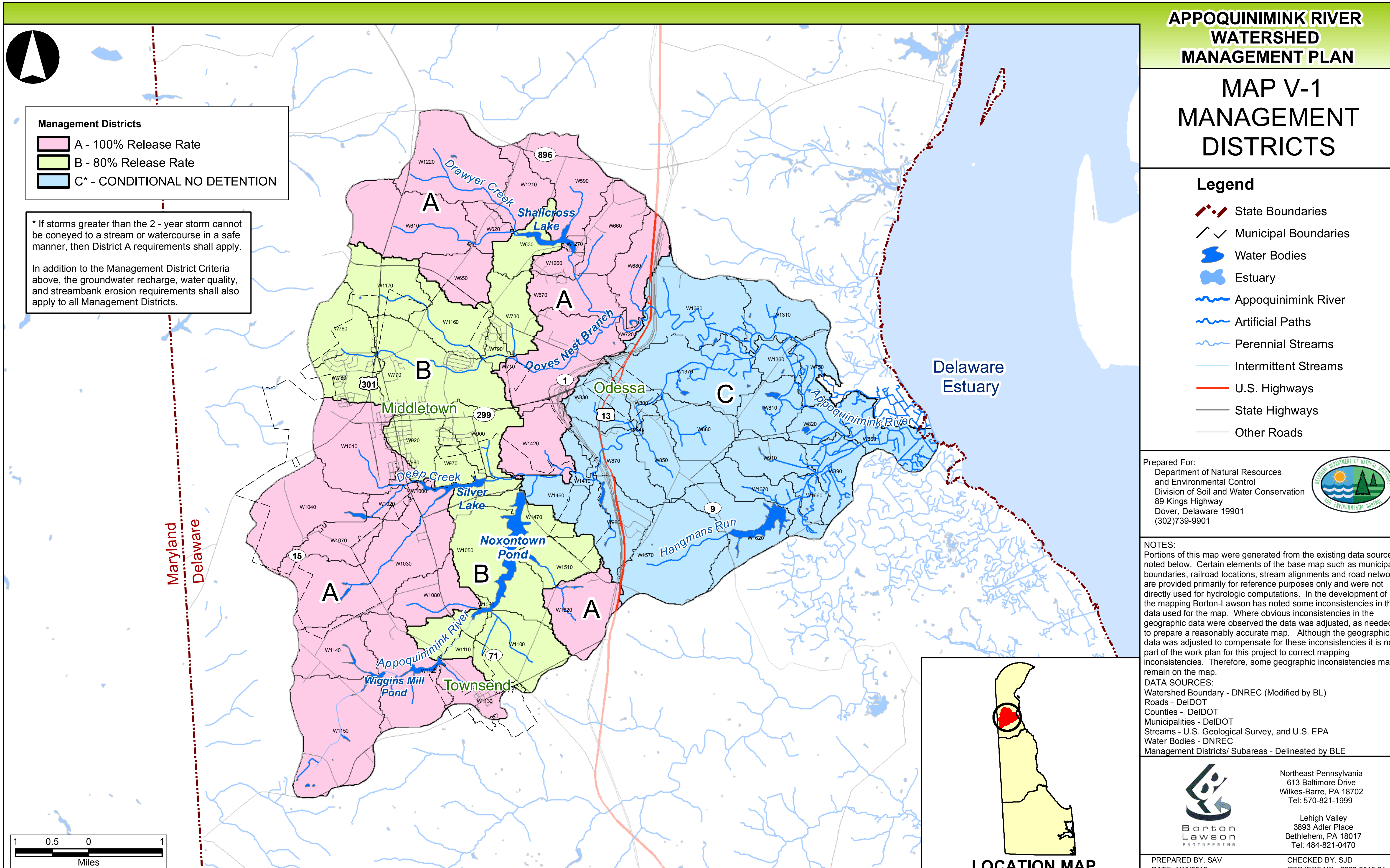
To develop the release rate criteria for the Appoquinimink River watershed, the watershed model was run using the existing land use condition. Subareas identified with approximately the same release rates were grouped together to form the Management Districts. The Management District Map developed to manage peak flow rates in the Appoquinimink River Watershed is Map V-1. The final release rates for application in the watershed vary from 80% to 100%, depending on location in the watershed, with one Conditional No Detention District. This strategy was chosen because it controls future peak flows at the points of interest to existing flows for events with return periods ranging from 10- to 100-years.

In certain situations where a site may be in close proximity to a district boundary, the appropriate management district should be identified by field investigations to determine the direction in which the stormwater runoff is flowing. The findings from these field investigations shall take precedence in determining the appropriate management district and performance criteria necessary to manage post construction peak flows from a site.

<u>District C - Conditional No Detention Districts</u>

The following management criteria shall be provided for all sites located within District C, Conditional No Detention District:

> *Development sites or alterations to the existing land cover in District C, Conditional No Detention District may discharge directly to the Appoquinimink main channel, major tributaries or indirectly to the main channel through an existing stormwater drainage system (i.e., storm sewer or tributary) without control of post-development peak rate of runoff for storm events with a return interval greater than the 2-year storm. Regardless of condition, all sites in District C shall comply with the groundwater recharge criteria, the water quality criteria, and streambank erosion criteria.*
>
> *If the post-development runoff is intended to be conveyed by an existing stormwater drainage system to the main channel, computations must be provided that demonstrate such a system has adequate capacity to convey the intended flows for all events up to and including the 100-year existing condition peak flow or shall be provided with improvements to furnish the required conveyance capacity. If adequate conveyance capacity exists in an existing downstream conveyance system only that portion of the available conveyance capacity that is proportionate to the ratio of the drainage area of the site to the drainage area of the system may be used for conveyance from an individual site where changes to the existing hydrologic regime are proposed.*
>
> *Owners and/or operators of downstream conveyance systems are not required to provide additional conveyance capacity to accommodate changes in flow that they are not responsible for creating. Alterations to downstream conveyance systems may be completed by those individuals or entities proposing changes to upstream drainage area only if authorized to make such alterations by the owner and/or operators of the downstream conveyance systems.*



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When adequate capacity in the downstream system does not exist and will not be provided through improvements, the post-development peak rate of runoff must be controlled to the existing peak rate as required in District A.

It is only permissible to release a proposed conditions flow that is greater than the existing conditions flow if it would not aggravate a significant obstruction, existing problem area or overload existing storm sewer networks.

When discharging post-construction flows that are greater than existing conditions peak flow rates, proper analysis of channel capacity downstream of a development site is essential to ensure that the goal of not creating any new problem areas or aggravating existing drainage problem areas is achieved. The analysis shall include the assumption of complete build-out of the tributary areas to the conveyance system being evaluated based upon the latest zoning revision after plan adoption. The analysis must also analyze the future conditions flow in all Conditional Detention Districts assuming that stormwater detention on development sites is not implemented.

No Harm Option

A "no harm" option may be applied to any development site or site proposing an alteration to the existing land cover within the Appoquinimink River watershed. With the "no harm" option, the Applicant has the alternative of using a less restrictive runoff control than specified for an A, B or C Management District if the Applicant can prove that "no harm" would be caused by discharging at a higher runoff rate than that specified by the Stormwater Management Plan. The "no harm" option is used when an Applicant can prove that the proposed conditions hydrographs can match existing conditions hydrographs and if it can be proved that the proposed conditions will not cause increases in peaks at any points downstream. Proven performance based upon the "no harm" option shall under no circumstances relieve the Applicant from the groundwater recharge, water quality, and streambank erosion protection requirements of this plan.

Proof of "no harm" shall be demonstrated based upon a "downstream impact evaluation" which shall include a downstream hydraulic capacity analysis to demonstrate adequate hydraulic capacity exists downstream of any site applying for the "no harm" option. The downstream impact evaluation shall include:

1. A hydrologic and hydraulic analysis that extends to a point downstream where any increase in flow caused by a proposed development or alteration of the existing land cover is indistinguishable.

2. A comparison of existing condition peak flows for downstream areas to proposed flows created by a proposed development or alteration of existing land cover in the watershed. To satisfactorily demonstrate proof of "no harm" the peak flow analysis shall apply the Twenty-five percent (25%) meadow condition to all non-forest, non-meadow areas in the existing condition only for the site where the changes in land cover are proposed. The existing hydrologic variables defining all other unchanged sites and subareas in this analysis shall be equal to the values in the calibrated Appoquinimink River watershed hydrologic model for all design storms included in the analysis (2-, 10-, 25-, 50-, and 100-year).

3. Computations demonstrating the existing condition hydrologic regime of the watershed are maintained in a post-construction condition. Any runoff controls which generate increased peak flow rates at a storm drainage problem area are precluded from the "no harm" option, except when proposed in conjunction with mitigation or remediation measures for the problem areas. No mitigation or remediation measures may be proposed or constructed without authorization from the owner and operator of the downstream facilities. Included in this authorization shall be an agreement indicating the type of improvements proposed the entity responsible for constructing the improvements, a date when the improvements will be constructed, and an indication of the entity responsible for maintenance of the facilities.

4. Hydrologic and hydraulic calculations that demonstrate the potential changes to the existing condition hydrograph timing or peak flows, caused by the proposed development or alteration of the existing land cover within the watershed, will not adversely impact any downstream dam, highway, structure, natural point of restricted streamflow, or any stream channel section.

5. A tabulation comparing the existing and proposed streamflows for a series of design events (2-, 10-, 25-, 50-, and 100-year) at each downstream obstruction identified on Map II-10 or known problem area, either identified by this plan or first hand knowledge, where the proposed site contributes stormwater runoff. This tabulation shall at a minimum include all obstructions or problem areas located between the proposed site and the point downstream where changes in streamflow caused by the proposed changes in land cover are imperceptible.

6. A complete description and supporting hydraulic computations of all proposed capacity improvements to conveyance facilities or obstructions necessary to implement the "no harm" option.

7. All justifications and pertinent data supporting the "no harm" option. Financial distress shall not constitute sufficient justification for the "no harm" option.

8. Computations demonstrating all man-made channels or swales have sufficient capacity to convey the increased runoff associated with the 2- through 10-year design event within their banks at non-erosive hydraulic conditions.

9. Hydraulic calculations demonstrating that natural channels or swales possess sufficient capacity to convey any proposed increase in the rate and/or volume of stormwater runoff without creating temporary or permanent damage to the environment or a hazard to persons or property.

10. A risk assessment that demonstrates that the unrestricted stormwater runoff can be safely conveyed downstream without causing either temporary or permanent damage to the environment, private property and public property; and without endangering the safety, health and welfare of the public.

DNREC, Division of Soil and Water Conservation or the appropriate plan approval agency that is jurisdictionally responsible for the review and approval of stormwater management plans shall have the sole authority to make the determination that the all of the requirements demonstrating no harm for a proposed development or change in land cover are satisfactorily met.

<u>Exemptions, Waivers, and Variances</u>

The following activities are exempt from stormwater management requirements established by this Plan:

1. Developments or construction that disturbs less than 5,000 square feet

2. Land development activities which are regulated under specific State or federal laws which provide for managing sediment control and stormwater runoff.

3. Projects which are emergency in nature that are necessary to protect life or property such as bridge, culvert, or pipe repairs and above ground or underground electric and gas utilities or public utility restoration. The emergency nature of a project may preclude prior plan review and approval, but subsequent review and approval may be required if deemed necessary by the appropriate plan approval agency. The appropriate plan approval agency shall be notified orally and in writing within 48 hours of the initiation of such emergency activity.

4. The appropriate plan approval agency shall determine and approve the emergency nature of a project. If the nature of the emergency will require more than 120 days to complete the construction, formal approval shall be obtained for stormwater management. These activities must comply with all applicable federal, state, and local requirements.

5. Commercial forest harvesting operations that meet the requirements of the Department of Agriculture under 3 Del.C**.** Ch. 29, Subchapter VI.

6. Appropriate Approval Agencies may grant waivers from the stormwater management requirements of this plan for individual developments provided that a written request is submitted by the applicant containing descriptions, drawings, and any other information that is necessary to evaluate the proposed development. A separate written waiver request shall be required if there are subsequent additions, extensions, or modifications which would alter the approved stormwater runoff characteristics to a development receiving a waiver.

7. A project may be eligible for a waiver of stormwater management for both quantitative and qualitative control if the applicant can demonstrate that:

    i. The proposed project will return the disturbed area to a pre-development runoff condition and the pre-development cover is unchanged at the conclusion of the project; or

ii. The project is for an individual residential detached unit or agricultural structure, and the total disturbed area of the site is less than one-quarter of an acre; or

iii. The proposed project is for agricultural structures in locations included in current soil and water conservation plans that have been approved by the appropriate Conservation District.

8. A project may be eligible for a waiver or variance of stormwater management for water quantity control if the applicant can demonstrate that:

   i. Provisions will be made or exist for a nonerosive conveyance system to tidewater by either a closed drainage system or by open channel flow that has adequate capacity to contain the runoff events being considered as a requirement of these regulations; or

   ii. The location of a project within a watershed would aggravate downstream flooding by the imposition of peak control requirements.

Application for the exemptions waivers and variances shall be made to DNREC, Division of Soil and Water Conservation or to the appropriate plan approval agency that is jurisdictionally responsible for the review and approval of stormwater management plans.

D. Stormwater Hotspots

Untreated stormwater runoff from all hotspots identified in Table V-1, shall not be recharged into groundwater where it can potentially contaminate water supplies. Groundwater recharge volume requirements shall NOT apply to development sites that are identified as a hotspot. However, all other stormwater management criteria described in this Plan are applicable; this includes the streambank erosion criteria, the water quality volume criteria, the overbank event criteria, and extreme event criteria. Designation as a hotspot, or the spatial limits of a designated hotspot, shall remain the exclusive right of DNREC. No site shall be exempt from the groundwater recharge requirements without written concurrence from DNREC's Division of Soil and Water Resources (or appropriate plan reviewing agency with authority to approve stormwater plans) that the proposed development is a hotspot and exempt from the groundwater recharge requirements of this Plan.

In lieu of implementing groundwater recharge requirements at proposed stormwater hotspots, a greater level of stormwater treatment shall be considered at hotspot sites to prevent pollutant washoff after construction. It is recommended that all proposed stormwater hotspots within the Appoquinimink River watershed create and implement a stormwater pollution prevention plan. While large highways (average daily traffic volume (ADT) greater than 30,000) are not designated as stormwater hotspots, it is important to ensure that stormwater runoff from all highway facilities is properly managed to minimize the conveyance of pollutants produced from man-made activities using structural and nonstructural BMPs to adequately protect groundwater.

TABLE V-1
Stormwater Hotspots

<table>
<tr><td>Vehicle salvage yards and recycling facilities.</td><td>Outdoor liquid container storage.</td></tr>
<tr><td>Vehicle fueling stations.</td><td>Outdoor loading/unloading facilities.</td></tr>
<tr><td>Vehicle service and maintenance facilities.</td><td>Public works storage areas.</td></tr>
<tr><td>Vehicle and equipment cleaning facilities.</td><td rowspan="2">Facilities that generate or store hazardous Materials.</td></tr>
<tr><td>Fleet storage areas (bus, truck, etc.).</td></tr>
<tr><td>Marinas (service and maintenance).</td><td rowspan="2">Commercial Nurseries or other agriculture uses in the immediate vicinity of where large quantities of containerized chemicals are stored.</td></tr>
<tr><td>Industrial sites (based on the selection of Standard Industrial Codes outlined by the National Pollutant Discharge Elimination System as administered by DNREC).</td></tr>
<tr><td colspan="2">Other land uses and activities as designated by DNREC, Division of Soil and Water Resources or an appropriate reviewing authority designated by DNREC.</td></tr>
</table>

E. Riparian Buffers

Maintaining or restoring natural riparian buffers along existing waterways and the tributaries of the Appoquinimink River has many stormwater related benefits (see Table V-2) including aiding in groundwater recharge, improving the water quality of runoff and protecting streambanks from erosion.

Therefore, if a perennial or intermittent stream passes through a site, the Applicant shall provide a stream buffer on both sides of the channel. The buffer shall extend from the mean daily highwater mark a minimum of fifty feet landward away from the channel. Native plant species are preferred in all riparian buffers. However, replanting of a riparian buffer with a native plant species is not required in undisturbed areas. Whenever earth disturbance occurs in the riparian buffer the buffer area shall be replanted with native vegetation (*Green Technology: The Delaware Urban Runoff Management Approach*, Chapter 3, provides a plant lists for difference selection criteria). Only if it can be demonstrated through several plantings of native plant species, in no less than three separate growing seasons, that a native plant species cannot survive within a riparian buffer that a non-native plant species may be considered as a substitute with approval by the County Conservation District. If an existing buffer is legally prescribed (i.e., deed, covenant, easement, etc.) the existing buffer shall be protected and maintained.

TABLE V-2
Twenty Benefits of Riparian Buffers

1. Reduce watershed impervious area.
2. Maintain distance from impervious cover.
3. Help prevents small drainage problems and complaints.
4. Allow for lateral movement of the stream.
5. Provide effective flood water storage.
6. Protect streambanks from erosion.
7. Increase property values.
8. Increase pollutant removal.
9. Provide foundation for present or future greenways.
10. Provide food and habitat for wildlife.
11. Mitigate stream warming.
12. Protect adjoining wetlands and marshes.
13. Prevent disturbance to steep slopes.
14. Preserve important terrestrial and aquatic habitat.
15. Create conservation corridors.
16. Discourage stream enclosures and armoring of channels.

F. Redevelopment

It is not the intent of this Plan to create a disincentive for redevelopment of existing urbanized areas. The stormwater management criteria established by this Plan are based upon flows and volumes of stormwater runoff calculated using the existing condition for a series of design storms. Since the existing condition includes any impervious area existing at the site at the time of the proposed development, the criteria, by default, relaxes the stormwater criteria by allowing the proposed condition to match existing conditions. However, in order to promote redevelopment of urban areas and preservation of existing open space, an Applicant may be exempt from the Plan's groundwater recharge criteria and streambank erosion criteria if it can be demonstrated that such redevelopment will result in a 20% reduction of the existing impervious surface.

G. Process to Accomplish Standards and Criteria

Table V-3 provides a process to accomplish the required standards and criteria, on a priority basis, identifying alternate management approaches other than detention to promote recharge, improve water quality, and prevent streambank erosion, and to reduce proposed conditions peak flows to the required existing conditions rate.

TABLE V-3
Process to Achieve the Standards and Criteria
(Ultimate Goal - Match Existing Conditions Hydrograph)

1.	Maximize use of Nonstructural Stormwater Management Alternatives (apply GTBMPS) • Protect and preserve natural features • Minimize disturbance and grading • Minimize impervious surfaces, consider pervious surfaces • Break up large impervious surfaces • Apply nonstructural BMPs near the source of the runoff
2.	Satisfy groundwater recharge (infiltration) requirements
3.	Satisfy water quality requirements
4.	Satisfy streambank erosion requirements
5.	Apply structural BMPs near the source of the runoff (GTBMPs preferred)
6.	Satisfy the runoff peak attenuation objective considering all measures other than detention basins
7.	After satisfying the above requirements, incorporate dual purpose detention measures, if necessary, to attenuate peaks. Dual purpose detention is recommended (e.g., recycling water, stormwater wetlands, water storage for irrigation, fire flow, etc.)

H. Runoff Control Techniques

All development sites or areas proposing alteration to the existing land cover shall provide runoff controls that are able to achieve the management standards set forth in this Plan. Runoff controls will likely be obtained by applying a series of stormwater BMPs. Typically, the most appropriate controls are selected based upon type of project and physical characteristics of the site. The following parameters should be considered in determining the combination of measures to needed to obtain the intended stormwater management control:

1. Soil characteristics (hydrologic soil group, etc.)
2. Subsurface conditions (high water table, depth to bedrock or limiting zone, etc.)
3. Topography (steepness of slope, etc.)
4. Existing drainage patterns
5. Source of stormwater runoff (i.e., impervious surface, stormwater hotspot)
6. Downstream obstruction or problem areas
7. Existing infrastructure
8. Economics
9. Effectiveness
10. Advantages and disadvantages of each technique
11. Maintenance
12. Safety

Whenever possible, stormwater BMPs shall be placed in series, with one control discharging downstream to another BMP, in order to maximize the effectiveness of the proposed controls. This is especially important when it comes to water quality, as this approach creates a treatment train with primary, secondary and tertiary treatment facilities. Table V-4 provides an overview of common stormwater BMPs that can be applied to reduce or delay stormwater runoff as well as the advantages and disadvantages of each type of measure.

TABLE V-4
Possible On-Site Stormwater Control Methods

AREA	REDUCING RUNOFF	DELAYING RUNOFF
Large Flat Roof	1. Cistern storage. 2. Rooftop gardens. 3. Pool storage or fountain storage.	1. Ponding on roof by constricted downspouts.
Parking Lots	1. Porous pavement. a. Gravel parking lots. b. Porous asphalt. 2. Concrete vaults and cisterns beneath parking lots in high value areas. 3. Vegetated ponding areas around parking lots. 4. Gravel trenches.	1. Grassy strips on parking lots. 2. Grassed waterways draining parking lot. 3. Ponding and detention measures for impervious areas. a. Rippled pavement b. Depressions c. Basins
Residential	1. Cisterns for individual homes or groups of home. 2. Gravel driveways (porous). 3. Contoured landscape. 4. Groundwater recharge: a. Perforated pipe b. Gravel (sand) c. Trench d. Porous pipe e. Dry wells 5. Vegetated depressions.	1. Reservoir or detention basin. 2. Planting a high delaying grass (high roughness). 3. Gravel driveways. 4. Grassy gutters or channels. 5. Increased length of travel of runoff by means of gutters, diversions, etc.
General	1. Porous sidewalks. 2. Mulched planters.	1. Gravel alleys.

While some runoff control techniques are “structural” stormwater management controls, meaning they are physical facilities constructed for runoff abatement, others are “nonstructural” controls, referring to land use management techniques geared toward minimizing storm runoff impacts through control of the type and extent of new development. The Appoquinimink River Watershed Stormwater Management Plan is based on the assumption that both types of controls will be necessary to minimize implications of additional stormwater runoff caused by alteration of the watershed’s existing land cover.

1. Nonstructural Runoff Controls

Nonstructural methods such as innovative site planning, impervious surface reduction, protection of natural resources and open space are an essential component of managing stormwater runoff quantity and quality and are strongly encouraged for application as part of all stormwater management plans. In most cases, nonstructural BMPs shall be combined with structural BMPs to meet the stormwater requirements contained in this Plan. The key benefit of nonstructural BMPs is that they can reduce the generation of stormwater runoff from the site thereby reducing the size and cost of structural BMP while augmenting the natural resources and aesthetics of a site. In addition, addition the benefits to stormwater rate and volume controls they can provide partial removal of many pollutants and contribute to stormwater quality control.

2. Structural Runoff Controls

Structural controls for managing storm runoff can be categorized as either volume controls or rate controls. Volume controls are designed to prevent a certain amount of the total rainfall from becoming runoff by providing an opportunity for the rainfall to infiltrate into the ground. Greater opportunity for infiltration can be provided by minimizing the amount of impervious cover associated with development, by draining impervious areas over undisturbed areas or into specific infiltration devices, and by using grassed swales or channels to convey runoff in lieu of storm sewer systems. Rate controls are designed to regulate the peak discharge of runoff by providing temporary storage of runoff which otherwise would leave the site at an unacceptable peak value. Rate controls, much more so than volume controls, are adaptable to regional considerations for controlling much larger watershed areas than one development site.

Table V-5 lists the advantages and disadvantages for several types of runoff control measures and Table V-6 explains the suitability of various structural and nonstructural control measures in the Appoquinimink River watershed.

3. Minimizing Nonpoint Source Pollutants

Nonpoint pollution is comprised of pollutants that are deposited on the surface of the watershed and are washed off the Earth's surface during every rainfall event. Nonpoint source pollutants cannot be attributed to a single source but are caused by small amounts of chemicals deposited throughout the surface of the watershed. It is the aggregate effect of the washing off of these pollutants into the watershed's rivers and waterways that can have a substantial adverse impact upon the water resources in the watershed.

As there is a significant amount of agricultural land cover in the Appoquinimink River watershed, fertilizers, pesticides and herbicides are a serious nonpoint source pollution concern. Agricultural runoff tends to have high nitrogen concentration which can create problems with invasive plant species and excessive growth of vegetation in streams. This vegetal growth in the streams reduces the dissolved oxygen in the water, which eventually impacts the wildlife living in the stream. Another pollution concern with agricultural lands is the high total suspended solids concentration which alters the turbidity of the water, causes sedimentation and also eventually impacts the wildlife in the stream.

Although agriculture is cited as one potential source of nonpoint source pollution there are actually many sources of this type of pollution within the watershed. As such, capturing this runoff and treating it for water quality is a major concern and objective of this Plan. Common sources of nonpoint source pollution include:

1. Fertilizer
2. Pesticides/Herbicides
3. Soil Erosion
4. Vegetative Decay (leaves, grass, etc.)
5. Litter
6. Animal waste
7. Petroleum products
8. Vehicles
9. Roadway maintenance materials

Particular types of BMP's tend to have a more direct impact on water quality than others. These are infiltration basins, infiltration trenches, media filtration, and wet ponds. For more description on the advantages of each, refer to Table V-5. Although these basins have some potential disadvantages, such as requiring more maintenance and costing more to construct, these BMPs represent the best management approaches to minimizing nonpoint source pollutants within the watershed.

a. Green Technology BMPs

Green Technology BMPs should given preferential consideration before proposing any other type of BMP for water quality. The report "Green Technology: The Delaware Urban Runoff Management Approach" (2004), provides a description of many Green Technology BMPs available to manage stormwater and meet the performance standards of this Plan, such as Filter Strips, Biofiltration Swales, Bioretention Facilities, Infiltration Basins and Infiltration Trenches BMPs.

b. Temperature Sensitive BMPs

Runoff from blacktop and other impervious surfaces can act as a source of thermal pollution, supplying a regular source of warm water to streams. The absence of vegetation or riparian buffers along the streams can further elevate the temperature of streams and waterways in the watershed which can adversely affect the aquatic habitat of the watershed. Therefore, it is essential that the potential implications of thermal pollution be considered for all stormwater management BMPs proposing surface storage of stormwater runoff. This is especially critical in high quality streams.

Temperature sensitive BMPs shall be preferentially selected in all stormwater management controls discharging to a high quality stream or other area sensitive to thermal pollution. Temperature sensitive BMPs are simply, those BMPs which help reduce the temperature of the discharge of the BMP, typically by shading or by providing underground storage in lieu of surface storage.

TABLE V-5
Advantages and Limitations of On-Site Stormwater Control Methods

Bioretention Facility

ADVANTAGES:

1. If designed properly, has shown ability to remove significant amounts of dissolved heavy metals, phosphorous, TSS, and fine sediments.
2. Requires relatively little engineering design in comparison to other stormwater management facilities (e.g., sand filters).
3. Provides groundwater recharge when the runoff is allowed to infiltrate into the subsurface.
4. Enhances the appearance of parking lots and provides shade and wind breaks, absorbs noise, and improves an area's landscape.
5. Maintenance on a bioretention facility is limited to the removal of leaves from the bioretention area each fall.
6. The vegetation recommended for use in bioretention facilities is generally hardier than the species typically used in parking lot landscapes. This is a particular advantage in urban areas where plants often fair poorly due to poor soils and air pollution.

LIMITATIONS:

1. Low removal of nitrates.
2. Not applicable on steep, unstable slopes or landslide areas (slopes greater than 20 percent).
3. Requires relatively large areas.
4. Not appropriate at locations where the water table is within 6 feet of the ground surface and where the surrounding soil stratum is unstable.
5. Clogging may be a problem, particularly if the BMP receives runoff with high sediment loads.

Catch Basin/Storm Drain Inserts

ADVANTAGES:

1. Provides moderate removal of larger particles and debris as pretreatment.
2. Prefabricated for different standard storm drain designs
3. Low installation costs.
4. Units can be installed in existing traditional stormwater infrastructure.
5. Ease of installation.
6. Requires no additional land area.

LIMITATIONS:

1. Vulnerable to accumulated sediments being re-suspended at low flow rates.
2. Severe clogging potential if exposed soil surfaces exist upstream. Can only handle limited amounts of sediment and debris.
3. Maintenance and inspection of catch basin inserts may be required before and after each rainfall event, excessive cleaning, and maintenance (i.e. high maintenance costs).
4. Available head to meet design criteria (i.e. hydraulic loss by insert).
5. Dissolved pollutants are not captured by filter media.
6. Limited pollutant removal capabilities.

Cisterns

ADVANTAGES:

1. Low installation cost.
2. Requires little space for installation.
3. Reduces amount of stormwater runoff.
4. Conserves water usage.

LIMITATIONS:

1. Limited amount of stormwater runoff can be captured.
2. Restricted to structure runoff.
3. Aesthetically unpleasing.

TABLE V-5 (cont.)
Advantages and Limitations of On-Site Stormwater Control Methods (continued)

Constructed Wetlands

ADVANTAGES:

1. Artificial wetlands offer natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal.
2. Artificial wetlands can offer good treatment following treatment by other BMPs, such as wet ponds, that rely upon settling of larger sediment particles (Urbonas, 1992). They are useful for large basins when used in conjunction with other BMPs.
3. Wetlands that are permanently flooded are less sensitive to polluted water inflows because the ecosystem does not depend upon the polluted water inflow.
4. Can provide uptake of soluble pollutants such as phosphorous, through plant uptake.
5. Can be used as a regional facility.

LIMITATIONS:

1. Although the use of natural wetlands may be more cost effective than the use of an artificial wetland; environmental, permitting and legal issues may make it difficult to use natural wetlands for this purpose.
2. Wetlands require a continuous base flow.
3. If not properly maintained, wetlands can accumulate salts and scum which can be flushed out by large storm flows.
4. Regular maintenance, including plant harvesting, is required to provide nutrient removal.
5. Frequent sediment removal is required to maintain the proper functioning of the wetland.
6. A greater amount of space is required for a wetland system than is required for an extended/dry detention basin treating the same amount of area.
7. Although artificial wetlands are designed to act as nutrient sinks, on occasion, the wetland may periodically become a nutrient source.
8. Wetlands that are not permanently flooded are more likely to be affected by drastic changes in inflow of polluted water.
9. Cannot be used on steep unstable slopes or densely populated areas.
10. Threat of mosquitoes.
11. Hydraulic capacity may be reduced with plant overgrowth.

Dry Wells

ADVANTAGES:

1. Recommended in Residential Areas.
2. Requires minimal space to install.
3. Low installation costs.
4. Reduces amount of runoff.
5. Provides groundwater recharge.
6. Can serve small impervious areas like rooftops.
7. Helps to disconnect impervious surfaces.

LIMITATIONS:

1. Offers little pretreatment which may cause clogging.
2. Dry wells should not be installed where hazardous or toxic materials are used, handled, stored or where a spill of such materials would drain into the dry well.
3. Risk of groundwater contamination in very coarse soils may require groundwater monitoring.
4. Not suitable on fill sites or steep slopes.
5. Must have a minimum of 3 to 4 feet between the bottom of the dry well and the seasonal high water table.
6. Dry wells service a limited drainage area, typically only rooftop runoff.
7. Dry wells must be located at least 10 feet away, on the down slope side of the structure, from building foundations to prevent seepage.

TABLE V-5 (cont.)
Advantages and Limitations of On-Site Stormwater Control Methods (continued)

Dry Wells

LIMITATIONS (cont.):

8. Stormwater runoff carrying bacteria, sediment, fertilizer, pesticides, and other chemicals may flow directly into the groundwater.
9. Loss of infiltrative capacity and high maintenance cost in fine soils.
10. Low removal of dissolved pollutants in very coarse soils.
11. Soils must be permeable.
12. Not recommended for use with commercial rooftops unless adequacy of pretreatment is assured.

Extended / Dry Detention Basins or Underground Tanks

ADVANTAGES:

1. Modest removal efficiencies for the larger particulate fraction of pollutants.
2. Removal of sediment and buoyant materials. Nutrients, heavy metals, toxic materials, and oxygen-demanding particles are also removed with sediment substances associated with the particles.
3. Can be designed for combined flood control and stormwater quality control.
4. Requires less capital cost and land area when compared to wet pond BMP.
5. Downstream channel protection when properly designed and maintained.

LIMITATIONS:

1. Require sufficient area and hydraulic head to function properly.
2. Generally not effective in removing dissolved and finer particulate size pollutants from stormwater.
3. Some constraints other than the existing topography include, but are not limited to, the location of existing and proposed utilities, depth to bedrock, location and number of existing trees, and wetlands.
4. Extended/dry detention basins have moderate to high maintenance requirements.
5. Sediments can be resuspended if allowed to accumulate over time and escape through the hydraulic control to downstream channels and streams.
6. Some environmental concerns with using extended/dry detention basins include potential impact on wetlands, wildlife habitat, aquatic biota, and downstream water quality.
7. May create mosquito breeding conditions and other nuisances.

Infiltration Basins

ADVANTAGES:

1. High removal capability for particulate pollutants and moderate removal for soluble pollutants.
2. Groundwater recharge helps to maintain dry-weather flows in streams.
3. Can minimize increases in runoff volume.
4. When properly designed and maintained, it can replicate pre-development hydrology more closely than other BMP options.
5. Basins provide more habitat value than other infiltration systems.

LIMITATIONS:

1. High failure rate due to clogging and high maintenance burden.
2. Low removal of dissolved pollutants in very coarse soils.
3. Not suitable on fill slopes or steep slopes.
4. Risk of groundwater contamination in very coarse soils may require groundwater monitoring.
5. Should not be used if significant upstream sediment load exists.
6. Slope of contributing watershed needs to be less than 20 percent.
7. Not recommended for discharge to a sole source aquifer.
8. Cannot be located within 100 feet of drinking water wells.
9. Metal and petroleum hydrocarbons could accumulate in soils to potentially toxic levels.
10. Relatively large land requirement.
11. Only feasible where soil is permeable and there is sufficient depth to bedrock and water table.

TABLE V-5 (cont.)
Advantages and Limitations of On-Site Stormwater Control Methods (continued)

Infiltration Basins

LIMITATIONS (cont.):

12. Need to be located a minimum of 10 feet down gradient and 100 feet up gradient from building foundations because of seepage problems.

Infiltration Trenches

ADVANTAGES:

1. Provides groundwater recharge.
2. Trenches fit into small areas.
3. Good pollutant removal capabilities.
4. Can minimize increases in runoff volume.
5. Can fit into medians, perimeters, and other unused areas of a development site.
6. Helps replicate pre-development hydrology and increases dry weather baseflow.

LIMITATIONS:

1. Slope of contributing watershed needs to be less than 20 percent.
2. Soil should have infiltration rate greater than 0.3 inches per hour and clay content less than 30 percent.
3. Drainage area should be between 1 to 10 acres.
4. The bottom of infiltration trench should be at least 4 feet above the underlying bedrock and the seasonal high water table.
5. High failure rates of conventional trenches and high maintenance burden.
6. Low removal of dissolved pollutants in very coarse soils.
7. Not suitable on fill slopes or steep slopes.
8. Risk of groundwater contamination in very coarse soils may require groundwater monitoring.
9. Cannot be located within 100 feet of drinking water wells.
10. Need to be located a minimum of 10 feet down gradient and 100 feet up gradient from building foundations because of seepage problems.
11. Should not be used if upstream sediment load cannot be controlled prior to entry into the trench.
12. Metals and petroleum hydrocarbons could accumulate in soils to potentially toxic levels.

Media Filtration

ADVANTAGES:

1. May require less space than other treatment control BMPs and can be located underground.
2. Does not require continuous base flow.
3. Suitable for individual developments and small tributary areas up to 100 acres.
4. Does not require vegetation.
5. Useful in watersheds where concerns over groundwater quality or site conditions prevent use of infiltration.
6. High pollutant removal capability.
7. Can be used in highly urbanized settings.
8. Can be designed for a variety of soils.
9. Ideal for aquifer regions.

LIMITATIONS:

1. Given that the amount of available space can be a limitation that warrants the consideration of a sand filter BMP, designing one for a large drainage area where there is room for more conventional structures may not be practical.
2. Available head to meet design criteria.
3. Requires frequent maintenance to prevent clogging.
4. Not effective at removing liquid and dissolved pollutants.
5. Severe clogging potential if exposed soil surfaces exist upstream.

TABLE V-5 (cont.)
Advantages and Limitations of On-Site Stormwater Control Methods (continued)

Media Filtration

LIMITATIONS (cont.):

6. Sand filters may need to be placed offline to protect it during extreme storm events.

Porous Pavement

ADVANTAGES:

1. Porous pavements operate in a similar fashion to infiltration trenches and thus provide similar water quality benefits, including reductions in fine-grained sediments, nutrients, organic matter, and trace metals.
2. In addition to water quality benefits, porous pavements also provide significant reductions in surface runoff with up to 90 percent of rainfall retained within the BMP (Schueler, 1992).
3. An added benefit provided by the on-site infiltration is the extent to which the stormwater runoff is able to contribute to groundwater recharge.
4. Reduces pavement ponding.

LIMITATIONS:

1. Only applicable for low-traffic volume areas.
2. To maintain effectiveness, porous pavements require frequent maintenance.
3. Porous pavements are not intended to remove sediments.
4. Easily clogged by sediments if not situated properly.
5. Porous pavements are limited to treating small areas (0.25 to 10 acres).
6. Contributing drainage area slopes should be 5 percent or less to limit the amount of sediments that could potentially lead to clogging of the porous pavement.
7. On average, porous pavements clog within 5 years.
8. Underlying soil strata must have an adequate infiltration capacity of at least 0.3 inches per hour but preferably 0.50 in/hr or more. Adequate soil permeability should extend for a depth of at least 4 feet.
9. The bottom of the reservoir layer should be at least 4 feet above the seasonally high water table. Porous pavements should be no closer than 100 feet from drinking wells and 100 feet upgradient and 10 feet down gradient from building foundations. Due to the risk of groundwater contamination, porous pavements should not be used for gas stations or other areas with a relatively high potential for chemical spills. Similarly, special consideration should be given to the use of porous pavements in wellhead protection areas serviced by sole source aquifers.
10. The porous pavement should not be located where run-off from adjacent areas can introduce sediments to the pavement surface. Similarly, areas subject to wind-blown sediment loads should be avoided.
11. Extended rain can reduce the pavement's load bearing capacity.
12. More expensive than traditional paving surfaces.

Vegetated Swale

ADVANTAGES:

1. Relatively easy to design, install and maintain.
2. Vegetated areas that would normally be included in the site layout, if designed for appropriate flow patterns, may be used as a vegetated swale.
3. Relatively inexpensive.
4. Vegetation is usually pleasing to residents.

LIMITATIONS:

1. Irrigation may be necessary to maintain vegetative cover.
2. Potential for mosquito breeding areas.
3. Possibility of erosion and channelization over time.
4. Requires dry soils with good drainage and high infiltration rates for better pollutant removal.

TABLE V-5 (cont.)
Advantages and Limitations of On-Site Stormwater Control Methods (continued)

Vegetated Filter Strips

ADVANTAGES:

1. Lowers runoff velocity (Schueler, 1987).
2. Slightly reduces runoff volume (Schueler, 1987).
3. Slightly reduces watershed imperviousness (Schueler, 1987).
4. Slightly contributes to groundwater recharge (Schueler, 1987).
5. Aesthetic benefit of vegetated “open spaces” (Colorado Department of Transportation, 1992).
6. Preserves the character of riparian zones, prevents erosion along streambanks, and provides excellent urban wildlife habitat (Schueler, 1992).

LIMITATIONS:

1. Filter strips cannot treat high velocity flows, and do not provide enough storage or infiltration to effectively reduce peak discharges to predevelopment levels for design storms (Schueler, 1992). This lack of quantity control dictates use in rural or low-density development.
2. Requires slope less than 5%.
3. Requires low to fair permeability of natural subsoil.
4. Large land requirement.
5. Often concentrates water, which significantly reduces effectiveness.
6. Pollutant removal is unreliable in urban settings.

Wet Ponds

ADVANTAGES:

1. Wet ponds have recreational and aesthetic benefits due to the incorporation of permanent pools in the design.
2. Wet ponds offer flood control benefits in addition to water quality benefits.
3. Wet ponds can be used to handle a maximum drainage area of 10 mi^2.
4. High pollutant removal efficiencies for sediment, total phosphorus, and total nitrogen are achievable when the volume of the permanent pool is at least three times the water quality volume (the volume to be treated).
5. A wet pond removes pollutants from water by both physical and biological processes, thus they are more effective at removing pollutants than extended/dry detention basins.
6. Creation of aquatic and terrestrial habitat.

LIMITATIONS:

1. Wet ponds may be feasible for stormwater runoff in residential or commercial areas with a combined drainage area greater than 20 acres but no less than 10 acres.
2. An adequate source of water must be available to ensure a permanent pool throughout the entire year.
3. If the wet pond is not properly maintained or the pond becomes stagnant; floating debris, scum, algal blooms, unpleasant odors, and insects may appear.
4. Sediment removal is necessary every 5 to 10 years.
5. Heavy storms may cause mixing and subsequent resuspension of solids.
6. Evaporation and lowering of the water level can cause concentrated levels of salt and algae to increase.
7. Cannot be placed on steep unstable slopes.
8. Pending volume and depth, pond designs may require approval from State Division of Dams Safety.

Note: *Advantages / Limitations adapted from Los Angeles County Development Planning for Stormwater Management Manual, September 2002.*

TABLE V-6
Suitability of Different Control Measures
in the Appoquinimink River Watershed

1) Groundwater Recharge (infiltration):
Recommended throughout the watershed particularly in areas with HSGA and HSG B soils; depending on the size of the facility, expensive to construct.

2) Porous Pavement:
Recommended in areas having HSGA and HSG B soils for sites with small to large parking facilities, not recommended for roadways and driveways or areas with significant truck traffic; promotes groundwater recharge; moderate in expense to construct compared to typical paving; low maintenance costs.

3) Grassed Channels and Vegetated Filter Strips:
Recommended wherever possible throughout the watershed to slow velocity and reduce erosion; minimal slopes recommended; help filter sediment from stormwater to improve water quality; low installation and maintenance costs.

4) Routing Flow Over Lawns:
Recommended in residential areas throughout the entire watershed; delays runoff, entraps sediment, reduces velocities, reduces erosion potential; relatively inexpensive installation and maintenance costs.

5) Rooftop Gardens:
Recommended for structures that are designed to support the weight associated with the gardens; costs vary depending on the size of the BMP.

6) Stormwater Wet Ponds:
Recommended for sites with existing surface depressions or on more porous soils for groundwater recharge; relatively inexpensive to install and maintain; helps entrap sediment to improve the water quality of the receiving stream.

7) Cisterns and Covered Ponds:
Recommended in industrial parks where water could be utilized for fire protection; costs vary on size of cistern and material used; low maintenance costs (usually requires periodic sediment removal). Also may be used in existing or newly developed residential areas.

8) Rooftop Storage (Ponding on Roof):
Possible on large buildings; usually require structure modifications to accomplish on existing buildings; costs can be expensive to construct; low maintenance costs unless leaks occur.

9) Ponding and Detention on Pavement:
Recommended in entire watershed except in "No Detention" areas; inexpensive to construct with low maintenance costs; impact of freezing should be considered.

10) Reservoirs or Detention Basin:
Recommended in entire watershed except in "No Detention" areas; moderate installation to expensive construction costs depending on the size of the facility; low maintenance costs.

Temperature sensitive BMPs include:

1. Provide shading of stormwater management ponds and channels.
2. Maintain existing forested buffers.
3. Bypass baseflow and/or flow from springs around BMPs with surface storage. Use underground storage where possible to prevent the storage facility from storing solar radiation.
4. Application of turf reinforcement mats in lieu of hard armoring practices such as riprap in channels subject to high shear stress and/or velocities.
5. Use groundwater recharge BMPs to eliminate the need to discharge to surface waters.

I. Maintenance

Regular BMP maintenance is an essential part of preserving the stormwater management functions of a facility. Therefore, a description of proper operation and maintenance of both nonstructural and structural stormwater BMPs is an essential part of a stormwater management plan and necessary to maintaining the intended performance of proposed facilities. Poorly maintained BMPs often function less efficiently and may cause more problems than they were intended to resolve.

Maintenance of BMPs is generally divided into two categories: routine and non-routine. Routine maintenance needs to be ongoing, such as mowing grass, removing debris, removing invasive vegetation, planting seed, removing debris and trash. Non-routine maintenance is done on an "as needed" basis and can include sediment removal, replacement of worn parts, completing needed structural repairs, restoring of materials used for outlet protection and other activities associated with a particular practice. Depending on the type of BMP maintenance, activities can represent a significant commitment of time, money and resources to ensure long term proper function of the stormwater management practice.

An important part of any maintenance program is routine and periodic inspections to ensure proper function of all system components on a regular basis. Individuals conducting these inspections need to be trained to recognize when a problem exists and what steps need to be taken to rectify common maintenance problems. Identifying an individual or organization responsible for operation and maintenance of a BMP can sometimes be difficult. This can be a problem in new subdivisions or institutional sites where homeowner associations or maintenance personnel may not have the expertise, awareness, or inclination to address operation and maintenance obligations or problems. In these cases, it may be necessary to assign or contract with a third party to complete the maintenance responsibilities.

Implications of improper maintenance include diminished performance of the BMP, increased flooding, increased pollutant loading, and in a worst case scenario, property damage and potential loss of life. Although maintenance can be a major expense, the ramifications of poorly maintained facilities may create a potential liability problem in the event of stormwater facility failure. Inspection logs need to be completed and given to those individuals responsible for the operation of the BMP in order to determine if common maintenance problems require a modification of the BMP to prevent common maintenance items.

The type and nature of required maintenance is an important aspect to consider when selecting a BMP for a particular location. Typically, it is best to select the least maintenance intensive BMP that will allow the stormwater management objectives to be achieved. All BMPs should be developed with a list of maintenance practices and a schedule of maintenance activities to be performed which will provide for the long term viability of the BMP. The maintenance schedule shall provide for both short term maintenance needs and long term rehabilitation items that may be necessary. Regardless of their location, all BMPs shall be designed with adequate access to the facility so that routine maintenance may be easily performed. Oftentimes, BMPs are placed in close proximity to other significant environmental resources, such as rivers, lakes, wetlands, or wooded areas; therefore, it is essential that BMPs be located in a way that they do not infringe upon these areas and that suitable points of access are provided such that routine maintenance operations at the facility can be accomplished without encroaching upon other known environmental resources.

Regardless of the BMP selected, basic minimum maintenance efforts should normally include the following activities:

1. Regular inspection.
2. Routine mowing.
3. Removal of accumulated debris and sediment.
4. Re-stabilization of pervious areas where vegetation has been destroyed.
5. Resolution of any known causes of accumulated debris and sediment.
6. Removal of invasive plant species and animal borrows.
7. Resolution of maintenance items which inhibit the BMP from functioning as intended.
8. Cleaning of outlet control structures, storm pipes, and outfalls.
9. Restoration of rock filters, level spreaders, earthen berms and energy dissipation devices.

Although it is preferential for proposed BMPs to blend in to the environment, oftentimes these features may be encroached upon or destroyed by activities of others who are not aware of their function or significance. To protect BMPs from unintentional abuse, it may be necessary to provide signs indicating the limits and purpose of the BMP and possibly restrict activities around the BMPs. This is especially important wherever infiltration facilities are proposed.

J. Safety

Safety is another factor to consider when planning BMP installation. A significant concern to public safety is the potential for drowning, overtopping, or embankment failure. Items to consider when specifying a stormwater BMP in a neighborhood, near a school, daycare, traffic facility or other facility where safety is a concern:

1. Include benches or mild slopes around the inside perimeter of the BMP.
2. Install trash racks on all orifices, weirs and outlet control structures, including the top of concrete inlet boxes providing an overflow through outlet control structures.
3. Provide trash racks and anti-vortex devices at the inlet end of pipe culverts.

4. Post signage indicating no trespassing.
5. Provide a recoverable clear zone between transportation facilities and proposed BMPs intended to store stormwater.
6. Install guide rail between transportation facilities and proposed BMPs intended to store stormwater.
7. Reduce the maximum ponding depth inside BMPs intended to store stormwater.
8. Provide a keyway into undisturbed earth beneath all proposed embankments.
9. Provide preferential treatment to emergency spillways placed in undisturbed soils.
10. Provide secondary overflow or emergency spillways that discharge to a safe area away from any embankment.
11. Construct emergency spillways of materials able to withstand the shear forces and velocities of the spillway design flood.
12. Provide properly-sized outlet protection at the outlet end of all features conveying concentrated stormwater discharge.
13. Perform regular maintenance and maintain a log of common maintenance problems that may warrant correction.
14. Remove accumulated sediment and debris on a regular basis that may reduce pipe capacity or block orifices.
15. Use only properly compacted embankment materials specified by a registered professional engineer or geotechnical engineer when constructing an embankment for a BMP intended to store stormwater.
16. Remove all woody vegetation growing on embankments intended to store stormwater.

SECTION VI

PRIORITIES FOR IMPLEMENTATION

A. DNREC Adoption of the Plan

The plan process was completed when DNREC adopted the Plan. This process included submittal of a Draft Plan to DNREC for review and approval. DNREC's review included a determination that all of the activities specified in the Scope of Study have been completed. DNREC also reviewed the Plan for consistency with municipal floodplain management plans, state programs that regulate dams, encroachments and other water obstructions, and state and federal flood control programs. The Plan was also reviewed for compatibility with other stormwater plans in the watershed, and with Title 7, Chapter 40. A regulatory advisory committee was formed, which included representatives from regulated communities and others affected by the Plan. It is recommended that the representatives be present at all public workshops and hearings. Prior to final promulgation of regulations, the secretary should explain, in writing, any differences between the advisory committee recommendations and the final regulations.

B. Becoming a Designated Watershed

According to Title 7, Section 5101, of Delaware's Administrative Code, DNREC will be responsible for implementation of the Plan. Approval of this Plan will allow DNREC to designate the Appoquinimink River System as a Watershed or Subwatershed. Upon approval of a designated Watershed or Subwatershed Plan, all projects undertaken in that Watershed or Subwatershed will need to meet requirements that are consistent with the Plan. This Plan will allow for unified development regulations for each municipality within the watershed.

C. Landowner's/Developer's Responsibilities

Landowners and persons engaged in land alteration or development that may affect stormwater runoff characteristics will be required to implement such measures consistent with the provisions of the applicable Watershed Plan. These measures shall include:

1. Ensuring the maximum rate and volume of stormwater runoff is no greater after development than prior to development activities;

2. Managing the quantity, velocity and direction of stormwater runoff in a manner that adequately protects health and property from possible injury; and

3. Ensuring the quality of the stormwater runoff after development will not impair receiving water bodies.

SECTION VII

PLAN REVIEW APPROVAL AND UPDATING PROCEDURES

A. DNREC Approval

Prior to Plan completion, DNREC transmitted a draft Plan to each of the municipalities within the watershed, the County Planning Department or Commission and the Watershed Plan Advisory Committee by official correspondence for their review. Their review included an evaluation of the Plan's consistency with other plans and programs affecting the watershed. The reviews and comments were submitted to DNREC by official correspondence.

Once the Plan was deemed acceptable by DNREC, a public meeting was held. A notice for the hearing was published twenty (20) days prior to the hearing date. The meeting notice was published in a newspaper of general circulation, which included a brief description of the Plan, the time and place of the hearing, and contain informed about where copies of the Plan could be obtained. Minutes from the hearing were documented and comments received were reviewed by DNREC and appropriate modifications to the Plan were made.

After the public meeting was held, DNREC was able to adopt and then implement the Plan. The Appoquinimink River watershed was henceforth noted as a designated watershed. This then regulated the immediate and long-range development and use of water resources within the watershed.

B. Provisions for Plan Revision

Title 7 of the Delaware Code, Chapter 40 Erosion and Sediment Control Plan allows for the Stormwater Management Plan to be updated whenever needed. As dictated by Chapter 40 §4006 (b).(3)., the Plan is to be reviewed every three years to determine if the plan requires updating to reflect changes in the watershed that are not adequately addressed in this plan. This allows adjustments in the management strategies set forth in the plan to account for changes in land use, obstructions, flood control projects, floodplain, and management objectives or policy that may take place within the watershed since the initial implementation of the Plan.

It will be necessary to collect and manage the required data in a consistent manner and preferably store it in a central location. This is not only to prepare an updated Plan, but also, if required, to make interim runs on the runoff simulation model to analyze the impact of a proposed major development or a proposed major stormwater management facility.

The following recommendations are the minimum requirements to maintain an effective technical position for periodically reviewing and revising the Plan.

1. It is recommended that DNREC undertakes the task of organizing stormwater management plans and supporting data submitted for review. The Planning Department should also assume responsibility for periodically reviewing, revising, and updating the Stormwater Management Plan.

2. It is recommended that DNREC prepare a workable program for the identification, collection and management of the required data. The program should not be limited to the cooperative efforts of the constituent member municipalities within the Appoquinimink River watershed, but should also include both state and county agencies concerned with stormwater management.

3. It is recommended that the Stakeholders convene biannually or as needed to review the Stormwater Management Plan and determine if the Plan is adequate for minimizing the runoff impacts of new development. At a minimum, the information (to be reviewed by the Committee) will be as follows:

   a. Development activity data as monitored by DNREC.

   b. Information regarding additional storm drainage problem areas as provided by the municipal representatives to the Stakeholders.

   c. Zoning and Subdivision amendments within the watershed that either conflict with the Plan or warrant changes to the Plan.

   d. Impacts associated with any regional or subregional detention alternatives implemented in the watershed.

   e. Adequacy of the administrative aspects of regulated activity review.

   f. Additional hydrologic data (i.e., precipitation measurements, stream flow, significant land cover changes, construction of new sizeable stormwater management facilities) available through preparation of the Stormwater Management Plan for the Appoquinimink River watershed.

The Committee will review the above data and make recommendations to DNREC for revisions to the Appoquinimink River Watershed Stormwater Management Plan. DNREC will review the recommendations of the Stakeholders and determine if revisions are to be made. A revised Plan would be subject to the same rules of adoption as the original Plan. Should DNREC determine that no revisions to the Plan are required, DNREC will adopt a resolution stating that the Plan has been reviewed and been found satisfactory.

SECTION VIII

WATERSHED PROBLEMS AND SOLUTIONS

A. Introduction

The goal of the Appoquinimink River Watershed Stormwater Management Plan is to maintain or improve the hydrologic regime of the watershed through ordinance implementation and other physical measures. Maintaining the hydrologic regime encompasses minimizing streambank erosion and flooding, promoting infiltration to recharge aquifers and stream baseflow, and improving water quality through management of runoff peak rates and volumes. Through the Stormwater Management Plan, it has been demonstrated that the watershed has been hydrologically and hydraulically stressed by changes in land cover, including increased impervious area. This stress has shown up as degradation of water quality, streambank erosion and subsequent sedimentation, and flooding.

B. Identification of Regional versus Localized Problems

The first step to addressing problem areas is to properly understand the cause and how they arose. Generally, problems can be broken down into one of two categories; regional problems and local problems. The key distinction between these problems is how they are caused.

Regional problems occur when a stream cannot convey the flow in the channel and water overtops the banks and spills into the floodplain. Areas submerged during large rainfall events, such as 100-year storms, are identified on FEMA Flood Insurance Rate Maps (FIRM). Very often, the flood flows cannot be conveyed due to increases in runoff from changes in upstream land cover. Problem areas resulting from the channel not being able to convey flood flows would be denoted as a regional problem.

Localized problems are centered around a particular point and do not impact a substantial portion of the watershed. Generally these types of problems are the result of conveyance systems not functioning properly. Such examples include backwater from insufficient sized bridges/culverts, blocked/clogged culverts, inadequate stormwater conveyance systems, and depression areas that pond. The causes of localized problems tend to be evident and are many times easy to determine.

Note that the type of problem does not dictate the priority of rehabilitation. Engineering analysis should be completed for all problem areas to determine the cause of the problem.

C. Generalized Solutions to Problem Areas

The development of the Watershed Plan, which provides a general framework for the correction of existing drainage problems, is a logical first step in the process of implementation of a stormwater management ordinance. Implementing measures recommended in the Plan will prevent the worsening of existing drainage problems and prevent the creation of new drainage problems. The step-by-step outline below is one method of approaching problems uniformly throughout the watershed:

- List and prioritize the storm drainage problems within the municipalities based on frequency of occurrence, potential for injury, and property damage history.

- Develop a detailed engineering evaluation to determine the exact nature of the top priority drainage problems within the municipalities in order to determine solutions, cost estimates, and a recommended course of municipal action.

- Incorporate implementation of recommended solutions regarding stormwater runoff in the annual municipal capital or maintenance budget.

Although the adoption of this Plan in and by itself will not resolve any existing problems, the Plan will help prevent the worsening of existing drainage problems and prevent the creation of new drainage problems through the application of a watershed-wide management approach to stormwater runoff. Drainage problems can be classified into the following categories, each of which will be discussed in more detail below.

1. Deficient Bridges/Culverts
2. Undersized Culverts and Insufficient Storm Sewer Capacity
3. Erosion and Sedimentation Problems
4. Flooding
5. Management Measures Unique to Tidal Effects

1. <u>Deficient Bridges/Culverts</u>

   Although the obstruction map does not distinguish between culverts and bridges, those individual obstructions located on various streams within the Appoquinimink River watershed are most likely bridges or large culverts. See the Obstruction Map, Map III-10, for the location of obstructions within the watershed. On state roads, these bridges are normally designed based upon the road classification with the design event selected based on this same roadway classification. As the bridges are typically sized based upon the design flow at the time of the design, if a bridge has been in place for an extended period of time it is very likely that the conveyance capacity of the structure is inadequate to convey increased flows created by development within the watershed. Often these structures require replacement or significant modification to provide adequate capacity. Key bridges or obstructions that are undersized can be easily identified by examining the creek profile in the FIS. When the water surface upstream of a bridge or other obstruction is flatter than the slope of the channel this is indicative of a backwater problem potentially created by an undersized bridge or drainage structure. Similarly, high sediment bed loads of streams within the watershed and corresponding gravel deposits reduce the waterway opening area which reduces the conveyance capacity of bridges. This is particularly a problem in the downstream portions of the Appoquinimink River watershed along the main stem of the creek.

TABLE VIII-1
Existing Obstruction Problems

ID	Existing Capacity	Future Capacity
7	UNDERSIZED	UNDERSIZED
8	UNDERSIZED	UNDERSIZED
407A	UNDERSIZED	UNDERSIZED
425	UNDERSIZED	UNDERSIZED
442	UNDERSIZED	UNDERSIZED
443A	UNDERSIZED	UNDERSIZED

Listed in Table VIII-1 are six (6) existing structures which have been identified as being undersized and form an obstruction to flow. They were obtained from examining the obstruction map for bridges or culverts that were not able to pass the lowest design storms. Note that if the design storm was not known for a given bridge, it was not included on the list.

Seen below in Table VIII-2 are the four (4) additional bridges that will have future problems. These are bridges whose capacity will be decreased due to changes in land cover. If release rate methodology is not implemented, these bridges will require additional funding due to the maintenance needed to keep them functional. Note that this table assumes that debris and sediment are not causing an obstruction to flow.

TABLE VIII-2
Future Obstruction Problems

ID	Existing Capacity	Future Capacity
1	25YR	10YR
393	25YR	10YR
400	25YR	10YR
402	25YR	10YR

It should be noted that the flow generated from the hydrologic model is for planning purposes only. A detailed analysis should be completed to confirm the problem. In order to alleviate these problems, several different steps can be taken. As a first step, sediment deposits surrounding the bridge should be identified and removed from the opening to restore the conveyance capacity of the waterway opening. Once the capacity is restored, an active maintenance schedule can be enacted to maintain the capacity of the bridges. If sedimentation is a frequent problem, the size of the waterway opening can be reduced for lower stream stages to maintain the water velocity through the bridge and prevent the water from slowing and depositing sediment around the bridge. Excessive scour at select locations around a bridge or a constriction in a waterway can result in sedimentation downstream of the scour at a location where the velocity slows. In these locations, often the best solution is to evaluate the cause of the scour and design counter measures to minimize the effects of the scour. An active maintenance program does not require a hydraulic study to initiate; however, any modification of the waterway opening or the channel configuration around a bridge typically involves a hydraulic study. The solution costs are typically borne by the owner of the bridge.

2. Undersized Culverts and Insufficient Storm Sewer Capacity

Some of the problems identified in Section II of the Plan are the result of inadequately-sized storm sewers, undersized culverts, and/or unstable outlets from storm sewers that traverse state, township, or private roads. Regular maintenance of existing culverts and storm sewers is typically the starting point to resolving some of these issues. In certain instances, storm sewer system appurtenances such as trash racks, sediment basins or energy dissipaters to prevent clogging of pipes can be constructed. These appurtenances would be helpful for those pipes that are prone to frequent clogging. However, when routine maintenance is incapable of solving the drainage problems, the typical solution involves performing a hydraulic study to modify pipe sizes and improve the capacity of the pipes or system. The costs for such a study are typically borne by the owner of the road.

The Obstruction Map (Map II-10) and Problem Areas Map (II-11) are useful in identifying the location of problem culverts and storm sewer problem areas. Many of the obstructions, cited on the Standards and Criteria Map, are located on the main stem of the Appoquinimink River, or one of its major tributaries. The most significant obstructions are most likely culverts that were installed at an earlier point in time when the watershed was less developed. With the development of the watershed, the flows to particular culverts may have surpassed their design capacity, thus warranting either replacement of the culvert, or modification of the inlet to add culvert capacity. In some instances, clogging with sediment or debris may be a problem. In this case, placing a sediment collection device or trash rack upstream of the culvert may be useful. Regardless of the location or means of improving conveyance capacity, the resolution of these conveyance problems will likely reduce flooding that occurs at the inlet of the pipes.

The General Procedures for Municipalities to determine size of replacement culverts using the Plan is as follows:

a. Determine the location of the obstruction from the Obstruction Map and obtain the obstruction number.
b. Determine the appropriate design storm frequency from Section 3.2.5 of DelDOT Bridge Design Manual or Township Ordinances.
c. Locate the municipality and obstruction number from "Municipal Stream Obstruction Data" tables. Obtain the flow value (cfs) for the design storm

frequency determined in “b” above. Use this flow as a starting point to determine the preliminary size of the replacement culvert.

d. Conduct a hydraulic analysis to properly size the culvert for this design flow and obtain any necessary approvals/permits.

Note: The data contained in this Plan is suitable for planning purposes. However, the design of any replacement structures should not be proposed without a thorough, site-specific hydrologic and hydraulic investigation to obtain the most appropriate design flows and an accurate understanding of the hydraulic behavior of the water flowing through and around culverts.

3. <u>Erosion and Sedimentation</u>

The main stem of the Appoquinimink River, as well as several of its tributaries, contain several reaches of substantial length which are severely eroded. This has been documented by DNREC, the Center for Watershed Protection, and most recently by A.D. Marble. The A.D. Marble report is based upon the completion of severe erosion forms as well as field observations in conducting a Bank Erosion Hazard Index (BEHI) and a Near-Bank Stress Assessment (NBS). Results show that within the Appoquinimink River watershed, erosion rates for various streams range from 11 cubic feet per year, to 2,700 cubic feet per year. The A.D. Marble report indicates that the increase in bed and bank erosion was a result of increased runoff from agricultural and residential development. For a full analysis and explanation of these problems, see the A.D. Marble Report entitled, *Appoquinimink Watershed Assessment Streambank Erosion Inventory and Tidal Marsh Assessment Summary Report*, dated May 2009.

Since these problems are directly connected with increased stormwater runoff in the watershed, correction of the problems requires better management of stormwater runoff. The addition of buffers can help stabilize the channel banks, but without watershed-based stormwater management standards and criteria, the impact of these buffers will be limited. There are many stabilization techniques that are available with bioengineering, typically the preferred approach as it is more sensitive to the environment. Bioengineering techniques include items such as turf reinforcement mats, natural fiber rolls, reforestation with live plantings, and hooks and veins to divert flow away from sensitive point problems designated on the maps. However, in certain areas with high shear stress and where velocities are high, hard armoring may be required.

Permanent stabilization of exposed areas and proper stabilization of conveyance channels will reduce erosion problems. Improvements in the watershed can be realized by reviewing plans for new developments to make certain that appropriate methods and techniques are being specified, conducting inspections to ensure the methods specified are being installed properly and maintained, and investigating and documenting any existing sources of prolonged problems.

4. Flooding

Flooding is prevalent throughout the entire watershed. Areas adjacent to streams and in various low lying areas are generally subject to flooding during and after rain events. This flooding in the watershed can be classified into two categories: 1) local flooding caused by inadequately-sized storm sewers or culverts; and 2) regional flooding caused by large amounts of stormwater runoff flowing to a location which may be conveyed by an undersized structure or blocked by a floodplain encroachment.

Of the localized flooding problem sites identified, many are caused by inadequate conveyance systems in developed areas. To fix these problems, municipalities must first identify and prioritize the problems based upon their severity, frequency of occurrence, and threat to vital resources and the public. After the problems are prioritized to identify the most urgent problems, the municipality should complete a site specific hydraulic analysis to identify the causes of the problem and propose a feasible solution. Some of the existing problems can be fixed with a more aggressive maintenance program to clear blockages while others may be helped through the volume control measures and the release rates prescribed by this Plan. Although the stormwater management measures incorporated into this Plan can help alleviate some of the problems, often the permanent solution to these problems requires an engineered solution which may necessitate the removal of an obstruction or the construction of flood mitigation measures such as a floodwall, regional detention, or property acquisition.

5. Management Measures Unique to Tidal Effects

For the Tidal Marsh Assessment, A.D. Marble compared two pristine marshes to two supposedly contaminated marshes. The results of the survey indicate that increases in development will not cause a detectable impact on the watershed. Water quality concerns such as an increase in invasive plant life, decrease in macro invertebrate diversity, or decrease in water quality were not observed by A.D. Marble in their report. Three potential explanations were provided in the report.

1. The “pristine” wetlands/tidal marshes used as a control for the survey were equally affected as the affected wetlands and thus no difference was observed.
2. The methodologies used may not be robust enough to pick up the differences.
3. The sample size may have been too small to identify differences.

For a full analysis and explanation of these problems, see the A.D. Marble Report entitled, *Appoquinimink Watershed Assessment Streambank Erosion Inventory and Tidal Marsh Assessment Summary Report*, dated May 2009. Note that implementation of the standards and criteria from the model ordinance will also help protect these tidal marsh areas.

D. Significant Problem Areas

Of the problems provided by DNREC and the Town of Middletown, certain locations exhibited a more advanced state of decay. These locations, denoted as significant problem areas, require correction urgently. As stated in Section II, these areas were selected based upon the problem area and the priority assigned to it by the Center for Watershed Protection in their 2005 Implementation Plan. Most of the points provided in Map II-11 were from the Implementation Plan. Each had varying degrees of priority ranging from high to low. Of all the high priority sites chosen, cost estimates and in-depth analysis was undertaken for 12 erosion/buffer locations and 12 retrofit locations. None of these locations had been addressed at the time of this report preparation.

The scope of this report focuses on water quantity problems. High priority problems identified in the Center for Watershed Protection report were excluded from being considered significant problem areas as they are water quality related. This precluded outfalls, stream and utility crossings, and erosion sites from being denoted as significant. Examination of the outfalls showed that they were generally the result of a local drainage issue that resulted in flooding. As such, none of the outfalls were considered significant. All crossing locations were documented in the obstruction map and no obstructions were denoted as significant. Thus, only locations from the Appoquinimink Implementation Plan with severe, significant, substantial erosion were denoted as significant for the context of this Plan.

Areas noted in the Problem Area forms from Middletown were also reviewed. The lone flooding site was included as significant because of the noted property damage. Sedimentation areas identified on the forms were not included as they were examined in GIS and determined to be located in the headwaters of the watershed. Since the headwater areas have relatively small flows, they could not be considered regions.

A total of nine (9) significant problem areas have been identified. Schematics of these problem areas are provided in the Technical Appendix. Solutions could be implemented by following the detailed steps listed in the general solution to problem areas earlier in this section. These areas should be addressed as soon as possible to have the most substantial impact on the restoration of the watershed.

E. Coordination Efforts with Concurrent Studies to Prevent Duplication of Work

Stormwater problems can vary from small localized problems to large regional issues. As such, many different organizations could potentially be involved in numerous projects involving rehabilitation of the watersheds. Therefore, there is potential for a duplication of work or overlap in project goals and objectives. For example, the planned replacement of a bridge to reduce upstream flooding designed and constructed independently from a flood control facility for the area upstream of the bridge would be a duplication of work. To prevent duplication of work, a recommended contact list is provided in Table VIII-3 to facilitate a coordinated approach to resolving some of the problems within the watershed.

TABLE VIII-3
Recommended Project Contact List and Prioritization of Contact

Type of Work	Local Municipality	New Castle County	DNREC	DelDOT	FEMA	Army Corps of Engineers	New Castle County Conservation District	Appoquinimink River Association
Bridge/Culvert Maintenance (Private Road)	2nd	2nd	1st				2nd	
Bridge/Culvert Maintenance (Local Road)	1st	1st	2nd				2nd	
Bridge/Culvert Maintenance (State Road)	3rd	3rd	2nd	1st			2nd	
Bridge/Culvert Replacement (Private Road)	2nd	2nd	1st				1st	
Bridge/Culvert Replacement (Local Road)	1st	1st	2nd				2nd	
Bridge/Culvert Replacement (State Road)	3rd	3rd	2nd	1st			2nd	
Stream Bank Stabilization	3rd	3rd	1st				1st	2nd
Sediment /Debris Removal from Stream	3rd	3rd	1st				1st	2nd
Stream Buffer Establishment	3rd	3rd	1st				2nd	2nd
BMP Retrofit	1st	1st	2nd				2nd	3rd
Stormwater Collection System (Local Road)	1st	1st	2nd					
Stormwater Collection System (State Road)	3rd	3rd	2nd	1st				
Stormwater Facility	1st	1st	2nd	4th			3rd	4th
Wetland Impact or Alteration	2nd	2nd	1st			1st	4th	3rd
Regional Stormwater Management	1st	1st	2nd					
Floodplain Alteration-major	2nd	2nd	3rd		1st	4th	3rd	5th
Floodplain Alteration-minor	1st	1st	2nd		3rd	4th	3rd	
Flood Control Facility	1st	1st	2nd		3rd	4th		5th

Table VIII-3 is not intended to be an exhaustive list of potential agencies and stakeholders but is intended to direct project teams toward key agencies and stakeholders that will have an interest in and oversight of such projects. Generally, the number of agencies, organizations and other stakeholders involved in a project will increase with the size of the project and the magnitude of the problem it is attempting to resolve. Therefore, agency coordination is a critical component of any watershed work to minimize complications and increase the likelihood of successful completion of the project.

Pre-application meetings are strongly recommended as part of the planning process for all projects in the watershed to discover unforeseen problems before the design is initiated and to gain consensus from all stakeholders concerning the need for the project, the project scope and the necessary steps needed to complete the project. When considering a potential project that has possible stormwater implications, certain key topics should be discussed with the agencies and organizations. Possible topics to discuss at a pre-application meeting with the agencies and stakeholders include:

- Project Scope - defines the purpose of the project, what it is intended to accomplish, and the activities necessary to successfully complete the project.
- Location - delineates the project and sets the project limits.
- Municipal Boundaries - defines the stakeholders included in the project.
- Potential Impacts - defines the stakeholders in the project and critical issues that must be considered or evaluated as part of the analysis.
- Permits - identifies the regulatory approvals that are required to complete the project.
- Schedule - sets a realistic estimation of when the project can be fully implemented and its intended function realized.
- Coordination - recognizes efforts needed by various stakeholders to bring a project to an efficient and timely completion.
- Project Partnering - determines potential opportunities for multiple projects to work together to increase the benefit of any single project implemented independently.
- Funding - spots opportunities for supplementing private funding with additional private or public funding to realize a greater benefit to the watershed.

F. Potential Funding Sources

In order to help restore the watershed, funding can be obtained from several different sources. The list that appears below is not intended to be a comprehensive list of all the providers of funds for stormwater maintenance and implementation. Instead, it is an introductory list of agencies and a description of the type of work for which they provide funding. The type of funding is broken into four categories: assessment, planning, implementation, and other. Although the first three are self descriptive, the other category includes research, education, publication, and any other related activity not listed above. When seeking funding for a stormwater related project, the list should be examined and any sources related to the project should be contacted.

TABLE VIII-4
Potential Funding Sources

SOURCE OF ASSISTANCE	WORK NUMBER	BRIEF DESCRIPTION OF PROGRAM	ASSESS -MENT	PLANNING	IMPLE-MENTA -TION	OTHER
National Fish & Wildlife Foundation. Delaware Estuary Watersheds Grants Program	202-857-0166	Encourage innovative community or locally-based programs or projects that restore important habitats and living resources within the Delaware Estuary Watershed.	X	X	X	X
U.S. EPA Environmental Education Grants Region III Philadelphia, PA	215-566-5546	Grants awarded to small nonprofit groups for various projects in Region III.		X	X	
U.S. EPA National Estuary Grant Program	202-260-6502	Supports the development of programs to protect coastal watersheds in estuaries of national significance, including the Delaware Estuary		X		
U.S. EPA Sustainable Development Challenge Grants (SDCG)	206-553-2634	Grants to support communities in establishing partnerships to encourage environmentally and economically sustainable practices.				X
U.S. Environmental Protection Agency Office of Wetlands, Oceans, and Watersheds (4501 F) Ariel Rios Building 1200 Pennsylvania Avenue NW Washington, DC 20460	202-260-4538	EPA establishes a cooperative agreement with one or more nonprofit organization(s) or other eligible entities to support watershed partnership organizational development and long- term effectiveness. Funding supports organizational development and capacity building for watershed partnerships with diverse membership.		X	X	
U.S. Environmental Protection Agency Office of Wetlands, Oceans, and Watersheds (4502F) Ariel Rios Building 1200 Pennsylvania Avenue NW Washington, DC 20460	202-260-4538	This Five-Star Program seeks to support restoration projects in 500 watersheds by 2005, a key action of the Clean Water Action Plan. Competitive projects will have a strong on-the-ground habitat restoration component that provides long-term ecological, educational, and/or socioeconomic	X	X	X	

SOURCE OF ASSISTANCE	WORK NUMBER	BRIEF DESCRIPTION OF PROGRAM	ASSESS -MENT	PLANNING	IMPLE-MENTA -TION	OTHER
		benefits to the people and their community.				
American Canoe Association Springfield, VA	703-451-0141	May provide funding for various watershed-related projects including starting groups and lobbying.	X	X		X
Charles A. and Anne Morrow Lindburgh Foundation Minneapolis, MN	612-338-1703	Grants for research and educational projects that promote a balance between advance of technology and preservation of the human/natural environment in areas including water resources.		X		X
Fish America Foundation Alexandria, VA	703-548-6338	Grants awarded for stream bank stabilization materials, instream habitat improvements, contracted heavy equipment, and stream morphology work.			X	
U.S. Department of Agriculture Natural Resource Conservation Service P.O. Box 2890 Washington, DC 20013-9770	202-720-3534	Technical assistance and cost sharing for implementation of NRCS-authorized watershed plans. Technical assistance on watershed surveys and planning.	X	X	X	
U.S Department of the Interior U.S. Fish and Wildlife Service North America Waterfowl and Wetlands Office (NAO) 4401 North Fairfax Drive, Room 110 Arlington, VA 22203	703-358-1784	The North American Wetlands Conservation Act of 1989 provides matching grants to carry out wetlands conservation projects in the United States, Canada and Mexico. Both the standard and small grants programs help deliver funding to on-the-ground projects through protection, restoration or enhancement of an array of wetland habitats.			X	
U.S. Department of Commerce National Oceanic and Atmospheric Administration National Ocean Service 1305 East-West Highway Silver Spring, MD 20910	301-713-3155 x195	This program assists states in implementing and enhancing Coastal Zone Management (CZM) programs that have been approved by the Secretary of Commerce. Funds are available in areas such as coastal wetlands management and protection, natural hazards management, public access improvements, reduction of	X	X	X	X

SOURCE OF ASSISTANCE	WORK NUMBER	BRIEF DESCRIPTION OF PROGRAM	ASSESS -MENT	PLANNING	IMPLE-MENTA -TION	OTHER
		marine debris, assessment of impacts of coastal growth and development, special area management planning, regional management issues, and demonstration projects with potential to improve coastal zone management.				
U.S. Department of Commerce National Oceanic and Atmospheric Administration National Sea Grant College Program 1315 East-West Highway Silver Spring, MD 20910	301-713-2448	The National Sea Grant College Program encourages the wise use and stewardship of our marine resources and coastal environment through research, education, outreach and technology transfer.				X
U.S. Department of Agriculture Cooperative State Research Education, and Extension Service Ag Box 2201 Washington, DC 20250-22021	202-401-5971	This program is targeted directly to the identification and resolution of agriculture-related degradation of water quality.		X	X	
Headquarters: U_S. Department of Agriculture Farm Service Agency Conservation Reserve Program Stop 0513 Washington, DC 20250-0513	202-720-6221	(CRP) is a voluntary program that offers long-term rental payments and cost-share assistance to establish long-term, resource-conserving cover on environmentally sensitive cropland or, in some cases, marginal pastureland.				X
U.S. Department of Agriculture Natural Resource Conservation Service 2430 Old Country Road Newark, DE 19702	302-832-3100 x3	Non-profit public/private partnership involving local community members working voluntarily on a multi-county basis to resolve environmental issues and develop opportunities for rural development. Technical and financial assistance is available in the form of grants, loans and other funding.		X	X	
U.S. Department of	302-832-3100	The Environmental Quality		X	X	X

SOURCE OF ASSISTANCE	WORK NUMBER	BRIEF DESCRIPTION OF PROGRAM	ASSESS -MENT	PLANNING	IMPLE-MENTA -TION	OTHER
Agriculture Natural Resource Conservation Service 2430 Old Country Road Newark, DE 19702	x3	Incentives Program (EQIP) was established to provide a single, voluntary conservation program for farmers and ranchers to address significant natural resource needs and objectives.				
U.S. Department of Agriculture Natural Resource Conservation Service 2430 Old Country Road Newark, DE 19702	302-832-3100 x3	This program provides technical and financial assistance to address resources and related economic problems on a watershed basis. Projects related to watershed protection, flood prevention, water supply, water quality, erosion and sediment control, wetland creation and restoration, fish and wildlife habitat enhancement, and public recreation are eligible for assistance.		X	X	
USDA. Natural Resources Conservation Service 2430 Old Country Road Newark, DE 19702	302-832-3100	This voluntary program provides Wetlands Reserve Program landowners with financial incentives to restore and protect wetlands in exchange for retiring marginal agricultural land. Landowners voluntarily limit future use of the land, but retain private ownership.			X	
U.S. Watershed Protection and Flood Prevention Program 'Small Watershed Program"	Your local NRCS Office	This program provides technical assistance and cost sharing for implementation of NRCS authorized watershed plans, as well as watershed surveys and planning.		X		X
U.S.D.A. Natural Resources Conservation Service 2430 Old Country Road Newark, DE 19702	302-832-3100	Soil and Water Conservation Assistance is a voluntary effort for farmers and ranchers that provides cost share and incentive payments to address threats to soil, water and related natural resources.				X
U.S.D.A. Natural Resources Conservation Service 2430 Old Country	302-832-3100	The Emergency Watershed Protection Program provides assistance to owners, managers and users of			X	X

SOURCE OF ASSISTANCE	WORK NUMBER	BRIEF DESCRIPTION OF PROGRAM	ASSESS -MENT	PLANNING	IMPLE-MENTA -TION	OTHER
Road Newark, DE 19702		public, private or tribal lands if their watershed has been damaged by a natural disaster.				
U.S.D.A. Natural Resources Conservation Service 2430 Old Country Road Newark, DE 19702	302-832-3100	The Resource Conservation and Development Program (RC&D) program provides a way for local residents to actively solve economic, environmental and social problems. Assistance is available for planning and installation of approved projects.		X	X	
U.S.D.A. Natural Resources Conservation Service 2430 Old Country Road Newark, DE 19702	302-832-3100	The Wildlife Habitat Incentive Program (WHIP) is a voluntary program for people who want to develop and improve wildlife habitat on private lands.		X		
County Conservation District Offices	See Local Listings	The Agriculture-Linked Investment Program (AgriLink) is a low interest loan program established by the state Treasury to assist operators in the implementation of approved nutrient management plans. Low interest loan funds are provided for the implementation of Best Management Practices (BMP's) identified in an approved nutrient management plan.		X	X	
U.S.D.A. – Farm Service Agency One Credit Union Place, Suite 320 Harrisburg, PA 17110-2994	717-237-2113	The Conservation Reserve Enhancement Program (CREP) is a state/federal conservation partnership program targeted to address specific state and nationally significant water quality, soil erosion and wildlife habitat issues related to agricultural use. The program uses financial incentives to encourage farmers to remove lands from agricultural production.		X	X	
U.S.D.A.	717-237-2210	The Conservation Technical		X	X	

SOURCE OF ASSISTANCE	WORK NUMBER	BRIEF DESCRIPTION OF PROGRAM	ASSESS-MENT	PLANNING	IMPLE-MENTA-TION	OTHER
Natural Resources Conservation Service One Credit Union Place, Suite 340 Harrisburg, PA 17110-2993		Assistance Program (CTA) assists landowners, communities, units of state and local government in planning and implementing conservation systems.				

G. Feasibility of the Establishment of a Stormwater Utility or Maintenance Fund

Section 4005, Chapter 40, Title 7 of the Delaware Code states that the conservation districts, counties and municipalities shall have the authority to adopt a fee system to help fund program implementation. This fund, also referred to as a stormwater utility, is a mechanism to fund the cost of municipal services directly related to the control and treatment of stormwater. Based upon document EPA 833-F-07-012, published in January 2008 by the United States Environmental Protection Agency (EPA), the following steps should be taken to fund a stormwater program. However, before the following steps are initiated, legal consultation should be sought to provide assistance and guidance.

1. Development of a Feasibility Study
2. Create a Billing System
3. Roll Out a Public Information Program
4. Adopt an Ordinance
5. Provide Credits/Exemptions
6. Implementation

SECTION IX

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APPOQUINIMINK RIVER WATERSHED STORMWATER MANAGEMENT PLAN

NEW CASTLE COUNTY, DELAWARE

VOLUME III – TECHNICAL APPENDIX

FINAL

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BL PROJECT NO. 2006-2013-01

PREPARED FOR:

DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL
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TECHNICAL APPENDIX

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APPENDIX 1

Watershed Peak Flows Summary – Existing Condition

APPOQUIMINK RIVER
SUMMARY FLOW TABLES

Subbasin	HMS Element	Subarea DA (sq mi)	EXISTING CONDITIONS SUBAREA PEAK FLOWS					
			2- Yr	5- Yr	10- Yr	25- Yr	50- Yr	100- Yr
1	W1000	0.03	10	15	19	25	31	38
2	W1010	1.21	196	285	358	466	565	688
3	W1020	0.21	43	64	82	107	131	161
4	W1030	2.14	116	183	239	304	386	489
5	W1040	1.25	147	230	300	385	487	616
6	W1050	1.29	189	280	355	483	590	723
7	W1070	0.50	23	37	48	61	78	99
8	W1080	0.66	73	109	139	190	234	289
9	W1090	0.03	16	24	30	41	50	61
10	W1100	1.01	197	292	372	507	620	762
11	W1110	0.50	75	113	144	197	243	300
12	W1120	1.17	192	288	368	504	619	764
13	W1130	0.47	123	184	235	321	394	486
14	W1140	0.76	133	198	253	346	425	524
15	W1150	1.71	302	448	570	777	951	1169
16	W1160	0.70	48	76	99	127	161	204
17	W1170	0.83	98	147	187	243	300	370
18	W1210	0.54	57	91	120	152	194	248
19	W1220	1.36	254	380	484	632	777	956
20	W1260	0.20	41	66	86	111	141	180
21	W1270	0.06	25	38	49	64	80	99
22	W1310	0.71	404	570	703	930	1105	1321
23	W1320	1.36	333	477	594	794	952	1148
24	W1360	0.30	132	182	222	287	338	401
25	W1370	1.44	279	408	512	668	811	986
26	W1410	0.17	58	86	108	142	173	212
27	W1420	0.78	132	203	262	340	424	529
28	W1460	0.39	141	210	266	349	427	523
29	W1470	0.47	100	148	188	255	311	380
30	W1510	0.58	74	110	141	192	236	291
31	W1520	0.87	324	464	578	773	927	1118
32	W1570	1.42	272	417	537	698	869	1083
33	W1620	0.96	223	341	439	573	712	886
34	W1660	0.23	90	124	152	196	232	276
35	W1670	0.52	158	236	300	393	483	594
36	W590	1.03	174	275	361	464	590	750
37	W610	1.41	167	255	329	426	531	662
38	W620	0.28	36	57	75	96	123	156
39	W630	0.48	69	110	144	185	235	298
40	W650	0.57	37	59	78	99	126	160
41	W660	0.72	93	150	199	252	325	417
42	W670	0.62	113	173	224	291	363	454
43	W680	0.68	135	208	269	349	436	545
44	W710	1.40	128	197	255	329	412	516
45	W720	0.08	57	80	99	130	154	184
46	W730	0.58	35	55	73	92	118	151
47	W750	0.40	352	471	564	719	838	981
48	W760	0.65	146	217	275	360	440	540

APPOQUIMINK RIVER
SUMMARY FLOW TABLES

Subbasin	HMS Element	Subarea DA (sq mi)	EXISTING CONDITIONS SUBAREA PEAK FLOWS					
			2- Yr	5- Yr	10- Yr	25- Yr	50- Yr	100- Yr
49	W770	1.59	112	169	217	280	348	433
50	W780	0.51	111	161	202	264	319	387
51	W790	0.14	19	31	40	51	66	84
52	W800	0.16	78	112	139	182	218	262
53	W810	0.56	121	181	231	302	372	458
54	W820	0.34	149	203	246	317	372	439
55	W830	0.56	98	152	198	256	322	404
56	W840	0.01	26	34	40	50	57	66
57	W850	0.63	98	149	193	250	312	389
58	W860	0.70	637	824	969	1216	1402	1628
59	W870	0.73	191	280	352	460	558	679
60	W880	0.68	106	163	211	274	342	428
61	W890	0.57	347	474	574	738	867	1023
62	W900	0.64	51	78	101	130	163	204
63	W910	0.55	100	152	196	254	316	393
64	W920	0.52	55	84	109	141	175	218
65	W950	0.02	5	7	9	12	15	18
66	W970a	0.49	61	94	121	157	196	246
67	w970b	0.09	30	44	56	74	91	111
68	W980	0.83	155	234	298	389	480	594
69	W990	0.11	21	32	40	52	65	79

APPOQUIMINK RIVER
SUMMARY FLOW TABLES

			EXISTING CONDITIONS CUMULATIVE FLOWS					
	HMS	Cumulative						
Subbasin	Element	DA	2- Yr	5- Yr	10- Yr	25- Yr	50- Yr	100- Yr
	J206	2.48	434	646	823	1,123	1,375	1,692
	J211	4.12	366	586	779	1,114	1,409	1,791
	J216	5.28	462	734	972	1,385	1,747	2,214
	J219	6.32	552	872	1,151	1,635	2,058	2,603
	J226	1.75	154	242	316	404	512	648
	J229	9.06	1,010	1,507	1,926	2,640	3,251	4,031
	J236	5.97	526	798	1,026	1,318	1,639	2,043
	J239	3.16	372	560	715	923	1,141	1,414
	J246	3.79	444	668	854	1,103	1,364	1,690
	J249	18.90	901	1,469	1,969	2,750	3,519	4,464
	J252	7.19	450	727	964	1,271	1,616	2,032
	J255	17.12	849	1,385	1,858	2,598	3,327	4,221
	J260	3.68	565	848	1,082	1,407	1,735	2,143
	J271	45.47	1,830	2,898	3,825	5,157	6,511	8,219
	J274	21.68	976	1,585	2,121	2,953	3,772	4,782
	J277	20.19	934	1,518	2,033	2,834	3,623	4,593
	J282	20.84	953	1,550	2,074	2,890	3,693	4,682
	J291	40.87	1,832	2,901	3,828	5,161	6,515	8,223
	J296	5.00	476	717	917	1,184	1,465	1,816
	J299	1.16	254	373	470	615	748	913
	J302	4.28	433	649	827	1,069	1,318	1,628
	J309	39.91	1,891	2,975	3,930	5,297	6,661	8,362
	J314	14.42	840	1,318	1,737	2,269	2,822	3,545
	J317	13.67	827	1,300	1,715	2,240	2,786	3,505
	J328	6.65	513	826	1,094	1,427	1,783	2,260
	J331	1.98	196	301	389	501	627	785
	J336	5.67	564	859	1,105	1,429	1,777	2,214
	J339	4.16	472	719	924	1,194	1,485	1,849
	OutletF	46.16	1,821	2,885	3,807	5,132	6,479	8,180
	Reservoir-Noxontown Pond Dam	9.53	407	671	910	1,336	1,721	2,190
	Reservoir-Shallcross Lake	5.73	483	777	1,029	1,341	1,675	2,122
	Reservoir-Silver Lake	6.46	412	667	885	1,167	1,485	1,868
	Reservoir-Wiggins Mill Pond	3.65	337	538	714	1,020	1,289	1,636
	UserPoint10	1.42	272	417	537	698	869	1,083
	UserPoint11	2.38	409	621	798	1,039	1,289	1,601
	UserPoint12	2.90	453	686	878	1,143	1,414	1,752
	UserPoint13	6.40	565	852	1,090	1,407	1,741	2,159
	UserPoint14	7.27	522	835	1,107	1,446	1,805	2,283
	UserPoint2	0.83	98	147	187	243	300	370
	UserPoint3	1.36	254	380	484	632	777	956
	UserPoint4	5.73	483	777	1,029	1,341	1,675	2,122
	UserPoint5	15.78	872	1,362	1,792	2,341	2,908	3,647
	UserPoint6	23.13	1,120	1,673	2,222	3,087	3,937	4,989

APPENDIX 2

HEC-HMS Model Output – Existing Condition

Project: AppoHMS | Simulation Run: Run1-yr-a
Start of Run: 29Jan2008, 00:00 | Basin Model: Basin 5yr-a
End of Run: 31Jan2008, 00:15 | Meteorologic Model: Met 1-yr

Hydrologic Element	Drainage Area (Sq. Mi.)	Discharge Peak (cfs)	Time of Peak	Volume (in)
J206	2.476094	327	29Jan2008, 13:11	1.07
J211	4.117244	260.5	29Jan2008, 16:01	1.04
J216	5.275207	330.8	29Jan2008, 16:13	1.03
J219	6.319032	397	29Jan2008, 15:46	1.04
J226	1.746722	110.3	29Jan2008, 13:50	0.86
J229	9.055726	760	29Jan2008, 14:06	1.08
J236	5.96524	387.1	29Jan2008, 14:47	0.98
J239	3.164736	276.3	29Jan2008, 14:13	1.06
J246	3.791736	329	29Jan2008, 14:21	1.06
J249	18.900431	631	29Jan2008, 21:07	0.93
J252	7.185169	314.9	29Jan2008, 19:41	0.93
J255	17.119121	593.5	29Jan2008, 20:54	0.92
J260	3.683513	419.8	29Jan2008, 14:35	1.08
J271	45.465436	1301	30Jan2008, 09:31	0.97
J274	21.682314	685	29Jan2008, 21:35	0.95
J277	20.188629	654.6	29Jan2008, 21:30	0.94
J282	20.836801	668.4	29Jan2008, 21:32	0.94
J291	40.87218	1302.9	30Jan2008, 08:46	0.95
J296	4.995762	353.1	29Jan2008, 15:29	1.04
J299	1.159547	191.4	29Jan2008, 13:09	1.27
J302	4.277284	322.4	29Jan2008, 15:03	1.09
J309	39.914953	1354.5	29Jan2008, 14:30	1
J314	14.423125	600.9	29Jan2008, 22:52	0.96
J317	13.670512	591	29Jan2008, 22:34	0.96
J328	6.652299	362.1	29Jan2008, 19:08	0.91
J331	1.977229	142.6	29Jan2008, 14:17	0.96
J336	5.668985	414.5	29Jan2008, 16:12	0.95
J339	4.155323	347.2	29Jan2008, 14:50	0.99
OutletF	46.16384	1294.6	30Jan2008, 11:47	0.97
R100	6.652299	359.5	29Jan2008, 23:02	0.9
R120	13.670512	589.5	29Jan2008, 22:53	0.96
R1280	5.668985	411.5	29Jan2008, 17:06	0.95
R130	15.778623	628.6	29Jan2008, 18:06	1
R1340	14.423125	600.1	29Jan2008, 23:07	0.96
R1390	21.682314	684.5	29Jan2008, 22:01	0.95
R1430	17.119121	593.4	29Jan2008, 21:06	0.92
R1480	9.055726	758.6	29Jan2008, 14:21	1.08
R160	0.825311	70.3	29Jan2008, 15:51	1.13
R1640	1.420341	195.2	29Jan2008, 14:08	1.02
R1680	2.380154	288.4	29Jan2008, 14:43	1.02

	Project: AppoHMS		Simulation Run: Run1-yr-a	
	Start of Run: 29Jan2008, 00:00		Basin Model: Basin 5yr-a	
	End of Run: 31Jan2008, 00:15		Meteorologic Model: Met 1-yr	

Hydrologic Element	Drainage Area (Sq. Mi.)	Discharge Peak (cfs)	Time of Peak	Volume (in)
R170	4.277284	321.1	29Jan2008, 15:30	1.09
R190	4.995762	344.9	29Jan2008, 17:24	1.04
R20	1.363547	183.7	29Jan2008, 14:11	1.15
R200	1.159547	184.8	29Jan2008, 14:10	1.27
R210	23.125735	824.4	29Jan2008, 14:46	0.97
R220	39.914953	1302.9	30Jan2008, 08:46	0.93
R240	20.836801	668.3	29Jan2008, 21:43	0.94
R260	20.188629	654.4	29Jan2008, 21:39	0.94
R280	40.87218	1300.5	30Jan2008, 09:32	0.94
R30	4.155323	342.7	29Jan2008, 16:24	0.99
R300	45.465436	1294.6	30Jan2008, 11:47	0.94
R310	18.900431	630.4	29Jan2008, 21:39	0.93
R330	3.683513	409.2	29Jan2008, 15:31	1.08
R350	7.185169	314.6	29Jan2008, 20:13	0.93
R360	17.900955	609.5	29Jan2008, 21:17	0.92
R380	3.164736	275.8	29Jan2008, 14:22	1.06
R400	3.791736	328.3	29Jan2008, 14:32	1.06
R410a	5.96524	385.4	29Jan2008, 15:28	0.98
R410b	6.459381	287.3	29Jan2008, 19:50	0.93
R430	9.526469	284	29Jan2008, 22:35	0.9
R440	1.746722	109.3	29Jan2008, 14:34	0.85
R470	2.902616	334.7	29Jan2008, 14:42	1.04
R490	0.867494	218.7	29Jan2008, 14:07	1.4
R500	6.319032	396.5	29Jan2008, 16:14	1.04
R520	5.275207	330.8	29Jan2008, 16:18	1.03
R540	4.117244	259.9	29Jan2008, 16:38	1.03
R570	2.476094	321	29Jan2008, 13:40	1.07
R60	1.977229	141.1	29Jan2008, 15:36	0.96
R80	5.730305	340.7	29Jan2008, 19:13	0.93
Reservoir-Noxontown Pond Dam	9.526469	284.1	29Jan2008, 22:04	0.91
Reservoir-Shallcross Lake	5.730305	341	29Jan2008, 18:44	0.93
Reservoir-Silver Lake	6.459381	287.7	29Jan2008, 19:04	0.93
Reservoir-Wiggins Mill Pond	3.646534	240.1	29Jan2008, 16:20	1.03
UserPoint10	1.420341	199.3	29Jan2008, 13:01	1.02
UserPoint11	2.380154	300.5	29Jan2008, 14:01	1.02
UserPoint12	2.902616	334.7	29Jan2008, 14:38	1.04
UserPoint13	6.396094	418.7	29Jan2008, 17:15	1.02
UserPoint14	7.274418	369.1	29Jan2008, 23:01	0.9
UserPoint2	0.825311	72.7	29Jan2008, 14:22	1.13
UserPoint3	1.363547	189.2	29Jan2008, 13:15	1.15

Project:	AppoHMS	Simulation Run:	Run1-yr-a
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 5yr-a
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 1-yr

Hydrologic Element	Drainage Area (Sq. Mi.)	Discharge Peak (cfs)	Time of Peak	Volume (in)
UserPoint4	5.730305	341	29Jan2008, 18:44	0.93
UserPoint5	15.778623	632.9	29Jan2008, 17:33	1
UserPoint6	23.125735	835.3	29Jan2008, 14:19	0.97
UserPoint7	17.900955	610	29Jan2008, 20:56	0.92
UserPoint8	9.526469	284.1	29Jan2008, 22:04	0.91
UserPoint9	0.867494	250.1	29Jan2008, 12:33	1.4
W1000	0.030062	7.2	29Jan2008, 12:29	1.07
W1010	1.211266	148.8	29Jan2008, 13:51	1.34
W1020	0.206748	32	29Jan2008, 13:05	1.16
W1030	2.143442	83.5	29Jan2008, 16:44	0.83
W1040	1.24776	105.2	29Jan2008, 13:45	0.88
W1050	1.292659	143.1	29Jan2008, 13:38	1.12
W1070	0.498962	16.5	29Jan2008, 17:29	0.78
W1080	0.655154	54.3	29Jan2008, 14:08	1.01
W1090	0.029189	12.3	29Jan2008, 12:11	1.15
W1100	1.014636	148.1	29Jan2008, 13:03	1.09
W1110	0.502809	56.2	29Jan2008, 13:22	1.01
W1120	1.17044	144.2	29Jan2008, 13:13	1.02
W1130	0.47071	92.4	29Jan2008, 12:38	1.04
W1140	0.764056	99.6	29Jan2008, 13:09	1.04
W1150	1.712038	227.5	29Jan2008, 13:12	1.09
W1160	0.697758	34.6	29Jan2008, 15:27	0.84
W1170	0.825311	72.7	29Jan2008, 14:22	1.13
W1210	0.536814	40.1	29Jan2008, 13:46	0.8
W1220	1.363547	189.2	29Jan2008, 13:15	1.15
W1260	0.201059	28.9	29Jan2008, 12:40	0.8
W1270	0.06132	17.9	29Jan2008, 12:17	0.97
W1310	0.706712	316	29Jan2008, 12:18	1.54
W1320	1.355498	257.3	29Jan2008, 13:04	1.41
W1360	0.303883	104	29Jan2008, 12:37	1.74
W1370	1.443421	212.1	29Jan2008, 13:25	1.33
W1410	0.171094	43.5	29Jan2008, 12:33	1.22
W1420	0.781834	96.2	29Jan2008, 13:11	1
W1460	0.391321	105.7	29Jan2008, 12:29	1.18
W1470	0.470743	76	29Jan2008, 12:59	1.15
W1510	0.576541	55.2	29Jan2008, 13:46	1.03
W1520	0.867494	250.1	29Jan2008, 12:33	1.4
W1570	1.420341	199.3	29Jan2008, 13:01	1.02
W1620	0.959813	163.5	29Jan2008, 12:46	1.02
W1660	0.233739	70.6	29Jan2008, 12:44	1.71

	Project:	AppoHMS	Simulation Run:	Run1-yr-a
	Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 5yr-a
	End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 1-yr

Hydrologic Element	Drainage Area (Sq. Mi.)	Discharge Peak (cfs)	Time of Peak	Volume (in)
W1670	0.522462	117.2	29Jan2008, 12:36	1.14
W590	1.033966	123.3	29Jan2008, 12:56	0.83
W610	1.409771	122.1	29Jan2008, 14:04	1.01
W620	0.277733	25.4	29Jan2008, 13:20	0.81
W630	0.479696	49.4	29Jan2008, 13:11	0.84
W650	0.567458	26.7	29Jan2008, 15:31	0.81
W660	0.720935	65.2	29Jan2008, 13:12	0.75
W670	0.622119	82	29Jan2008, 13:04	0.98
W680	0.675874	98.6	29Jan2008, 12:55	0.99
W710	1.400332	93.3	29Jan2008, 14:47	0.97
W720	0.076739	44.6	29Jan2008, 12:11	1.56
W730	0.582909	24.4	29Jan2008, 15:44	0.76
W750	0.397301	286.1	29Jan2008, 12:12	2.02
W760	0.647041	109.2	29Jan2008, 13:00	1.19
W770	1.594668	82.3	29Jan2008, 16:23	1.04
W780	0.512506	84.6	29Jan2008, 13:16	1.36
W790	0.135569	13.5	29Jan2008, 13:08	0.79
W800	0.162366	60.2	29Jan2008, 12:24	1.45
W810	0.559926	89.5	29Jan2008, 13:00	1.13
W820	0.338891	118.7	29Jan2008, 12:40	1.85
W830	0.562318	70.7	29Jan2008, 13:02	0.93
W840	0.014675	22.2	29Jan2008, 12:01	2.59
W850	0.633497	71.3	29Jan2008, 13:23	1.01
W860	0.698404	532.9	29Jan2008, 12:14	2.44
W870	0.72588	145	29Jan2008, 12:54	1.3
W880	0.683147	76.9	29Jan2008, 13:18	0.97
W890	0.570852	277	29Jan2008, 12:23	1.84
W900	0.638152	37	29Jan2008, 15:22	0.96
W910	0.547158	73.1	29Jan2008, 13:07	1.04
W920	0.516191	40.7	29Jan2008, 14:25	1.03
W950	0.016162	3.9	29Jan2008, 12:43	1.33
W970a	0.494141	44.5	29Jan2008, 13:52	0.98
w970b	0.087636	22.2	29Jan2008, 12:31	1.16
W980	0.828382	114.6	29Jan2008, 13:11	1.11
W990	0.110809	15.7	29Jan2008, 13:13	1.15

Project: AppoHMS | Simulation Run: Run2-yr-a
Start of Run: 29Jan2008, 00:00 | Basin Model: Basin 5yr-a
End of Run: 31Jan2008, 00:15 | Meteorologic Model: Met 2-yr

Hydrologic Element	Drainage Area (Sq. Mi.)	Discharge Peak (cfs)	Time of Peak	Volume (in)
J206	2.476094	434	29Jan2008, 13:11	1.41
J211	4.117244	366	29Jan2008, 15:48	1.37
J216	5.275207	462	29Jan2008, 16:03	1.36
J219	6.319032	552	29Jan2008, 15:41	1.37
J226	1.746722	154	29Jan2008, 13:48	1.17
J229	9.055726	1,010	29Jan2008, 14:07	1.43
J236	5.96524	526	29Jan2008, 14:46	1.32
J239	3.164736	372	29Jan2008, 14:12	1.41
J246	3.791736	444	29Jan2008, 14:20	1.41
J249	18.900431	901	29Jan2008, 20:36	1.26
J252	7.185169	450	29Jan2008, 19:12	1.27
J255	17.119121	849	29Jan2008, 20:23	1.25
J260	3.683513	565	29Jan2008, 14:34	1.44
J271	45.465436	1,830	30Jan2008, 09:05	1.31
J274	21.682314	976	29Jan2008, 21:06	1.28
J277	20.188629	934	29Jan2008, 20:58	1.28
J282	20.836801	953	29Jan2008, 21:01	1.28
J291	40.87218	1,832	30Jan2008, 08:20	1.28
J296	4.995762	476	29Jan2008, 15:27	1.39
J299	1.159547	254	29Jan2008, 13:09	1.66
J302	4.277284	433	29Jan2008, 15:01	1.45
J309	39.914953	1,891	29Jan2008, 22:54	1.34
J314	14.423125	840	29Jan2008, 22:32	1.3
J317	13.670512	827	29Jan2008, 22:14	1.3
J328	6.652299	513	29Jan2008, 18:51	1.24
J331	1.977229	196	29Jan2008, 14:15	1.29
J336	5.668985	564	29Jan2008, 16:10	1.28
J339	4.155323	472	29Jan2008, 14:49	1.33
OutletF	46.16384	1,821	30Jan2008, 11:21	1.3
R100	6.652299	509	29Jan2008, 22:44	1.22
R120	13.670512	825	29Jan2008, 22:33	1.3
R1280	5.668985	560	29Jan2008, 17:04	1.28
R130	15.778623	869	29Jan2008, 23:15	1.34
R1340	14.423125	839	29Jan2008, 22:46	1.3
R1390	21.682314	975	29Jan2008, 21:31	1.28
R1430	17.119121	849	29Jan2008, 20:34	1.25
R1480	9.055726	1,008	29Jan2008, 14:22	1.43
R160	0.825311	95	29Jan2008, 15:49	1.5
R1640	1.420341	267	29Jan2008, 14:08	1.37
R1680	2.380154	392	29Jan2008, 14:42	1.37

	Project: AppoHMS	Simulation Run: Run2-yr-a		
	Start of Run: 29Jan2008, 00:00	Basin Model: Basin 5yr-a		
	End of Run: 31Jan2008, 00:15	Meteorologic Model: Met 2-yr		

Hydrologic Element	Drainage Area (Sq. Mi.)	Discharge Peak (cfs)	Time of Peak	Volume (in)
R170	4.277284	431	29Jan2008, 15:28	1.45
R190	4.995762	465	29Jan2008, 17:22	1.39
R20	1.363547	247	29Jan2008, 14:10	1.53
R200	1.159547	245	29Jan2008, 14:09	1.66
R210	23.125735	1,105	29Jan2008, 14:45	1.31
R220	39.914953	1,832	30Jan2008, 08:20	1.27
R240	20.836801	953	29Jan2008, 21:12	1.28
R260	20.188629	934	29Jan2008, 21:07	1.27
R280	40.87218	1,829	30Jan2008, 09:05	1.27
R30	4.155323	466	29Jan2008, 16:22	1.33
R300	45.465436	1,821	30Jan2008, 11:21	1.27
R310	18.900431	900	29Jan2008, 21:08	1.26
R330	3.683513	551	29Jan2008, 15:30	1.44
R350	7.185169	450	29Jan2008, 19:44	1.27
R360	17.900955	872	29Jan2008, 20:46	1.25
R380	3.164736	372	29Jan2008, 14:21	1.41
R400	3.791736	443	29Jan2008, 14:31	1.41
R410a	5.96524	523	29Jan2008, 15:26	1.32
R410b	6.459381	412	29Jan2008, 19:20	1.26
R430	9.526469	407	29Jan2008, 21:55	1.22
R440	1.746722	152	29Jan2008, 14:32	1.17
R470	2.902616	453	29Jan2008, 14:41	1.39
R490	0.867494	283	29Jan2008, 14:07	1.8
R500	6.319032	551	29Jan2008, 16:09	1.37
R520	5.275207	462	29Jan2008, 16:08	1.36
R540	4.117244	365	29Jan2008, 16:25	1.37
R570	2.476094	426	29Jan2008, 13:40	1.41
R60	1.977229	194	29Jan2008, 15:33	1.29
R80	5.730305	482	29Jan2008, 18:56	1.26
Reservoir-Noxontown Pond Dam	9.526469	407	29Jan2008, 21:24	1.23
Reservoir-Shallcross Lake	5.730305	483	29Jan2008, 18:27	1.26
Reservoir-Silver Lake	6.459381	412	29Jan2008, 18:34	1.26
Reservoir-Wiggins Mill Pond	3.646534	337	29Jan2008, 16:05	1.37
UserPoint10	1.420341	272	29Jan2008, 13:01	1.37
UserPoint11	2.380154	409	29Jan2008, 14:00	1.37
UserPoint12	2.902616	453	29Jan2008, 14:37	1.39
UserPoint13	6.396094	565	29Jan2008, 17:13	1.37
UserPoint14	7.274418	522	29Jan2008, 22:43	1.23
UserPoint2	0.825311	98	29Jan2008, 14:20	1.5
UserPoint3	1.363547	254	29Jan2008, 13:15	1.53

Project: AppoHMS | Simulation Run: Run2-yr-a
Start of Run: 29Jan2008, 00:00 | Basin Model: Basin 5yr-a
End of Run: 31Jan2008, 00:15 | Meteorologic Model: Met 2-yr

Hydrologic Element	Drainage Area (Sq. Mi.)	Discharge Peak (cfs)	Time of Peak	Volume (in)
UserPoint4	5.730305	483	29Jan2008, 18:27	1.26
UserPoint5	15.778623	872	29Jan2008, 22:42	1.35
UserPoint6	23.125735	1,120	29Jan2008, 14:18	1.31
UserPoint7	17.900955	872	29Jan2008, 20:26	1.25
UserPoint8	9.526469	407	29Jan2008, 21:24	1.23
UserPoint9	0.867494	324	29Jan2008, 12:33	1.8
W1000	0.030062	10	29Jan2008, 12:29	1.43
W1010	1.211266	196	29Jan2008, 13:50	1.74
W1020	0.206748	43	29Jan2008, 13:05	1.53
W1030	2.143442	116	29Jan2008, 16:41	1.14
W1040	1.24776	147	29Jan2008, 13:42	1.21
W1050	1.292659	189	29Jan2008, 13:37	1.47
W1070	0.498962	23	29Jan2008, 17:26	1.08
W1080	0.655154	73	29Jan2008, 14:06	1.34
W1090	0.029189	16	29Jan2008, 12:11	1.51
W1100	1.014636	197	29Jan2008, 13:03	1.43
W1110	0.502809	75	29Jan2008, 13:22	1.33
W1120	1.17044	192	29Jan2008, 13:13	1.35
W1130	0.47071	123	29Jan2008, 12:37	1.37
W1140	0.764056	133	29Jan2008, 13:09	1.37
W1150	1.712038	302	29Jan2008, 13:12	1.43
W1160	0.697758	48	29Jan2008, 15:24	1.16
W1170	0.825311	98	29Jan2008, 14:20	1.5
W1210	0.536814	57	29Jan2008, 13:44	1.1
W1220	1.363547	254	29Jan2008, 13:15	1.53
W1260	0.201059	41	29Jan2008, 12:39	1.1
W1270	0.06132	25	29Jan2008, 12:17	1.31
W1310	0.706712	404	29Jan2008, 12:18	1.96
W1320	1.355498	333	29Jan2008, 13:04	1.81
W1360	0.303883	132	29Jan2008, 12:37	2.19
W1370	1.443421	279	29Jan2008, 13:25	1.73
W1410	0.171094	58	29Jan2008, 12:33	1.6
W1420	0.781834	132	29Jan2008, 13:10	1.34
W1460	0.391321	141	29Jan2008, 12:28	1.56
W1470	0.470743	100	29Jan2008, 12:59	1.5
W1510	0.576541	74	29Jan2008, 13:45	1.36
W1520	0.867494	324	29Jan2008, 12:33	1.8
W1570	1.420341	272	29Jan2008, 13:01	1.37
W1620	0.959813	223	29Jan2008, 12:46	1.37
W1660	0.233739	90	29Jan2008, 12:44	2.17

Project:	AppoHMS	Simulation Run:	Run2-yr-a
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 5yr-a
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 2-yr

Hydrologic Element	Drainage Area (Sq. Mi.)	Discharge Peak (cfs)	Time of Peak	Volume (in)
W1670	0.522462	158	29Jan2008, 12:36	1.51
W590	1.033966	174	29Jan2008, 12:56	1.14
W610	1.409771	167	29Jan2008, 14:01	1.36
W620	0.277733	36	29Jan2008, 13:18	1.12
W630	0.479696	69	29Jan2008, 13:10	1.15
W650	0.567458	37	29Jan2008, 15:28	1.12
W660	0.720935	93	29Jan2008, 13:11	1.05
W670	0.622119	113	29Jan2008, 13:03	1.33
W680	0.675874	135	29Jan2008, 12:55	1.33
W710	1.400332	128	29Jan2008, 14:44	1.31
W720	0.076739	57	29Jan2008, 12:11	1.98
W730	0.582909	35	29Jan2008, 15:41	1.05
W750	0.397301	352	29Jan2008, 12:12	2.5
W760	0.647041	146	29Jan2008, 13:00	1.58
W770	1.594668	112	29Jan2008, 16:19	1.39
W780	0.512506	111	29Jan2008, 13:15	1.77
W790	0.135569	19	29Jan2008, 13:07	1.09
W800	0.162366	78	29Jan2008, 12:24	1.87
W810	0.559926	121	29Jan2008, 12:59	1.5
W820	0.338891	149	29Jan2008, 12:39	2.31
W830	0.562318	98	29Jan2008, 13:02	1.26
W840	0.014675	26	29Jan2008, 12:01	3.09
W850	0.633497	98	29Jan2008, 13:22	1.36
W860	0.698404	637	29Jan2008, 12:14	2.93
W870	0.72588	191	29Jan2008, 12:54	1.7
W880	0.683147	106	29Jan2008, 13:17	1.32
W890	0.570852	347	29Jan2008, 12:22	2.3
W900	0.638152	51	29Jan2008, 15:18	1.3
W910	0.547158	100	29Jan2008, 13:07	1.39
W920	0.516191	55	29Jan2008, 14:23	1.39
W950	0.016162	5	29Jan2008, 12:42	1.74
W970a	0.494141	61	29Jan2008, 13:49	1.33
w970b	0.087636	30	29Jan2008, 12:31	1.54
W980	0.828382	155	29Jan2008, 13:10	1.47
W990	0.110809	21	29Jan2008, 13:12	1.52

Project:	AppoHMS	Simulation Run:	Run5-yr-a
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 5yr-a
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 5-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
J206	2.476094	646	29Jan2008, 13:11	2.08
J211	4.117244	586	29Jan2008, 15:31	2.03
J216	5.275207	734	29Jan2008, 15:49	2.02
J219	6.319032	872	29Jan2008, 15:32	2.03
J226	1.746722	242	29Jan2008, 13:46	1.8
J229	9.055726	1,507	29Jan2008, 14:08	2.1
J236	5.96524	798	29Jan2008, 14:44	1.98
J239	3.164736	560	29Jan2008, 14:11	2.1
J246	3.791736	668	29Jan2008, 14:18	2.1
J249	18.900431	1,469	29Jan2008, 20:01	1.92
J252	7.185169	727	29Jan2008, 18:39	1.93
J255	17.119121	1,385	29Jan2008, 19:46	1.9
J260	3.683513	848	29Jan2008, 14:33	2.14
J271	45.465436	2,898	30Jan2008, 08:30	1.96
J274	21.682314	1,585	29Jan2008, 20:34	1.94
J277	20.188629	1,518	29Jan2008, 20:25	1.93
J282	20.836801	1,550	29Jan2008, 20:29	1.94
J291	40.87218	2,901	30Jan2008, 07:46	1.93
J296	4.995762	717	29Jan2008, 15:24	2.08
J299	1.159547	373	29Jan2008, 13:08	2.41
J302	4.277284	649	29Jan2008, 14:59	2.15
J309	39.914953	2,975	29Jan2008, 22:35	2.01
J314	14.423125	1,318	29Jan2008, 22:21	1.97
J317	13.670512	1,300	29Jan2008, 22:04	1.96
J328	6.652299	826	29Jan2008, 18:29	1.88
J331	1.977229	301	29Jan2008, 14:13	1.96
J336	5.668985	859	29Jan2008, 16:07	1.94
J339	4.155323	719	29Jan2008, 14:46	2
OutletF	46.16384	2,885	30Jan2008, 10:47	1.95
R100	6.652299	817	29Jan2008, 22:23	1.87
R120	13.670512	1,296	29Jan2008, 22:21	1.96
R1280	5.668985	853	29Jan2008, 17:01	1.94
R130	15.778623	1,356	29Jan2008, 23:03	2.02
R1340	14.423125	1,315	29Jan2008, 22:34	1.97
R1390	21.682314	1,583	29Jan2008, 21:00	1.94
R1430	17.119121	1,385	29Jan2008, 19:58	1.9
R1480	9.055726	1,504	29Jan2008, 14:23	2.1
R160	0.825311	142	29Jan2008, 15:47	2.22
R1640	1.420341	407	29Jan2008, 14:07	2.05
R1680	2.380154	596	29Jan2008, 14:41	2.05
R170	4.277284	645	29Jan2008, 15:26	2.15

	Project: AppoHMS		Simulation Run: Run5-yr-a	
	Start of Run: 29Jan2008, 00:00		Basin Model: Basin 5yr-a	
	End of Run: 31Jan2008, 00:15		Meteorologic Model: Met 5-yr	

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
R190	4.995762	700	29Jan2008, 17:19	2.08
R20	1.363547	368	29Jan2008, 14:09	2.25
R200	1.159547	360	29Jan2008, 14:08	2.41
R210	23.125735	1,662	29Jan2008, 21:13	1.97
R220	39.914953	2,900	30Jan2008, 07:46	1.92
R240	20.836801	1,549	29Jan2008, 20:40	1.93
R260	20.188629	1,518	29Jan2008, 20:35	1.93
R280	40.87218	2,896	30Jan2008, 08:31	1.92
R30	4.155323	709	29Jan2008, 16:20	2
R300	45.465436	2,885	30Jan2008, 10:47	1.92
R310	18.900431	1,467	29Jan2008, 20:34	1.91
R330	3.683513	827	29Jan2008, 15:28	2.14
R350	7.185169	726	29Jan2008, 19:11	1.92
R360	17.900955	1,422	29Jan2008, 20:10	1.9
R380	3.164736	559	29Jan2008, 14:20	2.1
R400	3.791736	666	29Jan2008, 14:30	2.1
R410a	5.96524	795	29Jan2008, 15:25	1.98
R410b	6.459381	665	29Jan2008, 18:46	1.92
R430	9.526469	671	29Jan2008, 21:04	1.86
R440	1.746722	239	29Jan2008, 14:30	1.8
R470	2.902616	686	29Jan2008, 14:40	2.08
R490	0.867494	405	29Jan2008, 14:06	2.55
R500	6.319032	871	29Jan2008, 16:00	2.03
R520	5.275207	734	29Jan2008, 15:54	2.02
R540	4.117244	584	29Jan2008, 16:08	2.03
R570	2.476094	634	29Jan2008, 13:39	2.08
R60	1.977229	298	29Jan2008, 15:31	1.95
R80	5.730305	776	29Jan2008, 18:32	1.92
Reservoir-Noxontown Pond Dam	9.526469	671	29Jan2008, 20:33	1.87
Reservoir-Shallcross Lake	5.730305	777	29Jan2008, 18:03	1.92
Reservoir-Silver Lake	6.459381	667	29Jan2008, 18:00	1.92
Reservoir-Wiggins Mill Pond	3.646534	538	29Jan2008, 15:45	2.03
UserPoint10	1.420341	417	29Jan2008, 13:00	2.05
UserPoint11	2.380154	621	29Jan2008, 13:59	2.05
UserPoint12	2.902616	686	29Jan2008, 14:36	2.08
UserPoint13	6.396094	852	29Jan2008, 17:11	2.05
UserPoint14	7.274418	835	29Jan2008, 22:22	1.88
UserPoint2	0.825311	147	29Jan2008, 14:15	2.22
UserPoint3	1.363547	380	29Jan2008, 13:14	2.25
UserPoint4	5.730305	777	29Jan2008, 18:03	1.92
UserPoint5	15.778623	1,362	29Jan2008, 22:32	2.02

Project:	AppoHMS	Simulation Run:	Run5-yr-a
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 5yr-a
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 5-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
UserPoint6	23.125735	1,673	29Jan2008, 14:17	1.97
UserPoint7	17.900955	1,423	29Jan2008, 19:49	1.9
UserPoint8	9.526469	671	29Jan2008, 20:33	1.87
UserPoint9	0.867494	464	29Jan2008, 12:33	2.55
W1000	0.030062	15	29Jan2008, 12:28	2.13
W1010	1.211266	285	29Jan2008, 13:49	2.51
W1020	0.206748	64	29Jan2008, 13:04	2.26
W1030	2.143442	183	29Jan2008, 16:36	1.76
W1040	1.24776	230	29Jan2008, 13:38	1.85
W1050	1.292659	280	29Jan2008, 13:36	2.16
W1070	0.498962	37	29Jan2008, 17:21	1.69
W1080	0.655154	109	29Jan2008, 14:04	1.98
W1090	0.029189	24	29Jan2008, 12:11	2.19
W1100	1.014636	292	29Jan2008, 13:02	2.1
W1110	0.502809	113	29Jan2008, 13:21	1.98
W1120	1.17044	288	29Jan2008, 13:12	2
W1130	0.47071	184	29Jan2008, 12:37	2.03
W1140	0.764056	198	29Jan2008, 13:08	2.02
W1150	1.712038	448	29Jan2008, 13:11	2.1
W1160	0.697758	76	29Jan2008, 15:19	1.79
W1170	0.825311	147	29Jan2008, 14:15	2.22
W1210	0.536814	91	29Jan2008, 13:39	1.71
W1220	1.363547	380	29Jan2008, 13:14	2.25
W1260	0.201059	66	29Jan2008, 12:38	1.71
W1270	0.06132	38	29Jan2008, 12:17	1.98
W1310	0.706712	570	29Jan2008, 12:18	2.76
W1320	1.355498	477	29Jan2008, 13:03	2.57
W1360	0.303883	182	29Jan2008, 12:37	3.03
W1370	1.443421	408	29Jan2008, 13:24	2.49
W1410	0.171094	86	29Jan2008, 12:33	2.34
W1420	0.781834	203	29Jan2008, 13:10	2.02
W1460	0.391321	210	29Jan2008, 12:28	2.29
W1470	0.470743	148	29Jan2008, 12:58	2.19
W1510	0.576541	110	29Jan2008, 13:44	2.01
W1520	0.867494	464	29Jan2008, 12:33	2.55
W1570	1.420341	417	29Jan2008, 13:00	2.05
W1620	0.959813	341	29Jan2008, 12:45	2.05
W1660	0.233739	124	29Jan2008, 12:44	3
W1670	0.522462	236	29Jan2008, 12:36	2.23
W590	1.033966	275	29Jan2008, 12:55	1.77
W610	1.409771	255	29Jan2008, 13:57	2.04

Project:	AppoHMS	Simulation Run:	Run5-yr-a
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 5yr-a
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 5-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
W620	0.277733	57	29Jan2008, 13:17	1.73
W630	0.479696	110	29Jan2008, 13:09	1.78
W650	0.567458	59	29Jan2008, 15:23	1.74
W660	0.720935	150	29Jan2008, 13:09	1.64
W670	0.622119	173	29Jan2008, 13:02	2
W680	0.675874	208	29Jan2008, 12:54	2
W710	1.400332	197	29Jan2008, 14:40	1.97
W720	0.076739	80	29Jan2008, 12:11	2.78
W730	0.582909	55	29Jan2008, 15:36	1.65
W750	0.397301	471	29Jan2008, 12:12	3.37
W760	0.647041	217	29Jan2008, 12:59	2.31
W770	1.594668	169	29Jan2008, 16:13	2.08
W780	0.512506	161	29Jan2008, 13:14	2.54
W790	0.135569	31	29Jan2008, 13:06	1.7
W800	0.162366	112	29Jan2008, 12:23	2.66
W810	0.559926	181	29Jan2008, 12:58	2.21
W820	0.338891	203	29Jan2008, 12:39	3.16
W830	0.562318	152	29Jan2008, 13:01	1.92
W840	0.014675	34	29Jan2008, 12:01	3.98
W850	0.633497	149	29Jan2008, 13:21	2.04
W860	0.698404	824	29Jan2008, 12:14	3.83
W870	0.72588	280	29Jan2008, 12:53	2.46
W880	0.683147	163	29Jan2008, 13:16	1.99
W890	0.570852	474	29Jan2008, 12:22	3.15
W900	0.638152	78	29Jan2008, 15:14	1.97
W910	0.547158	152	29Jan2008, 13:06	2.08
W920	0.516191	84	29Jan2008, 14:19	2.07
W950	0.016162	7	29Jan2008, 12:42	2.5
W970a	0.494141	94	29Jan2008, 13:46	2
w970b	0.087636	44	29Jan2008, 12:30	2.26
W980	0.828382	234	29Jan2008, 13:09	2.18
W990	0.110809	32	29Jan2008, 13:11	2.24

Project: AppoHMS		Simulation Run: Run10-yr-a		
Start of Run: 29Jan2008, 00:00		Basin Model: Basin 5yr-a		
End of Run: 31Jan2008, 00:15		Meteorologic Model: Met 10-yr		

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
J206	2.476094	823	29Jan2008, 13:10	2.63
J211	4.117244	779	29Jan2008, 15:21	2.57
J216	5.275207	972	29Jan2008, 15:42	2.56
J219	6.319032	1,151	29Jan2008, 15:26	2.57
J226	1.746722	316	29Jan2008, 13:44	2.33
J229	9.055726	1,926	29Jan2008, 14:09	2.65
J236	5.96524	1,026	29Jan2008, 14:43	2.53
J239	3.164736	715	29Jan2008, 14:10	2.67
J246	3.791736	854	29Jan2008, 14:18	2.67
J249	18.900431	1,969	29Jan2008, 19:43	2.46
J252	7.185169	964	29Jan2008, 18:22	2.47
J255	17.119121	1,858	29Jan2008, 19:27	2.44
J260	3.683513	1,082	29Jan2008, 14:32	2.72
J271	45.465436	3,825	30Jan2008, 08:13	2.51
J274	21.682314	2,121	29Jan2008, 20:18	2.49
J277	20.188629	2,033	29Jan2008, 20:09	2.48
J282	20.836801	2,074	29Jan2008, 20:13	2.48
J291	40.87218	3,828	30Jan2008, 07:28	2.48
J296	4.995762	917	29Jan2008, 15:22	2.64
J299	1.159547	470	29Jan2008, 13:07	3.02
J302	4.277284	827	29Jan2008, 14:58	2.73
J309	39.914953	3,930	29Jan2008, 22:21	2.57
J314	14.423125	1,737	29Jan2008, 22:04	2.52
J317	13.670512	1,715	29Jan2008, 21:46	2.51
J328	6.652299	1,094	29Jan2008, 18:14	2.42
J331	1.977229	389	29Jan2008, 14:12	2.51
J336	5.668985	1,105	29Jan2008, 16:05	2.49
J339	4.155323	924	29Jan2008, 14:45	2.56
OutletF	46.16384	3,807	30Jan2008, 10:30	2.49
R100	6.652299	1,084	29Jan2008, 22:08	2.41
R120	13.670512	1,710	29Jan2008, 22:05	2.51
R1280	5.668985	1,097	29Jan2008, 17:00	2.49
R130	15.778623	1,784	29Jan2008, 22:48	2.58
R1340	14.423125	1,734	29Jan2008, 22:18	2.52
R1390	21.682314	2,117	29Jan2008, 20:44	2.49
R1430	17.119121	1,858	29Jan2008, 19:39	2.44
R1480	9.055726	1,924	29Jan2008, 14:25	2.65
R160	0.825311	180	29Jan2008, 15:45	2.81
R1640	1.420341	525	29Jan2008, 14:06	2.62
R1680	2.380154	765	29Jan2008, 14:40	2.62
R170	4.277284	822	29Jan2008, 15:24	2.72

	Project: AppoHMS		Simulation Run: Run10-yr-a	
	Start of Run: 29Jan2008, 00:00		Basin Model: Basin 5yr-a	
	End of Run: 31Jan2008, 00:15		Meteorologic Model: Met 10-yr	

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
R190	4.995762	895	29Jan2008, 17:18	2.64
R20	1.363547	469	29Jan2008, 14:08	2.84
R200	1.159547	453	29Jan2008, 14:07	3.02
R210	23.125735	2,218	29Jan2008, 20:59	2.52
R220	39.914953	3,828	30Jan2008, 07:28	2.46
R240	20.836801	2,073	29Jan2008, 20:24	2.48
R260	20.188629	2,032	29Jan2008, 20:18	2.48
R280	40.87218	3,822	30Jan2008, 08:14	2.46
R30	4.155323	912	29Jan2008, 16:19	2.56
R300	45.465436	3,807	30Jan2008, 10:30	2.46
R310	18.900431	1,966	29Jan2008, 20:15	2.46
R330	3.683513	1,055	29Jan2008, 15:28	2.72
R350	7.185169	963	29Jan2008, 18:55	2.47
R360	17.900955	1,907	29Jan2008, 19:52	2.44
R380	3.164736	714	29Jan2008, 14:19	2.67
R400	3.791736	852	29Jan2008, 14:30	2.67
R410a	5.96524	1,021	29Jan2008, 15:24	2.53
R410b	6.459381	883	29Jan2008, 18:28	2.46
R430	9.526469	909	29Jan2008, 20:35	2.4
R440	1.746722	313	29Jan2008, 14:29	2.33
R470	2.902616	878	29Jan2008, 14:39	2.65
R490	0.867494	504	29Jan2008, 14:06	3.17
R500	6.319032	1,149	29Jan2008, 15:54	2.57
R520	5.275207	972	29Jan2008, 15:47	2.56
R540	4.117244	776	29Jan2008, 15:58	2.57
R570	2.476094	807	29Jan2008, 13:39	2.63
R60	1.977229	385	29Jan2008, 15:29	2.51
R80	5.730305	1,028	29Jan2008, 18:19	2.47
Reservoir-Noxontown Pond Dam	9.526469	910	29Jan2008, 20:04	2.41
Reservoir-Shallcross Lake	5.730305	1,029	29Jan2008, 17:50	2.47
Reservoir-Silver Lake	6.459381	885	29Jan2008, 17:43	2.47
Reservoir-Wiggins Mill Pond	3.646534	714	29Jan2008, 15:34	2.57
UserPoint10	1.420341	537	29Jan2008, 12:59	2.62
UserPoint11	2.380154	798	29Jan2008, 13:58	2.62
UserPoint12	2.902616	878	29Jan2008, 14:35	2.65
UserPoint13	6.396094	1,090	29Jan2008, 17:09	2.62
UserPoint14	7.274418	1,107	29Jan2008, 22:07	2.42
UserPoint2	0.825311	187	29Jan2008, 14:13	2.81
UserPoint3	1.363547	484	29Jan2008, 13:13	2.84
UserPoint4	5.730305	1,029	29Jan2008, 17:50	2.47
UserPoint5	15.778623	1,792	29Jan2008, 22:17	2.58

Project:	AppoHMS	Simulation Run:	Run10-yr-a
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 5yr-a
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 10-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
UserPoint6	23.125735	2,222	29Jan2008, 20:32	2.52
UserPoint7	17.900955	1,910	29Jan2008, 19:31	2.45
UserPoint8	9.526469	910	29Jan2008, 20:04	2.41
UserPoint9	0.867494	578	29Jan2008, 12:33	3.17
W1000	0.030062	19	29Jan2008, 12:28	2.7
W1010	1.211266	358	29Jan2008, 13:48	3.13
W1020	0.206748	82	29Jan2008, 13:04	2.85
W1030	2.143442	239	29Jan2008, 16:31	2.29
W1040	1.24776	300	29Jan2008, 13:37	2.38
W1050	1.292659	355	29Jan2008, 13:36	2.72
W1070	0.498962	48	29Jan2008, 17:17	2.2
W1080	0.655154	139	29Jan2008, 14:03	2.52
W1090	0.029189	30	29Jan2008, 12:11	2.76
W1100	1.014636	372	29Jan2008, 13:02	2.65
W1110	0.502809	144	29Jan2008, 13:21	2.51
W1120	1.17044	368	29Jan2008, 13:12	2.54
W1130	0.47071	235	29Jan2008, 12:37	2.57
W1140	0.764056	253	29Jan2008, 13:08	2.57
W1150	1.712038	570	29Jan2008, 13:11	2.66
W1160	0.697758	99	29Jan2008, 15:16	2.31
W1170	0.825311	187	29Jan2008, 14:13	2.81
W1210	0.536814	120	29Jan2008, 13:38	2.22
W1220	1.363547	484	29Jan2008, 13:13	2.84
W1260	0.201059	86	29Jan2008, 12:38	2.23
W1270	0.06132	49	29Jan2008, 12:16	2.54
W1310	0.706712	703	29Jan2008, 12:18	3.39
W1320	1.355498	594	29Jan2008, 13:03	3.19
W1360	0.303883	222	29Jan2008, 12:37	3.69
W1370	1.443421	512	29Jan2008, 13:24	3.11
W1410	0.171094	108	29Jan2008, 12:32	2.94
W1420	0.781834	262	29Jan2008, 13:09	2.58
W1460	0.391321	266	29Jan2008, 12:28	2.89
W1470	0.470743	188	29Jan2008, 12:58	2.76
W1510	0.576541	141	29Jan2008, 13:43	2.55
W1520	0.867494	578	29Jan2008, 12:33	3.17
W1570	1.420341	537	29Jan2008, 12:59	2.62
W1620	0.959813	439	29Jan2008, 12:45	2.62
W1660	0.233739	152	29Jan2008, 12:44	3.66
W1670	0.522462	300	29Jan2008, 12:35	2.82
W590	1.033966	361	29Jan2008, 12:54	2.29
W610	1.409771	329	29Jan2008, 13:55	2.61

Project:	AppoHMS	Simulation Run:	Run10-yr-a	
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 5yr-a	
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 10-yr	

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
W620	0.277733	75	29Jan2008, 13:16	2.25
W630	0.479696	144	29Jan2008, 13:08	2.31
W650	0.567458	78	29Jan2008, 15:20	2.26
W660	0.720935	199	29Jan2008, 13:09	2.15
W670	0.622119	224	29Jan2008, 13:02	2.56
W680	0.675874	269	29Jan2008, 12:54	2.56
W710	1.400332	255	29Jan2008, 14:38	2.53
W720	0.076739	99	29Jan2008, 12:11	3.41
W730	0.582909	73	29Jan2008, 15:33	2.16
W750	0.397301	564	29Jan2008, 12:12	4.05
W760	0.647041	275	29Jan2008, 12:59	2.91
W770	1.594668	217	29Jan2008, 16:09	2.65
W780	0.512506	202	29Jan2008, 13:14	3.16
W790	0.135569	40	29Jan2008, 13:05	2.22
W800	0.162366	139	29Jan2008, 12:23	3.29
W810	0.559926	231	29Jan2008, 12:58	2.8
W820	0.338891	246	29Jan2008, 12:39	3.84
W830	0.562318	198	29Jan2008, 13:00	2.47
W840	0.014675	40	29Jan2008, 12:01	4.68
W850	0.633497	193	29Jan2008, 13:20	2.61
W860	0.698404	969	29Jan2008, 12:14	4.53
W870	0.72588	352	29Jan2008, 12:53	3.08
W880	0.683147	211	29Jan2008, 13:16	2.54
W890	0.570852	574	29Jan2008, 12:22	3.82
W900	0.638152	101	29Jan2008, 15:11	2.53
W910	0.547158	196	29Jan2008, 13:05	2.65
W920	0.516191	109	29Jan2008, 14:16	2.64
W950	0.016162	9	29Jan2008, 12:42	3.12
W970a	0.494141	121	29Jan2008, 13:45	2.56
w970b	0.087636	56	29Jan2008, 12:30	2.86
W980	0.828382	298	29Jan2008, 13:09	2.76
W990	0.110809	40	29Jan2008, 13:11	2.83

	Project:	AppoHMS	Simulation Run:	Run25-yr-a
	Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 100yr-a
	End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 25-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
J206	2.476094	1,123	29Jan2008, 13:10	3.55
J211	4.117244	1,114	29Jan2008, 15:10	3.48
J216	5.275207	1,385	29Jan2008, 15:34	3.46
J219	6.319032	1,635	29Jan2008, 15:21	3.48
J226	1.746722	404	29Jan2008, 13:46	2.97
J229	9.055726	2,640	29Jan2008, 14:12	3.57
J236	5.96524	1,318	29Jan2008, 14:44	3.24
J239	3.164736	923	29Jan2008, 14:11	3.42
J246	3.791736	1,103	29Jan2008, 14:18	3.43
J249	18.900431	2,750	29Jan2008, 19:31	3.27
J252	7.185169	1,271	29Jan2008, 18:12	3.18
J255	17.119121	2,598	29Jan2008, 19:14	3.26
J260	3.683513	1,407	29Jan2008, 14:33	3.49
J271	45.465436	5,157	30Jan2008, 08:03	3.29
J274	21.682314	2,953	29Jan2008, 20:09	3.3
J277	20.188629	2,834	29Jan2008, 19:58	3.29
J282	20.836801	2,890	29Jan2008, 20:03	3.29
J291	40.87218	5,161	30Jan2008, 07:19	3.25
J296	4.995762	1,184	29Jan2008, 15:23	3.39
J299	1.159547	615	29Jan2008, 13:07	3.89
J302	4.277284	1,069	29Jan2008, 14:59	3.5
J309	39.914953	5,297	29Jan2008, 22:08	3.36
J314	14.423125	2,269	29Jan2008, 21:59	3.23
J317	13.670512	2,240	29Jan2008, 21:42	3.22
J328	6.652299	1,427	29Jan2008, 18:12	3.1
J331	1.977229	501	29Jan2008, 14:13	3.21
J336	5.668985	1,429	29Jan2008, 16:07	3.19
J339	4.155323	1,194	29Jan2008, 14:46	3.29
OutletF	46.16384	5,132	30Jan2008, 10:21	3.26
R100	6.652299	1,414	29Jan2008, 22:05	3.09
R120	13.670512	2,234	29Jan2008, 22:00	3.22
R1280	5.668985	1,419	29Jan2008, 17:01	3.19
R130	15.778623	2,332	29Jan2008, 22:43	3.31
R1340	14.423125	2,266	29Jan2008, 22:13	3.23
R1390	21.682314	2,948	29Jan2008, 20:35	3.29
R1430	17.119121	2,597	29Jan2008, 19:25	3.26
R1480	9.055726	2,637	29Jan2008, 14:27	3.57
R160	0.825311	234	29Jan2008, 15:46	3.62
R1640	1.420341	683	29Jan2008, 14:06	3.36
R1680	2.380154	996	29Jan2008, 14:40	3.36
R170	4.277284	1,064	29Jan2008, 15:25	3.5

Project:	AppoHMS	Simulation Run:	Run25-yr-a
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 100yr-a
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 25-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
R190	4.995762	1,155	29Jan2008, 17:19	3.39
R20	1.363547	612	29Jan2008, 14:08	3.66
R200	1.159547	592	29Jan2008, 14:07	3.89
R210	23.125735	3,082	29Jan2008, 20:51	3.33
R220	39.914953	5,161	30Jan2008, 07:19	3.23
R240	20.836801	2,888	29Jan2008, 20:14	3.29
R260	20.188629	2,832	29Jan2008, 20:08	3.29
R280	40.87218	5,153	30Jan2008, 08:04	3.23
R30	4.155323	1,178	29Jan2008, 16:19	3.29
R300	45.465436	5,132	30Jan2008, 10:21	3.23
R310	18.900431	2,744	29Jan2008, 20:04	3.27
R330	3.683513	1,371	29Jan2008, 15:28	3.49
R350	7.185169	1,269	29Jan2008, 18:45	3.18
R360	17.900955	2,664	29Jan2008, 19:39	3.26
R380	3.164736	922	29Jan2008, 14:20	3.42
R400	3.791736	1,101	29Jan2008, 14:30	3.43
R410a	5.96524	1,312	29Jan2008, 15:25	3.24
R410b	6.459381	1,165	29Jan2008, 18:19	3.17
R430	9.526469	1,336	29Jan2008, 20:04	3.3
R440	1.746722	400	29Jan2008, 14:30	2.97
R470	2.902616	1,143	29Jan2008, 14:39	3.41
R490	0.867494	674	29Jan2008, 14:06	4.2
R500	6.319032	1,631	29Jan2008, 15:49	3.48
R520	5.275207	1,385	29Jan2008, 15:39	3.46
R540	4.117244	1,110	29Jan2008, 15:48	3.48
R570	2.476094	1,101	29Jan2008, 13:38	3.55
R60	1.977229	495	29Jan2008, 15:30	3.21
R80	5.730305	1,339	29Jan2008, 18:16	3.16
Reservoir-Noxontown Pond Dam	9.526469	1,336	29Jan2008, 19:34	3.31
Reservoir-Shallcross Lake	5.730305	1,341	29Jan2008, 17:47	3.16
Reservoir-Silver Lake	6.459381	1,167	29Jan2008, 17:33	3.17
Reservoir-Wiggins Mill Pond	3.646534	1,020	29Jan2008, 15:22	3.48
UserPoint10	1.420341	698	29Jan2008, 13:00	3.36
UserPoint11	2.380154	1,039	29Jan2008, 13:59	3.36
UserPoint12	2.902616	1,143	29Jan2008, 14:35	3.41
UserPoint13	6.396094	1,407	29Jan2008, 17:10	3.36
UserPoint14	7.274418	1,446	29Jan2008, 22:04	3.1
UserPoint2	0.825311	243	29Jan2008, 14:13	3.62
UserPoint3	1.363547	632	29Jan2008, 13:13	3.66
UserPoint4	5.730305	1,341	29Jan2008, 17:47	3.16
UserPoint5	15.778623	2,341	29Jan2008, 22:11	3.32

	Project: AppoHMS		Simulation Run: Run25-yr-a	
	Start of Run: 29Jan2008, 00:00		Basin Model: Basin 100yr-a	
	End of Run: 31Jan2008, 00:15		Meteorologic Model: Met 25-yr	
Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
UserPoint6	23.125735	3,087	29Jan2008, 20:24	3.34
UserPoint7	17.900955	2,669	29Jan2008, 19:18	3.26
UserPoint8	9.526469	1,336	29Jan2008, 19:34	3.31
UserPoint9	0.867494	773	29Jan2008, 12:32	4.2
W1000	0.030062	25	29Jan2008, 12:28	3.47
W1010	1.211266	466	29Jan2008, 13:48	4.03
W1020	0.206748	107	29Jan2008, 13:04	3.67
W1030	2.143442	304	29Jan2008, 16:35	2.92
W1040	1.24776	385	29Jan2008, 13:38	3.05
W1050	1.292659	483	29Jan2008, 13:36	3.66
W1070	0.498962	61	29Jan2008, 17:21	2.79
W1080	0.655154	190	29Jan2008, 14:02	3.41
W1090	0.029189	41	29Jan2008, 12:11	3.71
W1100	1.014636	507	29Jan2008, 13:02	3.57
W1110	0.502809	197	29Jan2008, 13:20	3.4
W1120	1.17044	504	29Jan2008, 13:12	3.43
W1130	0.47071	321	29Jan2008, 12:37	3.47
W1140	0.764056	346	29Jan2008, 13:08	3.47
W1150	1.712038	777	29Jan2008, 13:11	3.58
W1160	0.697758	127	29Jan2008, 15:19	2.95
W1170	0.825311	243	29Jan2008, 14:13	3.62
W1210	0.536814	152	29Jan2008, 13:40	2.83
W1220	1.363547	632	29Jan2008, 13:13	3.66
W1260	0.201059	111	29Jan2008, 12:38	2.83
W1270	0.06132	64	29Jan2008, 12:16	3.25
W1310	0.706712	930	29Jan2008, 12:18	4.46
W1320	1.355498	794	29Jan2008, 13:03	4.23
W1360	0.303883	287	29Jan2008, 12:36	4.73
W1370	1.443421	668	29Jan2008, 13:23	4
W1410	0.171094	142	29Jan2008, 12:32	3.79
W1420	0.781834	340	29Jan2008, 13:09	3.31
W1460	0.391321	349	29Jan2008, 12:28	3.72
W1470	0.470743	255	29Jan2008, 12:58	3.71
W1510	0.576541	192	29Jan2008, 13:43	3.44
W1520	0.867494	773	29Jan2008, 12:32	4.2
W1570	1.420341	698	29Jan2008, 13:00	3.36
W1620	0.959813	573	29Jan2008, 12:45	3.37
W1660	0.233739	196	29Jan2008, 12:43	4.69
W1670	0.522462	393	29Jan2008, 12:35	3.63
W590	1.033966	464	29Jan2008, 12:55	2.92
W610	1.409771	426	29Jan2008, 13:56	3.35

Project:	AppoHMS	Simulation Run:	Run25-yr-a
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 100yr-a
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 25-yr

Hydrologic	Drainage Area	Discharge Peak	Time of Peak	Volume
Element	(sq mi)	(cfs)		(in)
W620	0.277733	96	29Jan2008, 13:17	2.87
W630	0.479696	185	29Jan2008, 13:09	2.94
W650	0.567458	99	29Jan2008, 15:23	2.87
W660	0.720935	252	29Jan2008, 13:10	2.72
W670	0.622119	291	29Jan2008, 13:02	3.29
W680	0.675874	349	29Jan2008, 12:54	3.29
W710	1.400332	329	29Jan2008, 14:39	3.24
W720	0.076739	130	29Jan2008, 12:11	4.49
W730	0.582909	92	29Jan2008, 15:37	2.73
W750	0.397301	719	29Jan2008, 12:12	5.16
W760	0.647041	360	29Jan2008, 12:59	3.74
W770	1.594668	280	29Jan2008, 16:11	3.4
W780	0.512506	264	29Jan2008, 13:14	4.07
W790	0.135569	51	29Jan2008, 13:06	2.82
W800	0.162366	182	29Jan2008, 12:23	4.23
W810	0.559926	302	29Jan2008, 12:58	3.6
W820	0.338891	317	29Jan2008, 12:39	4.9
W830	0.562318	256	29Jan2008, 13:01	3.16
W840	0.014675	50	29Jan2008, 12:01	5.87
W850	0.633497	250	29Jan2008, 13:20	3.35
W860	0.698404	1,216	29Jan2008, 12:14	5.7
W870	0.72588	460	29Jan2008, 12:53	3.96
W880	0.683147	274	29Jan2008, 13:16	3.26
W890	0.570852	738	29Jan2008, 12:22	4.88
W900	0.638152	130	29Jan2008, 15:13	3.24
W910	0.547158	254	29Jan2008, 13:06	3.4
W920	0.516191	141	29Jan2008, 14:17	3.4
W950	0.016162	12	29Jan2008, 12:41	4.02
W970a	0.494141	157	29Jan2008, 13:45	3.28
w970b	0.087636	74	29Jan2008, 12:30	3.68
W980	0.828382	389	29Jan2008, 13:09	3.56
W990	0.110809	52	29Jan2008, 13:11	3.65

Project:	AppoHMS	Simulation Run:	Run50-yr-a
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 100yr-a
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 50-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
J206	2.476094	1,375	29Jan2008, 13:10	4.32
J211	4.117244	1,409	29Jan2008, 15:03	4.25
J216	5.275207	1,747	29Jan2008, 15:27	4.23
J219	6.319032	2,058	29Jan2008, 15:16	4.25
J226	1.746722	512	29Jan2008, 13:44	3.72
J229	9.055726	3,251	29Jan2008, 14:14	4.35
J236	5.96524	1,639	29Jan2008, 14:43	4.01
J239	3.164736	1,141	29Jan2008, 14:10	4.21
J246	3.791736	1,364	29Jan2008, 14:17	4.21
J249	18.900431	3,519	29Jan2008, 19:18	4.04
J252	7.185169	1,616	29Jan2008, 18:00	3.95
J255	17.119121	3,327	29Jan2008, 18:59	4.02
J260	3.683513	1,735	29Jan2008, 14:32	4.29
J271	45.465436	6,511	30Jan2008, 07:45	4.05
J274	21.682314	3,772	29Jan2008, 19:57	4.07
J277	20.188629	3,623	29Jan2008, 19:44	4.06
J282	20.836801	3,693	29Jan2008, 19:50	4.06
J291	40.87218	6,515	30Jan2008, 07:00	4.02
J296	4.995762	1,465	29Jan2008, 15:22	4.18
J299	1.159547	748	29Jan2008, 13:06	4.72
J302	4.277284	1,318	29Jan2008, 14:58	4.3
J309	39.914953	6,661	29Jan2008, 21:48	4.13
J314	14.423125	2,822	29Jan2008, 21:53	4
J317	13.670512	2,786	29Jan2008, 21:35	3.99
J328	6.652299	1,783	29Jan2008, 18:08	3.86
J331	1.977229	627	29Jan2008, 14:12	3.99
J336	5.668985	1,777	29Jan2008, 16:05	3.96
J339	4.155323	1,485	29Jan2008, 14:45	4.06
OutletF	46.16384	6,479	30Jan2008, 10:04	4.02
R100	6.652299	1,767	29Jan2008, 22:01	3.84
R120	13.670512	2,780	29Jan2008, 21:53	3.99
R1280	5.668985	1,765	29Jan2008, 16:59	3.96
R130	15.778623	2,898	29Jan2008, 22:36	4.09
R1340	14.423125	2,818	29Jan2008, 22:07	4
R1390	21.682314	3,765	29Jan2008, 20:22	4.06
R1430	17.119121	3,326	29Jan2008, 19:10	4.02
R1480	9.055726	3,249	29Jan2008, 14:29	4.35
R160	0.825311	288	29Jan2008, 15:44	4.42
R1640	1.420341	849	29Jan2008, 14:06	4.15
R1680	2.380154	1,235	29Jan2008, 14:40	4.15
R170	4.277284	1,311	29Jan2008, 15:24	4.3

	Project:	AppoHMS	Simulation Run:	Run50-yr-a
	Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 100yr-a
	End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 50-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
R190	4.995762	1,428	29Jan2008, 17:18	4.18
R20	1.363547	751	29Jan2008, 14:07	4.47
R200	1.159547	721	29Jan2008, 14:07	4.72
R210	23.125735	3,929	29Jan2008, 20:40	4.1
R220	39.914953	6,514	30Jan2008, 07:01	3.99
R240	20.836801	3,691	29Jan2008, 20:01	4.06
R260	20.188629	3,620	29Jan2008, 19:54	4.06
R280	40.87218	6,504	30Jan2008, 07:47	4
R30	4.155323	1,465	29Jan2008, 16:18	4.06
R300	45.465436	6,479	30Jan2008, 10:04	3.98
R310	18.900431	3,512	29Jan2008, 19:50	4.03
R330	3.683513	1,691	29Jan2008, 15:27	4.29
R350	7.185169	1,613	29Jan2008, 18:33	3.94
R360	17.900955	3,411	29Jan2008, 19:25	4.02
R380	3.164736	1,139	29Jan2008, 14:19	4.21
R400	3.791736	1,361	29Jan2008, 14:29	4.21
R410a	5.96524	1,631	29Jan2008, 15:24	4.01
R410b	6.459381	1,481	29Jan2008, 18:06	3.93
R430	9.526469	1,720	29Jan2008, 19:43	4.06
R440	1.746722	506	29Jan2008, 14:28	3.72
R470	2.902616	1,414	29Jan2008, 14:39	4.2
R490	0.867494	807	29Jan2008, 14:05	5.04
R500	6.319032	2,053	29Jan2008, 15:44	4.25
R520	5.275207	1,747	29Jan2008, 15:32	4.23
R540	4.117244	1,404	29Jan2008, 15:40	4.25
R570	2.476094	1,347	29Jan2008, 13:38	4.32
R60	1.977229	620	29Jan2008, 15:29	3.98
R80	5.730305	1,673	29Jan2008, 18:12	3.93
Reservoir-Noxontown Pond Dam	9.526469	1,721	29Jan2008, 19:13	4.07
Reservoir-Shallcross Lake	5.730305	1,675	29Jan2008, 17:44	3.93
Reservoir-Silver Lake	6.459381	1,485	29Jan2008, 17:20	3.94
Reservoir-Wiggins Mill Pond	3.646534	1,289	29Jan2008, 15:14	4.25
UserPoint10	1.420341	869	29Jan2008, 12:59	4.15
UserPoint11	2.380154	1,289	29Jan2008, 13:58	4.15
UserPoint12	2.902616	1,414	29Jan2008, 14:35	4.2
UserPoint13	6.396094	1,741	29Jan2008, 17:08	4.14
UserPoint14	7.274418	1,805	29Jan2008, 22:00	3.86
UserPoint2	0.825311	300	29Jan2008, 14:12	4.42
UserPoint3	1.363547	777	29Jan2008, 13:13	4.47
UserPoint4	5.730305	1,675	29Jan2008, 17:44	3.93
UserPoint5	15.778623	2,908	29Jan2008, 22:05	4.09

Project:	AppoHMS	Simulation Run:	Run50-yr-a	
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 100yr-a	
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 50-yr	

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
UserPoint6	23.125735	3,937	29Jan2008, 20:13	4.11
UserPoint7	17.900955	3,417	29Jan2008, 19:04	4.02
UserPoint8	9.526469	1,721	29Jan2008, 19:13	4.07
UserPoint9	0.867494	927	29Jan2008, 12:32	5.04
W1000	0.030062	31	29Jan2008, 12:28	4.27
W1010	1.211266	565	29Jan2008, 13:48	4.87
W1020	0.206748	131	29Jan2008, 13:03	4.48
W1030	2.143442	386	29Jan2008, 16:31	3.66
W1040	1.24776	487	29Jan2008, 13:37	3.8
W1050	1.292659	590	29Jan2008, 13:35	4.44
W1070	0.498962	78	29Jan2008, 17:16	3.52
W1080	0.655154	234	29Jan2008, 14:02	4.17
W1090	0.029189	50	29Jan2008, 12:11	4.5
W1100	1.014636	620	29Jan2008, 13:01	4.35
W1110	0.502809	243	29Jan2008, 13:20	4.16
W1120	1.17044	619	29Jan2008, 13:11	4.19
W1130	0.47071	394	29Jan2008, 12:36	4.24
W1140	0.764056	425	29Jan2008, 13:08	4.24
W1150	1.712038	951	29Jan2008, 13:11	4.36
W1160	0.697758	161	29Jan2008, 15:16	3.7
W1170	0.825311	300	29Jan2008, 14:12	4.42
W1210	0.536814	194	29Jan2008, 13:38	3.56
W1220	1.363547	777	29Jan2008, 13:13	4.47
W1260	0.201059	141	29Jan2008, 12:38	3.56
W1270	0.06132	80	29Jan2008, 12:16	4.03
W1310	0.706712	1,105	29Jan2008, 12:18	5.32
W1320	1.355498	952	29Jan2008, 13:03	5.06
W1360	0.303883	338	29Jan2008, 12:36	5.6
W1370	1.443421	811	29Jan2008, 13:23	4.84
W1410	0.171094	173	29Jan2008, 12:32	4.61
W1420	0.781834	424	29Jan2008, 13:09	4.09
W1460	0.391321	427	29Jan2008, 12:28	4.54
W1470	0.470743	311	29Jan2008, 12:58	4.5
W1510	0.576541	236	29Jan2008, 13:42	4.21
W1520	0.867494	927	29Jan2008, 12:32	5.04
W1570	1.420341	869	29Jan2008, 12:59	4.15
W1620	0.959813	712	29Jan2008, 12:45	4.15
W1660	0.233739	232	29Jan2008, 12:43	5.57
W1670	0.522462	483	29Jan2008, 12:35	4.44
W590	1.033966	590	29Jan2008, 12:54	3.66
W610	1.409771	531	29Jan2008, 13:55	4.14

	Project: AppoHMS	Simulation Run: Run50-yr-a
Start of Run:	29Jan2008, 00:00	Basin Model: Basin 100yr-a
End of Run:	31Jan2008, 00:15	Meteorologic Model: Met 50-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
W620	0.277733	123	29Jan2008, 13:16	3.6
W630	0.479696	235	29Jan2008, 13:08	3.69
W650	0.567458	126	29Jan2008, 15:19	3.61
W660	0.720935	325	29Jan2008, 13:09	3.44
W670	0.622119	363	29Jan2008, 13:01	4.07
W680	0.675874	436	29Jan2008, 12:53	4.07
W710	1.400332	412	29Jan2008, 14:37	4.02
W720	0.076739	154	29Jan2008, 12:10	5.34
W730	0.582909	118	29Jan2008, 15:33	3.46
W750	0.397301	838	29Jan2008, 12:12	6.05
W760	0.647041	440	29Jan2008, 12:58	4.56
W770	1.594668	348	29Jan2008, 16:07	4.19
W780	0.512506	319	29Jan2008, 13:14	4.92
W790	0.135569	66	29Jan2008, 13:05	3.55
W800	0.162366	218	29Jan2008, 12:23	5.08
W810	0.559926	372	29Jan2008, 12:58	4.41
W820	0.338891	372	29Jan2008, 12:39	5.78
W830	0.562318	322	29Jan2008, 13:00	3.93
W840	0.014675	57	29Jan2008, 12:01	6.77
W850	0.633497	312	29Jan2008, 13:20	4.13
W860	0.698404	1,402	29Jan2008, 12:14	6.6
W870	0.72588	558	29Jan2008, 12:53	4.8
W880	0.683147	342	29Jan2008, 13:15	4.04
W890	0.570852	867	29Jan2008, 12:22	5.77
W900	0.638152	163	29Jan2008, 15:10	4.02
W910	0.547158	316	29Jan2008, 13:05	4.19
W920	0.516191	175	29Jan2008, 14:15	4.19
W950	0.016162	15	29Jan2008, 12:41	4.86
W970a	0.494141	196	29Jan2008, 13:44	4.06
w970b	0.087636	91	29Jan2008, 12:30	4.49
W980	0.828382	480	29Jan2008, 13:09	4.36
W990	0.110809	65	29Jan2008, 13:11	4.46

Project:	AppoHMS	Simulation Run:	Run100-yr-a
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 100yr-a
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 100-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
J206	2.48	1,692	29Jan2008, 13:09	5.29
J211	4.12	1,791	29Jan2008, 14:56	5.22
J216	5.28	2,214	29Jan2008, 15:21	5.19
J219	6.32	2,603	29Jan2008, 15:11	5.22
J226	1.75	648	29Jan2008, 13:41	4.67
J229	9.06	4,031	29Jan2008, 14:17	5.33
J236	5.97	2,043	29Jan2008, 14:42	4.99
J239	3.16	1,414	29Jan2008, 14:10	5.2
J246	3.79	1,690	29Jan2008, 14:17	5.2
J249	18.90	4,464	29Jan2008, 19:06	5.01
J252	7.19	2,032	29Jan2008, 17:53	4.91
J255	17.12	4,221	29Jan2008, 18:48	4.99
J260	3.68	2,143	29Jan2008, 14:31	5.28
J271	45.47	8,219	30Jan2008, 07:30	5.02
J274	21.68	4,782	29Jan2008, 19:44	5.04
J277	20.19	4,593	29Jan2008, 19:33	5.03
J282	20.84	4,682	29Jan2008, 19:38	5.03
J291	40.87	8,223	30Jan2008, 06:45	4.98
J296	5.00	1,816	29Jan2008, 15:20	5.17
J299	1.16	913	29Jan2008, 13:06	5.75
J302	4.28	1,628	29Jan2008, 14:57	5.3
J309	39.91	8,362	29Jan2008, 21:34	5.11
J314	14.42	3,545	29Jan2008, 21:48	4.98
J317	13.67	3,505	29Jan2008, 21:30	4.96
J328	6.65	2,260	29Jan2008, 17:58	4.82
J331	1.98	785	29Jan2008, 14:11	4.96
J336	5.67	2,214	29Jan2008, 16:03	4.93
J339	4.16	1,849	29Jan2008, 14:43	5.04
OutletF	46.16	8,180	30Jan2008, 09:50	4.97
R100	6.65	2,236	29Jan2008, 21:52	4.8
R120	13.67	3,495	29Jan2008, 21:48	4.96
R1280	5.67	2,198	29Jan2008, 16:58	4.93
R130	15.78	3,633	29Jan2008, 22:31	5.07
R1340	14.42	3,540	29Jan2008, 22:02	4.97
R1390	21.68	4,773	29Jan2008, 20:10	5.03
R1430	17.12	4,220	29Jan2008, 18:59	4.99
R1480	9.06	4,029	29Jan2008, 14:32	5.33
R160	0.83	356	29Jan2008, 15:43	5.43
R1640	1.42	1,058	29Jan2008, 14:05	5.14
R1680	2.38	1,534	29Jan2008, 14:39	5.14
R170	4.28	1,620	29Jan2008, 15:23	5.29

Project: AppoHMS Simulation Run: Run100-yr-a
Start of Run: 29Jan2008, 00:00 Basin Model: Basin 100yr-a
End of Run: 31Jan2008, 00:15 Meteorologic Model: Met 100-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
R190	5.00	1,770	29Jan2008, 17:16	5.16
R20	1.36	925	29Jan2008, 14:07	5.48
R200	1.16	880	29Jan2008, 14:06	5.75
R210	23.13	4,979	29Jan2008, 20:27	5.08
R220	39.91	8,223	30Jan2008, 06:45	4.95
R240	20.84	4,679	29Jan2008, 19:49	5.03
R260	20.19	4,590	29Jan2008, 19:42	5.02
R280	40.87	8,210	30Jan2008, 07:32	4.95
R30	4.16	1,824	29Jan2008, 16:17	5.04
R300	45.47	8,180	30Jan2008, 09:50	4.93
R310	18.90	4,455	29Jan2008, 19:38	5
R330	3.68	2,089	29Jan2008, 15:26	5.28
R350	7.19	2,029	29Jan2008, 18:25	4.91
R360	17.90	4,328	29Jan2008, 19:14	4.98
R380	3.16	1,411	29Jan2008, 14:18	5.2
R400	3.79	1,686	29Jan2008, 14:29	5.2
R410a	5.97	2,033	29Jan2008, 15:23	4.98
R410b	6.46	1,863	29Jan2008, 17:59	4.89
R430	9.53	2,189	29Jan2008, 19:28	5.02
R440	1.75	641	29Jan2008, 14:27	4.67
R470	2.90	1,752	29Jan2008, 14:38	5.19
R490	0.87	973	29Jan2008, 14:05	6.07
R500	6.32	2,595	29Jan2008, 15:39	5.22
R520	5.28	2,213	29Jan2008, 15:26	5.19
R540	4.12	1,783	29Jan2008, 15:33	5.22
R570	2.48	1,657	29Jan2008, 13:37	5.29
R60	1.98	776	29Jan2008, 15:28	4.96
R80	5.73	2,119	29Jan2008, 18:02	4.89
Reservoir-Noxontown Pond Dam	9.53	2,190	29Jan2008, 18:58	5.03
Reservoir-Shallcross Lake	5.73	2,122	29Jan2008, 17:34	4.9
Reservoir-Silver Lake	6.46	1,868	29Jan2008, 17:13	4.9
Reservoir-Wiggins Mill Pond	3.65	1,636	29Jan2008, 15:06	5.22
UserPoint10	1.42	1,083	29Jan2008, 12:59	5.14
UserPoint11	2.38	1,601	29Jan2008, 13:57	5.14
UserPoint12	2.90	1,752	29Jan2008, 14:34	5.19
UserPoint13	6.40	2,159	29Jan2008, 17:07	5.13
UserPoint14	7.27	2,283	29Jan2008, 21:51	4.82
UserPoint2	0.83	370	29Jan2008, 14:11	5.43
UserPoint3	1.36	956	29Jan2008, 13:13	5.48
UserPoint4	5.73	2,122	29Jan2008, 17:34	4.9
UserPoint5	15.78	3,647	29Jan2008, 22:00	5.07

Project: AppoHMS | Simulation Run: Run100-yr-a

Start of Run: 29Jan2008, 00:00 | Basin Model: Basin 100yr-a

End of Run: 31Jan2008, 00:15 | Meteorologic Model: Met 100-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
UserPoint6	23.13	4,989	29Jan2008, 20:00	5.08
UserPoint7	17.90	4,335	29Jan2008, 18:53	4.99
UserPoint8	9.53	2,190	29Jan2008, 18:58	5.03
UserPoint9	0.87	1,118	29Jan2008, 12:32	6.07
W1000	0.03	38	29Jan2008, 12:28	5.27
W1010	1.21	688	29Jan2008, 13:47	5.91
W1020	0.21	161	29Jan2008, 13:03	5.5
W1030	2.14	489	29Jan2008, 16:26	4.6
W1040	1.25	616	29Jan2008, 13:36	4.76
W1050	1.29	723	29Jan2008, 13:35	5.43
W1070	0.50	99	29Jan2008, 17:11	4.44
W1080	0.66	289	29Jan2008, 14:01	5.12
W1090	0.03	61	29Jan2008, 12:11	5.49
W1100	1.01	762	29Jan2008, 13:01	5.33
W1110	0.50	300	29Jan2008, 13:20	5.11
W1120	1.17	764	29Jan2008, 13:11	5.15
W1130	0.47	486	29Jan2008, 12:36	5.2
W1140	0.76	524	29Jan2008, 13:07	5.2
W1150	1.71	1,169	29Jan2008, 13:10	5.34
W1160	0.70	204	29Jan2008, 15:12	4.64
W1170	0.83	370	29Jan2008, 14:11	5.43
W1210	0.54	248	29Jan2008, 13:37	4.49
W1220	1.36	956	29Jan2008, 13:13	5.48
W1260	0.20	180	29Jan2008, 12:37	4.49
W1270	0.06	99	29Jan2008, 12:16	5.01
W1310	0.71	1,321	29Jan2008, 12:18	6.37
W1320	1.36	1,148	29Jan2008, 13:02	6.1
W1360	0.30	401	29Jan2008, 12:36	6.68
W1370	1.44	986	29Jan2008, 13:23	5.88
W1410	0.17	212	29Jan2008, 12:32	5.63
W1420	0.78	529	29Jan2008, 13:08	5.08
W1460	0.39	523	29Jan2008, 12:27	5.56
W1470	0.47	380	29Jan2008, 12:57	5.49
W1510	0.58	291	29Jan2008, 13:42	5.17
W1520	0.87	1,118	29Jan2008, 12:32	6.07
W1570	1.42	1,083	29Jan2008, 12:59	5.14
W1620	0.96	886	29Jan2008, 12:44	5.14
W1660	0.23	276	29Jan2008, 12:43	6.64
W1670	0.52	594	29Jan2008, 12:35	5.45
W590	1.03	750	29Jan2008, 12:54	4.61
W610	1.41	662	29Jan2008, 13:54	5.12

Project: AppoHMS | Simulation Run: Run100-yr-a
Start of Run: 29Jan2008, 00:00 | Basin Model: Basin 100yr-a
End of Run: 31Jan2008, 00:15 | Meteorologic Model: Met 100-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
W620	0.28	156	29Jan2008, 13:15	4.54
W630	0.48	298	29Jan2008, 13:07	4.63
W650	0.57	160	29Jan2008, 15:16	4.55
W660	0.72	417	29Jan2008, 13:08	4.36
W670	0.62	454	29Jan2008, 13:01	5.05
W680	0.68	545	29Jan2008, 12:53	5.05
W710	1.40	516	29Jan2008, 14:33	5
W720	0.08	184	29Jan2008, 12:10	6.4
W730	0.58	151	29Jan2008, 15:29	4.38
W750	0.40	981	29Jan2008, 12:12	7.14
W760	0.65	540	29Jan2008, 12:58	5.58
W770	1.59	433	29Jan2008, 16:03	5.18
W780	0.51	387	29Jan2008, 13:13	5.96
W790	0.14	84	29Jan2008, 13:04	4.48
W800	0.16	262	29Jan2008, 12:23	6.14
W810	0.56	458	29Jan2008, 12:57	5.42
W820	0.34	439	29Jan2008, 12:39	6.87
W830	0.56	404	29Jan2008, 13:00	4.9
W840	0.01	66	29Jan2008, 12:01	7.87
W850	0.63	389	29Jan2008, 13:19	5.12
W860	0.70	1,628	29Jan2008, 12:14	7.7
W870	0.73	679	29Jan2008, 12:52	5.83
W880	0.68	428	29Jan2008, 13:15	5.02
W890	0.57	1,023	29Jan2008, 12:22	6.85
W900	0.64	204	29Jan2008, 15:07	4.99
W910	0.55	393	29Jan2008, 13:05	5.18
W920	0.52	218	29Jan2008, 14:13	5.18
W950	0.02	18	29Jan2008, 12:41	5.9
W970a	0.49	246	29Jan2008, 13:43	5.04
w970b	0.09	111	29Jan2008, 12:29	5.5
W980	0.83	594	29Jan2008, 13:08	5.36
W990	0.11	79	29Jan2008, 13:10	5.47

	Project: AppoHMS	Simulation Run: Run500-yr-a		
	Start of Run: 29Jan2008, 00:00	Basin Model: Basin 100yr-a		
	End of Run: 31Jan2008, 00:15	Meteorologic Model: Met 500-yr		

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
J206	2.476094	2555	29Jan2008, 13:09	7.95
J211	4.117244	2765	29Jan2008, 14:39	7.87
J216	5.275207	3451	29Jan2008, 15:00	7.84
J219	6.319032	4094	29Jan2008, 14:53	7.86
J226	1.746722	1024	29Jan2008, 13:38	7.28
J229	9.055726	6217	29Jan2008, 14:28	7.99
J236	5.96524	3142	29Jan2008, 14:41	7.64
J239	3.164736	2151	29Jan2008, 14:09	7.88
J246	3.791736	2572	29Jan2008, 14:15	7.89
J249	18.900431	7071	29Jan2008, 18:55	7.65
J252	7.185169	3176	29Jan2008, 17:41	7.55
J255	17.119121	6702	29Jan2008, 18:34	7.63
J260	3.683513	3240	29Jan2008, 14:30	7.99
J271	45.465436	12895	30Jan2008, 07:05	7.65
J274	21.682314	7544	29Jan2008, 19:34	7.69
J277	20.188629	7260	29Jan2008, 19:22	7.67
J282	20.836801	7394	29Jan2008, 19:28	7.68
J291	40.87218	12900	30Jan2008, 06:19	7.6
J296	4.995762	2767	29Jan2008, 15:18	7.85
J299	1.159547	1352	29Jan2008, 13:05	8.52
J302	4.277284	2465	29Jan2008, 14:55	8.01
J309	39.914953	13159	29Jan2008, 20:12	7.78
J314	14.423125	5454	29Jan2008, 21:37	7.63
J317	13.670512	5394	29Jan2008, 21:20	7.62
J328	6.652299	3501	29Jan2008, 17:51	7.46
J331	1.977229	1217	29Jan2008, 14:09	7.62
J336	5.668985	3398	29Jan2008, 16:00	7.58
J339	4.155323	2836	29Jan2008, 14:41	7.71
OutletF	46.16384	12829	30Jan2008, 09:26	7.57
R100	6.652299	3461	29Jan2008, 21:43	7.43
R120	13.670512	5381	29Jan2008, 21:38	7.62
R1280	5.668985	3373	29Jan2008, 16:55	7.58
R130	15.778623	5583	29Jan2008, 22:19	7.74
R1340	14.423125	5447	29Jan2008, 21:51	7.63
R1390	21.682314	7531	29Jan2008, 19:59	7.68
R1430	17.119121	6701	29Jan2008, 18:46	7.62
R1480	9.055726	6215	29Jan2008, 14:43	7.99
R160	0.825311	537	29Jan2008, 15:41	8.17
R1640	1.420341	1620	29Jan2008, 14:04	7.83
R1680	2.380154	2339	29Jan2008, 14:37	7.83
R170	4.277284	2452	29Jan2008, 15:20	8

Project:	AppoHMS	Simulation Run:	Run500-yr-a	
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 100yr-a	
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 500-yr	

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
R190	4.995762	2695	29Jan2008, 17:14	7.85
R20	1.363547	1390	29Jan2008, 14:06	8.22
R200	1.159547	1302	29Jan2008, 14:05	8.52
R210	23.125735	7832	29Jan2008, 20:18	7.73
R220	39.914953	12899	30Jan2008, 06:20	7.57
R240	20.836801	7390	29Jan2008, 19:38	7.68
R260	20.188629	7254	29Jan2008, 19:31	7.67
R280	40.87218	12878	30Jan2008, 07:07	7.57
R30	4.155323	2798	29Jan2008, 16:14	7.71
R300	45.465436	12829	30Jan2008, 09:26	7.53
R310	18.900431	7055	29Jan2008, 19:27	7.64
R330	3.683513	3160	29Jan2008, 15:25	7.99
R350	7.185169	3170	29Jan2008, 18:14	7.55
R360	17.900955	6867	29Jan2008, 19:01	7.62
R380	3.164736	2146	29Jan2008, 14:17	7.88
R400	3.791736	2566	29Jan2008, 14:27	7.89
R410a	5.96524	3126	29Jan2008, 15:21	7.64
R410b	6.459381	2913	29Jan2008, 17:47	7.53
R430	9.526469	3521	29Jan2008, 19:04	7.65
R440	1.746722	1011	29Jan2008, 14:25	7.27
R470	2.902616	2661	29Jan2008, 14:37	7.89
R490	0.867494	1413	29Jan2008, 14:05	8.85
R500	6.319032	4075	29Jan2008, 15:22	7.86
R520	5.275207	3450	29Jan2008, 15:05	7.84
R540	4.117244	2758	29Jan2008, 15:17	7.86
R570	2.476094	2502	29Jan2008, 13:37	7.95
R60	1.977229	1201	29Jan2008, 15:25	7.62
R80	5.730305	3282	29Jan2008, 17:54	7.54
Reservoir-Noxontown Pond Dam	9.526469	3522	29Jan2008, 18:34	7.67
Reservoir-Shallcross Lake	5.730305	3287	29Jan2008, 17:25	7.54
Reservoir-Silver Lake	6.459381	2921	29Jan2008, 17:01	7.54
Reservoir-Wiggins Mill Pond	3.646534	2517	29Jan2008, 15:00	7.87
UserPoint10	1.420341	1659	29Jan2008, 12:58	7.83
UserPoint11	2.380154	2440	29Jan2008, 13:56	7.83
UserPoint12	2.902616	2661	29Jan2008, 14:33	7.89
UserPoint13	6.396094	3291	29Jan2008, 17:04	7.81
UserPoint14	7.274418	3528	29Jan2008, 21:43	7.46
UserPoint2	0.825311	560	29Jan2008, 14:10	8.17
UserPoint3	1.363547	1438	29Jan2008, 13:12	8.22
UserPoint4	5.730305	3287	29Jan2008, 17:25	7.54
UserPoint5	15.778623	5601	29Jan2008, 21:48	7.74

Project:	AppoHMS	Simulation Run:	Run500-yr-a
Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 100yr-a
End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 500-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
UserPoint6	23.125735	7848	29Jan2008, 19:51	7.74
UserPoint7	17.900955	6880	29Jan2008, 18:40	7.63
UserPoint8	9.526469	3522	29Jan2008, 18:34	7.67
UserPoint9	0.867494	1624	29Jan2008, 12:32	8.85
W1000	0.030062	58	29Jan2008, 12:27	7.98
W1010	1.211266	1013	29Jan2008, 13:46	8.7
W1020	0.206748	242	29Jan2008, 13:02	8.24
W1030	2.143442	776	29Jan2008, 16:17	7.19
W1040	1.24776	970	29Jan2008, 13:35	7.39
W1050	1.292659	1087	29Jan2008, 13:34	8.11
W1070	0.498962	158	29Jan2008, 17:00	6.99
W1080	0.655154	440	29Jan2008, 14:00	7.75
W1090	0.029189	91	29Jan2008, 12:10	8.19
W1100	1.014636	1149	29Jan2008, 13:01	7.99
W1110	0.502809	457	29Jan2008, 13:19	7.74
W1120	1.17044	1162	29Jan2008, 13:11	7.79
W1130	0.47071	735	29Jan2008, 12:36	7.84
W1140	0.764056	795	29Jan2008, 13:07	7.84
W1150	1.712038	1762	29Jan2008, 13:10	8
W1160	0.697758	323	29Jan2008, 15:06	7.25
W1170	0.825311	560	29Jan2008, 14:10	8.17
W1210	0.536814	398	29Jan2008, 13:35	7.07
W1220	1.363547	1438	29Jan2008, 13:12	8.22
W1260	0.201059	288	29Jan2008, 12:37	7.08
W1270	0.06132	152	29Jan2008, 12:16	7.68
W1310	0.706712	1891	29Jan2008, 12:18	9.19
W1320	1.355498	1671	29Jan2008, 13:02	8.88
W1360	0.303883	566	29Jan2008, 12:36	9.54
W1370	1.443421	1452	29Jan2008, 13:22	8.67
W1410	0.171094	314	29Jan2008, 12:32	8.39
W1420	0.781834	815	29Jan2008, 13:08	7.76
W1460	0.391321	778	29Jan2008, 12:27	8.31
W1470	0.470743	569	29Jan2008, 12:57	8.18
W1510	0.576541	443	29Jan2008, 13:41	7.8
W1520	0.867494	1624	29Jan2008, 12:32	8.85
W1570	1.420341	1659	29Jan2008, 12:58	7.83
W1620	0.959813	1355	29Jan2008, 12:44	7.83
W1660	0.233739	390	29Jan2008, 12:43	9.5
W1670	0.522462	891	29Jan2008, 12:34	8.19
W590	1.033966	1189	29Jan2008, 12:53	7.21
W610	1.409771	1019	29Jan2008, 13:53	7.81

	Project:	AppoHMS	Simulation Run:	Run500-yr-a
	Start of Run:	29Jan2008, 00:00	Basin Model:	Basin 100yr-a
	End of Run:	31Jan2008, 00:15	Meteorologic Model:	Met 500-yr

Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs)	Time of Peak	Volume (in)
W620	0.277733	249	29Jan2008, 13:14	7.13
W630	0.479696	473	29Jan2008, 13:07	7.24
W650	0.567458	256	29Jan2008, 15:10	7.14
W660	0.720935	674	29Jan2008, 13:07	6.92
W670	0.622119	700	29Jan2008, 13:00	7.73
W680	0.675874	839	29Jan2008, 12:52	7.73
W710	1.400332	802	29Jan2008, 14:29	7.67
W720	0.076739	263	29Jan2008, 12:10	9.22
W730	0.582909	244	29Jan2008, 15:22	6.93
W750	0.397301	1358	29Jan2008, 12:12	10.02
W760	0.647041	806	29Jan2008, 12:58	8.34
W770	1.594668	665	29Jan2008, 15:57	7.87
W780	0.512506	567	29Jan2008, 13:13	8.76
W790	0.135569	135	29Jan2008, 13:04	7.06
W800	0.162366	378	29Jan2008, 12:23	8.95
W810	0.559926	690	29Jan2008, 12:57	8.15
W820	0.338891	615	29Jan2008, 12:38	9.73
W830	0.562318	629	29Jan2008, 12:59	7.55
W840	0.014675	90	29Jan2008, 12:01	10.77
W850	0.633497	597	29Jan2008, 13:18	7.81
W860	0.698404	2223	29Jan2008, 12:14	10.6
W870	0.72588	999	29Jan2008, 12:52	8.62
W880	0.683147	662	29Jan2008, 13:14	7.69
W890	0.570852	1431	29Jan2008, 12:22	9.72
W900	0.638152	317	29Jan2008, 15:00	7.66
W910	0.547158	601	29Jan2008, 13:04	7.88
W920	0.516191	334	29Jan2008, 14:12	7.88
W950	0.016162	26	29Jan2008, 12:41	8.69
W970a	0.494141	380	29Jan2008, 13:42	7.72
w970b	0.087636	166	29Jan2008, 12:29	8.25
W980	0.828382	898	29Jan2008, 13:08	8.09
W990	0.110809	119	29Jan2008, 13:10	8.21

APPENDIX 3

Obstruction Data

Municipal Stream Obstruction Data
Watershed: Appoquimink River
Municipality/County: NEW CASTLE COUNTY, DELAWARE

Records completed by: ________________
Field work personnel: _______________
Date(s): ______________________________

T= Amount of fill
D= Diameter
HT = Height
W = Width
PW = Pier Width (if applicable)

msry = Stone Masonry Structure
CMP = Corrugated Metal Pipe
CPP = Corrugated Polyethylene Pipe
BCCMP = Bituminous Coated Corrugated Metal Pipe

Diagrams

Map ID. #	Municipality	Owner or Address of Obstruction	Capacity (CFS)	Nos. of?	Opening Type: Part of Bridge?	Opening Type: Culvert Purpose	Shape (✓) Culvert □	Shape (✓) Culvert ○	Shape (✓) Culvert ⬭	Shape (✓) Bridge ⌒	Shape (✓) Bridge ⊓	Measurements T (ft)	D (ft)	HT (ft)	W (ft)	PW (ft)	skew angle	material	NOTES
391		Silver Run Rd./ Appo. River									X	1.0		6.5	204.6	3.0	10"	Concrete	WW
392		Silver Run Rd.									X	1.0		6.0	204.0	3.0	0.0	Concrete	WW
393	Odessa	Main St./ Appo. River									X	1.0		4.5	98.8		0.0	Concrete	WW
393N		Route 13/ Appo. River									X	2.5		6.0	220.0		0.0	Concrete	WW
393S		Route 13/ Appo. River									X	2.5		6.0	220.0		0.0	Concrete	WW
394N		Route 13/ Drawyer Creek									X	2.5		5.0	128.3		0.0	Concrete	WW
394S		Route 13/ Drawyer Creek									X	2.5		5.0	161.0		0.0	Concrete	WW
400		Shallcross Lake Rd/ Drawyer Creek		1			X					3.5		7.0	15.0		0.0	Concrete	WW
401		Cedar Lane Rd/ Drawyer Creek							X			6.0		9.0	14.0		0.0	Steel	
402		Cedar Lane Rd		2			X					2.0		4.5	9.0		0.0	Concrete	WW
403	Middletown	Cedar Lane Rd		1			X					3.0		9.0	8.1		9"	Concrete	WW,HW
405		Marl Pit Rd/ Doves Nest Br.		2			X					1.5		3.0	12.0		0.0	Concrete	WW
406		Brick Mill Rd		3					X			5.0		5.5	14.0		0.0	Steel	
407		Silver Lake Rd/ Deep Creek									X	1.0		10.5	21.0		0.0	Concrete	WW
407A		Silver Lake Rd/ Deep Creek		1			X					2.5		4.0	8.4		0.0	Concrete	WW,HW
408		Summit Bridge Rd		1			X					2.0		7.5	12.0		0.0	Concrete	WW,HW
409		S. Broad St/ Deep Creek									X	16.0		8.0	22.0		0.0	Concrete encased	WW
423		Wiggins Mill Rd									X	3.0		4.0	14.5		0.0	Concrete encased	WW
424		Wiggins Mill Rd/ Appo. River									X	2.0		5.0	49.2		10"	Concrete	WW
425	Townsend	Wiggins Mill Rd		1			X					1.3		2.0	6.0		0.0	Concrete	WW
433	Middletown	Cedar Lane Rd							X			1.5		6.0	8.5			Steel	
438A		Rte 1/ Middletown Odessa Rd (Rte 299)									X	2.5		17.9	273.5		32"	Concrete/ Steel Girdle	WW
439	Townsend	Route 71		1			X					15.0		3.0	8.0		0.0	Concrete	WW,HW
440	Townsend	Route 71/ Appo. River									X	4.5		6.0	38.0		0.0	Concrete	WW,HW
441		Route 71		1			X					22.0		5.5	8.0		0.0	Concrete	WW,HW
442		Money Rd		1			X					1.0		5.5	12.0		0.0	Concrete	WW
443		Noxontown Rd/ Noxontown Pond		2			X					4.5		5.0	10.0		0.0	Concrete	WW,HW
443A		Noxontown Rd/ Noxontown Pond		1			X					9.0		3.0	7.5		25"	Concrete	WW,HW
445		Route 9/ Hangmans Run		1			X					1.5		5.3	22.0		0.0	Concrete	WW
504		Silver Lake Rd/ Silver Lake		2			X					2.0		10.0	12.0		0.0	Concrete	WW,HW
905N		Route 1/ Drawyer Creek									X			8.5	1136.5		0.0	Concrete	WW
905S		Route 1/ Drawyer Creek									X			8.5	1136.5		0.0	Concrete	WW
906N		Route 1/ Appo. River									X			11.8	871.0		0.0	Concrete	WW
906S		Route 1/ Appo. River									X			12.5	929.5		0.0	Concrete	WW
1		Junction of Routes 71 and 301						X				9.0	4.5					Concrete	
2		Cleaver Farms Road						X				6.0	6.5					Metal Pipe	
3																			No Data Collected
4		Old Corbitt Road									X	0.5		0.0	62.0				Water level to road or on road in some spots
5																			No Data Collected
6		Money Road						X					4.5					Concrete	
7		Greers Corner Road						X					6.0					Metal Pipe	
8		Dogtown Road						X					3.0					Concrete	
9		Marl Pit Road						X				6.0	4.0					Concrete	

APPENDIX 4

Data Collection Forms

FORM A - STORM WATER PROBLEM AREAS SHEET 2 OF 34

WATERSHED	FORM COMPLETED BY	Before Filling Out Form, See Instructions On Back
Name: Appoquinimink	Name: Tim DeSchepper	
Municipality: Town of Middletown	Telephone: 302-378-1164	For County Use:
County: New Castle County	Date:	

MAP NO. *	A-1	A-2	A-3	A-	A-	A-	A-	A-	A-	A-	A-	A-
Types of Storm Water Problems												
Flooding			1									
Accelerated Erosion												
Sedimentation	1	1										
Landslide												
Groundwater												
Water Pollution												
Other (Explain)												
Explanation Line No. (On Back)												
Cause (s)												
Storm Water Volume			X									
Storm Water Velocity	X	X										
Storm Water Direction												
Water Obstruction												
Other (Explain)												
Explanation Line No. (On Back)												
Frequency												
Year Most Recent Occurred												
Year First Known Occurred												
Regularity												
More Than 1 Year												
Less Than 1 Year	X	X	X									
Only During Agnes												
Duration (If Applicable)												
Less Than 1 Day												
1 Day + (Enter Days)	5	5	1									
Property Damage												
Loss of Life/Vital Services												
Private												
More Than One Owner												
Types of Properties												
Number of Properties												
Public (List Types)												
Explanation Line No. (On Back)												
Solutions												
Suggested												
Explanation Line No. (On Back)												
Formally Proposed	X	X	X									
Explanation Line No. (On Back)												

* Include Map ID No. if found on any other form listing proposed facilities.

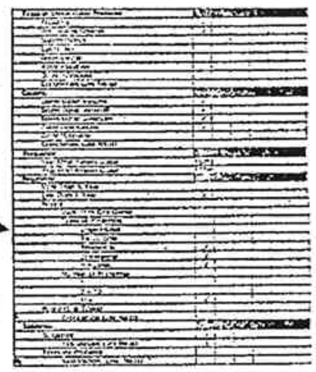
INSTRUCTIONS

Begin with A.1 as the first map number to identify the first' storm water problem area. Illustrate the defined problem on the watershed map provided, and identify it with its map number.

For each storm water problem area within your municipality, enter the map identification number at the head of the column. Describe the problem by placing a check (4 in the appropriate blocks of the column under this map identification number.

When an additional explanation is required, write the line number(s) used in the column marked "Explanation Line No. (s)".Example 1, 2-3, etc.

If storm water problem occurred during and after Agnes, describe the frequency of the problem after Agnes.



Use the explanation lines to list the types of public property damages ,e.g.roadways, hospitals, etc.

Enter the line no. (s) used to list the map ID no. (s) for the proposed facilities.

Definitions

Storm Water Problem Area
An area that defines the farthest extent of a storm water problem, including any area that experiences property damage, inundation, accelerated erosion, surface water pollution, groundwater pollution, landslides, or any other problem as a result of storm water runoff.

Groundwater
Water in the ground below the water table.

Accelerated Erosion
The removal of the surface of the land through the combined action of man's activities and the natural processes at a rate greater than would occur because of the natural process alone.

Sedimentation
The process by which soil or other surface materials, transported by surface water, is deposited on stream bottoms.

Water Obstruction
Any dike, bridge, culvert, wall, wingwall, fill, pier, wharf, embankment, abutment, or other structure located in, along, across, or projecting into any watercourse, floodway, or body of water.

EXPLANATION LINES (continued)

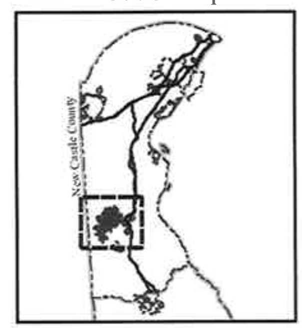
A-1	Sediment runoff into nearby Silver Lake from adjacent construction site
	during heaviest rainfall. Vegetative stabilization taking affect to anchor
	soil and minimize erosion. Proper stormwater improvements are proposed
	during the next phase of construction as presented in the Westown Improvement Plan.
A-2	Land development for local commercial site experiences sediment run off during
	heaviest rainfall events throughout the year. The discharges are occurring
	less now that vegetative stabilization covers majority of the construction site
	and the building pads are nearing completion.
A-3	Local farm pond overflows into wetlands during 500-year storm. Area to
	receive proper drainage during the construction of Westown.

Town of Middletown, Delaware

Map 1. Aerial View

Municipal Boundaries
Roads
Parcel Boundaries
Railroads
Hydrology

Locator Map



Sources:
Digital orthophotography - Produced by Earth Data International in False Color Infrared at a scale of 1 / 2,400 with a 1 foot pixel resolution. March 2002
Parcel Boundaries - New Castle County Planning Department, March 2004
Roads - Delaware Department of Transportation centerline file June 2005
Hydrology - USGS 7.5 Minute Series Topographic Maps. Created in cooperative agreement between the State of Delaware and the USGS, 1991-1993
Municipal Boundaries - Delaware Office of State Planning Coordination, April 2004

Note:
This map is provided by the Institute for Public Administration (IPA) solely for display and reference purposes and is subject to change without notice. No claims, either real or assumed, as to the absolute accuracy or precision of any data contained herein are made by IPA, nor will IPA be held responsible for any use of this document for purposes other than which it was intended.

0 0.3 0.6 1.2 Miles

November 2005

IPA University of Delaware
www.ipa.udel.edu
Institute for Public Administration
College of Human Services, Education & Public Policy

Municipal Stream Obstruction Data

Watershed:

Municipality/County:

Records completed by: ______

Field work personnel: ______

Date(s): ______

T= Amount of fill
D= Diameter
HT = Height
W = Width
PW = Pier Width

Material
msry = Stone Masonry Structure
CMP = Corrugated Metal Pipe
CPP = Corrugated Polyethylene Pipe
BCCMP = Bituminous Coated CMP
RCP = Reinforced Concrete Pipe
SP = Steel Pipe

Inlet Conditions
HW = Headwall
WW = Wingwall
SW = Sidewall

Map ID	Owner or Address Of Obstruction	Capacity (CFS)	Nos. of?	Opening: Type: Part of Bridge?	Culvert Purpose	Shape (✓): Culvert □	O	⬭	Bridge ∩	⊓	Measurements: T (ft)	D (ft)	HT (ft)	W (ft)	PW (ft)	skew angle	MATERIAL / INLET CONDITION	NOTES
	No obstructions are found at this time.																	

△ **FORM C** - EXISTING FLOOD CONTROL PROJECT SHEET ____7____ OF _____34_____

WATERSHED	FORM COMPLETED BY	TYPICAL TYPES OF FLOOD CONTROL PROJECTS
Name: ______ Municipality: ______ County: ______	Name: ______ Telephone: ______ Date: ______	Channel Excavation / Widening, Channel Realignment, Rock Riprap Levee, Gabions, Pipe Channel Dams, Floodwall, Concrete Lining

For County Use:

Map ID No.	Type of Flood Control Project	Year Constr Built	Expected Life Yrs.	Design Flood Frequency Yrs.	Design Flood Discharge C.F.S.	Owner Name, Address, and Phone
C-						
C-						
C-						
C-						
C-						
C-						
C-						

Flood Control Projects do not exist at this time.

△ **FORM C** - EXISTING FLOOD CONTROL PROJECT

WATERSHED	FORM COMPLETED BY	TYPICAL TYPES OF FLOOD CONTROL PROJECTS		
Name:	Name:	Channel Excavation / Widening	Levee	Dams
Municipality:	Telephone:	Channel Realignment	Gabions	Floodwall
County:	Date:	Rock Riprap	Pipe Channel	Concrete Lining

For County Use:

Map ID No.	Type of Flood Control Project	Year Constr Built	Expected Life Yrs.	Design Flood Frequency Yrs.	Design Flood Discharge C.F.S.	Owner Name, Address, and Phone
C-						
C-						
C-						
C-						
C-						
C-						
C-						

Flood Control Projects do not exist at this time.

FORM D - PROPOSED FLOOD CONTROL PROJECT

SHEET 8 OF 34

WATERSHED	FORM COMPLETED BY	TYPICAL TYPES OF FLOOD CONTROL PROJECTS
Name: Municipality: County:	Name: Telephone: Date:	Channel Excavation / Widening; Channel Realignment; Rock Riprap; Levee; Gabions; Pipe Channel; Dams; Floodwall; Concrete Lining

For County Use:

Map ID No.	Type of Flood Control Project	Study Phase Begun			Year Constr. Planned	Projected Compltn. Date	Expected Life Yrs.	Design Flood		Map ID No. Form A*	Owner Name, Address, and Phone
		YES		N0				Frequency Yrs.	Discharge C.F.S.		
		Prelim.	Final								
D-											
D-											
D-											
D-	Flood Control Projects are not proposed at this time.										
D-											
D-											
D-											

* Enter the storm water problem area's Map ID No., if the proposed project will solve or reduce any / all of an identified drainage problem.

FORM E - EXISTING STORM WATER CONTROL FACILITIES

SHEET 9 OF 34

WATERSHED

Name: Appoquinimink
Municipality: Town of Middletown
County: New Castle

FORM COMPLETED BY

Name: Tim DeSchepper
Telephone: 302-378-1164
Date: Jul-07

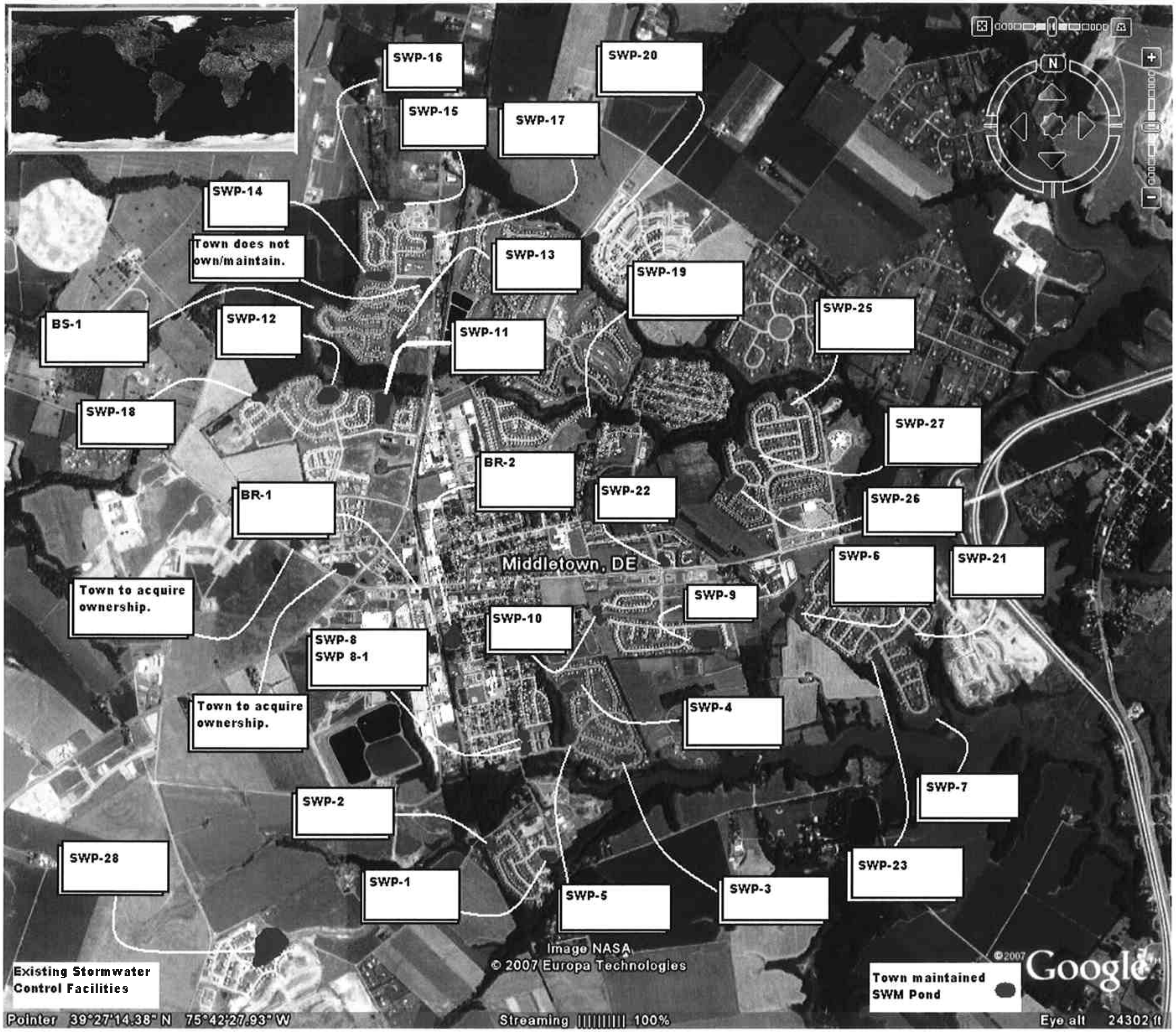
Definition of Storm Water Control Facility
A natural / man-made device or structure specifically designed and / or utilized to reduce the rate and / or volume of storm water runoff from a site or sites. **NOTE**: Map Id No. listed as SWP on attached map.

For County Use:

Map ID No.	Type of Storm Water Control Facility	Year Built	Contact Person	Address and Phone	Comments
E-1	Retention Pond	1996	Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine vegetation control and sediment removal to promote pond viability. Non-routine work done 01/27/2007.
E-2	Retention Pond	1999	Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine maintenance to remove invasive vegetation and control algae.
E-3	Retention Pond	2000	Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine maintenance to remove invasive and over-growing vegetation .
E-4	Retention Pond	1998	Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine vegetation control, inlet cleaning, and sediment removal to promote pond viability.
E-5	Retention Pond	1998	Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine maintenance to remove invasive and over-growing vegetation .
E-6	Retention Pond	1998	Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine vegetation control, inlet cleaning, and sediment removal to promote pond viability.
E-7	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine vegetation control and sediment removal to promote pond viability.
E-8	Retention Pond	2000	Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine vegetation control and sediment removal to promote pond viability.
E-8-1	Retention Pond	2000	Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine vegetation control and sediment removal to promote pond viability.
E-9	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	
E-10	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine maintenance to remove invasive and over-growing vegetation .
E-11	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine maintenance to remove invasive, or over-growing vegetation, and control algae.
E-12	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine vegetation control, inlet cleaning, and sediment removal to promote pond viability.
E-13	Retention Pond	2000	Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Barley straw added to pond for controlling algae growth.
E-14	Retention Pond	2000	Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Barley straw added to pond for controlling algae growth.
E-15	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Barley straw added to pond for controlling algae growth.
E-16	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Barley straw added to pond for controlling algae growth.
E-17	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Barley straw added to pond for controlling algae growth.
E-18	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	
E-19	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine maintenance to remove invasive and over-growing vegetation .
E-20	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	
E-21	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine maintenance to remove invasive and over-growing vegetation .
E-22	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine maintenance to remove invasive and over-growing vegetation .
E-23	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	
E-25	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine maintenance to remove invasive vegetation and control algae.
E-26	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine maintenance to remove invasive and over-growing vegetation .
E-27	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	Routine maintenance to remove invasive and over-growing vegetation .
E-28	Retention Pond		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	
BS-1	Bio-swale (Springmill)		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	
BR-1	Bio-retention (Haveg Road)		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	
BR-2	Bio-retention (MOT Senior Center)		Timothy D. DeSchepper, Town Planner	19 W. Green Street Middletown, DE. 19709; 302-378-1164	

TYPICAL TYPES OF STORM WATER CONTROL FACILITIES

Detention / Retention Basin
Natural Pond or Wetland
Parking Lot Pondling
Roof-Top Storage
Semi-Pervious Paving
Infiltration Device (Seepage /Recharge Basin or Underground Tank)


SWP-16
SWP-20
SWP-15
SWP-17
SWP-14
Town does not own/maintain.
SWP-13
SWP-19
SWP-25
BS-1
SWP-12
SWP-11
SWP-18
SWP-27
BR-2
SWP-22
BR-1
SWP-26
Middletown, DE
SWP-6
SWP-21
Town to acquire ownership.
SWP-9
SWP-10
SWP-8
SWP 8-1
Town to acquire ownership.
SWP-4
SWP-7
SWP-2
SWP-28
SWP-1
SWP-5
SWP-3
SWP-23
Image NASA
© 2007 Europa Technologies
Existing Stormwater Control Facilities
Town maintained SWM Pond
Pointer 39°27'14.38" N 75°42'27.93" W
Streaming 100%
Eye alt 24302 ft

FORM F - PROPOSED STORM WATER CONTROL FACILITIES

WATERSHED		FORM COMPLETED BY		DEFINITION
Name:	Appoquinimink	Name:	Tim DeSchepper	Storm Water Control Facility A natural / man-made device or structure specifically designed and / or utilized to reduce the rate and / or volume of storm water runoff from a site or sites.
Municipality:	Town of Middletown	Telephone:	302-378-1164	
County:	New Castle County	Date:	31-Jul-07	

For County Use:

Map ID No.	Type of Storm Water Control Facility	Proposed Constr. Dates Start	Proposed Constr. Dates End	Map No. Form A*	Contact Person Name, Address and Phone	Comments
F-1	Retention Pond				Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-2	Retention Pond				Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-3	Retention Pond				Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-4	Retention Pond				Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-5	Retention Pond				Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-6	Retention Pond				Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-7	Retention Pond				Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-8	Retention Pond				Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-9	Retention Pond				Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-10	Dry Pond				Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-11	Retention Pond				Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-12	Retention Pond				Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-13	Retention Pond	Jan-08	10-Jan-10		Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	

Detention / Retention Basin
Natural Pond or Wetland
Parking Lot Pondling

Roof-Top Storage
Semi-Pervious Paving
Infiltration Device (Seepage / Recharge Basin or Underground Tank)

FORM F - PROPOSED STORM WATER CONTROL FACILITIES

WATERSHED	FORM COMPLETED BY	DEFINITION
Name: Appoquinimink Municipality: Town of Middletown County: New Castle County	Name: Tim DeSchepper Telephone: 302-378-1164 Date: 31-Jul-07	Storm Water Control Facility A natural / man-made device or structure specifically designed and / or utilized to reduce the rate and / or volume of storm water runoff from a site or sites.

For County Use:

Map ID No.	Type of Storm Water Control Facility	Proposed Constr. Dates Start	End	Map No. Form A*	Contact Person Name, Address and Phone	Comments
F-14	Bioswale	2005	2007		Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-15	Bioswale	2005	2007		Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-16	Bioswale	2005	2007		Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-17	Bioswale	2005	2007		Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-18	Bioswale	2005	2007		Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-19	Bioswale	2005	2007		Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
F-20	Dry Pond	2005	2007		Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
					Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
					Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
					Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
					Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
					Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	
					Tim DeSchepper, 302-378-1164 19 West Green Street Middletown, DE. 19709	

Detention / Retention Basin
Natural Pond or Wetland
Parking Lot Pondling

Roof-Top Storage
Semi-Pervious Paving
Infiltration Device (Seepage / Recharge Basin or Underground Tank)

FORM G - EXISTING STORM WATER COLLECTION SYSTEMS

SHEET 28 OF 34

WATERSHED	FORM COMPLETED BY	INSTRUCTIONS
Name: Appoquinimink Municipality: Middletown County: New Castle County	Name: Tim DeSchepper Telephone: 302-378-1164 Date: 7/31/2007	Diagram each system on the appropriate map. Establish map points to show changes in system elements, pipe size, or pipe direction. (If unknown, outline the system extent.) Complete this form only where specific information on construction is available. Use a separate form for each system. Identify the points within a system consecutively (ex. G-1,G-2,G-3). Start the first point in each additional system 20 numbers higher. For example, G-3 ends one system, so G-23 begins the next. See Sample Diagrams & Form on Reverse.

Map I.D. No.		System's Elements (x)			Measurements *				Material	Year Constr.	Design Data Available	Contact Person Name and Phone	Name of Final Ownership and Maintenance Responsibility
					Pipe	Channel / Swale							
From	To	Pipe	Open Channel	Swale	D	TW	B	Depth					
G-	G-												
G-	G-												
G-	G-												
G-	G-												
G-	G-												
G-	G-												
G-	G-												
G-	G-												
G-	G-												
G-	G-												
G-	G-												
G-	G-												
G-	G-												
G-	G-												
G-	G-												

* See measurement key on reverse side.

****See disc for information pertaining to the existing stormwater collection system.**

FORM H - PROPOSED STORM WATER COLLECTION SYSTEMS SHEET ____30____ OF ____34____

WATERSHED	FORM COMPLETED BY	INSTRUCTIONS
Name: ______ Municipality: ______ County: ______	Name: ______ Telephone: ______ Date: ______	On the map for proposed storm water collection systems, diagram each proposed system. Indicate a map point to show changes in system elements, pipe size, pipe direction and connections to existing systems. For proposed additions to existing systems, diagram only the additions and their connection point into the existing system. Complete a separate form for each proposed, new system and one for each existing system having one or more proposed additions. Identify the points within a system consecutively (ex. H-1, H-2, H-3). Start the first point in each additional system 20 numbers higher (if H-3 ends one system, begin the next with H-23). Be sure to show the point where proposed additions connect into existing systems, using the map point number from the existing system form and map. See Sample Diagrams and Form on Reverse.

Map I.D. No.		System's Elements (x)			Measurements *				Material	Map I.D. Nos.** Form A	Proposed Const. Dates		Design Data Avail.	Contact Person Name and Phone	Name of Final Ownership and Maintenance Responsibility
					Pipe	Open Channel / Swale									
From	To	Pipe	Open Channel	Swale	D	TW	B	Depth			Start	End			
H-	H-														
H-	H-														
H-	H-														
H-	H-														
H-	H-														
H-	H-														
H-	H-														
H-	H-														
H-	H-														
H-	H-														
H-	H-														
H-	H-														
H-	H-														
H-	H-														
H-	H-														

* See measurement key on reverse side. ** Enter the storm water problem areas' Map I.D. Nos., if proposed project will solve or reduce any / all of the drainage problems.

****See disc for information pertaining to the proposed stormwater collection system.**

FORM I - PRESENT & PROJECTED DEVELOPMENT IN THE FLOOD HAZARD AREA

SHEET ____32_____ OF _____34_____

WATERSHED	FORM COMPLETED BY	DEFINITION
Name: ________ Municipality: ________ County: ________	Name: ________ Telephone: ________ Date: ________	FLOOD HAZARD AREA: A NORMALLY DRY LAND AREA THAT HAS BEEN OR IS SUSCEPTABLE TO BEING INUNDATED BY THE 100-YEAR FLOOD.

For County Use:

Map ID No.	TYPE OF DEVELOPMENT	Year Built	Contact Person Name, Address and Phone	Comments
I -				
I -				
I -				
I -				
I -				
I -				
I -				
I -				
I -				

No development is permitted in floodplains, flood hazard areas, or riparian buffer areas.

FORM J - WATER QUALITY PROBLEM AREAS SHEET 33 OF 34

WATERSHED		FORM COMPLETED BY	
Name:	Appoquinimink	Name:	Tim DeSchepper
Municipality:	Town of Middletown	Telephone:	302-378-1164
County:	New Castle County	Date:	

SITE	J-1	J-2	J-	J-	J-	J-	J-	J-	J-	J-	J-	J-
Types of Water Quality Problems												
High Community Tolerence												
High Temperature												
High Turbidity												
Hydrocarbon Pollution												
Low Community Diversity												
Low Dissolved Oxygen												
Low pH												
Nutrient Enrichment												
Poor Habitat												
Other/Explanation Line No.	1	1										
Potential Cause(s)												
Agriculture												
Construction Site	1	1										
Erosion												
Lake Discharge												
STP Outfall												
Other/Explanation Line No.												
Frequency												
Year Most Recent Occurence	2007	2007										
Year First Known Occurence	2006	2006										
Source of Information												
BWA Streamwatch												
County Water Quality Study												
Driveby												
UCCD Complaint Investigation												
Other/Explanation Line No.												

EXPLANATION LINES

1	Sediment runoff from construction site causing murky conditions down stream and in nearby Silver Lake.
2	Sediment runoff from construction site causing murky conditions down stream and in nearby Silver Lake.
3	
4	
5	
6	
7	
8	
9	
10	

Date: 07/30/2007 -- Time: 15:17:13

APPENDIX 5

Comment Response Log

Appoquinimink River Watershed Stormwater Management Plan Comment Response Log

No.	Volume	Section	Page	Comment Provided By	Comment	Response
1	I	Exec. Summary	I-1	Sara Wozniak (DNREC)	"Appoquinimink Watershed is the first watershed to the south of the Delaware Canal" This is not a true statement there are other watersheds found below the canal between the canal and the Appo	The text was revised to indicate that "It is one of the first major watersheds located to the south of the Chesapeake and Delaware Canal"
2	II	Introduction	I-1	Sara Wozniak (DNREC)	"Appoquinimink Watershed is the first watershed to the south of the Delaware Canal" This is not a true statement there are other watersheds found below the canal between the canal and the Appo	The text was revised to indicate that "It is one of the first major watersheds located to the south of the Chesapeake and Delaware Canal"
3	II	Introduction	II-1	Sara Wozniak (DNREC)	"Appoquinimink Watershed is the first watershed to the south of the Delaware Canal" This is not a true statement there are other watersheds found below the canal between the canal and the Appo	The text was revised to indicate that "It is one of the first major watersheds located to the south of the Chesapeake and Delaware Canal"
4	I	Exec. Summary	I-1	Sara Wozniak (DNREC)	Make sure the canal is correctly called the Chesapeake and Delaware Canal	The name of the canal was revised as noted
5	II	Introduction	I-1	Sara Wozniak (DNREC)	Make sure the canal is correctly called the Chesapeake and Delaware Canal	The name of the canal was revised as noted
6	II	Introduction	II-1	Sara Wozniak (DNREC)	Make sure the canal is correctly called the Chesapeake and Delaware Canal	The name of the canal was revised as noted
7	I	Methodology	I-2	Sara Wozniak (DNREC)	It should read the Appoquinimink River Association not the Appoquinimink Creek Valley Association	The name of the watershed association was revised as noted.
8	I	Methodology	I-2	Sara Wozniak (DNREC)	DNREC does not have a Division of Dam Safety	The citation for the Division of Dam Safety was removed from the narrative

Appoquinimink River Watershed Stormwater Management Plan Comment Response Log

No.	Volume	Section	Page	Comment Provided By	Comment	Response
9	I	Implementation	I-4	Sara Wozniak (DNREC)	"All municipalities within the watershed that administer their own Subdivision/Land Development ordinances will be required to adopt the standards and criteria set forth Appoquinimink River Watershed Stormwater Management Plan. The standards and criteria contained in this Plan will apply only to those portions of the municipality that are located within the boundaries of the Appoquinimink River watershed" Is this True? I was not aware that this would become regulations?? Perhaps needs some further explanation	No r+G26esponse needed
10	II	Forward	i	Sara Wozniak (DNREC)	Why is the New Castle County Planning Board Included in the report	Reference to the New Castle County Planning Board was removed.
11	II	Forward	ii	Sara Wozniak (DNREC)	In the lost of steering committee members should we have the people who have left their positions in the list	The list of steering committee members was revised to include only those individuals on the steering committee as of January 2010
12	II	Forward	ii	Sara Wozniak (DNREC)	List my organization and name as follows: Appoquinimink River Association and Delaware Department of Natural Resources and Environmental Control, Sara Wozniak, Watershed Coordinator	The list of steering committee members was revised accordingly.
13	II	General Description of Watershed	II-15	John Gysling (NCCD)	The study should reference Southern New Castle County Priority Watershed Strategy, prepared by Institute of Public Administration, Water Resource Agency, University of Delaware, August 2006	The noted study was referenced in the land cover section of Volume II Section II and cited in the references.
14	II	General Description of Watershed	II-27	John Gysling (NCCD)	The study should reference the Work Plan for Wetlands Program Development, Southern New Castle County, DE prepared by TRC Omni Environmental dated May 2004	The noted study was referenced in the wetland portion of Volume II Section II and cited in the references.
15	I	Methodology	I-2	Elaine Webb (DNREC)	It should read the Appoquinimink River Association not the Appoquinimink Creek Valley Association	The name of the watershed association was revised as noted.

Appoquinimink River Watershed Stormwater Management Plan Comment Response Log

No.	Volume	Section	Page	Comment Provided By	Comment	Response
16	II	Introduction	I-1	Elaine Webb (DNREC)	Delaware Canal Should be Chesapeake and Delaware Canal	The name of the canal was revised as noted
17	II	Data Collection	II-3	Elaine Webb (DNREC)	Clarify that the Soils Mapping was developed by NRCS not DNREC	The text of the plan was adjusted to indicate that NRCS developed the soils mapping
18	II	Standards and Criteria	V-5	Elaine Webb (DNREC)	Groundwater recharge management criteria d.ii - the criteria should be the same as our requirements for all infiltration testing. (tests at the hydraulically most restrictive layer 0-3 feet below the bottom of the infiltration surface.)	The section on groundwater recharge was revised as suggested.
19	II	Standards and Criteria	V-6	Elaine Webb (DNREC)	Minimum design requirements for infiltration BMPs ii-S&S regs currently does not allow infiltration in fill material; this is less restrictive	The section was revised to not permit infiltration in fill conditions or areas.
20	II	Standards and Criteria	V-6	Elaine Webb (DNREC)	Minimum design requirements for infiltration BMPs iii-S&S regs currently requires 3 feet of separation; this is less restrictive	The minimum depth to the limiting zone, bedrock or water table for infiltration facilities was revised to indicate 36 inches.
21	II	Standards and Criteria	V-6	Elaine Webb (DNREC)	Minimum design requirements for infiltration BMPs v-S&S we should include the loading requirements in our infiltration design guidance	No action required.
22	II	Standards and Criteria	V-8	Elaine Webb (DNREC)	Water quality requirements for infiltration BMPs, item ii-should order of BMPs be specified, for example, filter strips must precede storage BMPs, not vice-versa?	The section was revised to indicate non-structural BMPs should precede structural BMPs.
23	II	Standards and Criteria	V-11	Elaine Webb (DNREC)	Tidal marsh habitat management criteria - will stormwater outfalls be permitted within a buffer? What about a filter strip.	The narrative was revised to indicate "Properly stabilized outfalls may be constructed within the vegetated buffer as long as all earth disturbance necessary to construct or maintain the facility is immediately revegetated with native plant species after constructing the outfall or performing maintenance. No development including stormwater management facilities shall be permitted within the buffer area adjacent to a tidal marsh."

Appoquinimink River Watershed Stormwater Management Plan Comment Response Log

No.	Volume	Section	Page	Comment Provided By	Comment	Response
24	NA	Standards and Criteria	NA	Elaine Webb (DNREC)	Generally, these recommendations require management back to some reference to the predevelopment discharge rate of the site. How will we handle this when our regs are revised? Will these requirements remain, or the new regs supersede, or will the designer have to design to the most restrictive.	No modification to the plan is required to address this comment..
25	II	Standards and Criteria	V-22	Elaine Webb (DNREC)	No Harm Option- clarify that groundwater recharge, water quality, streambank erosion protection requirements must still be met when invoking the No Harm Option.	The plan was modified to indicate "Proven performance based upon the “no harm” option shall under no circumstances relieve the Applicant from the groundwater recharge, water quality, and streambank erosion protection requirements of this plan."
26	II	Standards and Criteria	V-23	Elaine Webb (DNREC)	Stormwater Hotspots-can these uses all be tied to an SIC Code or a zoning classification? Zoning may require the development of a new zoning class and application for rezoning to the stormwater hotspots zoning class. There is bound to be some use that tries to qualify for this recharge requirement exemption criteria that we do not agree with based upon the proposed land use.	The section was revised to indicate that the designation of a hotspot or the spatial limits of the hotspot shall remain the exclusive right of DNREC. No site shall be exempt from the groundwater recharge requirements without written concurrence from DNREC’s Division of Water Resources that the existing or proposed development is a hotspot and exempt from the groundwater recharge requirements of this plan.
27	II	Standards and Criteria	V-23	Elaine Webb (DNREC)	Stormwater Hotspots-What about other agricultural uses other than a commercial nursery? Ag structures are regulated under the sediment and stormwater regulations	Table V-1 was revised to allow for other agricultural uses where large quantities of containerized chemicals area stored.
28	II	Standards and Criteria	V-24	Elaine Webb (DNREC)	Buffer requirements-what is meant by "whenever possible"-why not just require native vegetation?	The section was revised to indicate that "Only if it can be demonstrated through several plantings of native plant species, in no less than three separate growing seasons, that a native plant species cannot survive within a riparian buffer that a non-native plant species may be considered as a substitute with approval by the County Conservation District."

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29	II	Standards and Criteria	V-25	Elaine Webb (DNREC)	Table V-3 why not include item 5 "apply BMPs near source" in with item 1 "maximize use of nonstructural BMPs	Table V-3 was revised to indicate both nonstructural and structural BMPs should be applied near the source of the runoff.
30	II	Standards and Criteria	V-31	Elaine Webb (DNREC)	Table V-4 how are Storm Drain Inserts different form Catch Basin Inserts listed earlier in the table? Can they be combined?	The respective BMPs were combined into one location in Table V-4.
31	II	Standards and Criteria	V-34	Elaine Webb (DNREC)	Table V-6 items 1 and 2-include HSG A soils as well.	HSG A soils were added to Table V-6 items 1 and 2.
32	II	Standards and Criteria	V-38	Elaine Webb (DNREC)	Safety- Bullet 5-we do not recommend fencing around BMPs as it becomes an attraction rather than a deterrent and inhibits maintenance	The recommendation for fencing around the perimeter of a BMP was removed as directed.
33	II	Plan Approval and Updating Procedures	VII-1	Elaine Webb (DNREC)	Provisions for the plan revision-not sure that the three year review applies to designated watersheds. This has not been the case on previous designated watersheds, however, it could be specified as part of the plan.	The noted section was revised to indicate that the plan will be reviewed every three years to determine if an update to the plan is required. This does not mandate an update of the plan but just a determination if the existing plan is still adequate and appropriate.
34	II	Watershed Technical Analysis	IV-19	Vincent W Davis, P.E. (DelDOT)	2nd Paragraph, 1st sentence, were diverter structures considered at all during the analysis.	The use of diverter structures were not considered in the analysis and would have no impact upon the amount of annual runoff.
35	II	Standards and Criteria	V-4	Vincent W Davis, P.E. (DelDOT)	5th Paragraph, 2nd sentence, what is the NRCS Loss Equation? Is this the Rainfall Runoff equation?	The plan was revised to reference the NRCS Runoff Equation.
36	II	Standards and Criteria	V-4	Vincent W Davis, P.E. (DelDOT)	5th paragraph, last sentence, for the new composite curve number, does the 25% meadow apply to all storm events? How was the percentage chosen?	The 25% meadow condition applies to all storm events. It is based upon the concepts presented in Section II. J where it is cited that historically a large percentage of the watershed consisted of agricultural lands with a minimum of 25% meadow-like land cover.
37	II	Standards and Criteria	V-4	Vincent W Davis, P.E. (DelDOT)	6th paragraph, 2nd sentence, so if you can't do any BMP's due to site conditions, you still need to install them anyway? This sentence needs to be rewritten.	The plan was revised to indicate that when infiltration BMPs are limited by physical constraints of the site the BMP's shall be designed to infiltrate as much stormwater runoff as possible based upon the site testing.

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38	II	Standards and Criteria	V-5	Vincent W Davis, P.E. (DelDOT)	Under part a. What other GTBMPs and nonstructural practices infiltrate besides trenches, basins and subsurface infiltration facilities?	The section was revised to provide examples of GTBMPS that infiltrate (i.e. vegetated filter strips, vegetated buffers, bioretention, rain gardens)
39	II	Standards and Criteria	V-5	Vincent W Davis, P.E. (DelDOT)	Under part b., how are proposed stormwater management facilities supposed to conform to local building standards?	The section was revised to require conformance with local zoning and subdivision and land development requirements?
40	II	Standards and Criteria	V-5	Vincent W Davis, P.E. (DelDOT)	Part d. and Part e. basically state the same thing, couldn't these be combined?	Part d. is intended to address issues pertaining to soils whereas Part e. contains general design guidelines that are separate from the soils. The sections are retained as separate sections.
41	II	Standards and Criteria	V-5	Vincent W Davis, P.E. (DelDOT)	Part d., subpart ii, hydraulic conductivity tests are DNREC acceptable?	The section was revised to indicate that other infiltration methods may be accepted as long as they are consistent with current DNREC policies.
42	II	Standards and Criteria	V-5	Vincent W Davis, P.E. (DelDOT)	Part d., subpart iii, need examples of nonstructural GTBMP's.	Examples of GTBMPs are provided at the top of the page. Most GTBMPs do not require infiltration testing; therefore, they were not included in Part d.
43	II	Standards and Criteria	V-5	Vincent W Davis, P.E. (DelDOT)	Part d., subpart iv. Who would inspect and maintain individual on-lot infiltration structures?	The section was revised to indicate that individual homeowners or property owners are responsible for inspection and maintenance of these systems.
44	II	Standards and Criteria	V-6	Vincent W Davis, P.E. (DelDOT)	Part e., subparts iv. and vi., is the infiltration rate as measured or after dividing by 2?	The section was revised to indicate that establishment of the soil infiltration rate must be consistent with current DNREC policies.
45	II	Standards and Criteria	V-6	Vincent W Davis, P.E. (DelDOT)	Part e., subpart v. from where was the 7:1 ratio derived and why is this ration significant.	One of the common causes of infiltration BMP failure is clogging caused by overloading the system with larger amounts of stormwater runoff. The ratio is based on the PA Stormwater BMP manual, and several other studies from Villanova University and other watersheds in Pennsylvania.

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No.	Volume	Section	Page	Comment Provided By	Comment	Response
46	II	Standards and Criteria	V-6	Vincent W Davis, P.E. (DelDOT)	Part e., subpart ix, what is the definition of a structure. Houses, shops, sheds, outlet structures, bridges, certain pipe sizes, etc..?	The narrative was revised to define a structure as any building, foundation, or other elements of construction that when constructed were not intentionally designed to be regularly inundated by groundwater or stormwater runoff and were not deliberately designed to mitigate the effects of such inundation upon the structure and its surroundings.
47	II	Standards and Criteria	V-6	Vincent W Davis, P.E. (DelDOT)	Part e., subpart xi. What is non erosive velocity? For grass, stone..? I believe a better declaration would be to state that the outfall protection shall be in accordance with HEC-14 and or within acceptable velocity and shear stress limits for turf reinforcement mats.	The section was revised to reference HEC-14 and indicate that turf reinforcement mats may be used if their performance is within the accepted performance standards for velocity and shear stress and consistent with current DNREC policy on application of such materials.
48	II	Standards and Criteria	V-7	Vincent W Davis, P.E. (DelDOT)	Part e. subpart xv, what kinds of safeguards need to be installed and what kind of caution needs to be exercised in Source Water Protection Areas?	The section was revised to indicate examples of safeguards that may be used and the type of caution necessary to protect such facilities in source water protection areas.
49	II	Standards and Criteria	V-8	Vincent W Davis, P.E. (DelDOT)	Part i., does this water quality volume represent the difference between the 1" runoff and what can possibly be infiltrated or the total volume of the 1" runoff? Even if infiltration is achieved partially, I would like to request that computationally the whole 1" runoff volume be considered, because otherwise you could have orifice sizes too small for any practical purposes.	The water quality volume is equivalent to 1-inch of stormwater runoff. The section reducing the amount of the water quality volume based upon groundwater recharge was eliminated.

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50	II	Standards and Criteria	V-8	Vincent W Davis, P.E. (DelDOT)	Part ii., two BMP's have to be used even if one works?	Demonstration of meeting the plan's water quality performance standards are intended to be achieved qualitative instead of quantitatively. Therefore, if it can be shown that two methods of treatment are applied along with the other standards mentioned in the plan to address water quality, the water quality standard is considered .
51	II	Standards and Criteria	V-8	Vincent W Davis, P.E. (DelDOT)	Under part iii., what about areas that for all intense and purposes cannot be treated? Ex. Bridges	The section was revised to indicate that in cases where it can be demonstrated that achieving this standard may require significantly more disturbance to the environment than not implementing this standard, this criteria may be waived upon approval from DNREC.
52	II	Standards and Criteria	V-8	Vincent W Davis, P.E. (DelDOT)	Part iv., This paragraph conflicts with the first paragraph . Is the 1" runoff being treat or the 2 yr, 24 hour storm event? Different sub-areas will have different curve numbers.	This section of the plan was revised to indicate that if the Groundwater Recharge Volume is greater than the Water Quality Volume and it can be demonstrated that the groundwater recharge volume is recharged on site, the water quality requirements shall be considered satisfied
53	II	Standards and Criteria	V-8	Vincent W Davis, P.E. (DelDOT)	Under 1rst full paragraph, so what is actually going to govern for water quality aspects? Basically what will be the order of compliance: DSSR, NPDES, Watershed Plan?	The most stringent standards will apply. For instance, if an NPDES permit is required and it indicates peak rate controls cannot exceed existing conditions, then the maximum post construction release rate would be 100% regardless if the project is in a conditional no detention district or not. Conversely, if the project is in management district where a release rate is applied, then the watershed plan's release rates would be appropriate and not the post development to predevelopment peak rate of release allowed by NPDES.

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54	II	Standards and Criteria	V-8	Vincent W Davis, P.E. (DelDOT)	Part a., which water body resource areas are designated for protection? Will there be a list made available?	The plan was revised to indicate that a list of water resources designated for special protection can be obtained from DNREC's Division of Water Resources, Watershed Assessment Section.
55	II	Standards and Criteria	V-8	Vincent W Davis, P.E. (DelDOT)	Part b, would this apply to roads that have a 1-2 foot widening, sidewalks, new maintenance strips for guide rail, etc.? Offsite areas are not required to be included, but they wouldn't be included anyway, correct? Does this mean that if an offsite area flows through a particular BMP, then it doesn't have to be included for that particular BMP sizing?	Exemption criteria was added to the plan to exempt small projects from the plan requirements. Regardless, many small projects such as those cited can be adequately managed with non-structural BMPs. Offsite areas are not subject to the water quality requirements
56	II	Standards and Criteria	V-10	Vincent W Davis, P.E. (DelDOT)	Under 3rd paragraph, what is the definition of partially disturbed?	The cited paragraph was revised to clarify the partial disturbance of drainage area.
57	II	Standards and Criteria	V-10	Vincent W Davis, P.E. (DelDOT)	The 1rst and 3rd paragraphs seem to contradict one another?	The third paragraph was revised for clarification.
58	II	Standards and Criteria	V-10	Vincent W Davis, P.E. (DelDOT)	Part a. how was the maximum allowable velocity determined? What is the definition of "natural resource area"?	The noted section was revised to indicate that in the absence of supporting data and computations that indicate otherwise the maximum velocity to unstabilized natural channels shall not exceed 2.5 ft/s. The maximum velocity was established as the minimum velocity necessary to transport fine non-colloidal sand.
59	II	Standards and Criteria	V-10	Vincent W Davis, P.E. (DelDOT)	Parts b. and c., shouldn't this design work be done anyway? I think it would be more prevalent to reference HEC manuals than the DNREC E&S Handbook for the reason being that the HEC manuals are on-line and changes to those manuals would happen quicker than the handbook	Parts b and c are coincidental with most erosion and sediment pollution controls applied to many development sites. The section was revised to indicate that HEC documentation is an acceptable source for alternative methods of engineering analysis.

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No.	Volume	Section	Page	Comment Provided By	Comment	Response
60	II	Standards and Criteria	V-10	Vincent W Davis, P.E. (DelDOT)	Part d. required to use a perforated vertical riser? What about a V-notch weir? Or an orifice with a trash rack/hood? I know at Del DOT, we were not specifying perforated vertical risers as they were very maintenance intensive.	A weir is an acceptable means of controlling the flow. Part d. was revised to indicate that other means of preventing clogging of a small orifice or weir are acceptable.
61	II	Standards and Criteria	V-11	Vincent W Davis, P.E. (DelDOT)	DelDOT would like to request some detailed maps of all the district boundaries, so as to make sure we know their locations.	Detailed maps can be obtained from DNREC at the conclusion of the project. In areas where a site may be in close proximity to a district boundary the appropriate management district should be identified by field investigations to determine where the stormwater runoff is flowing.
62	II	Standards and Criteria	V-12	Vincent W Davis, P.E. (DelDOT)	Under 3rd paragraph, how does the discharge rate compare to the new state wide regulations?	The peak rate controls proposed by the plan for overbank events are more stringent than the state wide regulations.
63	II	Standards and Criteria	V-18	Vincent W Davis, P.E. (DelDOT)	Under 1rst paragraph last sentence, what would be the definition of "safe conveyance"? Would the same definition apply to a ditch flowing through a woods/field versus next to a road? What about a closed drainage system	As defined in the text, safe conveyance is any means that conveys runoff downstream without causing either temporary or permanent damage to the environment, private property and public property; and without endangering the safety, health and welfare of the public. Regardless of the location or situation any feature that fulfills this criteria would be considered safe conveyance.
64	II	Standards and Criteria	V-20	Vincent W Davis, P.E. (DelDOT)	Under District C, 2nd paragraph, last sentence, this sentence is not very clear. Are DelDOT, Municipalities, and other entities that own conveyance systems required to provide capacity for anyone that wants it? What about right of way issues, drainage design standards, etc.	The referenced sentence was revised to provide clarification as to the amount of available conveyance any single developer may claim for use in a no detention district. Owners of downstream conveyance systems are not required to provide additional conveyance for changes that occur upstream in the watershed that they are not responsible for.

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65	II	Standards and Criteria	V-22	Vincent W Davis, P.E. (DelDOT)	Under 1st paragraph, last sentence, who decides what points to pick downstream to compare pre and post-developed hydrographs?	The plan was revised to identify locations where flows shall be quantified to complete the analysis. DNREC or a designated agency with authority to approve stormwater plans will have authority to accept and approve the no harm option.
66	II	Standards and Criteria	V-22	Vincent W Davis, P.E. (DelDOT)	Under 1st bullet, who decides when the hydrologic regime of a post construction condition is maintained?	DNREC or a designated agency with authority to approve stormwater plans will have authority to accept and approve the no harm option.
67	II	Standards and Criteria	V-22	Vincent W Davis, P.E. (DelDOT)	Under 2nd bullet, who decides what is and what is not an adverse impact?	DNREC or a designated agency with authority to approve stormwater plans will have authority to accept and approve the no harm option.
68	II	Standards and Criteria	V-22	Vincent W Davis, P.E. (DelDOT)	Under 4th bullet, are comparisons of peak flow done with or without the 25% meadow condition?	Proof of no harm should be demonstrated by applying the 25% meadow condition to the existing condition.
69	II	Standards and Criteria	V-22	Vincent W Davis, P.E. (DelDOT)	Under the 5th bullet who will make the decision of approving capacity improvements if the items in question are owned by another entity and/or person(s)? Who would inspect and sign off on the upgrades once they are in construction?	All proposed modifications to downstream offsite improvements not owned by the entity responsible for changing the hydrologic regime of the watershed must be authorized and approved by the owner and/or operator of the offsite facilities.
70	II	Standards and Criteria	V-23	Vincent W Davis, P.E. (DelDOT)	Under 1st bullet, were DelDOT drainage standards (DelDOT roadside Design Guide, Chapter 6) not considered? A 25 yr return period would not work for any closed drainage system as they are only designed for 10-year storm events.	The referenced section was deleted from the plan.
71	II	Standards and Criteria	V-23	Vincent W Davis, P.E. (DelDOT)	D. Stormwater Hotspots, 1st paragraph, who decides what areas are "hotspots" and how big of an area that covers?	The section was revised to indicate, designation as a hotspot or the spatial limits of a hotspot shall remain the exclusive right of DNREC.

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##	II	Standards and Criteria	V23	Vincent W Davis, P.E. (DelDOT)	D. Stormwater Hotspots, 2nd paragraph last sentence, what is the definition of proper management?	The paragraph was revised to clarify that stormwater runoff from large highways should be properly managed to minimize the conveyance of pollutants.
##	II	Standards and Criteria	V25 & V26	Vincent W Davis, P.E. (DelDOT)	Wrong tables are referenced in the verbiage.	The table references were revised to reference the appropriate tables.

DISCIPLINES

Architecture

Automation

Bridge Design

Drainage Design

Environmental

Electrical Design

Highway Design

Hydraulics & Hydrology

Land Development

Land Surveying

Mechanical Design

Structural Design

Traffic Design

Water & Wastewater Design

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