PUBLIC MEETING NOTICE

Pennypack Watershed Act 167
Stormwater Management Plan

Date: June 14th, 2011

Time: 7:00 P.M. - 8:30 P.M.

Where: Upper Moreland Township Building
117 Park Avenue
Willow Grove, PA 19090

Pennypack Creek Watershed
Act 167 Plan

Prepared by the

Center for Sustainable Communities
TEMPLE UNIVERSITY®

Edited by Richard Fromuth, P.E., Research Fellow
April 2011

Table of Contents

		Page
Introduction		i
Section 1: Watershed Location and Setting		
Section 2: Watershed Characteristics and Runoff		
2.1	Precipitation	2-1
2.2	Surface Features	2-3
2.3	Projected Growth and Land Use Projections	2-14
Section 3: Stormwater Problems		
3.1	Flooding	3-1
3.2	Stream Impairment	3-3
3.3	Drainage and Stormwater Collection Systems	3-4
Section 4: Model Development and Application		
4.1	Testing of the Original 10 Subbasin Model	4-1
4.2	Development of the Act 167 Hydrologic Model	4-2
4.3	Hydrologic Model Test Results	4-9
4.4	Modeling Assumptions	4-11
4.5	Model Applications	4-12
Section 5: Criteria and Standards for New Development		
5.1	Model Ordinance Summary	5-1
5.2	Applicability and Exemptions	5-2
5.3	Stormwater Management Criteria	5-5
Section 6: Stormwater Improvements		
6.1	Detention Storage Facilities	6-2
6.2	Potential Infiltrations Sites	6-3
6.3	Riparian Buffer Restoration	6-5
6.4	Hydrologic Impact of the Proposed Improvements	6-6
6.5	Improvement Site Ranking	6-11
Section 7: Plan Implementation		
7.1	Municipal Adoption of Ordinance	7-1
7.2	Municipal Implementation of Stormwater Improvements	7-3
7.3	County-Wide Coordination	7-4
7.4	Commonwealth of Pennsylvania Actions	7-4
7.5	Landowners' and Developers' Responsibilities	7-5
7.6	Plan Review	7-5
7.7	Milestones	7-5

Appendix A: Model Ordinance
Appendix B: Hydrologic Model Parameters and Release Rates
Appendix C: Recommended Improvements
Appendix D: Pennypack Watershed Culverts

List of Figures

1.A	Watershed Overview	1-2
1.B	Major Tributaries and Basins	1-3
2.1.A	Precipitation Events in the Pennypack Watershed	2-2
2.2.A	Elevation (DEM)	2-6
2.2.B	Hydrologic Soil Groups	2-7
2.2.C	Soil Erodibility	2-8
2.2.D	2005 Land Use	2-9
2.2.E	Flash Flood Potential Index	2-10
2.2.F	Detention Basin and Pond Locations	2-11
2.2.G	Stormwater Collection and Outfalls	2-12
2.2.H	Stormwater Outfalls	2-13
2.2.I	Sample Stormwater Collection System Map (Horsham Twp)	2-14
2.3.A	Trend Projection Land Use	2-21
2.3.B	Green Projection Land Use	2-22
3.1.A	Pennypack Watershed Floodplains	3-6
3.1.B	Huntington Valley Creek 100-Year Floodplain Focus Area	3-7
3.1.C	Flood Insurance Claims	3-8
3.1.D	Recurring Flood Insurance Claims	3-9
3.1.E	Obstructions	3-10
3.1.F	Floods Exceeding Obstruction Capacity	3-11
3.1.G	Vulnerable Bridges	3-12
3.2.A	Stormwater Problem Locations (Suburban Municipalities)	3-13
3.2.B	Stream Bank Erosion Example (Lower Moreland Twp)	3-14
3.2.C	Water Quality Impairment	3-15
4.1.A	Pennypack 10 Subbasin Model Diagram	4-1
4.1.B	Development and Calibration of the Subbasin Hydrologic Model	4-2
4.1.C	Distribution of Observed Precipitation for Testing of Model	4-3
4.1.D	Observed vs. Modeled Peak Flows - Original 10 Subbasin Model	4-3
4.1.E	Observed vs. Modeled Event Volume - Original 10 Subbasin Model	4-4
4.2.A	Subbasins Overview	4-5
4.2.B	Runoff Curve Numbers	4-6
4.2.C	Impervious Cover	4-7
4.2.D	Sample Stream Reaches	4-8
4.3.A	Points of Comparison for Testing of Act 167 Model	4-10
4.3.B	Model Test Results – Upper Portion of Pennypack Creek	4-10
4.3.C	Model Test Results – Lower Portion of Pennypack Creek	4-11
4.5.A	Comparison of Existing vs. “Undeveloped” Runoff Conditions	4-13
4.5.B	Changes in Impervious Cover for Land Use Projections	4-14
4.5.C	Hydrologic Impact of Projections at Rhawn Street	4-15
4.5.D	Subbasins with Highest Volume Increases – Trend Scenario	4-16
4.5.E	Subbasins with Highest Volume Increases – Green Scenario	4-16
4.5.F	Points of Interest Used for Modeling to Determine Release Rates	4-19
4.5.G	Proposed Peak Rate Control Management Districts	4-20

4.5.H	Impact on Peak Discharge and Runoff Volume of Improvements	4-21
5.3.A	Proposed Peak Rate Control Management Districts	5-9
6.A	Potential Improvements in the Watershed	6-1
6.1.A	Sample Detention Basin Site Map	6-3
6.2.A	Sample Infiltration Site Map	6-4
6.3.A	Sample Riparian Buffer Restoration Site Map	6-6
6.4.A	Peak Discharge Reduction by Subbasin	6-8
6.4.B	Runoff Volume Reduction by Subbasin	6-9
6.4.C	Huntington Valley Creek Improvements Model Output	6-10
6.4.D	Southampton Creek Improvements Model Output	6-10
6.4.E	Tributary to Pennypack Creek Improvements Model Output	6-11
6.5.A	Improvement Scores	6-12

List of Tables

i.1	Required Contents of Stormwater Plans	v
1.1.A	Population by Municipality	1-1
2.1.A	Storm rainfall totals for 24 hour storms	2-2
2.3.A	Forecasted Population Growth and Housing Unit Construction	2-15
2.3.B	Land Consumption Rates: Trend Development Scenario	2-16
2.3.C	Trend Scenario Land Allocation	2-18
2.3.D	Land Consumption Rates: Green Development Scenario	2-19
2.3.E	Green Scenario Land Allocation	2-20
3.1.A	Buildings Affected by Floodplains	3-5
5.2.A	Eligibility for Exemptions for Bucks and Montgomery Portions	5-3
5.2.B	Eligibility for Exemptions for Philadelphia County Portion	5-4
5.3.A	Peak Rate Control Standards	5-8
6.3.A	Potential Total Riparian Buffer Restoration Areas by Municipality	6-5
7.1.A	Status of Ordinances	7-2
7.2.A	Reduced Volume Reduction Targets	7-4
7.7.A	Milestones for Implementing the Act 167 Plan	7-5

Introduction

This plan has been developed for the Pennypack Creek Watershed in Bucks, Montgomery, and Philadelphia counties, Pennsylvania, to comply with the requirements of the Pennsylvania Stormwater Management Act of 1978, also known as Act 167. The Act requires Pennsylvania counties to prepare and adopt stormwater management plans for each watershed located in the county, as designated by the Pennsylvania Department of Environmental Protection (DEP). It also requires municipalities to implement a stormwater management ordinance limiting stormwater runoff from new development and redevelopment.

The main objective of the plan is to control stormwater runoff on a watershed basis rather than on a site-by-site basis, taking into account how development and land cover in one part of the watershed will affect stormwater runoff in all other parts of the watershed. Consistent with Act 167, the plan seeks to:

- preserve and restore the flood carrying capacity of watershed streams;
- reduce erosion and sedimentation;
- preserve natural stormwater runoff regimes and the natural course, current and cross sections of streams; and
- protect and conserve ground water and ground water recharge areas.

The plan also seeks to address serious water quality problems that are noted in Section 3. The vast majority of the watershed's streams are considered impaired according to water quality reports prepared by the Department of Environmental Protection. Through implementation of the stormwater improvements recommended in Section 6 and Appendix C, the plan will simultaneously reduce flooding, erosion and sedimentation, and improve water quality.

The final plan offers a unique and highly analytical approach to the Act 167 planning process that incorporates watershed scale hydrologic and hydraulic modeling. While all study elements required for an Act 167 study were completed as listed in Table 1.1, the study team expanded the analytical work to include the evaluation of alternative stormwater improvements to determine their effectiveness in reducing runoff and improving water quality. They are listed in Section 6. As this watershed is essentially "built-out," we concentrated much of our research on identifying opportunities for retrofitting existing stormwater facilities and finding locations for new Best Management Practices, or BMPs, in areas that are not currently served by stormwater facilities. Restoration of riparian stream buffers is recommended as an opportunity to address the goal of preserving and restoring flood carrying capacity of streams. We strongly endorse the use of stormwater BMPs as the preferred means to achieve improved water quality, groundwater recharge and retention, stream bank protection, and volume control. The implementation of these retrofits and new BMPs in conjunction with regulation of new development and redevelopment through new stormwater ordinances will reduce stormwater problems in the Pennypack Creek Watershed. The plan encourages municipalities to construct the stormwater improvements over a ten-year period. The various improvements are assigned a priority according to their cost-effectiveness and capture potential, and municipalities can use this ranking as a basis for funding projects.

The final plan presents criteria and standards for new development and redevelopment in Section 5 and a model ordinance in Appendix A. Within six months of the adoption of the plan, each municipality shall adopt or amend ordinances and regulations, including zoning, subdivision and development, building codes, and erosion and sedimentation ordinances, as are necessary to regulate development within the municipality in a manner consistent with the plan. The project team recommends that the municipalities adopt the model ordinance in its entirety as part of its zoning regulations. If the municipality lies in more than one watershed, the applicable criteria and standards should be identified for the different watersheds.

The Pennypack Plan was prepared by Temple University's Center for Sustainable Communities (CSC) with assistance from NTM Engineering, Inc. The plan was funded by the Philadelphia Water Department and prepared in consultation with municipalities located in the watershed, working through a Watershed Plan Advisory Committee (WPAC) comprised of municipal officials and other interested parties. The plan provides uniform technical standards and criteria throughout the watershed for the management of stormwater runoff from new land development and redevelopment sites.

The plan consists of seven sections and four appendices:

Section 1:	Pennypack Watershed Location
Section 2:	Watershed Characteristics and Runoff
Section 3:	Stormwater Problems
Section 4:	Model Development and Application
Section 5:	Criteria and Standards for New Development
Section 6:	Stormwater Improvements
Section 7:	Plan Implementation
Appendix A:	Model Ordinance
Appendix B:	Hydrologic Model Parameters and Release Rates
Appendix C:	Recommended Improvements
Appendix D:	Pennypack Watershed Culverts

The Project Team and members of the Water Plan Advisory Committee follow. The team expresses its appreciation to Joanne Dahme, Marc Cammarata, and James Knighton of the Philadelphia Water Department for their oversight and technical support, and to Paul Racette of the Pennsylvania Environmental Council for his coordination of the work of the WPAC.

Project Team

Project Director

Jeffrey Featherstone, Ph.D., Center for Sustainable Communities and Department of Community and Regional Planning

Faculty, Research Fellows, and Staff

Manahel Awda, Ph.D., Adjunct Professor, Department of Civil and Environmental Engineering: Hydrologic and Hydraulic Modeling

Richard Fromuth, P.E., C.R.P., Research Fellow, Center for Sustainable Communities: Modeling Supervision, Stormwater Assessment

Md Mahbubur R. Meenar, M.U.P., Center for Sustainable Communities: GIS and Mapping

Richard Nalbandian, M.R.P., M.S., P.G., Center for Sustainable Communities and Department of Community and Regional Planning: Field Evaluation and Stormwater Assessment

Susan Spinella, M.S., Center for Sustainable Communities: Budgeting and Administration

Consultants

David Betzner, Aero2 Inc.: Orthophotography and Photogrammetry

Paul DeBarry, P.E. NTM Engineering Inc.: Technical Advisor

Derron LaBrake, PWS, Matrix New World Engineering, Inc.: BMP Cost Estimation

Graduate Student Assistants

Donna Fabry, Kyle Guie, Josiah Mount, Scott Murray, Matthew Popek, Sequoia Rock

Water Plan Advisory Committee Members

Alexis Melusky, Montgomery County Planning Commission
Alice Walters, Bucks County Planning Commission
Allison Hastings, Delaware Valley Regional Planning Commission
Bill Walker, Horsham Township
Brad Nyholm, Pennypack Ecological Restoration Trust
Carl Loscalzo, Upper Southampton Township Environmental Advisory Committee
Christopher Hoffman, Lower Moreland Township
David Burke, Pennsylvania Department of Environmental Protection
David Dodies, Upper Moreland Township
David Robertson, Pennypack Ecological Restoration Trust
Dick Sayer, Huntington Valley Country Club

Donna Pitz, GreenSpace Alliance
Dulcie Flaharty, Montgomery County Land Trust
Elaine Rosenberg-Cotton, Abington Environmental Advisory Council
Emma Gutzler, Delaware RiverKeeper and Abington Environmental Advisory Council
Gerald Bright, Philadelphia Water Department
Jason Cruz, Philadelphia Water Department
Jason Showmaker, Rockledge Borough
Jeffrey Featherstone, Temple University Center for Sustainable Communities
Jennifer Kehler, Pennsylvania Department of Environmental Protection
Jennifer Sherwood, Abington Environmental Advisory Council
Jim Kates, Friends of Fox Chase Farm
Jim Ryan, Friends of Pennypack Park
Joan Blaustien, Fairmount Park Commission
Joanne Dahme, Philadelphia Water Department
John Rogers, Keystone Conservation Trust
Jon Lesher, Montgomery County Planning Commission
Jonathan de Jonge, Upper Moreland Environmental Advisory Committee
Karen Thompson, watershed resident
Lauren Steel, Pennypack Ecological Restoration Trust
Lia Mastropolo, GreenSpace Alliance
Lisa Romaniello, Upper Moreland Township
Maggie Allio, Philadelphia Water Department
Mahbubur Meenar, Temple University Center for Sustainable Communities
Michael Coll, Pennypack Ecological Restoration Trust
Michael Golden, Upper Southampton Township
Michelle Kaczalek, Abington Township Environmental Advisory Committee
Mickey Hartey, Hatboro Borough
Mike McGee, Horsham Township
Mike Wilson, Project Headwaters
Mindy Lemoine, Pennsylvania Environmental Council
Patrick Starr, Pennsylvania Environmental Council
Paul Racette, Pennsylvania Environmental Council
Peter Kurtz, Pennypack Environmental Center, Fairmount Park Commission
Randee Elton, Lower Moreland Township
Rea Monaghan, Bucks County Planning Commission
Richard Booth, Pennypack Greenway Partnership, Pennypack Ecological Restoration Trust, and Upper Moreland Township
Richard Fromuth, Temple University Center for Sustainable Communities
Richard Greer, Bryn Athyn Borough
Richard Nalbandian, Temple University Center for Sustainable Communities
Scott Anderson, Huntington Valley Country Club
Scott Morgan, Lorimer Park, Montgomery County
Stephanie Hoffer, Philadelphia Parks and Recreation Department
Susan Harris, Montgomery County Conservation District
Tiffany Ledesma Groll, Philadelphia Water Department
Tony Federici, URS Corporation

Table i.1 Required Contents of Watershed Storm Water Plans Under Sections 5(b) and 5(c) of Act 167

Required Elements Under Section 5(b)	Location in Pennypack Plan
(1) A survey of existing runoff characteristics in small as well as large storms, including the impact of soils, slopes, vegetation and existing development;	Section 2
(2) A survey of existing significant obstructions and their capacities;	Section 3, Appendix D
(3) An assessment of projected and alternative land development patterns in the watershed, and the potential impact of runoff quantity, velocity and quality;	Section 2
(4) An analysis of present and projected development in flood hazard areas, and its sensitivity to damages from future flooding or increased runoff;	Section 2, Section 3
(5) A survey of existing drainage problems and proposed solutions;	Section 3, Section 6, Appendix C
(6) A review of existing and proposed storm water collection systems and their impacts;	Section 2
(7) An assessment of alternative runoff control techniques and their efficiency in the particular watershed;	Section 6, Appendix C
(8) An identification of existing and proposed State, Federal and local flood control projects located in the watershed and their design capacities;	There are no Flood Control Projects located in the watershed
(9) A designation of those areas to be served by storm water collection and control facilities within a ten>year period, an estimate of the design capacity and costs of such facilities, a schedule and proposed methods of financing the development, construction and operation of such facilities, and an identification of the existing or proposed institutional arrangements to implement and operate the facilities;	Section 6, Section 7, Appendix C
(10) An identification of flood plains within the watershed;	Section 3
(11) Criteria and standards for the control of storm water runoff from existing and new development which are necessary to minimize dangers to property and life and carry out the purposes of this act;	Section 5, Appendix A
(12) Priorities for implementation of action within each plan; and	Section 7
(13) Provisions for periodically reviewing, revising and updating the plan.	Section 7

Table i.1 Continued

Required Elements Under Section 5(c)	Location in Pennypack Plan
(1) contain such provisions as are reasonably necessary to manage storm water such that development or activities in each municipality within the watershed do not adversely affect health, safety and property in other municipalities within the watershed and in basins to which the watershed is tributary; and	Section 5, Appendix A
(2) consider and be consistent with other existing municipal, county, regional and State environmental and land use plans.	Section 5

Section 1: Watershed Location and Setting

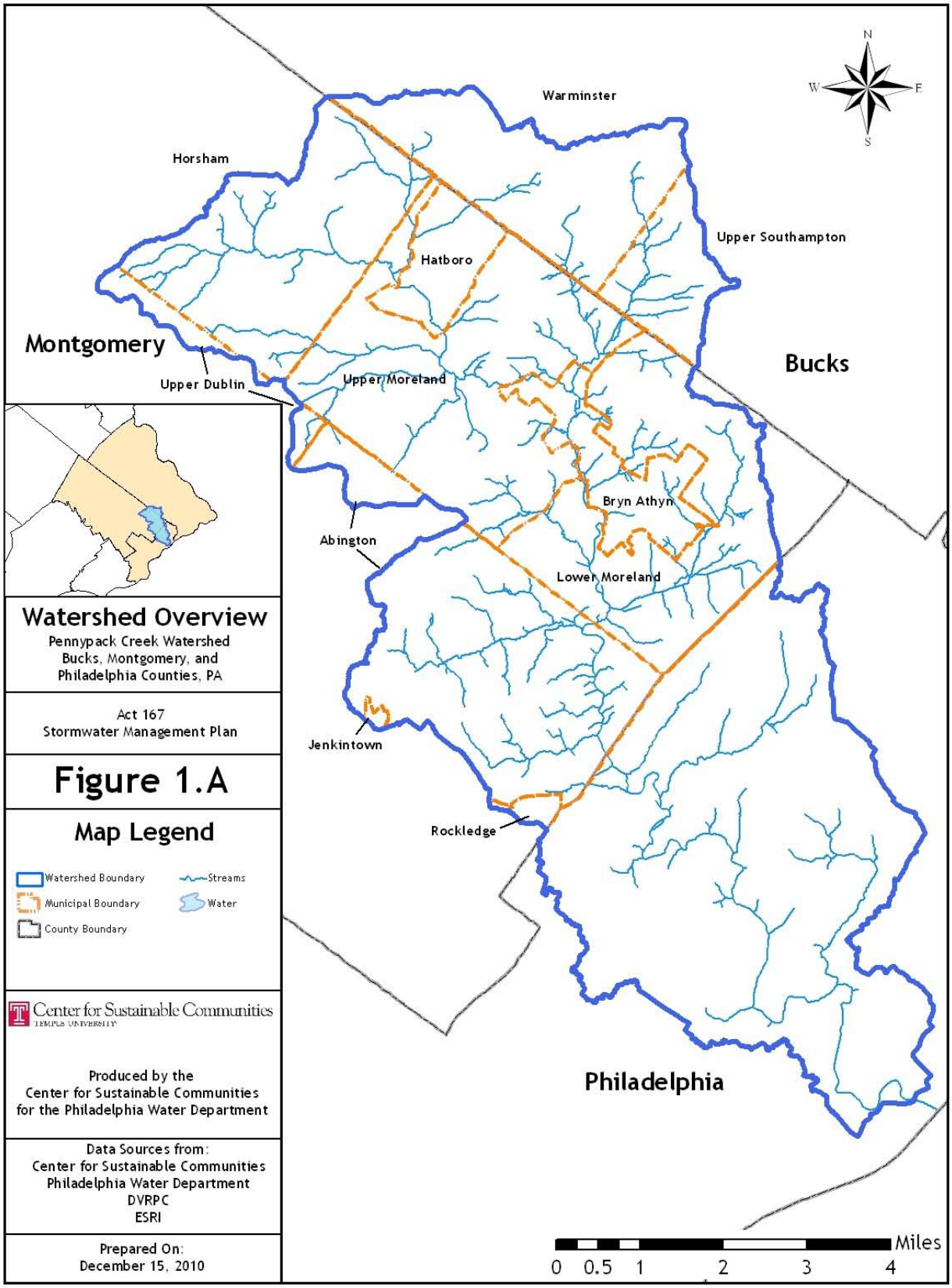
The Pennypack Creek Watershed is located in southeastern Pennsylvania. It covers 56 square miles and includes a population of approximately 300,000 people (2000 Census). The watershed includes the 1,334 acre Pennypack Park, part of the Fairmount Park system; Lorimer Park in Montgomery County; the Pennypack Ecological Restoration Trust, which protects 720 acres of land in Montgomery County; as well as many additional suburban "pocket" parks and preserves.

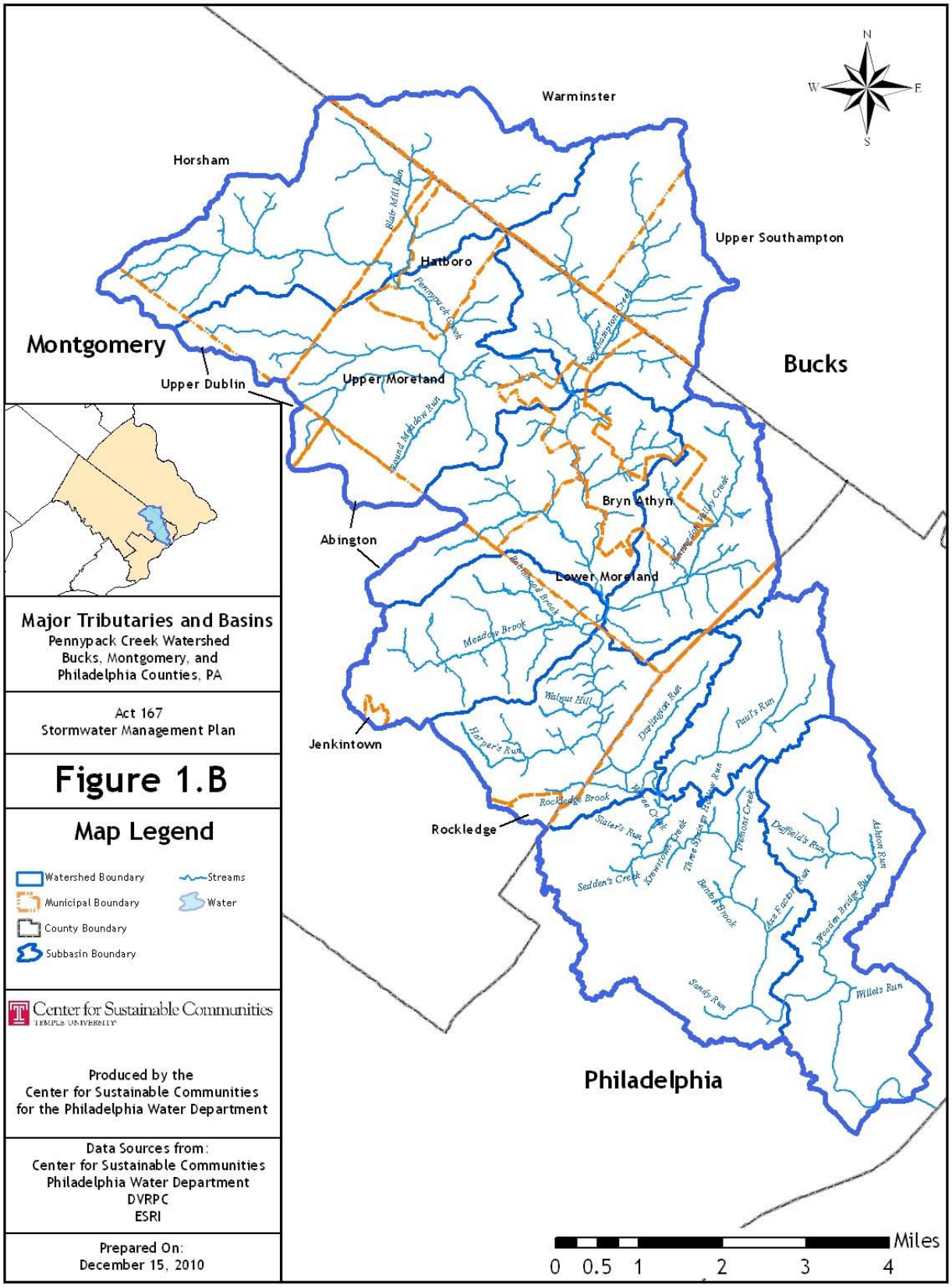
The watershed lies within the lower Delaware River Basin and discharges to the Delaware River in the City of Philadelphia. Most of the watershed is located in Montgomery County, with additional smaller portions in Bucks and Philadelphia Counties (Figure 1.A). A total of 12 municipalities lie either all or partially within the watershed. The population of those municipalities is provided in Table 1.1.A, along with the percentage of the watershed draining each municipality.

The flow regimen in Pennypack Creek and the interrelationships between surface and groundwater within its watershed are complicated not only by development and other human activities within the basin, but also by its complex environmental character. In particular, the bedrock geology is highly diverse and the geologic history spans more than 600 million years. There are great differences in the physical characteristics of the many different rock types within the watershed. Their textures, mineral compositions, hardnesses, permeabilities; the differences in the ways in which they weather and decompose, and the resulting differences in the soils and terrains developed on them; all these factors influence the ways in which water moves over, into, and through them. Consequently, the hydrologic regimen of the Pennypack Creek and its tributaries varies greatly from place to place within the larger watershed. Figure 1.B shows the main stem and major tributaries to the Pennypack Creek.

Table 1.1.A Population by Municipality

Municipality	2000 Census	2008 DVRPC Estimates	Municipality % in Watershed	2008 Est. Pop in Watershed
Abington Township	56,105	53,980	50.45%	27,233
Bryn Athyn Borough	1,350	1,327	100.00%	1,327
Hatboro Borough	7,390	7,125	100.00%	7,125
Horsham Township	24,234	24,720	42.70%	10,556
Jenkintown Borough	4,475	4,299	9.57%	411
Lower Moreland Township	11,280	12,646	80.93%	10,234
Rockledge Borough	2,575	2,478	64.31%	1,594
Upper Dublin Township	25,875	25,910	6.08%	1,577
Upper Moreland Township	24,990	24,183	99.45%	24,050
Upper Southampton Township	15,765	15,249	24.46%	3,730
Warminster Township	31,383	33,651	48.31%	16,255
Philadelphia County	1,517,549	1,447,395	14.62%	211,566


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Miles
0 0.5 1 2 3 4
Watershed Overview
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 1.A
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
Blair Mill Run
Pennypack Creek
Southampton Creek
Round Meadow Run
Hunsdon Valley Creek
Meadow Brook
Walnut Hill
Harper's Run
Darlington Run
Paul's Run
Rockledge Brook
Slater's Run
Sedden's Creek
Krewstown Creek
Three Springs Hollow Run
Tremont Creek
Duffield's Run
Ashton Run
Benton Brook
Axe Factory Run
Wooden Bridge Run
Sandy Run
Willets Run
N
S
E
W
Miles
0 0.5 1 2 3 4
Major Tributaries and Basins
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 1.B
Map Legend
Watershed Boundary
Municipal Boundary
County Boundary
Subbasin Boundary
Streams
Water
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010

Section 2: Watershed Characteristics and Runoff

The hydrologic regimen of the Pennypack Creek and its tributaries varies greatly from place to place within the larger watershed. Stormwater management planning must take numerous surface features into account, including topography, soils, land use, and impervious cover, as well as existing stormwater collection and discharge. This section describes the primary factors defining the storm runoff in the watershed. In addition, because of the close linkage between land cover and runoff, an analysis of land development alternatives to meet projected future growth is provided.

2.1 Precipitation

Precipitation in the Pennypack Watershed averages 42 inches per year, yet extreme events can bring one-fifth of that total in a single day. Flood events can occur during any month of the year, and may be caused by different types of weather events including severe thunderstorms, tropical storms, or even colder weather events when heavy rains can combine with snowmelt. Under certain conditions precipitation events in the watershed are influenced by its location at the boundary between the Coastal Plain and Piedmont physiographic provinces. This boundary is often referred to as the Fall Line. During some events when moisture from the Atlantic Ocean is moving northward, the humid air moving from the south and east is lifted and cooled slightly as it is forced over the watershed's higher elevations. Although the elevation change is not dramatic, it can enhance triggering of heavy precipitation under certain conditions.

Table 2.1.A lists design rainfall totals that have been applied to the hydrologic analyses in this study and to the recent flood insurance study for the Pennypack Watershed. These totals were obtained from NOAA Atlas 14, which is based on statistical analysis of rainfall for given storm durations. The values listed are for the upper limit of the 90 percent confidence interval for 24-hour rainfall events of a given frequency. The meaning of the terminology used in storm frequency is as follows: a 5-year event would have a 20 percent chance of occurring in a given year; a 10-year event would have a 10 percent chance of occurring in a given year, etc. The rainfall totals in the table provide a means of predicting the magnitude of storms for planning and design purposes. They are a statistical product based on what has occurred in the past. They are not predictive of the timing or sequence of individual storm events or their rainfall distribution in the watershed. The extreme precipitation events caused by tropical storms Floyd and Allison occurred less than two years apart.

Although extreme storm events trigger the most damaging flooding in the Pennypack Watershed, most storms produce less than one inch of rainfall. In fact, the majority of the annual runoff volume is produced by such storms. For this reason, stormwater management measures designed for infiltration or extended detention of these smaller runoff events is effective in reducing non-point pollution loadings and stream erosion. Precipitation data for 2007 in the central portion of the Pennypack watershed is presented in Figure 2.1.A. The graph shows the total precipitation for each event and the distribution of these events during the January through November period. Of the 57 events, only two produced a total rainfall exceeding two inches, and only seven events (13 percent) exceeded one inch.

Table 2.1.A Storm Rainfall Totals for 24-Hour Storms

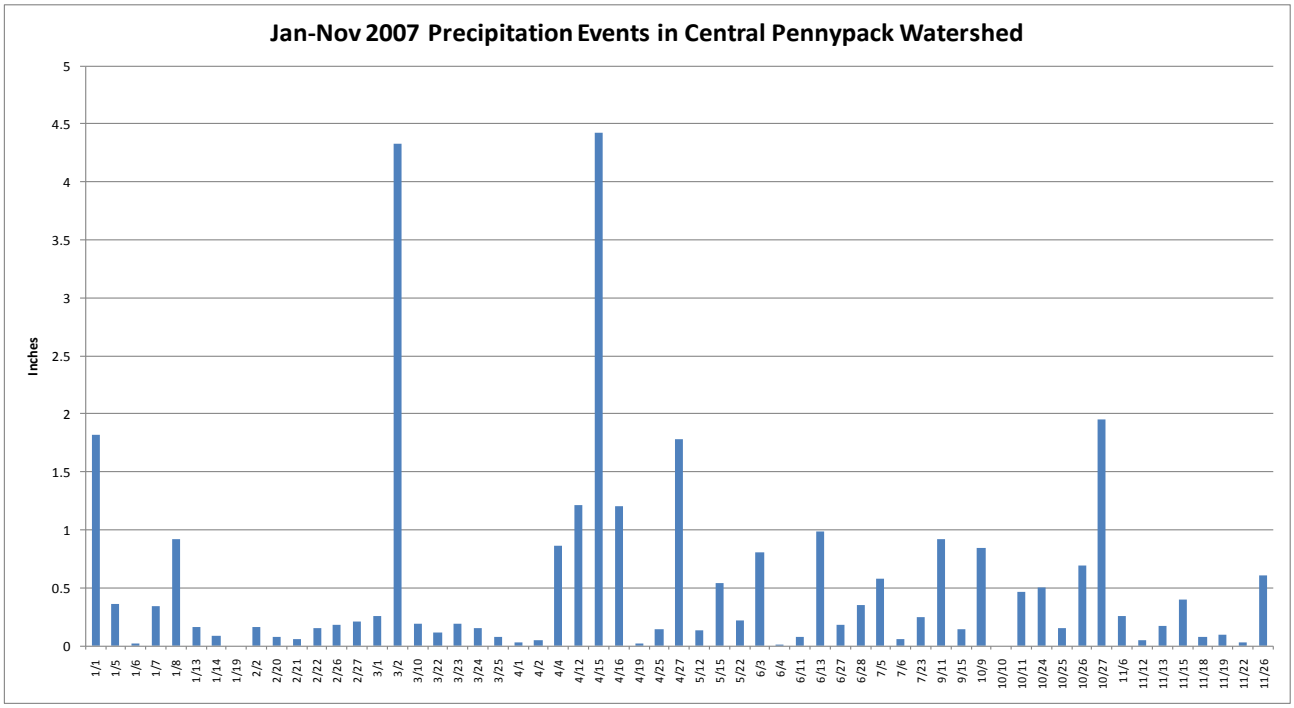
Based on the upper limit of the 90% confidence interval from NOAA Atlas 14 for the 24 hour storm.

Storm Frequency	Total Precipitation (in)
1-Yr	2.98
2-Yr	3.60
5-Yr	4.55
10-Yr	5.35
25-Yr	6.50
50-Yr	7.50
100-Yr	8.60
500-Yr	11.61

These totals are the averages for three locations in the lower, middle and upper portions of the Pennypack watershed.

Lower Pennypack: Lat: 40.041 Lon: -75.053
Middle Pennypack: Lat: 40.115 Lon: -75.096
Upper Pennypack: Lat: 40.147 Lon: -75.128

Figure 2.1.A Precipitation Events in the Pennypack Watershed



2.2 Surface Features

The topography of the Pennypack Watershed is characterized by gently rolling hills in the headwaters, a moderately sloping valley in the central part of the watershed, and tidal flats draining to the Delaware River. The elevations over the whole watershed range from 436 feet to less than 10 feet.

Figure 2.2.A provides a graphical presentation of elevation from a Digital Elevation Model or DEM. The DEM was created from 2003 digital orthophotography flown for the Center for Sustainable Communities (CSC). It includes high resolution, high quality data with two-foot contours.

Based on their runoff characteristics, soils of the U.S. are classified by the Natural Resource Conservation Service (NRCS) into four hydrologic groups A, B, C, D. Group A soils have low runoff potential with high infiltration rates, while Group D soils have high runoff with very slow infiltration rates. The other two groups are in between. Runoff characteristics of various land uses vary with the underlying hydrologic soil group designation, and information on the location of hydrologic soils groups was used in the hydrologic modeling for this study. As noted on Figure 2.2.B, hydrologic soils in the Pennypack Watershed are predominately groups B and C with some D soils.

Group B soils have moderate infiltration rates even when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well drained to well drained soils with moderately fine to moderately coarse textures.

Group C soils have slow infiltration rates even when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures.

Soil erodibility in the Pennypack Watershed is depicted in Figure 2.2.C. Soil erodibility in the watershed ranges from slight in most upland areas to severe in riparian areas along the central and lower main stem of the Pennypack Creek and the downstream portions of some tributaries in Abington Township and in the City of Philadelphia.

Current land use in the Pennypack Watershed is shown in Figure 2.2.D. The watershed has been heavily developed with residential use, and includes many areas of commercial and light industrial use along with highway and rail corridors. Despite the high degree of development, lands in Pennypack Park in Philadelphia and lands preserved through donations and efforts of the Pennypack Restoration Trust have preserved long reaches of the main stem corridor in a relatively undeveloped condition. Had these lands been developed to the degree of many other riparian stream reaches in urban areas during the past 200 years, the flood damage potential in these areas would be much higher.

As of 2005, approximately 38 percent of the Pennypack Watershed was in single-family residential use, with an additional 12 percent used for multi-family residences. Commercial and light industrial use comprised 5 percent and 4 percent of the watershed, respectively. Parking to support commercial and community activities comprised an additional 5 percent of the land use. Woodland covered 14 percent of the watershed, with recreation and community activity space occupying and additional 9 percent. The remaining land use (13 percent) was comprised of transportation, military land, water, agricultural lands, utility operations, and vacant properties. A detailed analysis

of alternative land use scenarios to meet projected future growth in the Pennypack watershed is provided in Section 2.3. A summary of a hydrologic model evaluation of the two scenarios is presented in Section 4.

Taken together, the surface features of the Pennypack Watershed, along with antecedent soil moisture conditions, define how it responds to rainfall. In order to provide more precise information about potential for flash flooding in small watersheds, the National Weather Services' Mount Holly Weather Forecast Office recently conducted a GIS-based analysis of flash flood potential for its forecast area. The product of the analysis is the map shown in Figure 2.2.E, which shows relative flash flood potential in the Pennypack Watershed based on digital data available for soils, slope, forest density, and land use. The map indicates the combined potential for these land-based parameters to generate flash flooding, with the highest index numbers representing the areas of highest potential. Comparison of this map with Figure 2.2.D shows the close correlation with flash flood potential and land use. The map provides a good picture of the areas in the watershed that would be expected to generate the largest runoff volumes, and supports the representation of surface conditions by the hydrologic model described in Section 4.

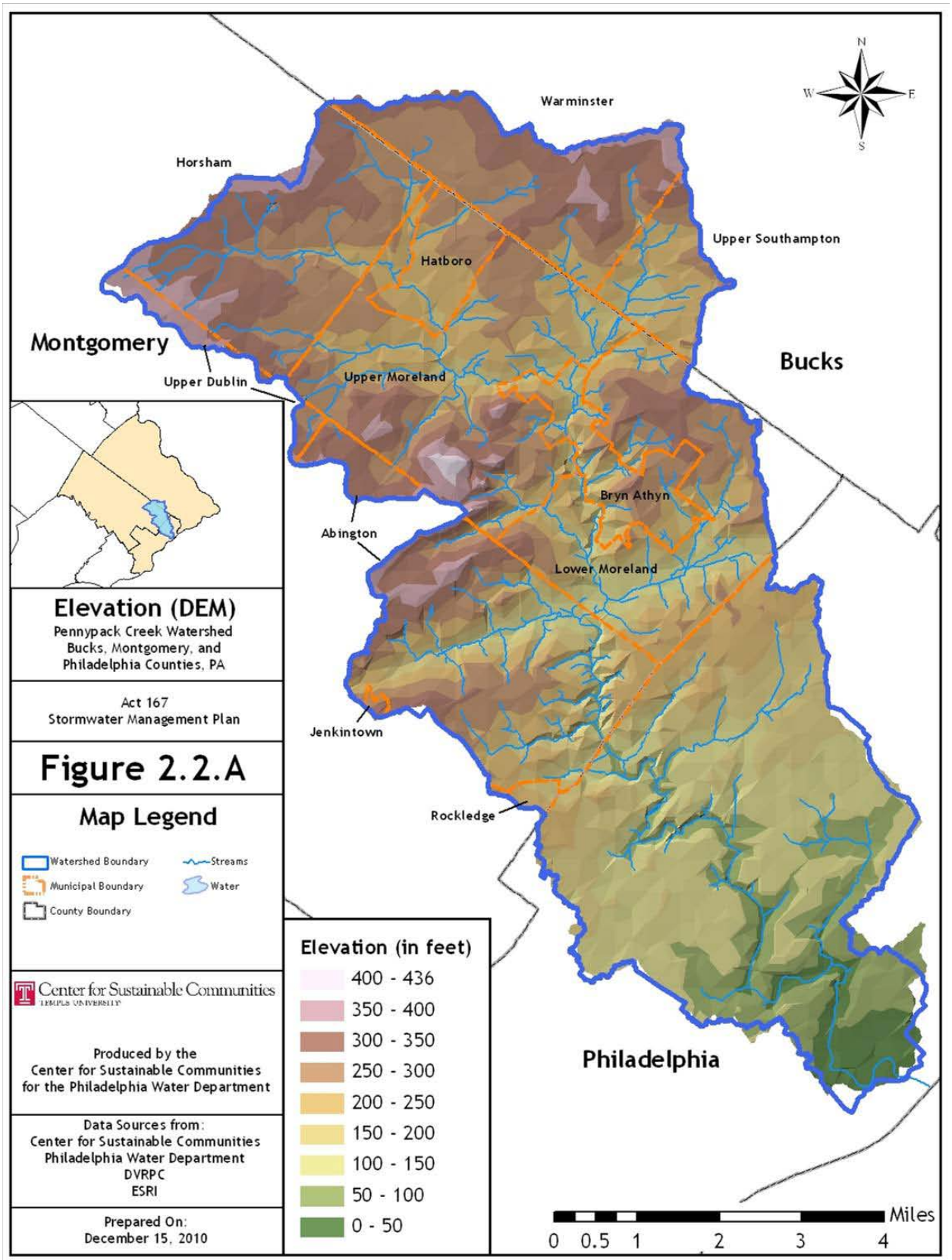
Once runoff occurs, constructed surface storage that intercepts and holds the runoff can delay flow and lower flood peaks. For this study, the Philadelphia Water Department provided an inventory with 141 existing detention basins in the watershed. This was supplemented by data collected by the CSC during field inspections of additional detention facilities and ponds. Figure 2.2.F shows the distribution of these facilities in the watershed. The majority are located in the upper third of the watershed where development has been most recent and occurred subsequent to the implementation of stormwater management regulations. The storage provided by these facilities was estimated and totals for each modeled subbasin were included in the hydrologic model. The estimated total storage of all existing facilities is approximately 300 acre-feet. These are local facilities designed to control site runoff from specific development sites. If spread over the entire area of the Pennypack Watershed, this amounts to the equivalent of one-tenth of an inch of runoff. Many existing facilities are not designed for extended detention, and runoff from smaller storms passes directly through the facility. These structures represent opportunities for retrofitting to provide extended detention. In addition, ponds with low freeboard heights can provide storage in small storms, but are not able provide additional storage during larger flood events.

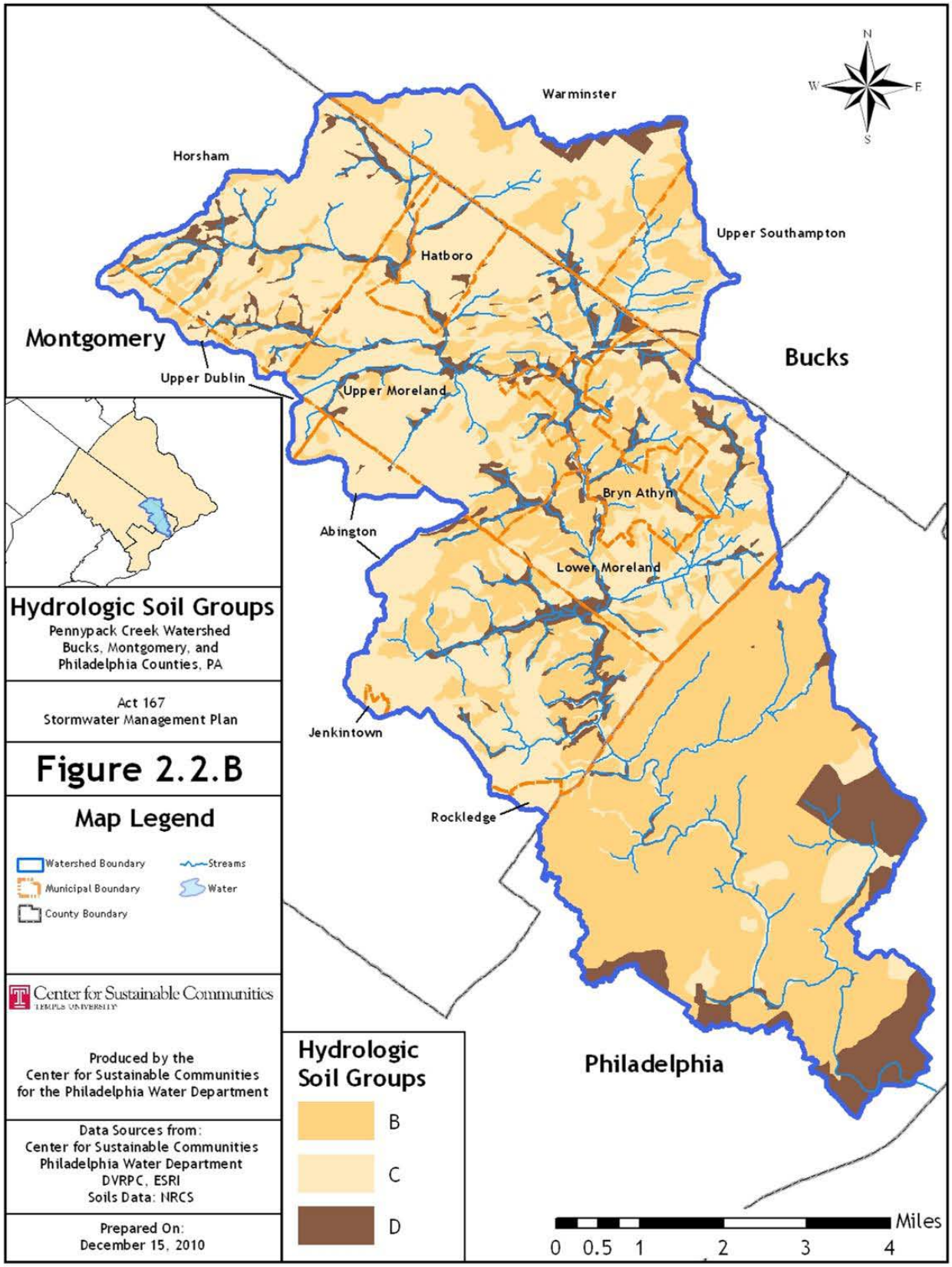
Stormwater collection, piping, and discharge through outfalls affect the pathway and timing of runoff in developed watersheds such as the Pennypack. Stormwater collection systems are located in each of the municipalities in the Pennypack Watershed. The collection systems are located primarily in the residential, commercial, and industrial areas served by curbed streets, and along arterial and secondary roadways. Areas not served include the parkland and Trust lands along the main stem of the Pennypack Creek, agricultural and open space, and some older residential sections outside of the Philadelphia city limits. Although a detailed survey of stormwater piping was not conducted as part of this study, estimates of the extent of coverage were made based on field observations, orthophotography, land use data, and outfall and drainage shed data provided by the Philadelphia Water Department. Based on this information, it is estimated stormwater collection systems of various capacities have been installed in approximately 65 percent of the Pennypack Watershed.

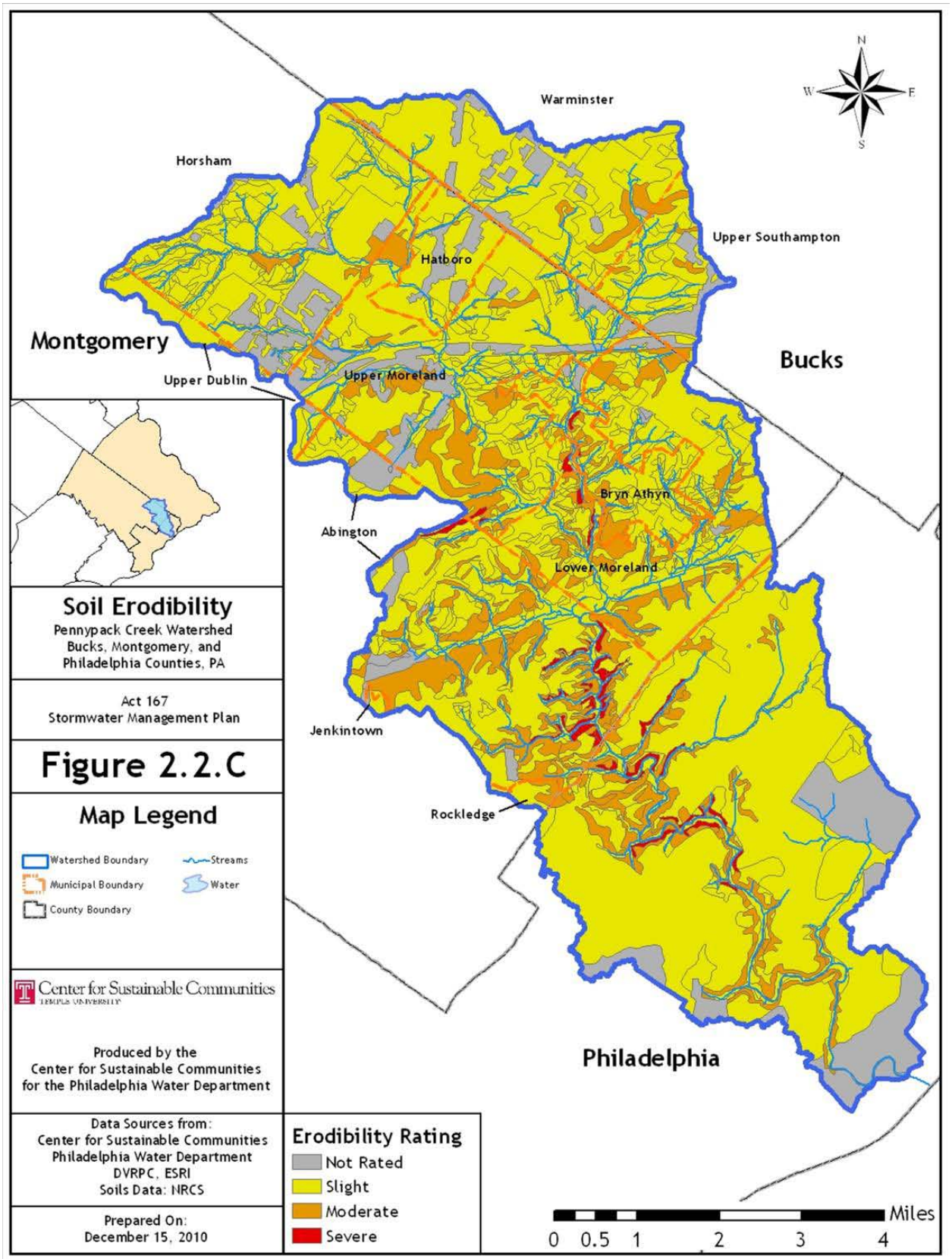
The single largest land use category in the Pennypack Watershed is single-family residential. In most residential areas, only a portion of the water falling on roofs and properties enters the street,

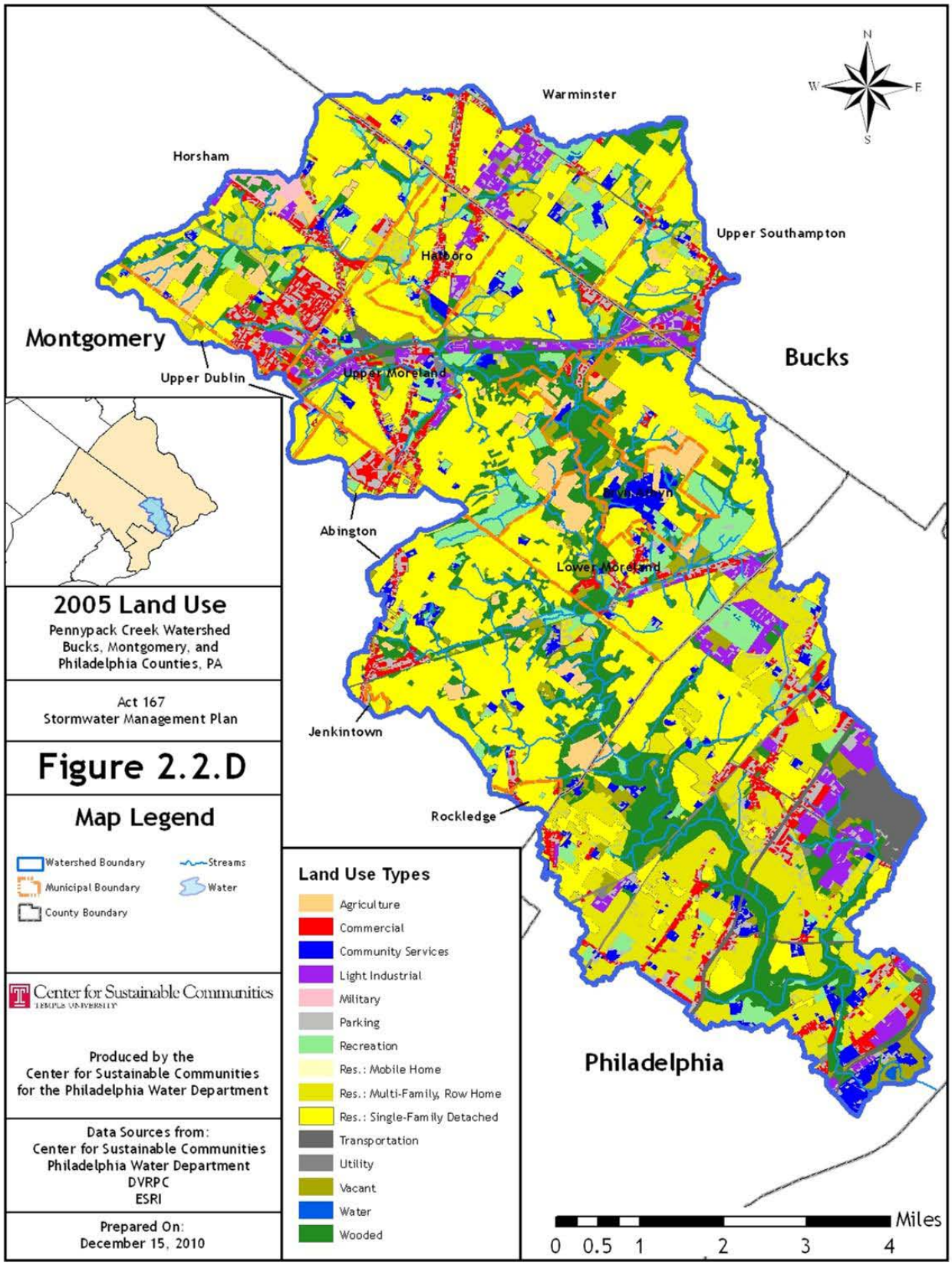
and subsequently the storm inlets, depending on the slope of the property and gutter drainage onto the property. The remainder of roof and property drainage infiltrates into the soil, and as the soil becomes saturated, runoff flows at an increasing rate to the street or to other drainage basins offsite. As housing density increases, a larger proportion of each property's drainage enters storm inlets. In the developed sections of the watershed with curbed roadways, the roadways channel runoff to the storm inlets during smaller storm events, and become stormwater channels once runoff exceeds the capacity of the inlets and/or pipe capacities. Development alters the local runoff pathway, particularly for smaller storms, and the runoff to stream channels is often controlled by the location of stormwater inlets, piping, detention basins, and outfalls. This situation is depicted in Figure 2.2.G. For the portion of the watershed within the Philadelphia city limits, stormwater shed boundaries were used to delineate subareas for modeling, due to the modification of drainage caused by streets, inlets and piping. The watershed boundaries and outfall locations also were used as guidance in delineating subareas outside of the City limits. A map showing outfall locations in the watershed is shown in Figure 2.2.H. In addition, an example of a municipal stormwater system map, provided by Horsham Township, is shown in Figure 2.2.I.

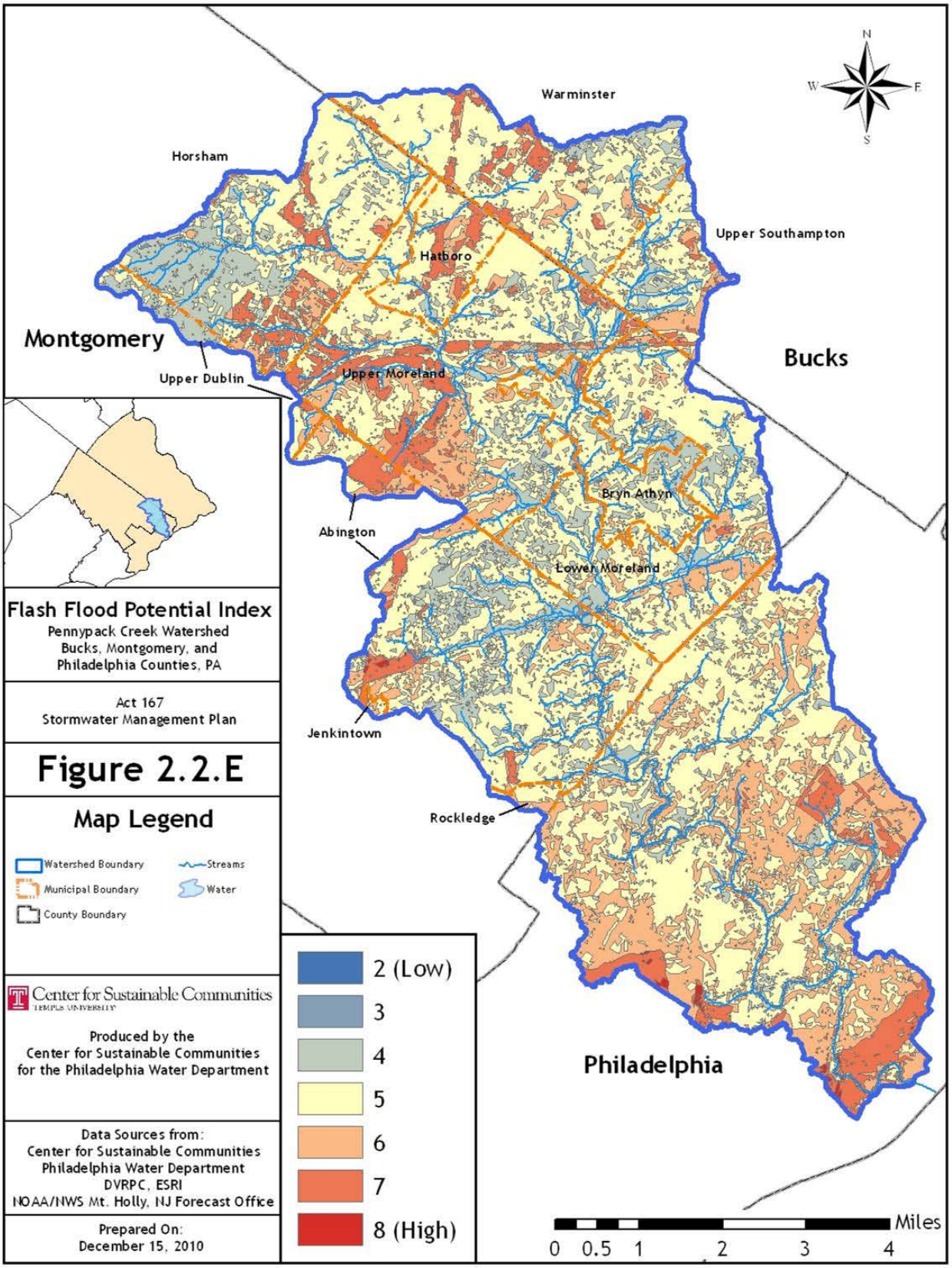
Based on the analysis of future land use presented in Section 2.3, areas with the most potential for growth are located in Montgomery County in Horsham, Upper Moreland, and Abington townships and Hatboro Borough, and in Bucks County in Warminster and Upper Southampton townships. Future stormwater collection modifications or expansions would be most likely in these areas.


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Elevation (DEM)
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.A
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Elevation (in feet)
400 - 436
350 - 400
300 - 350
250 - 300
200 - 250
150 - 200
100 - 150
50 - 100
0 - 50
Miles
0 0.5 1 2 3 4


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Hydrologic Soil Groups
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.B
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC, ESRI
Soils Data: NRCS
Prepared On:
December 15, 2010
Hydrologic
Soil Groups
B
C
D
Miles
0 0.5 1 2 3 4


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Soil Erodibility
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.C
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC, ESRI
Soils Data: NRCS
Prepared On:
December 15, 2010
Erodibility Rating
Not Rated
Slight
Moderate
Severe
Miles
0 0.5 1 2 3 4


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
2005 Land Use
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.D
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Land Use Types
Agriculture
Commercial
Community Services
Light Industrial
Military
Parking
Recreation
Res.: Mobile Home
Res.: Multi-Family, Row Home
Res.: Single-Family Detached
Transportation
Utility
Vacant
Water
Wooded
Miles
0 0.5 1 2 3 4


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Flash Flood Potential Index
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.E
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC, ESRI
NOAA/NWS Mt. Holly, NJ Forecast Office
Prepared On:
December 15, 2010
2 (Low)
3
4
5
6
7
8 (High)
Miles
0 0.5 1 2 3 4

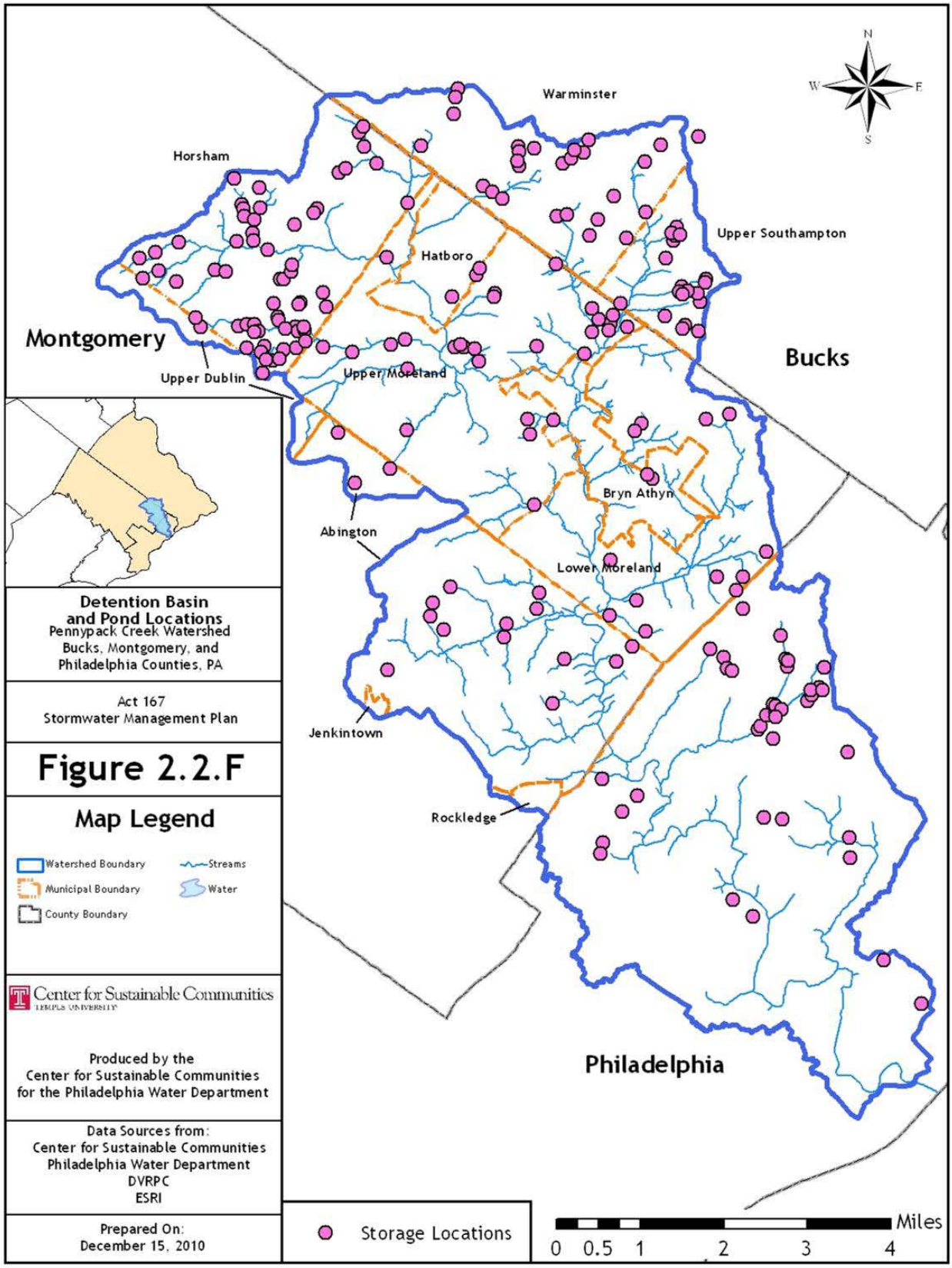
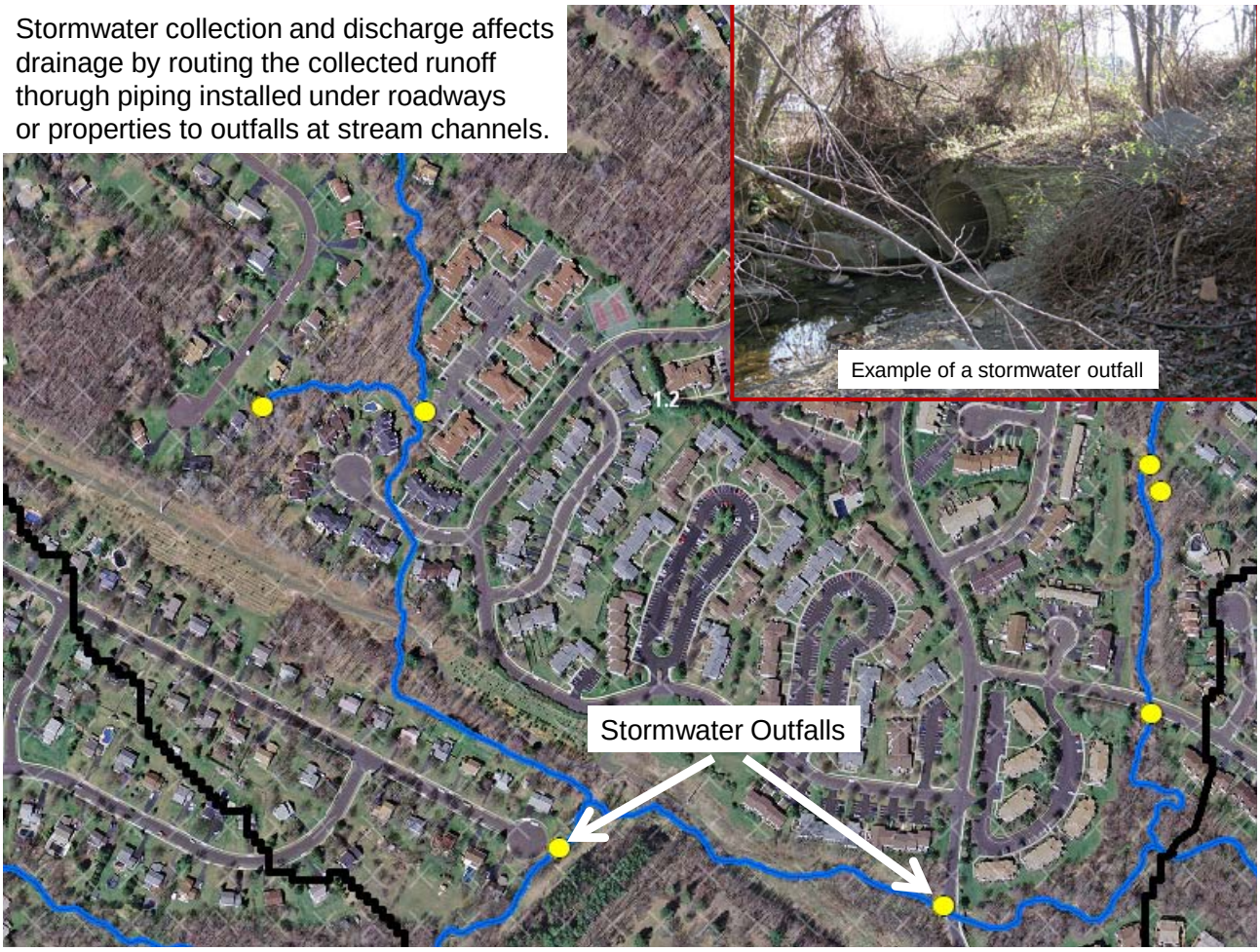

Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Detention Basin
and Pond Locations
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.F
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Storage Locations
Miles
0 0.5 1 2 3 4

Figure 2.2.G Stormwater Collection and Outfalls



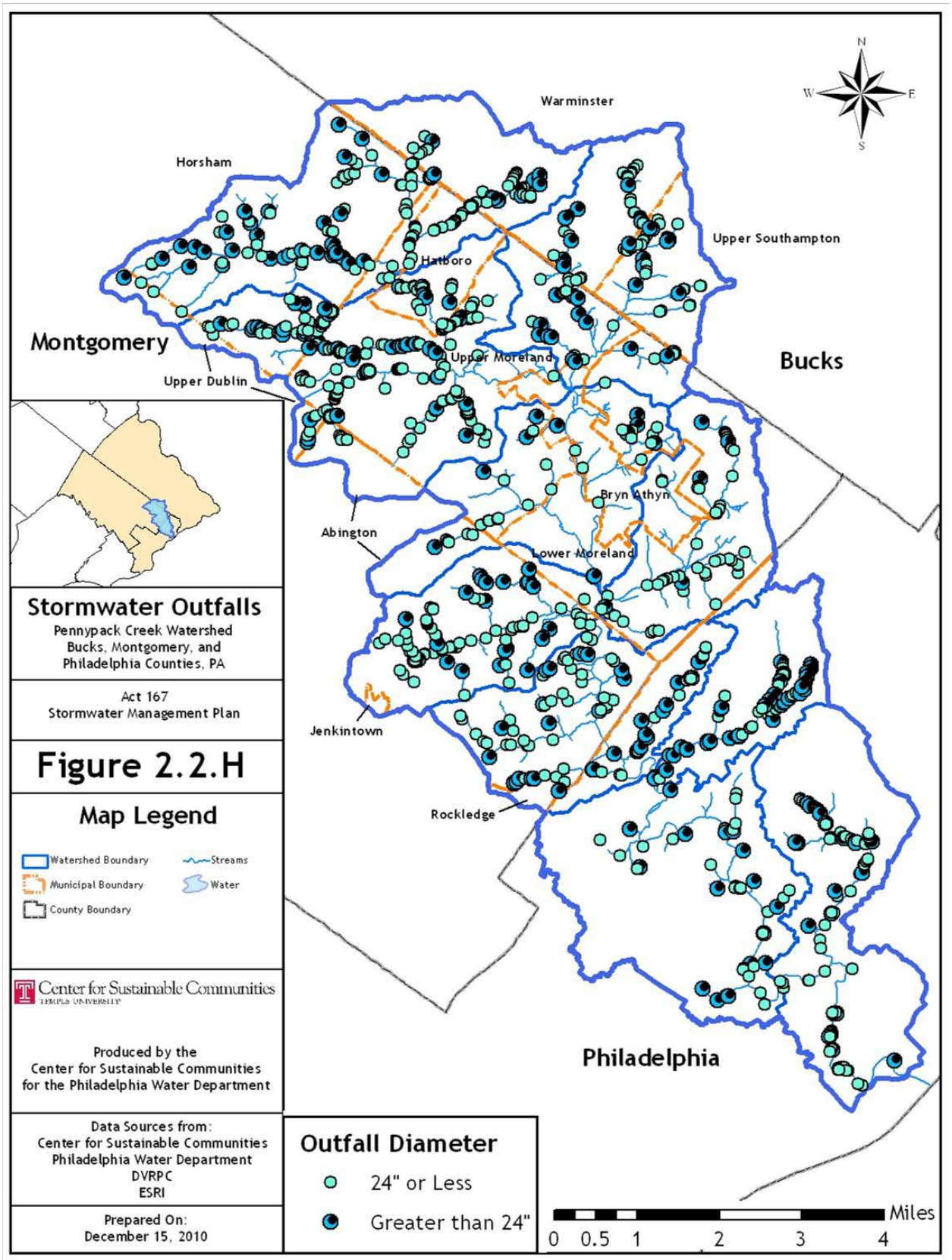
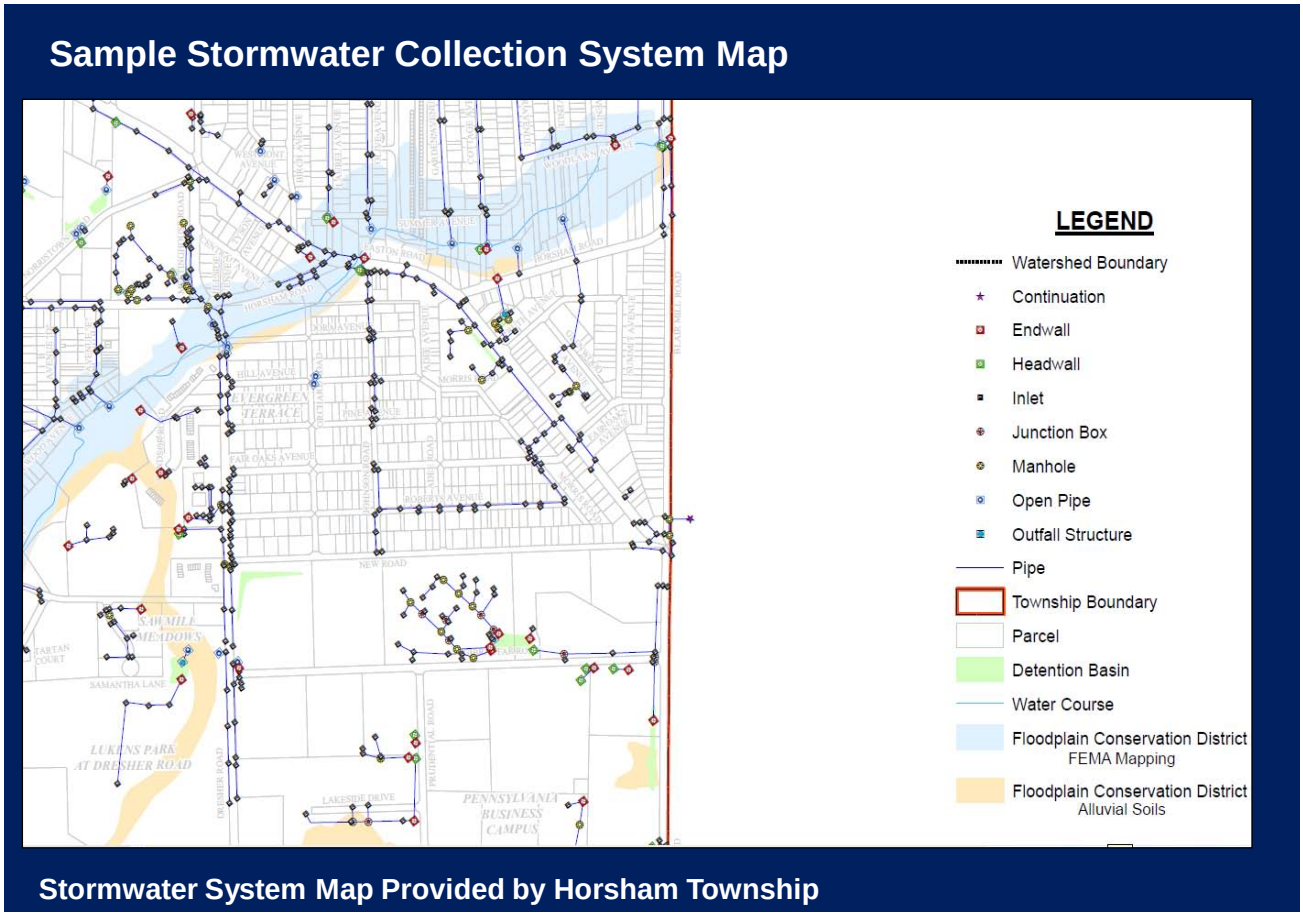

Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Upper Moreland
Bucks
Upper Dublin
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Stormwater Outfalls
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.H
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Outfall Diameter
24" or Less
Greater than 24"
Miles
0 0.5 1 2 3 4

Figure 2.2.I Sample Stormwater Collection System Map for a Portion of Horsham Township, Montgomery County, PA



Section 2.3 Projected Growth and Land Use Projections

The project team evaluated two possible future land use scenarios and futures. These scenarios are primarily focused on macro trends in land use change, and do not reflect site-specific innovations that might occur, such as floodplain acquisitions or increased use of site-level stormwater best management practices (BMPs). It is impossible at a regional scale to model site-specific land use attributes such as riparian buffer construction.

The project team examined the demand for land from projected population growth and used the official population forecasts from the Delaware Valley Regional Planning Commission (DVRPC). The forecasts were updated in 2008, to account for estimated changes in municipal populations since 2000. In this analysis, the team only examined the projected population growth rates in the 11 municipalities outside of the city of Philadelphia for two reasons. First, nearly all the land within the watershed in Philadelphia is already considered developed. Second, the neighborhoods within Philadelphia that lie within the Pennypack watershed were not forecasted to experience any significant population changes as of 2008, absent large-scale redevelopment efforts. The official population forecasts for each of the 11 non-Philadelphia municipalities which have some or all of their land area in the Pennypack region are then used to determine the proportion of the housing and

population growth needs of the areas of the municipalities which lie within the boundaries of the Pennypack.

Table 2.3.A presents the future population needs for Pennypack municipalities, representing only the future growth assigned to areas within the Pennypack Watershed. The first column represents the population growth estimates for 2035 for each municipality. Column 2 converts the population forecasts into an indication of aggregate housing unit needs. Based on standard practice, these are calculated as future population divided by average number of persons per occupied housing unit (for each municipality) in the 2000 Census. Thus, the assumption is that the average number of persons per occupied housing unit will remain the same over the 27 year planning horizon. Within the Pennypack Watershed, the average household size is 2.66 persons per household, ranging from a low of 2.2 persons per household in Jenkintown Borough to a high of 3.5 persons per household in Bryn Athyn Borough. Housing unit needs were also adjusted upwards by 2 percent to reflect an estimated average vacancy rate of 2 percent. In the year 2000 within the watershed, the vacancy rate was 2.4 percent, according to the Census Bureau.

Column 3 of Table 2.3.A converts the gross housing unit needs of 2035 into the number of new units which need to be constructed during the planning horizon. These figures are calculated by dividing the expected population increase inside the watershed by the current average household size with 2% additional vacancy factor. Overall, the results of the demographic analysis do not show much growth in the suburban (non-Philadelphia) municipalities of the Pennypack. The watershed's population is only expected to grow from approximately 100,000 in 2000 to slightly over 112,000 by 2035. Only 3,048 new housing units in a 30-year time period would be needed to accommodate this population growth. As demonstrated below in the land use scenarios, however, if these housing units are produced at lower densities, the amount of undeveloped land remaining in the Pennypack would be significantly reduced.

Table 2.3.A Forecasted Population Growth and Housing Unit Construction Needed, Pennypack Creek Watershed

Municipality	2035 Population Estimate	2035 Total Housing Unit Need	2035 New Unit Construction
Bucks County			
Upper Southampton Township	4,116	1,575	148
Warminster Township	18,252	6,601	722
Montgomery County			
Abington Township	28,362	10,965	436
Bryn Athyn Borough	1,433	400	30
Hatboro Borough	7,643	3,144	213
Horsham Township	12,874	4,811	866
Jenkintown Borough	427	194	7
Lower Moreland Township	10,259	3,740	9
Rockledge Borough	1,666	685	30
Upper Dublin Township	1,720	609	51
Upper Moreland Township	25,374	10,262	536
TOTAL	**112,127**	**42,985**	**3,048**

Scenario 1: Trend Development

Table 2.3.B represents the land use analysis associated with Scenario 1: Trend Development. In this scenario, each new housing unit is assumed to consume the same amount of land as the existing year 2000 average housing unit land consumption, for each municipality. That is, in this scenario current densities (reflecting current zoning and current development practices) are assumed to predict future densities. This assumption is still somewhat conservative in terms of land consumption, because newer housing units generally are produced at densities lower than existing average densities.

Table 2.3.B Land Consumption Rates: Trend Development Scenario

Municipality	2035 Residential Need	2035 Non-Residential Need	2035 Acreage Need
Bucks County			
Upper Southampton Township	63.4	17.7	81.2
Warminster Township	216.2	91.7	307.9
Montgomery County			
Abington Township	119.8	51.8	171.6
Bryn Athyn Borough	18.0	4.9	22.9
Hatboro Borough	39.6	23.8	63.4
Horsham Township	359.8	106.5	466.3
Jenkintown Borough	0.9	0.7	1.6
Lower Moreland Township	5.6	1.2	6.8
Rockledge Borough	4.2	3.3	7.6
Upper Dublin Township	25.8	6.6	32.4
Upper Moreland Township	138.2	60.8	199.0
TOTAL	**991.6**	**368.9**	**1,360.5**

Note: all figures expressed in acres

Using the high-resolution digital land data in this study, the project team determined gross residential housing unit densities, defined for each municipality as number of housing units divided by land classified as in residential use. Thus, the estimate of gross residential housing unit densities is a good estimate of the amount of land consumed per housing unit. Using the figures from 2000, aggregate residential land use consumption was projected in Table 2.3.B, shown in column 1. Development densities across the region range from a low of 1.6 housing units per acre in Bryn Athyn and Lower Moreland to a high of 8.1 housing units per acre in Jenkintown.

Estimates of the amount of land needed for non-residential development (including commercial, industrial, office, utility, and transportation land use needs) can be estimated with detailed employment growth forecasts to convert employment needs into space requirements. In this case, per capita demand projected for non-residential land under the trend development scenario will be approximately 2000 square feet. The analysis in Table 2.3.B indicates that, at current trend densities, the Pennypack region will see a total of 1,360.5 additional acres converted to urban

development between now and 2035, of which almost 992 acres will be residential, while nearly 369 acres will be non-residential.

For this scenario, in order to apportion future land use growth in the various scenarios, the suitability and capability of current land uses was analyzed to accommodate future land development, redevelopment, and growth. The first step was to create a layer that included all land uses identified as not "potentially developable." This layer included known permanently-preserved open space and conservation land (state, county and municipal parks, Pennypack Ecological Restoration Trust land, etc.). The project team restricted areas within the Pennypack Creek floodway, the 100-year floodplain, and an additional 50-foot buffer around the creek and its tributaries. Finally, wetland areas were also deemed not suitable for development. All remaining land is considered "potentially developable."

Within the land classified as potentially developable, four criteria were applied to identify the areas most suitable for development through a suitability study. The first criterion was the derived slope of the land, calculated in 100 square foot cells. Slope values over 25% were given a score of 0, while values from 15% to 25% were given a score of 4, and values under 15% were given a perfect score of 10. Only some of the municipalities in the Pennypack Watershed explicitly forbid building in areas of steep slope, which were included in the conservation land part of the restricted land layer. Other municipalities restrict how much building can be done in a steep slope area, but do not forbid it. Therefore, for the trend scenario, steep slope areas were scored lower than flat areas, but development was not prohibited in these areas except in special cases.

The second and third criteria used were proximity to major roads and schools. For each of these, a half-mile buffer was added around major arterial roads and highways, and public and private schools in the watershed. Areas within the half-mile buffer for roads and schools received a score of 10, while areas outside the school buffer area scored a 7 and areas outside the road buffer area scored a 5, on the grounds that developers are more likely to prefer proximity to arterial roads than schools for their development, be it residential or non-residential.

The final criterion accounted for the land use currently in place across the watershed. Agricultural and wooded areas were given scores of 10, based on an analysis of land use from 1990 to 2005 across the watershed, showing that agriculture and wooded lands decreased in coverage across the watershed, suggesting that these areas were most attractive to developers. Vacant areas were given a score of 3, balancing the availability of land for development with the general willingness of developers to use "virgin" land over previously developed areas for their projects. All current residential and commercial areas were given a score of 2, while all other land uses (including industrial, parking, community services, recreation, military, and utility) were given a score of 0, reflecting that it is still technically possible to use these areas for new development or redevelopment, but they should not be preferred.

Each criterion was combined to create a single raw score for all areas deemed "potentially developable", with a perfect score being 40. This layer with the raw score is then subdivided into municipalities within the watershed for purposes of analysis and assigning development areas. These subdivided layers were assigned to have "residential" or "non-residential" development based on the combined suitability score as well as the acreage of the continuous area receiving the same score; larger areas were given preference over smaller areas. Needed residential acreage was assigned to the high-scoring parcels first, followed by non-residential acreage. Areas were

chosen to add up to the required acreage for each municipality, but overrun was permitted if the result would mean concentrating development in fewer areas. Area selection using the trend scenario ended up exceeding the projected need by 4.62 acres across the entire watershed, or 0.34% of the projected need.

Out of the 1,365 acres assigned for development, 375 acres (28%) is in areas that received a perfect score of 40, meaning that the area has a slope of under 15%, is within a half-mile of a major arterial road and a school, and is currently classified as agriculture or wooded. Another 35% of the needed land was chosen from areas that scored a 37, meaning that they met all of the criteria above except the half-mile school buffer, and a further 11% of the needed land scored a 35, meaning it was not within the half-mile major road buffer. This means that 74% of the land chosen for development in the trend scenario is currently agriculture or wooded areas. Thus, one of the planning challenges facing the watershed is balancing the growth needs with preserving agricultural and forested landscapes. Even if an area in this analysis is classified as potentially suitable for development, it does not mean that development of these landscapes is the most appropriate policy choice. See Table 2.3.C below for a chart of how land was allocated to the individual municipalities based on suitability score.

Table 2.3.C Trend Scenario Land Allocation

	Res Need	Non Res Need	Total Acreage Need	40	37 (No School)	35 (No Roads)	33 (Vacant Land)	32	30	27	25	22	Total Allocated	Difference from Need
Abington	119.78	51.79	171.57	54.84	117.33								172.18	0.60
Bryn Athyn	18.00	4.87	22.86	23.90									23.90	1.04
Hatboro	39.59	23.78	63.37	12.11			9.93		41.9				63.96	0.59
Horsham	359.84	106.46	466.30	141.31	100.14	84.78	31.93		64.1	44.0			466.28	-0.02
Jenkintown	0.87	0.71	1.58		2.53								2.53	0.96
Lower Moreland	5.64	1.15	6.79	6.99									6.99	0.20
Rockledge	4.24	3.34	7.58	0.36	0.76			1.1					2.23	0.01
Upper Dublin	25.81	6.58	32.39		24.08				7.8	1.8			33.66	1.26
Upper Moreland	138.19	60.82	199.01	38.23	160.82								199.05	0.04
Upper Southampton	63.44	17.72	81.16	34.85	27.90	18.32							81.07	-0.09
Warminster	216.20	91.69	307.89	62.62	45.07	44.72	35.05	55.6	12.5	35.7	13.4	3.2	307.90	0.01
				5.36	in Philadelphia (40) (from Rockledge)									
Totals	991.58	368.91	1360.50	375.23	478.63	147.82	76.91	56.7	126.3	81.5	13.4	3.2	1365.11	4.62
				28%	**35%**	**11%**	**6%**	**4%**	**9%**	**6%**	**1%**	**0%**		

In this scenario each municipality accommodates its *own* projected land development needs and there is no sharing of uses among municipalities, with the only exception being Philadelphia accommodating 5.36 acres of development that would otherwise be located in Rockledge Borough.

In many ways, this represents the trend in Pennsylvania land use planning by municipalities, as each municipality is under an affirmative obligation to "accommodate reasonable overall community growth, including population and employment growth" (cf. 53 P.S. § 10604 [5]) absent a shared land-use agreement within a multi-municipal plan.

Figure 2.3.A shows the projected land use in 2035 under the Trend Development scenario. Much of the undeveloped land near the various streams of the watershed is protected in this scenario from development because of their environmental constraints. Most of the land conversion under this scenario occurs in the currently less developed townships in the northern portion of the watershed.

Scenario 2: "Green" Development

In this land use future scenario, municipalities accommodate their forecasted population growth needs, but accommodate the residential portion of that population growth at significantly higher gross residential housing unit densities and the non-residential portion of that development at slightly increased intensities. In order to illustrate this scenario, the project team chose to simulate all new residential development in the less dense "townships" occurring at densities of six units per gross residential acre.

Depending on the planning decisions of these municipalities accommodating growth at higher densities in terms of housing mix and design standards (e.g. cluster subdivisions) some of these housing units could be townhouses and others would be cluster houses on smaller lots (<8,000 square feet). Further, in this smart growth scenario, we assume only 1,500 square feet of residential land per new resident, in that commercial and other uses are developed at higher intensities. The results are shown in Table 2.3.D below.

Table 2.3.D Land Consumption Rates: Green Development Scenario

Municipality	2035 Residential Need	2035 Non-Residential Need	2035 Total Acreage Need	2035 Acreage Saved
Bucks County				
Upper Southampton Township	24.6	13.3	37.9	43.3
Warminster Township	120.4	68.8	189.1	118.8
Montgomery County				
Abington Township	72.7	38.8	111.5	60.1
Bryn Athyn Borough	4.9	3.7	8.6	14.3
Hatboro Borough	35.5	17.8	53.3	10.1
Horsham Township	144.4	79.8	224.3	242.0
Jenkintown Borough	1.2	0.5	1.7	-0.1
Lower Moreland Township	1.5	0.9	2.4	4.4
Rockledge Borough	5.0	2.5	7.5	0.1
Upper Dublin Township	8.5	4.9	13.4	19.0
Upper Moreland Township	89.3	45.6	134.9	64.1
TOTAL	**508.0**	**276.7**	**784.6**	**575.9**

Note: all figures expressed in acres

Land was scored following a suitability matrix designed by Alice Walters for a previous Temple University Center for Sustainable Communities study. The suitability factors were as follows:

- 25%: Water (areas outside of floodplain, wetlands, ponds, streams)
- 24%: Subdividable Parcels
- 10%: Suitable building soils
- 10%: Current Land Use
- 5%: Slope

Proximity to:

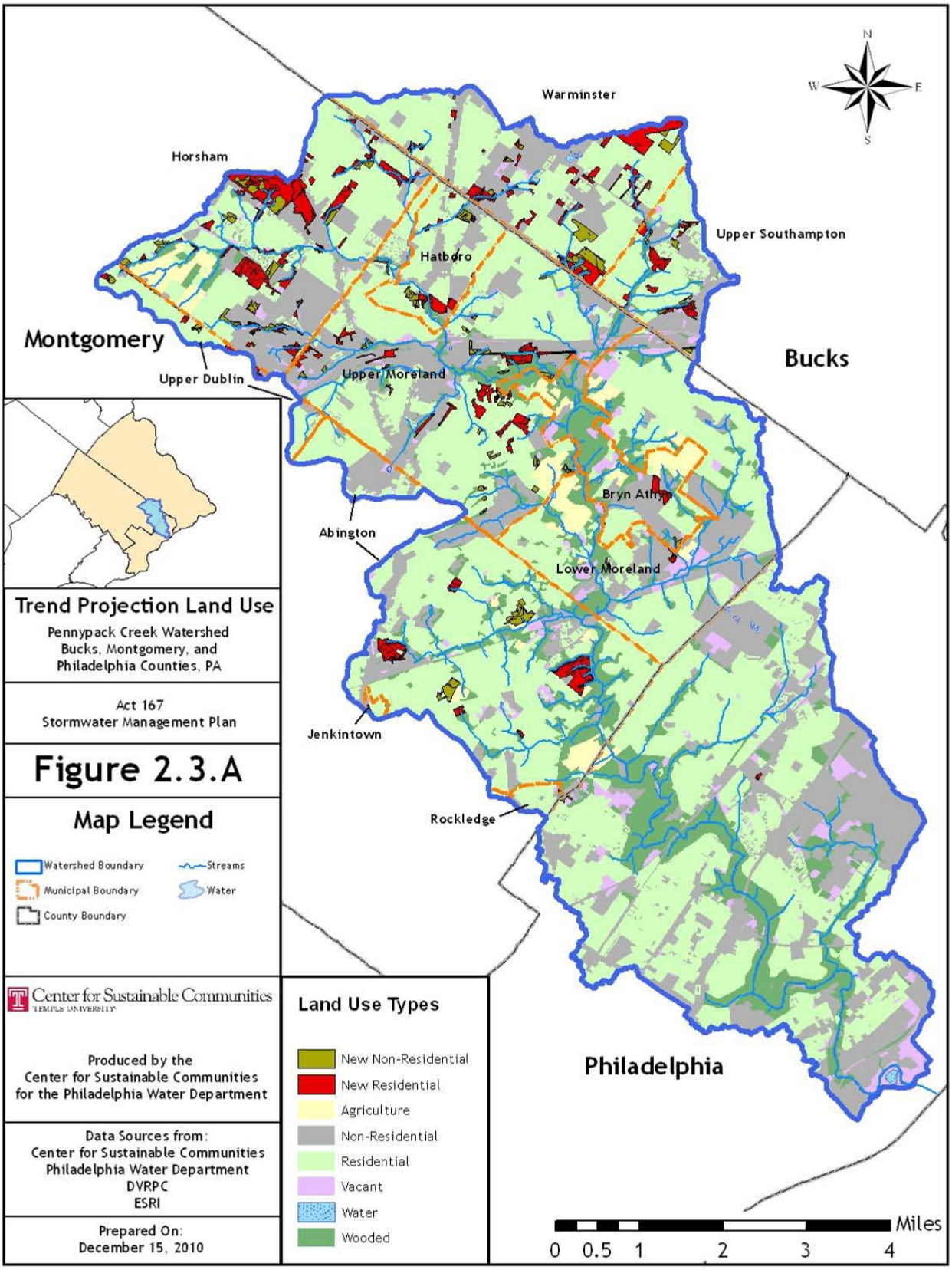
- 10%: Roads
- 10%: Rail Stations
- 2%: Institutions (schools, hospitals, employment centers, religious sites)
- 4%: Open Space (includes trails)

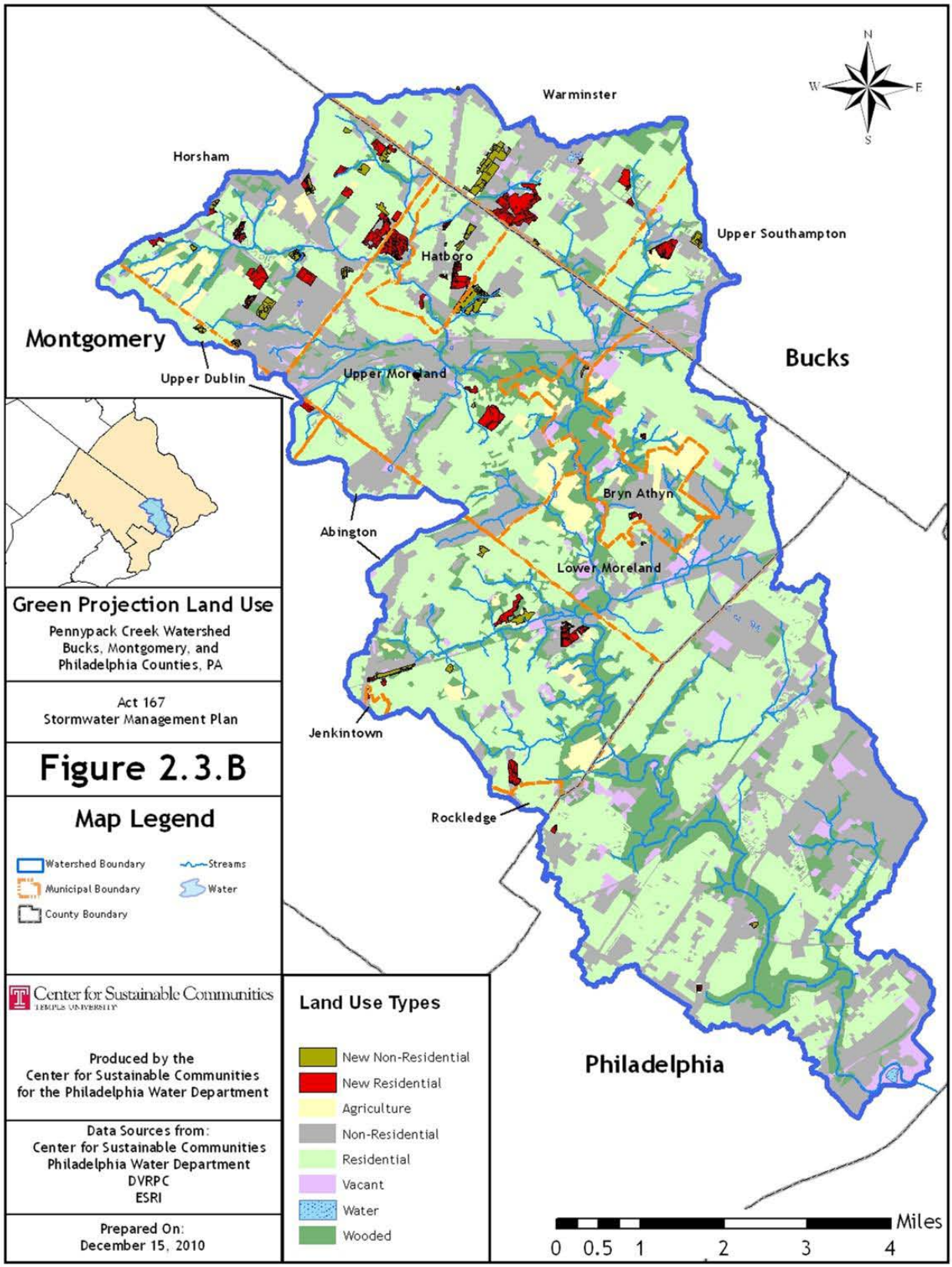
These factors were combined into a single score out of 10. Table 2.3.E shows how the development required for each municipality was allocated among the suitability scores.

Table 2.3.E Green Scenario Land Allocation

	Res Need	Non-Res Need	Total Acreage Need	**9**	**8**	**7**	Total Allocated	Difference from Need
Abington	72.69	38.85	111.54	8.71	102.76		111.47	-0.07
Bryn Athyn	4.93	3.65	8.58	5.19	3.42		8.61	0.04
Hatboro	35.51	17.84	53.35	14.93	38.44		53.37	0.02
Horsham	144.42	79.84	224.26	23.90	125.35	75.03	149.25	0.02
Jenkintown	1.17	0.53	1.71		1.71		1.71	0.01
Lower Moreland	1.52	0.86	2.39	2.38			2.38	-0.01
Rockledge	4.98	2.50	7.48	7.48	(PHILADELPHIA)		7.48	0.00
Upper Dublin	8.46	4.94	13.39	4.93	8.49		13.42	0.03
Upper Moreland	89.29	45.62	134.90	19.53	115.38		134.91	0.00
Upper Southampton	24.61	13.29	37.90		37.83	0.05	37.88	-0.02
Warminster	120.37	68.77	189.13	4.76	119.23	65.16	189.15	0.01
Totals	507.95	276.69	784.63	91.81	552.61	140.24	784.66	0.03
				12%	**70%**	**18%**		

The last column of Table 2.3.D indicates that, in comparison with the trend development scenario illustrated in Table 2.3.B, 575.9 additional acres of forested and agricultural landscapes would be preserved with accommodation by each municipality of its future residential needs at reasonably higher densities, consistent with smart growth. Figure 2.3.B shows the projected land use futures for 2035 under Scenario 2.


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Trend Projection Land Use
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.3.A
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Land Use Types
New Non-Residential
New Residential
Agriculture
Non-Residential
Residential
Vacant
Water
Wooded
Miles
0 0.5 1 2 3 4


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Green Projection Land Use
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.3.B
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Land Use Types
New Non-Residential
New Residential
Agriculture
Non-Residential
Residential
Vacant
Water
Wooded
Miles
0 0.5 1 2 3 4

Section 3: Stormwater Problems

The Pennypack Creek Watershed has undergone major development and urbanization. Much of the watershed area was developed as a part of the "inner ring suburbs" of Philadelphia in the 1950s through the 1980s. The pattern of growth has resulted in the densest development being located in the upper and lower thirds of the watershed, with riparian areas along much of the lower and central main stem and portions of the northwestern headwaters preserved as parks and preserves.

In the Pennypack Watershed, the conversion of land cover to less permeable surfaces has increased volume and frequency of runoff and led to a number of problems, including increased incidence of flooding, impaired water quality, and ecological degradation. The impaired water quality and ecological degradation are documented in detail in the Comprehensive Characterization Report for the Pennypack Watershed completed by the Philadelphia Water Department (PWD) in 2009.[1]

Of paramount concern is the increase in the amount of impervious cover (i.e., roads, rooftops, turf grass), which has contributed to the escalation of runoff and flood levels. Approximately one-third of the Pennypack Watershed is covered by impervious surfaces. Increased volumes of runoff are not only the result of increases in impervious surfaces, but also from the substantial areas of natural landscape converted to lawns or playing fields on highly compacted soil. Furthermore, stormwater runoff is subject to many pollutants such as nutrients (in fertilizers), pesticides, and bacteria that it encounters as it makes its way to the nearest water body.

Development in many of the watershed municipalities took place long before stormwater management plans and ordinances were adopted. As with many of the largely developed suburbs surrounding Philadelphia, ordinances that were in place during the suburban growth period did not adequately manage the increased volume of stormwater runoff resulting from the increase in impervious cover. It was not until the 1970s that municipalities began to recognize the need to get involved with this type of regulatory oversight. Impacts of uncontrolled urban runoff include: (1) faster timing of runoff, (2) non-point source pollution, (3) decreased groundwater recharge, and (4) increased stream temperatures, all of which result in increased flooding, increased streambank erosion, impaired water quality, and decreased aquatic diversity.[2]

3.1 Flooding

While flooding is a natural process and occurs in both developed and undeveloped watersheds, land conversion to less permeable surfaces in the absence of stormwater controls leads to higher flood peaks and flood volumes. This is the case for large storm events, and in particular for smaller more frequent storms.

Communities have faced devastating effects from large flood events, and have faced millions of dollars worth of damage as well as loss of life. During Hurricane Floyd, eight lives were lost along the banks of the Pennypack Creek.[3] Residents of the Huntingdon Valley Club condominiums

---

[1] *Philadelphia Water Department, Comprehensive Characterization Report for the Pennypack Watershed, 2009.*
[2] *DeBarry, Paul. 2004. Watersheds: Processes, Assessment, and Management. New Jersey: John Wiley & Sons.*
[3] *The Temple News Web Site, http://www.temple-news.com, accessed on August 5, 2005.*

were forced to move elsewhere as a result of this flooding, and the remnants of Tropical Storm Allison in 2001 rendered their homes uninhabitable. At the Village Green Apartment complex in Upper Moreland Township, six people were killed in an explosion when a clothing dryer became disconnected from the wall triggering a gas leak – believed to be the result of the flooding from Tropical Storm Allison. The dryer became disconnected when the room was inundated with over 2 feet of water; the dryer had been lifted up and floated across the room tearing the gas line from the wall. The Old Mill Inn in Hatboro Borough sits at the bank of the creek and sustained an estimated $18,000 to $20,000 in damages in the summer of 2001 when the first floor of the restaurant filled with over 20 inches of water.

Figure 3.1.A shows the floodway and the 100-year and 500-year floodplains for Pennypack Watershed streams. The circled area along Huntington Valley Creek in Lower Moreland Township is shown on an expanded map in Figure 3.1.B. This shows the extent of the floodplain versus the adjacent buildings and roadway. For the suburban communities, the floodplains shown are based on the recent study performed by Temple University and accepted by the Federal Emergency Management Agency (FEMA). The maps are currently undergoing public review. The floodplains for the streams in the City of Philadelphia are based on an earlier flood study. The number of buildings located within the 100-year floodway, 100-year floodplain, and 500-year floodplain is provided in Table 3.1.A, based on an overlay of orthophotography and with floodplain maps. The absence of buildings in Pennypack Park in Philadelphia and in other preserved areas along the main stem and tributaries have helped limit the number of flood-prone structures.

Flood insurance claims paid under FEMA's federal flood insurance program provide a partial measure of flood damage that has occurred since the late 1970s. This information can be used to indicate areas where flood damages are clustered, and also where repetitive flood claims have been filed. Figure 3.1.C shows the distribution of all flood insurance claims paid in the Pennypack Watershed for the period January 1978 thru March 2010. As of March 2010, a total of 484 claims had been paid with a total payout of $18 million. The dollar amount is not adjusted for inflation and is only a fraction of the actual damage that has occurred as the result of flooding. Damages to uninsured property, disaster assistance, and damage to public property is not included. Locations of repetitive flood claims are shown in Figure 3.1.D, along with the number of repetitive claims at the site.

Bridges and culverts can change the flow characteristics of waterways by restricting flow during flood events, temporarily raising the upstream water surface elevation. Hazards associated with this include upstream flooding, bridge deck overtopping and flooding of low-lying approach roadways. For downstream properties, the storage provided by obstructions may provide a flood reduction benefit, and removal of the obstruction may increase downstream flood levels, despite benefiting properties upstream. PWD provided a comprehensive survey of obstructions, which included 765 bridges and culverts throughout the Pennypack Watershed. The distribution of these obstructions is shown in Figure 3.1.E. With PWD's assistance, structures with drainage areas of one-half square mile or greater were evaluated to determine flood events that would exceed their flow capacity. The results are shown in Figure 3.1.F. Additionally, bridge overtopping was evaluated using the HEC-RAS model developed for the recent flood insurance study in the suburban portion of the watershed. Figure 3.1.G shows those bridges that are most prone to overtopping from smaller storms such as the 1-year and 2-year events. Profiles from the existing flood insurance study for the Pennypack Creek in the City of Philadelphia indicated that the major roadway bridges were not vulnerable to overtopping by these smaller events.

3.2 Stream Impairment

Surface water quality can become impaired from a lack of stormwater runoff management and non-point source pollution control.[4] Runoff from parking lots or other types of impervious surfaces increases stream temperatures and contributes to non-point source pollution. Pollutants come from automobile emissions, lawn and garden chemicals, and litter.[5]

Increasing urbanization in the Pennypack Watershed has also led to the destruction of riparian buffers, which has created additional pollution problems stemming from overland runoff into the watershed's streams, both the main stem Pennypack Creek and its tributaries. The destruction of riparian buffers also has increased erosion and sediment loadings. It has led to the widespread loss of habitat for both aquatic and terrestrial species, as well as propagation of invasive plant species.

Field investigations conducted during this study and during the 2006 Pennypack Watershed Study identified numerous locations in the suburban portion of the watershed where erosion and streambank undercutting were occurring. These locations are shown in Figure 3.2.A. An example of streambank undercutting in a tributary to Southampton Creek in Lower Moreland Township is shown in Figure 3.2.B.

The Pennsylvania Department of Environmental Protection (DEP) and Philadelphia Water Department have conducted several water quality studies and biological assessments in the Pennypack Creek Watershed. Monitoring conducted by DEP has determined that about 82 percent of the Pennypack Creek Watershed's stream miles are impaired for designated uses and have subsequently been listed on the Pennsylvania 303(d) list of impaired waters. The current designated use of the Pennypack Creek is Warm Water Fishery. The impaired reaches are shown in Figure 3.2.C. According to a 2003 DEP report, *Watershed Restoration Action Strategy for the Poquessing and Pennypack Creek Watersheds*, 66 of the 79 stream miles do not support the biological communities protected by the Clean Water Act. The report indicates that the majority of impairment is due to urban stormwater run-off, water flow variability and flow and habitat alterations. Recent studies of the creek and watershed also identify stormwater runoff as a primary challenge to protecting and restoring the stream's ecosystem. Urban runoff is listed as the primary cause of impairment in 78 percent of the designated streams.[6] Given the state of the watershed and widespread impacts of stormwater, a major part of this study focused on measures to improve control of existing runoff, in addition to criteria for future development.

In 1998 the Environmental Protection Agency approved the Pennypack Creek Total Maximum Daily Load (TMDL) to address the water quality impairments from point sources, in particular violations of standards for dissolved oxygen, fecal coliform bacteria, and trichloroethylene (TCE). The TMDL sets wasteload allocations (WLAs) for point sources for these contaminants. In 2008 the EPA approved a second TMDL for the watershed to address nutrients, organic enrichment/low dissolved oxygen, pathogens, and siltation contaminants from nonpoint sources in the

---

[4] *DeBarry, Paul. 2004. Watersheds: Processes, Assessment, and Management. New Jersey: John Wiley & Sons.*
[5] *Ibid.*
[6] *Table 2.12 and Figure 2.10 of the Comprehensive Characterization Report for the Pennypack Creek Watershed – Philadelphia Water Department, 2009.*

Southampton Creek subwatershed. This TMDL is established for sediments (1,075,668 lbs/ year) and allocated among five municipalities in the following manner:

Sediment TMDL	Sediment Loads (lbs/yr)	Sediment Loads (lbs/day)
Upper Southampton	349,977	959
Lower Moreland	123,449	338
Upper Moreland	229,252	628
Warminster	367,675	1,007
Bryn Athyn	5,400	15

The stormwater improvements recommended in Section 6 and Appendix C would enable the municipalities to mitigate the impairments identified in the TMDLs, particularly the TMDL for Southampton Creek. This is discussed in Section 7.

3.3 Drainage and Stormwater Collection Systems

As noted in Section 2.2, stormwater collection systems exist in most of the Pennypack Watershed. No reports of specific stormwater inlet or surcharge problems were received from the watershed municipalities based on the study team's request for problem locations. However, problem stream culverts were identified by study participants and through evaluation performed by the study team.

As noted in Section 3.1, bridges and culverts with drainage areas of one-half square mile or more in the Pennypack Watershed were evaluated to determine flood events that would exceed their flow capacity. The results are shown in Figure 3.1.F. Figure 3.1.G shows bridges that are most prone to overtopping from smaller storms such as the 1-year and 2-year events. Using the language from Act 167, these areas represent "drainage" problem areas. These are results based on a watershed scale model, and problem culverts and bridges should be verified by the municipality based on the experience with historic flooding at the structure. A list of the structures shown in Figure 3.1.F is provided in Appendix D and GIS files that can be used for mapping the structures are included on the disk accompanying this report.

Section 6 recommends projects that will reduce peak flows and volumes at downstream culverts and bridges. As a general approach, the project team recommends the construction of stormwater improvements to increase storage and reduce stormwater flows and volumes as the first consideration in addressing drainage problems. For cases where increased culvert capacity is the only viable means for solving a drainage problem, an evaluation of potential increases in downstream flood peaks should be performed to prevent adverse flooding or stream channel impacts. In addition, such actions might require municipalities to modify their flood insurance rate maps to outline additional areas subject to inundation during more extreme flood events.

Table 3.1.A Buildings affected by Floodways, 100-Year Floodplains, and 500-Year Floodplains

Municipality	Building Footprints in Flood Zones		
	Floodway	100-Year	500-Year
Abington	7	22	29
Bryn Athyn	0	5	16
Hatboro	28	80	102
Horsham	17	61	87
Lower Moreland	42	94	117
Upper Dublin	0	4	4
Upper Moreland	27	131	170
Upper Southampton	4	38	54
Warminster	0	8	9
Total	**125**	**443**	**588**

Source: FEMA

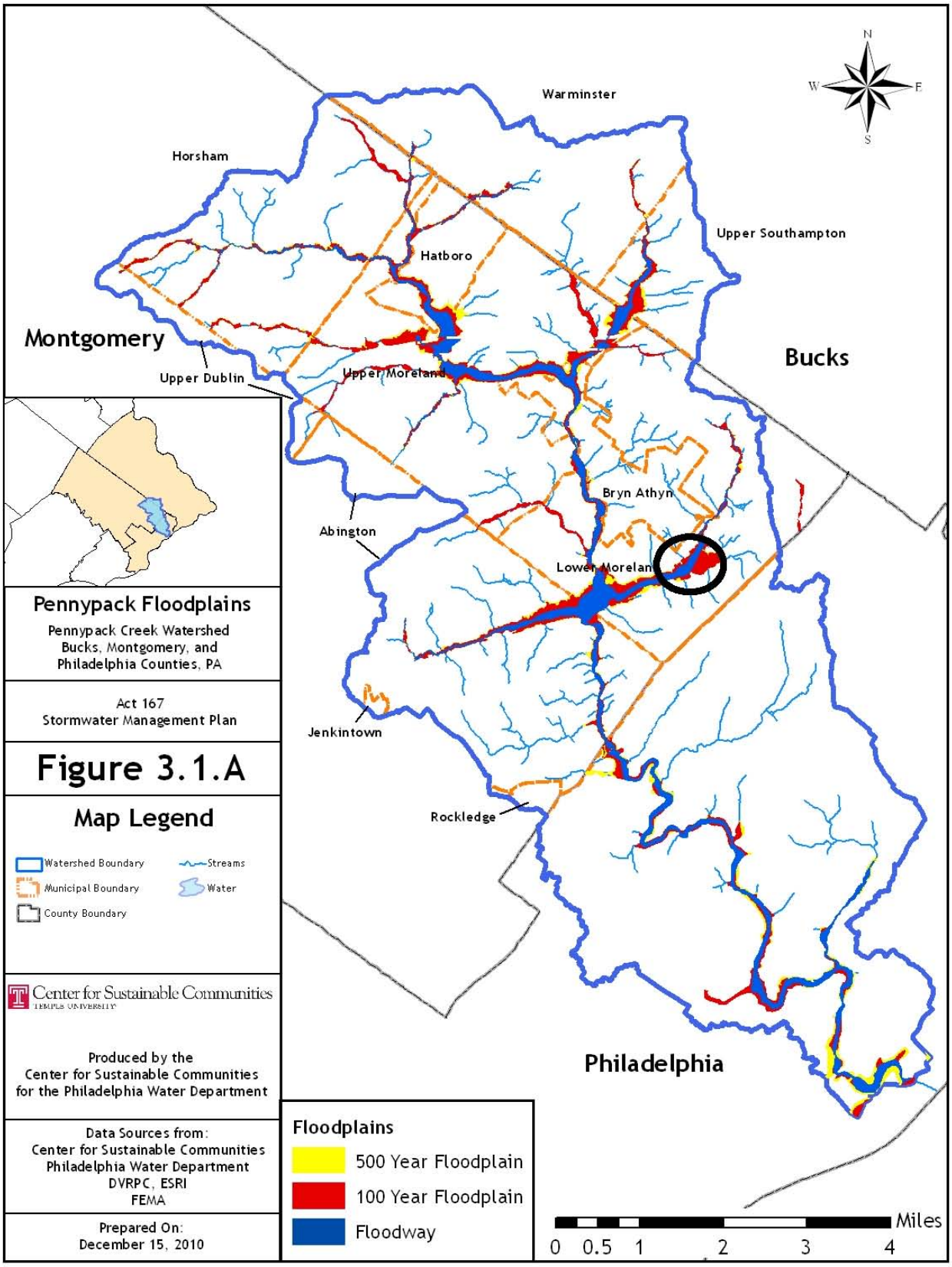
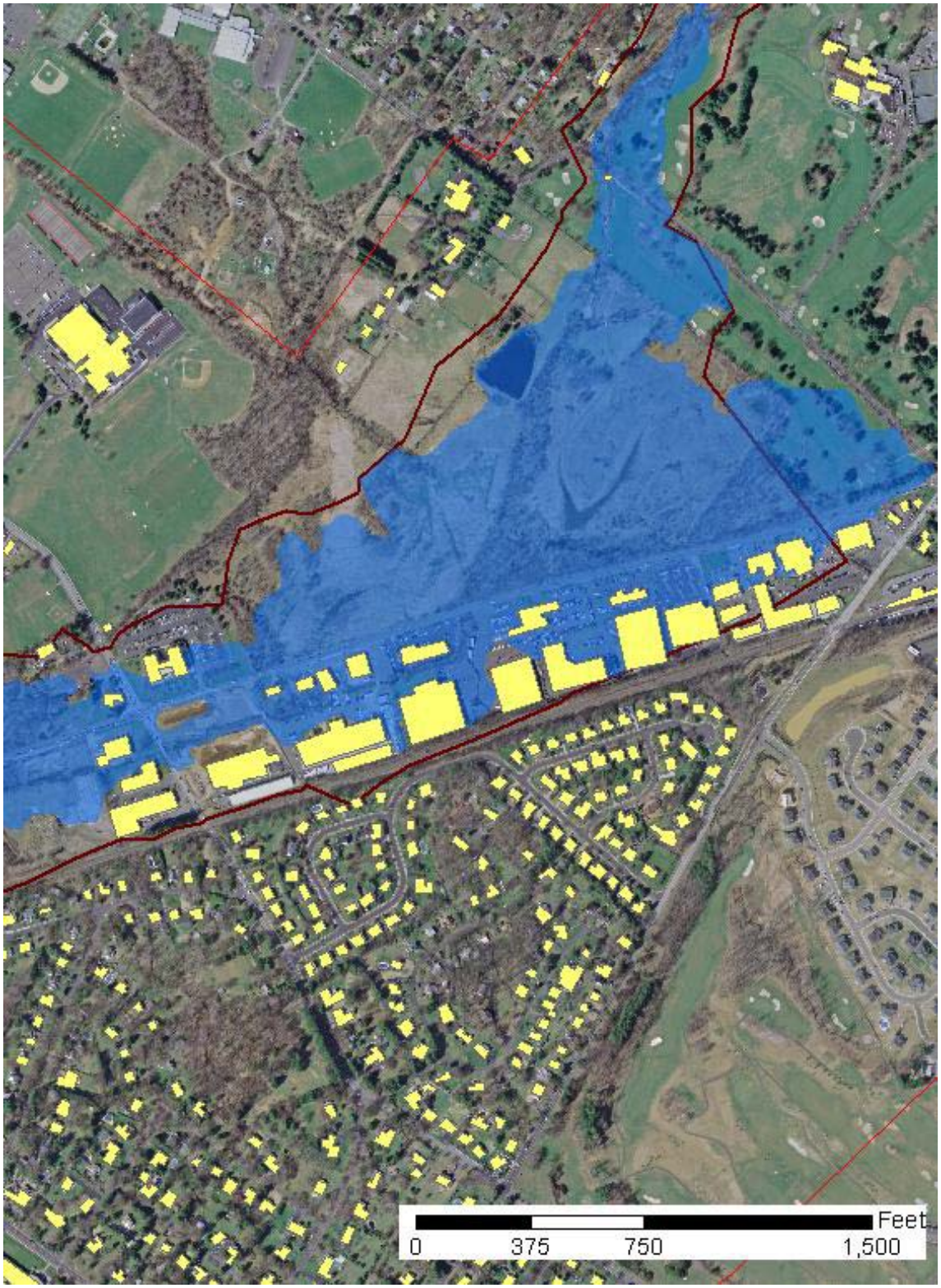
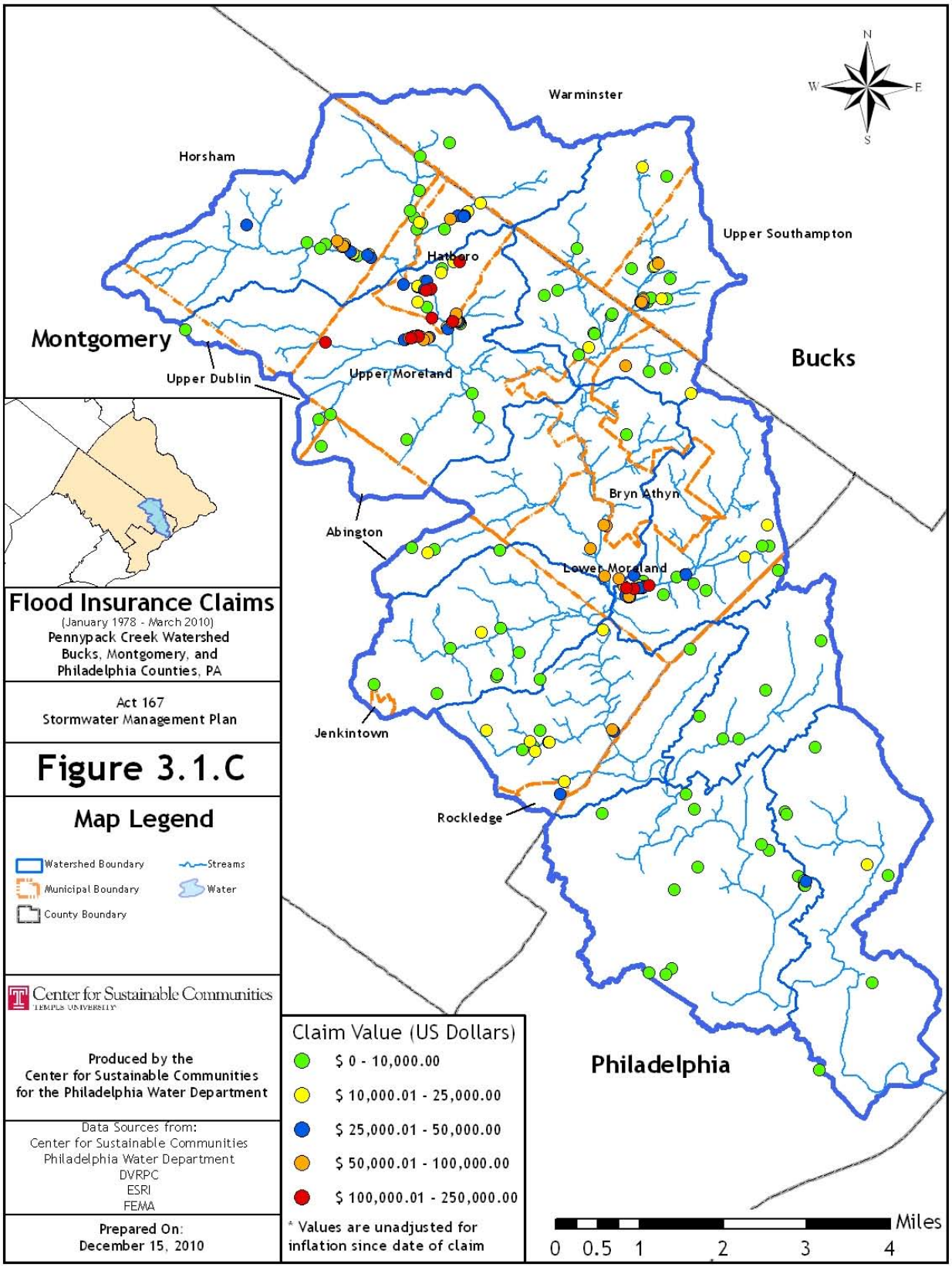
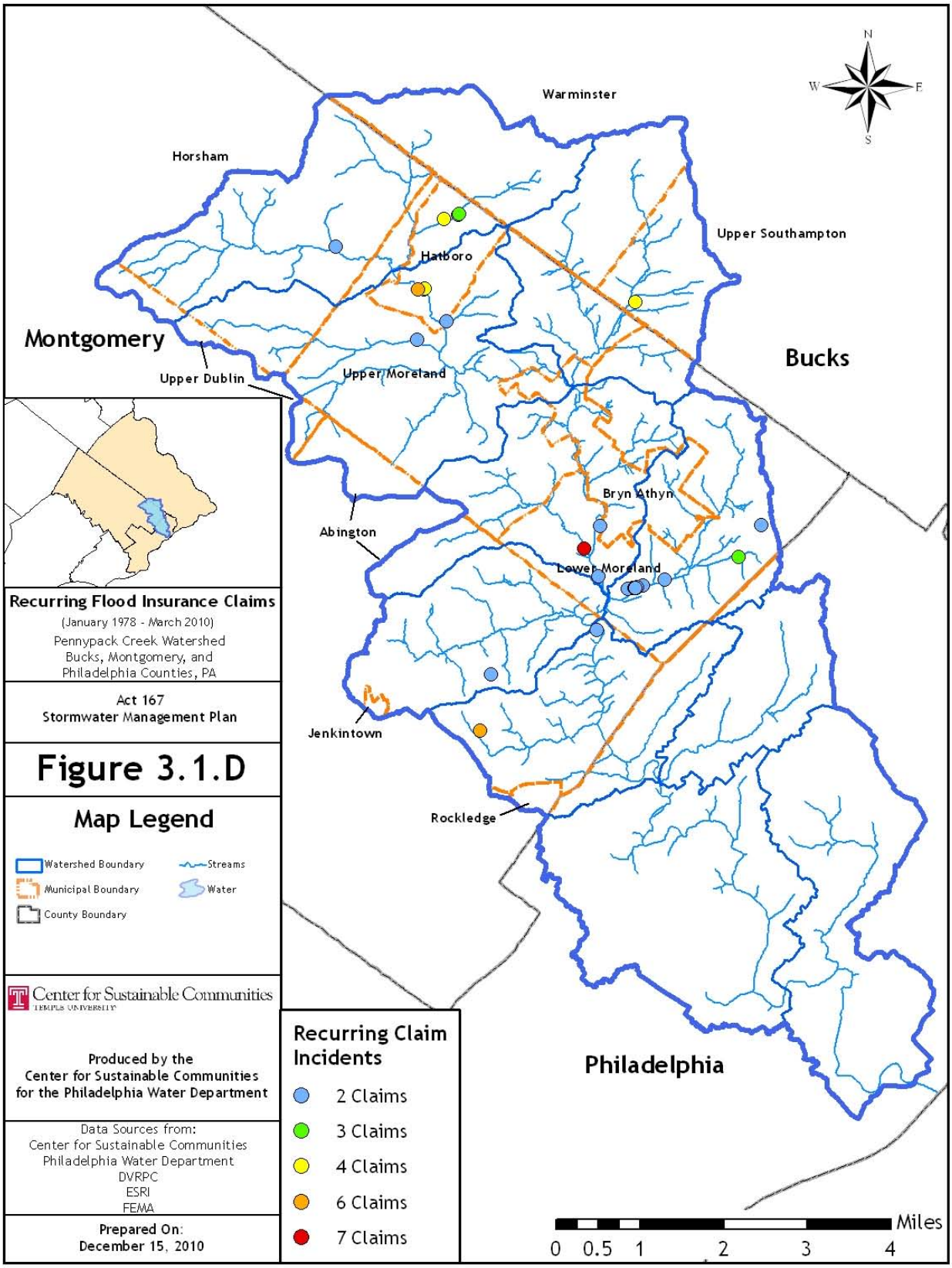
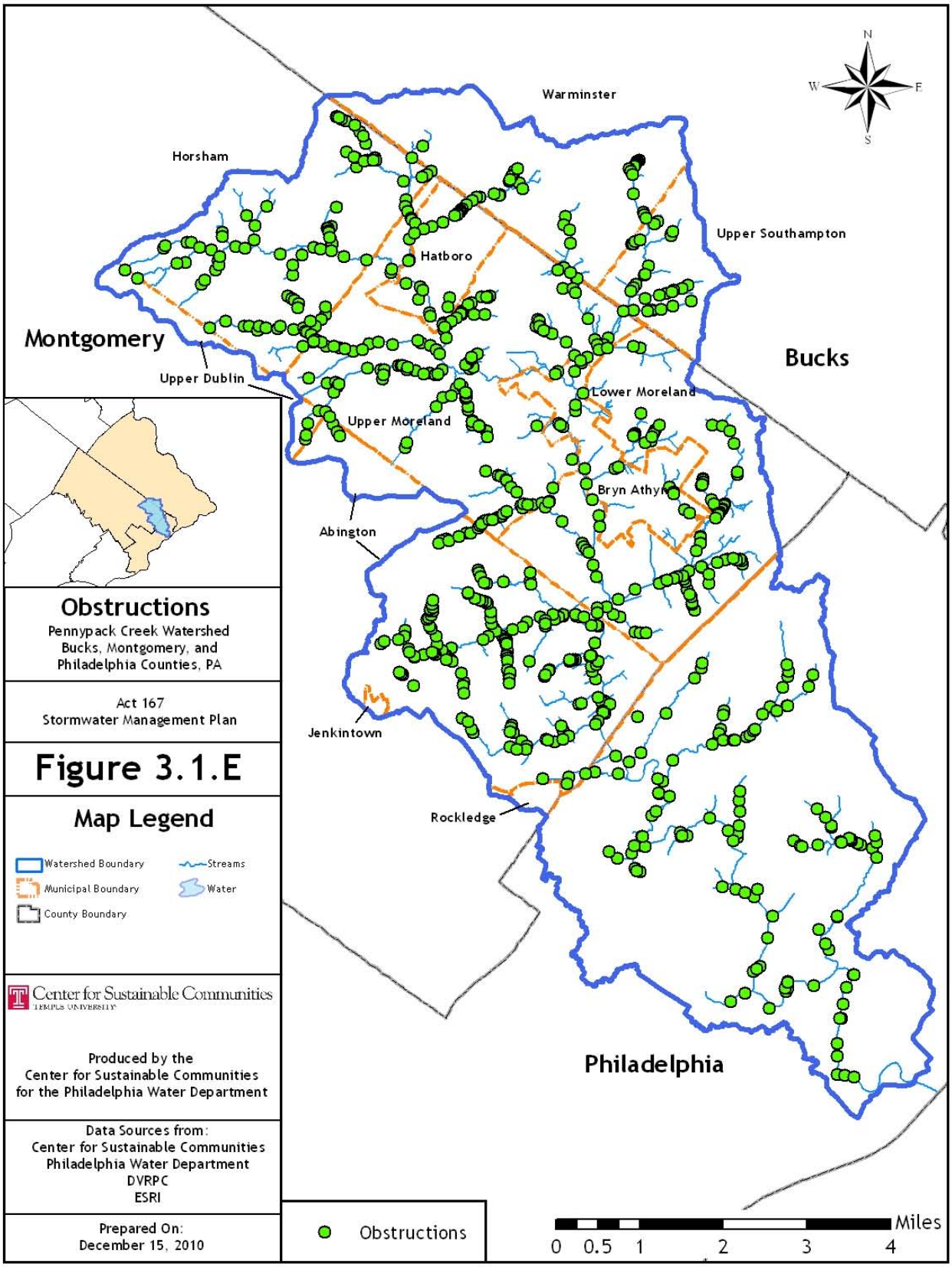

Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Pennypack Floodplains
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 3.1.A
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC, ESRI
FEMA
Prepared On:
December 15, 2010
Floodplains
500 Year Floodplain
100 Year Floodplain
Floodway
Miles
0 0.5 1 2 3 4

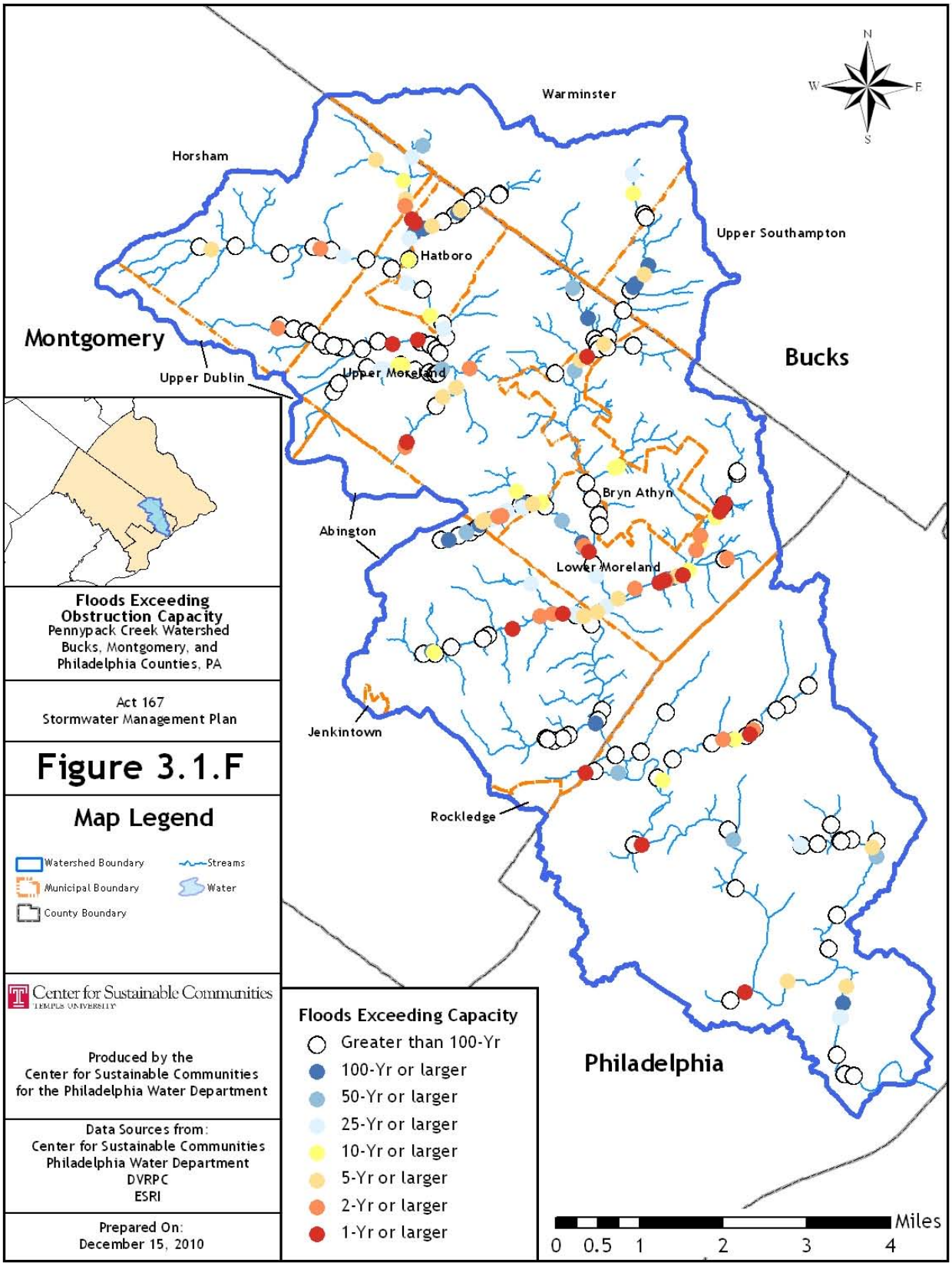
Figure 3.1.B 100-Year Floodplain - Huntington Valley Creek showing Flooding of Philmont Road – Lower Moreland Township, Montgomery Co., PA

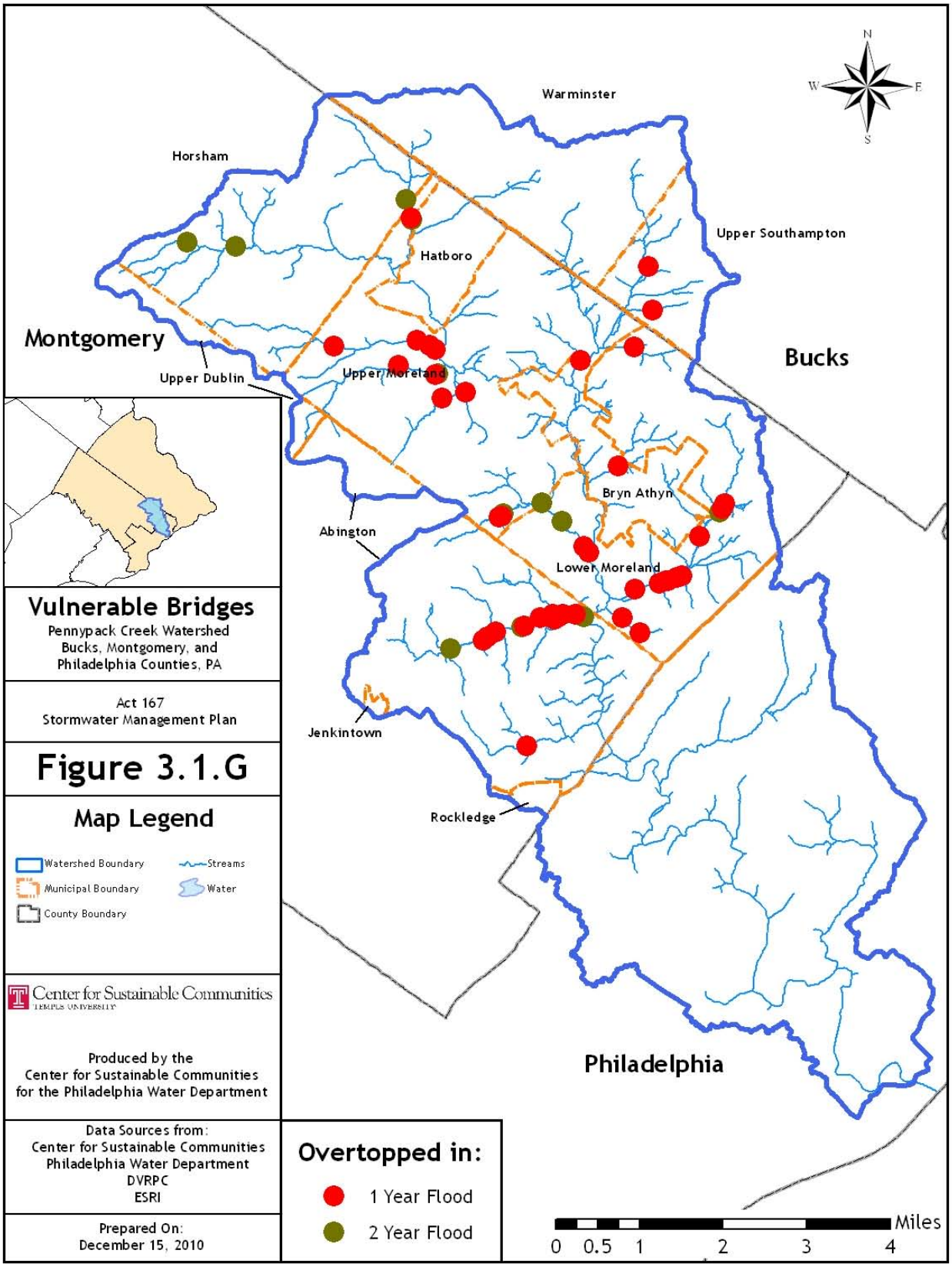



Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Flood Insurance Claims
(January 1978 - March 2010)
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 3.1.C
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
FEMA
Prepared On:
December 15, 2010
Claim Value (US Dollars)
$ 0 - 10,000.00
$ 10,000.01 - 25,000.00
$ 25,000.01 - 50,000.00
$ 50,000.01 - 100,000.00
$ 100,000.01 - 250,000.00
* Values are unadjusted for
inflation since date of claim
Miles
0 0.5 1 2 3 4


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Recurring Flood Insurance Claims
(January 1978 - March 2010)
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 3.1.D
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
FEMA
Prepared On:
December 15, 2010
Recurring Claim Incidents
2 Claims
3 Claims
4 Claims
6 Claims
7 Claims
Miles
0 0.5 1 2 3 4


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Lower Moreland
Upper Moreland
Bryn Athyn
Abington
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Obstructions
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 3.1.E
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Obstructions
Miles
0 0.5 1 2 3 4


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Floods Exceeding Obstruction Capacity
Pennypack Creek Watershed
Bucks, Montgomery, and Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 3.1.F
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Floods Exceeding Capacity
Greater than 100-Yr
100-Yr or larger
50-Yr or larger
25-Yr or larger
10-Yr or larger
5-Yr or larger
2-Yr or larger
1-Yr or larger
Miles
0 0.5 1 2 3 4


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Vulnerable Bridges
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 3.1.G
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Overtopped in:
1 Year Flood
2 Year Flood
Miles
0 0.5 1 2 3 4

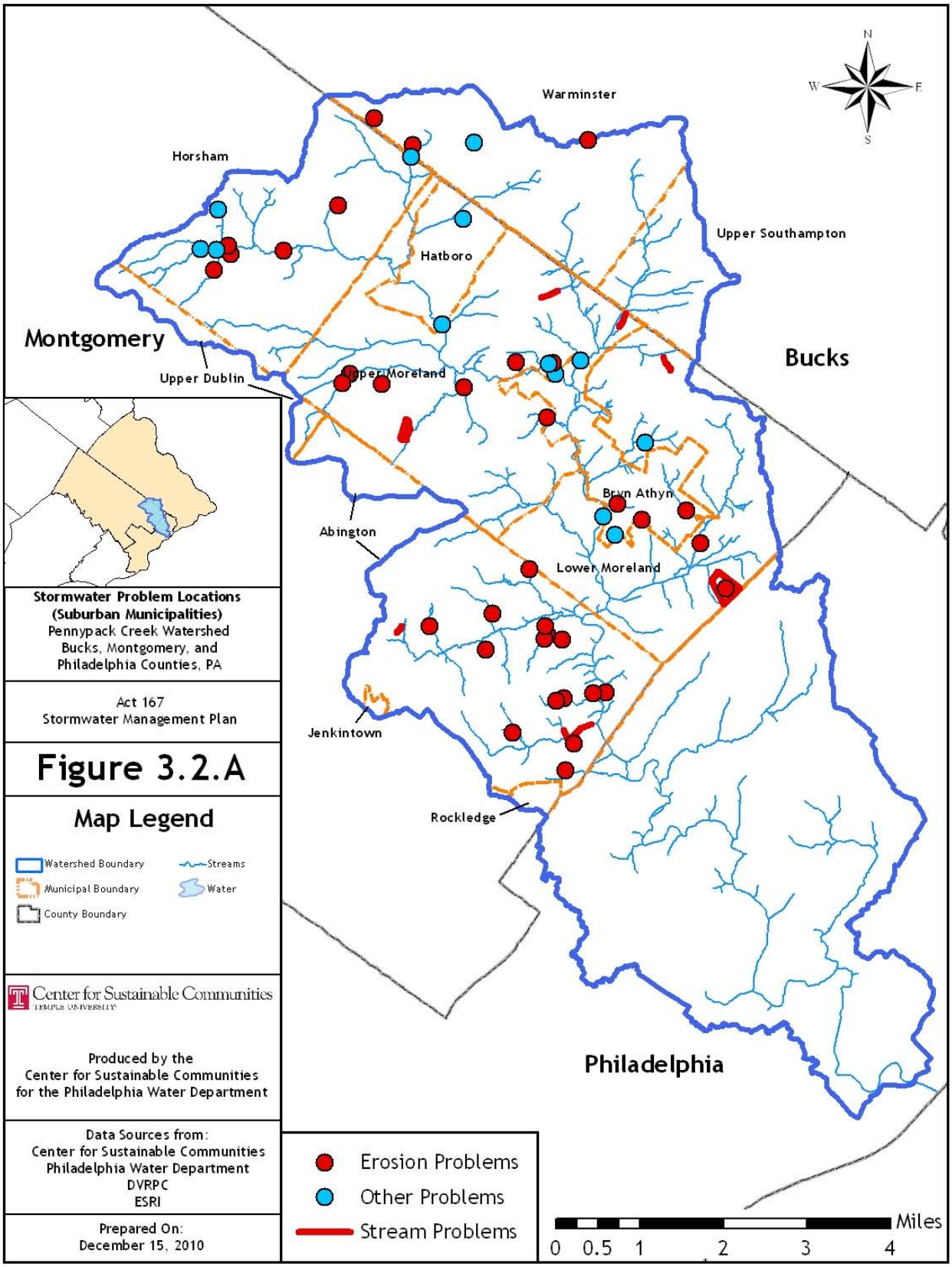

Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Stormwater Problem Locations
(Suburban Municipalities)
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 3.2.A
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Erosion Problems
Other Problems
Stream Problems
Miles
0 0.5 1 2 3 4

Figure 3.2.B Example of streambank erosion and bank undercutting tributary to Pennypack Creek, Lower Moreland Twp., Montgomery County, PA

Figure 3.2.C
Water Quality Impairment
Pennypack Watershed
Section 303 (d) – Clean Water Act

Four Designated Use Categories

- Aquatic Life
- Water Supply
- Fish Consumption
- Recreation

Summary of 303 (d) List Impairments
In the Pennypack Watershed

Impairment	Total Miles
Agriculture	0.4
Industrial/Municipal Point Source	9.5
Residential Runoff	7.3
Urban Runoff	61.8

Reference: Table 2.12 and Figure 2.10 of the Comprehensive Characterization Report for the Pennypack Creek Watershed – Philadelphia Water Department, 2009

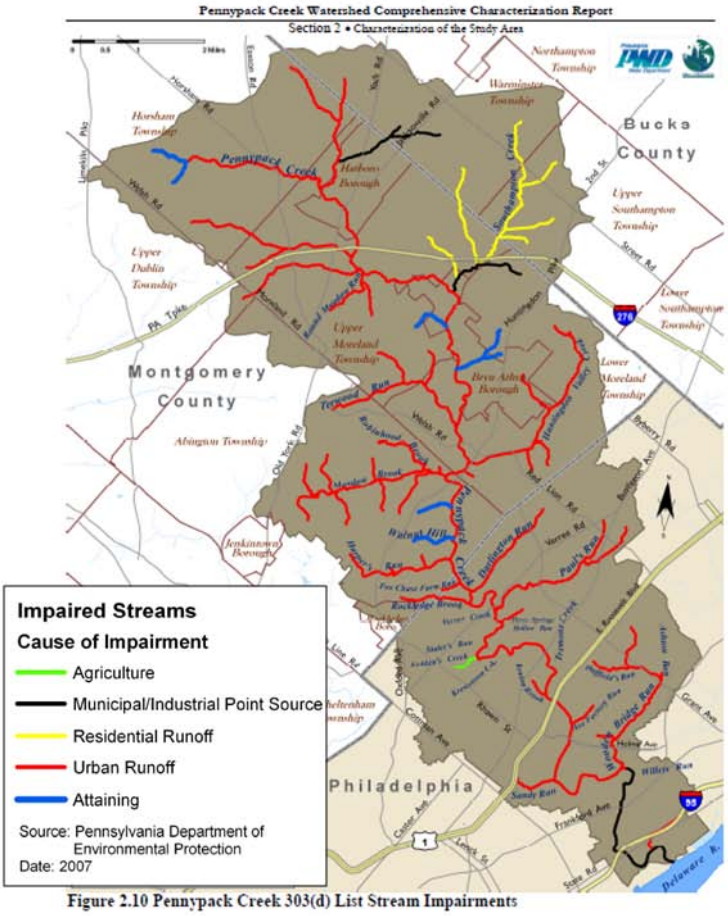


Figure 2.10 Pennypack Creek 303(d) List Stream Impairments

Section 4: Model Development and Application

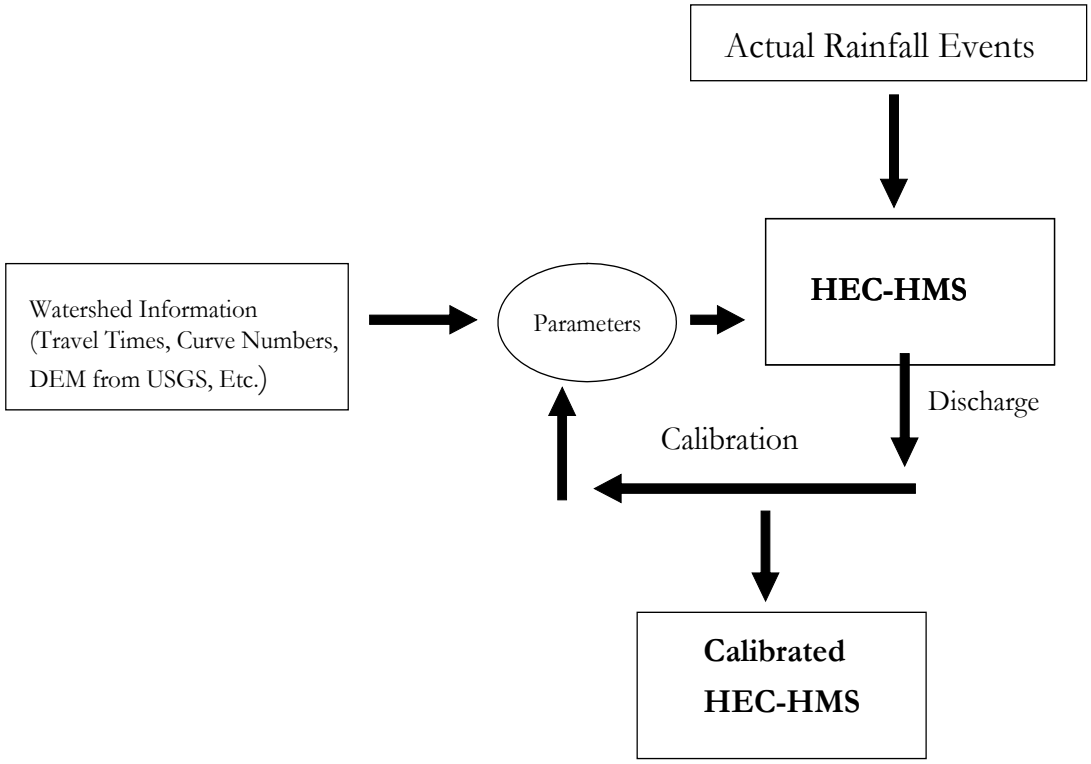
The modeling for the Act 167 study was built upon hydrologic and hydraulic modeling completed for the recent flood insurance study of the suburban Pennypack Watershed. The modeling for the flood insurance study has been approved by the Federal Emergency Management Agency (FEMA) and the associated flood maps are undergoing public review as of December 2010.

4.1 Testing of the Original 10-Subbasin Model

The hydrologic model developed for the flood insurance study included 10 subbasins for the 56-square mile Pennypack Watershed. A schematic diagram of the model is shown in Figure 4.1.A. The model was based on Natural Resource Conservation Service (NRCS) Curve Number and Unit Hydrograph procedures available within the HEC-HMS modeling software and was developed and calibrated by Temple University's Civil and Environmental Engineering Department following the general procedure outlined on Figure 4.1.B.

Figure 4.1.A Diagram of Pennypack 10-Subbasin Hydrologic Model used for Flood Insurance Study

Figure 4.1.B Development and Calibration of the 10-Subbasin Hydrologic Model



As an additional test on the predictive ability of the 10-subbasin model, the Philadelphia Water Department (PWD) Office of Watersheds provided rainfall and flow data for 60 storm events in 2007 and 2008 and provided analysis of the modeled versus the observed results for these events. Precipitation data was provided for eight stations within or near the Pennypack Watershed and distributed to the 10 subbasins using Thiessen Polygons as shown in Figure 4.1.C. The HEC-HMS model was then run for each of the 60 events. The results of the peak flow and volume comparison are shown in Figures 4.1.D and 4.1.E, respectively.

4.2 Development of the Act 167 Hydrologic Model

The objective of the Act 167 hydrologic modeling was to increase the number of subbasins in the model to provide more detailed peak flow analysis than was used for the flood insurance study. This was necessary for determining peak rate controls for stormwater management, as well as for evaluating the potential impacts of stormwater improvements. Results from the 10-subbasin HEC-HMS model, which had been tested and calibrated against the only long-term gage (Rhawn Street) in the watershed, were used as a guide to calibrate the new Act 167 model.

Figure 4.1.C Distribution of Observed Precipitation for Testing of the 10-Subbasin Model

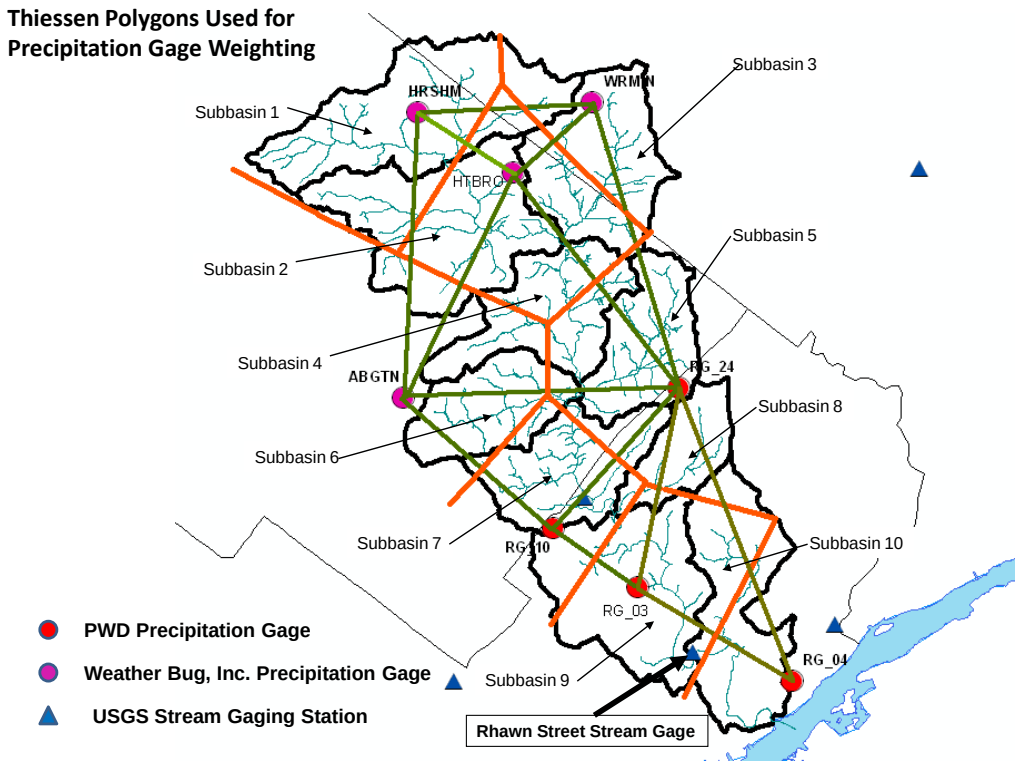
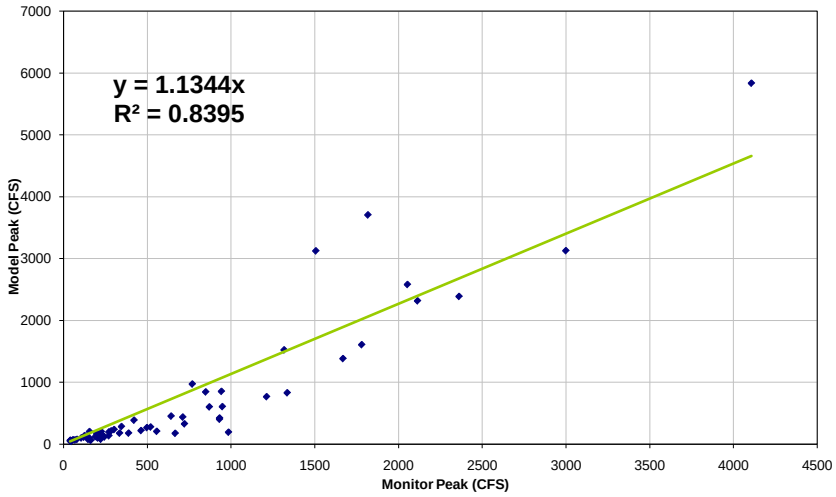


Figure 4.1.D Observed vs. Modeled Peak Flows – Original 10-Subbasin Model

Test Results for Sixty Precipitation Events – 2007-2008

The model output for each of 60 events and compared to Observed Data

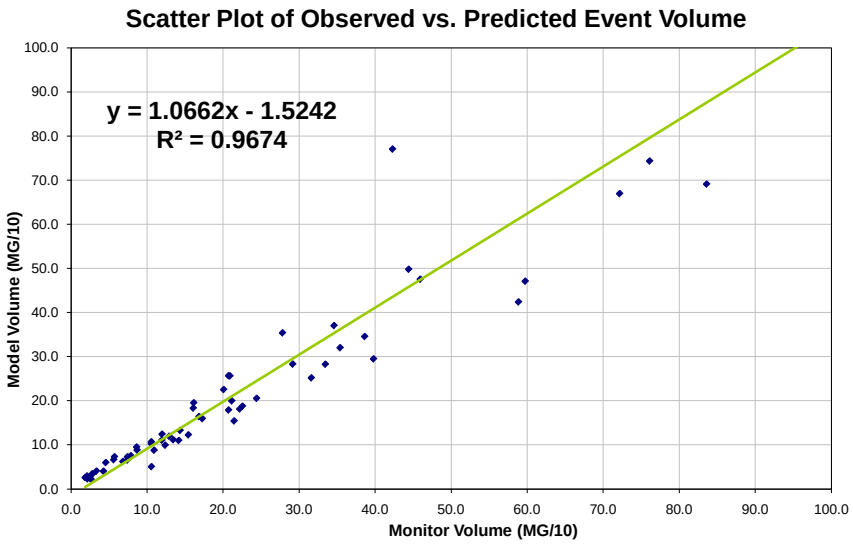
Scatter Plot of Observed vs. Predicted Peak Flows



Observed flow at USGS Stream Gage at Rhawn Street

Analysis of results was performed by the Philadelphia Water Department

Figure 4.1.E Observed vs. Modeled Event Volume – Original 10-Subbasin Model Test Results for Sixty Precipitation Events – 2007-2008

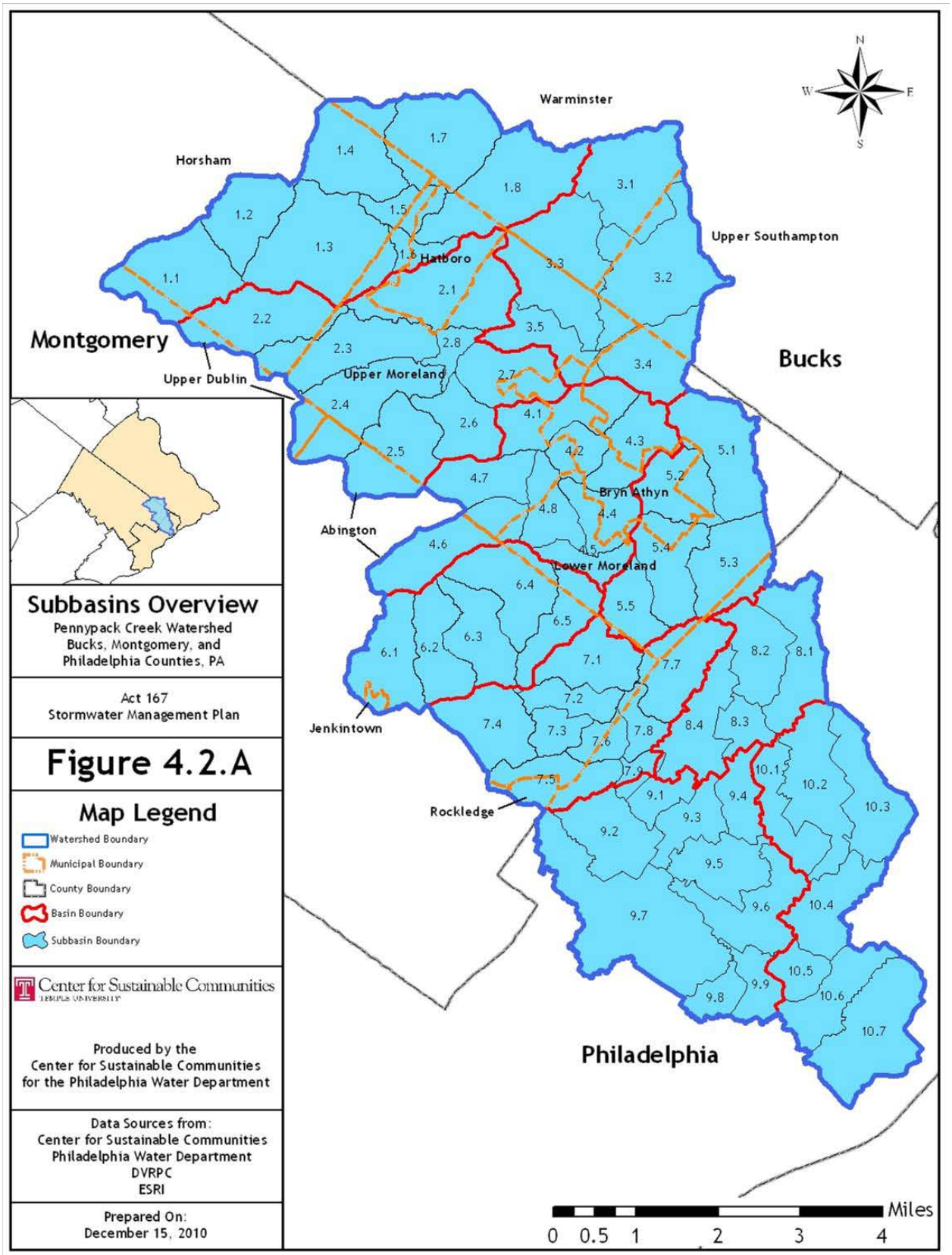


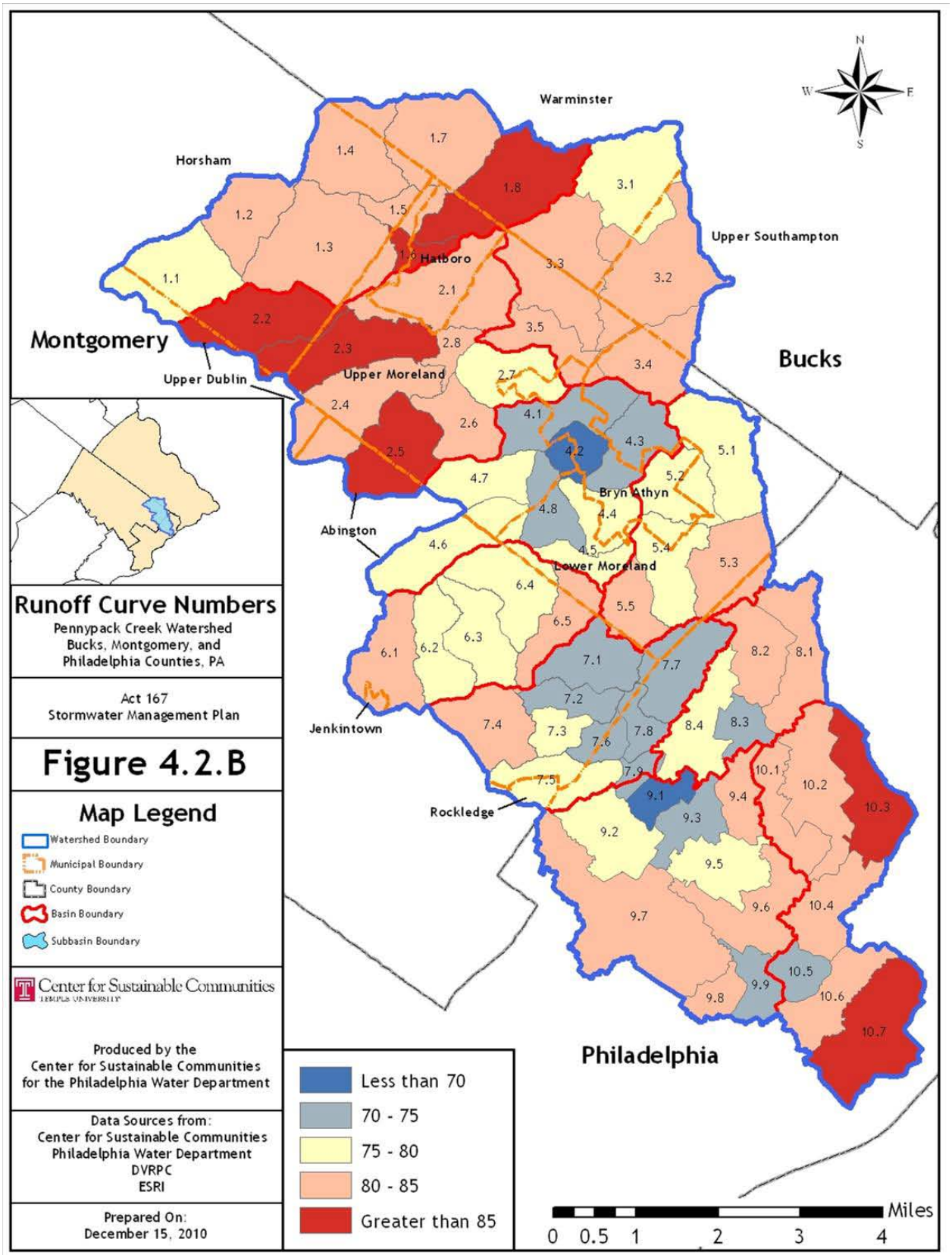
Observed volume at USGS Stream Gage at Rhawn Street
Analysis of results was performed by the Philadelphia Water Department

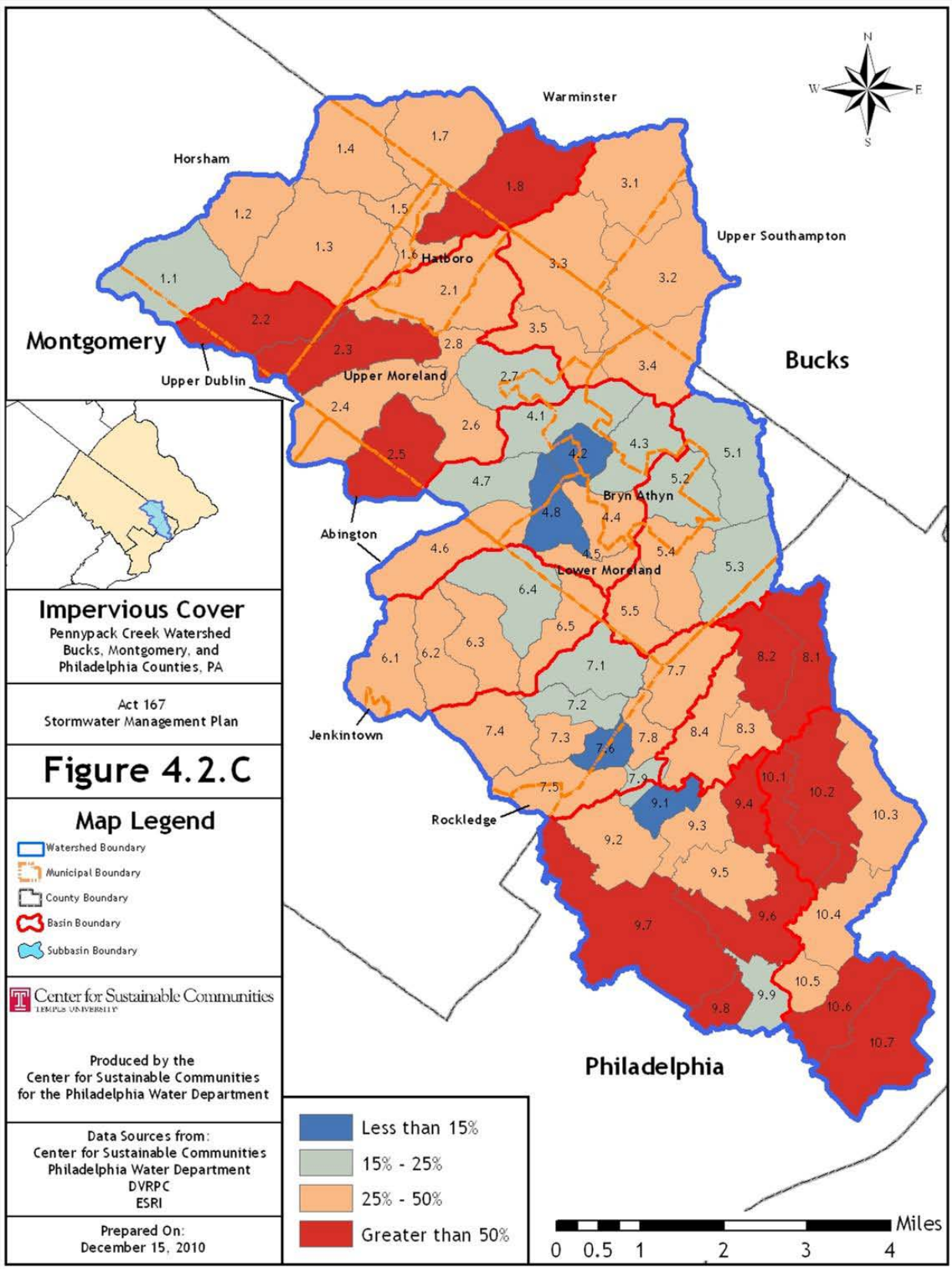
The 10 large subbasins used for the original flood insurance study model were divided into a total of 68 smaller subbasins for the new Act 167 model. Subbasin delineations were chosen primarily at stream confluence points and boundary delineations were based on several sources. These included a digital elevation model (DEM) and 2-foot contour interval data obtained by the Center for Sustainable Communities (CSC), 2-foot contour data provided by PWD, and, particularly within the city limits of Philadelphia, storm sewer shed delineations provided by PWD. Figure 4.2.A shows both the original 10 subbasins and the new 68 subbasin delineations used for the Act 167 model.

Land Use Data for 2005 from the Delaware Valley Regional Planning Commission (DVRPC) and NRCS data for Hydrologic Soil Groupings were used to generate NRCS runoff Curve Numbers for each of the 68 subbasins. Figure 4.2.B shows the distribution of runoff Curve Numbers calculated for the Pennypack Watershed. These are composite Curve Number values that include the effect of impervious cover, such as roof and parking areas, as well as pervious areas. While composite Curve Number values were useful for some model comparisons performed for the study, modeling of impervious cover as directly connected to the storm sewer and stream channels provided the best representation of existing conditions in the watershed which generally show a quick response to precipitation events. Impervious cover was calculated based on land use data and estimated percentages of impervious cover for different land uses.[1] Figure 4.2.C shows the distribution of impervious cover by subbasin. A Curve Number for the pervious portion of the watershed was then calculated and then adjusted for the aggregate total of detention storage in each subbasin. In total, approximately one-third of the Pennypack Watershed is covered by impervious surfaces.

[1] *Urban Hydrology for Small Watersheds, TR55, Natural Resources Conservation Service, 1986.*


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
Subbasins Overview
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 4.2.A
Map Legend
Watershed Boundary
Municipal Boundary
County Boundary
Basin Boundary
Subbasin Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Miles
0 0.5 1 2 3 4


Runoff Curve Numbers
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 4.2.B
Map Legend
Watershed Boundary
Municipal Boundary
County Boundary
Basin Boundary
Subbasin Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Less than 70
70 - 75
75 - 80
80 - 85
Greater than 85
Miles
0 0.5 1 2 3 4
N
S
E
W
Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Abington
Bryn Athyn
Lower Moreland
Jenkintown
Rockledge
Philadelphia

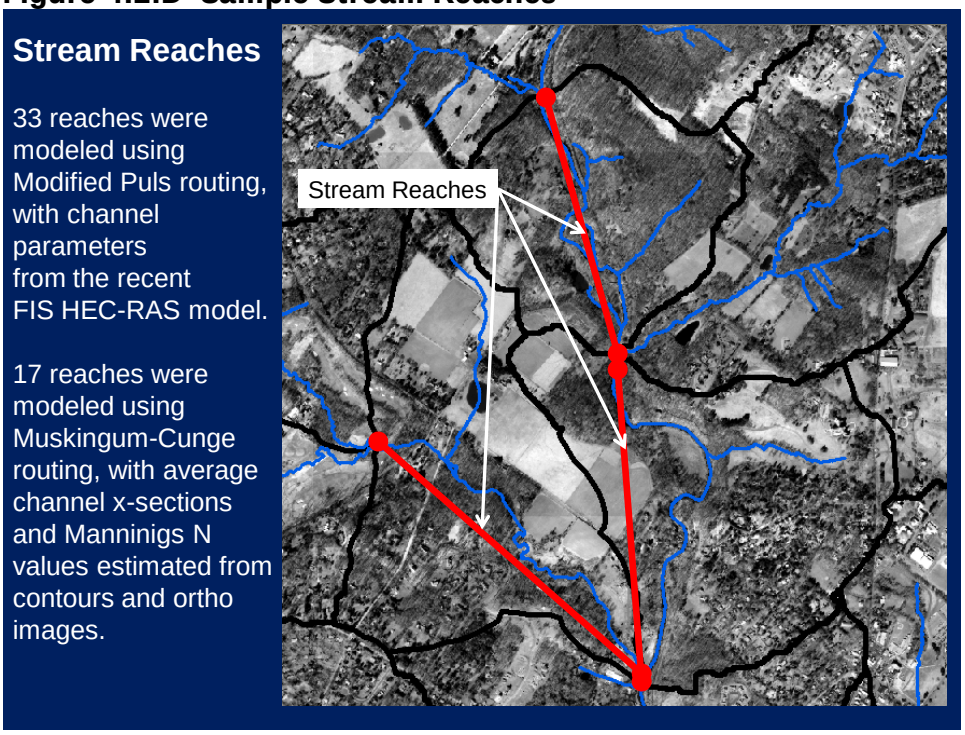

Impervious Cover
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 4.2.C
Map Legend
Watershed Boundary
Municipal Boundary
County Boundary
Basin Boundary
Subbasin Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Less than 15%
15% - 25%
25% - 50%
Greater than 50%
Miles
0 0.5 1 2 3 4
N
S
E
W
Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Abington
Bryn Athyn
Lower Moreland
Jenkintown
Rockledge
Philadelphia

In addition to the volume of precipitation that runs off the land surface, the shape and slope of each subbasin affect the timing of the runoff and the peak flow. For this study, these factors are represented by the subbasin time of concentration (Tc), which was calculated as the sum of sheet flow time, shallow concentrated flow time, and channel flow time for the longest flow path to the subbasin outlet. Orthophotography was used to estimate the length of each flow path and the maximum length of sheet flow was limited to 100 feet.[2]

The Act 167 hydrologic model also includes 50 stream reaches to convey flow from the subbasin outlets through the tributaries and main stem of the Pennypack Creek. Flow through reaches are influenced by storage defined by the shape of the channel and over banks and by the friction generated from the roughness of the stream channel, banks and adjacent submerged surfaces in the floodplain. Because a HEC-RAS hydraulic model was developed for the flood insurance study, it was used where possible to determine the relationship between storage and discharge in the stream reaches. This relationship was used to apply Modified Plus routing to 33 of the 50 stream reaches in the model. The remaining reaches were modeled using the Muskingum-Cunge method, which represents the reach using channel length, an average cross section, and Mannings roughness coefficients. Figure 4.2.D shows a sample schematization of stream reaches.

The Act 167 model parameters for subbasins and reaches are provided in Appendix B.

Figure 4.2.D Sample Stream Reaches



[2] *Merkel, References on Time of Concentration with Respect to Sheet Flow, National Water and Climate Center, 2001.*

4.3 Hydrologic Model Test Results

The new Act 167 hydrologic model was tested against the original model approved by FEMA for the recent flood insurance study. The comparison was made for the design precipitation totals listed in Figure 2.2.A. These totals were obtained from NOAA Atlas 14 using the values for the 90 percent confidence limit for the 1-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year events with a 24-hour duration.[3] Watershed precipitation totals were obtained by taking an average of values for locations representing the upper, middle, and lower portion of the watershed. A Type II rainfall distribution developed for interior portions of the continental United States was used for modeling the storm events. This was the distribution used for the flood insurance study modeling.[4]

Peak discharge and runoff volume were compared for each of the seven storm events at the model junction locations shown in Figure 4.3.A and for each of the 10 subbasins in the original model. Test results were used to adjust the subbasin and routing parameters to match the results between the two models. Based on the test results for the original 10-subbasin model, an effort was made to increase the runoff volume and quicken the response rate of the new Act 167 model for the 1-year storm event. To achieve this, impervious cover was modeled as directly connected to the stream network. This increased volume for the 1-year storm without significantly impacting larger events. A comparison of modeled peak flow and volume is shown for locations in the upper portion (Pennypack Creek below the confluence with Southampton Creek) and lower portion (Pennypack Creek at Rhawn Street) of the watershed in Figures 4.3.B and 4.3.C, respectively. Comparisons at the other junction points were similar for the two models. PWD has supported the U.S. Geological Survey Water Science Center in the recent development and operation of additional stream gages in the Pennypack Watershed. Data from these stations will provide an opportunity for improved calibration of the hydrologic model. In its current form, the model produces peak discharges and volumes along the main stem of the Pennypack Creek that are in close agreement with those of the original model used in the flood insurance study, and is believed to be a reasonable tool for establishing peak rate controls for the watershed. It is also useful for estimating culvert flows comparing development and stormwater improvement scenarios at the watershed scale. Because of the modeling scale, estimation of culvert flows using the model was limited to drainage areas of half a square mile or larger.

---

[3] *G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley, "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 2, Version 3, NOAA, National Weather Service, Silver Spring, Maryland, 2004, as provided by the web site: http://hdsc.nws.noaa.gov.*

[4] *Urban Hydrology for Small Watersheds, TR55, Natural Resources Conservation Service, 1986.*

Figure 4.3.A Points of Comparison for Testing of Act 167 Model

Comparison of Model Results for Design Storms – Pennypack Creek Watershed
***Peak flows and volumes for 1 year thru 100 year events were compared at junctions and for large subasin outlets**

Original 10 Subasin Model | **Detailed Model – 68 Subasins**

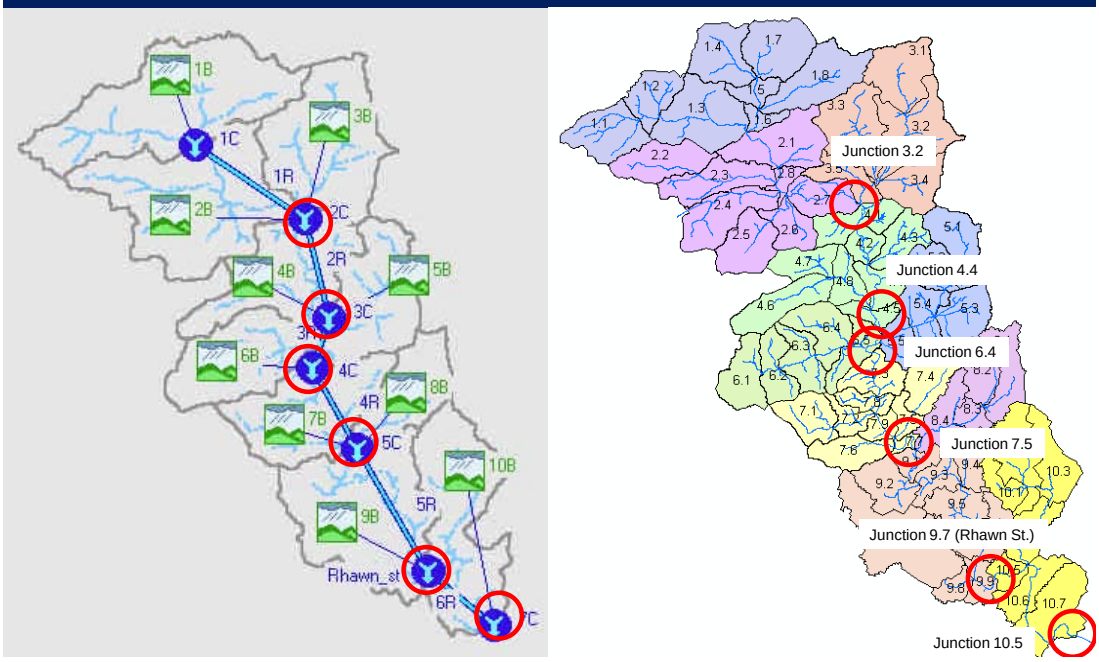
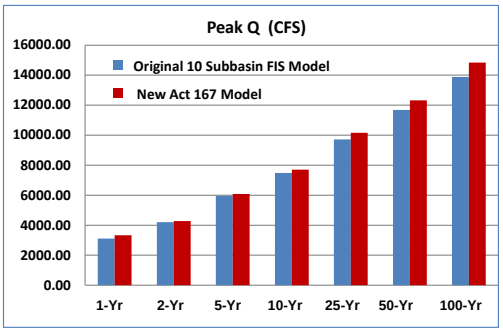
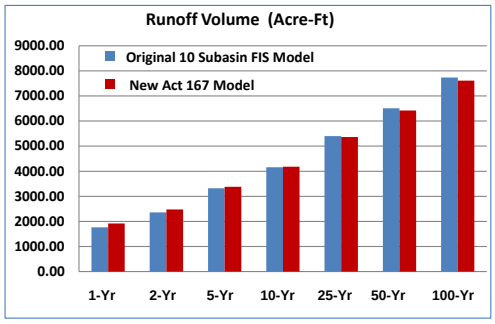


Figure 4.3.B Model Test Results – Upper Portion of Pennypack Creek

Comparison for Pennypack Creek below Confluence with Southampton Creek



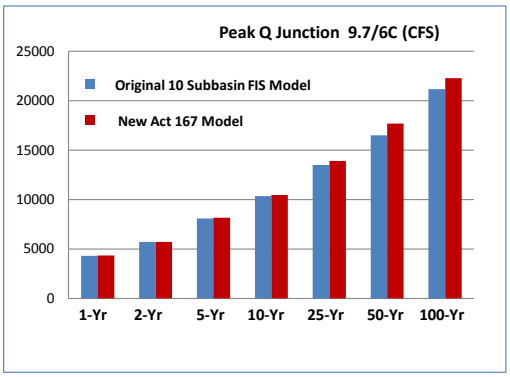


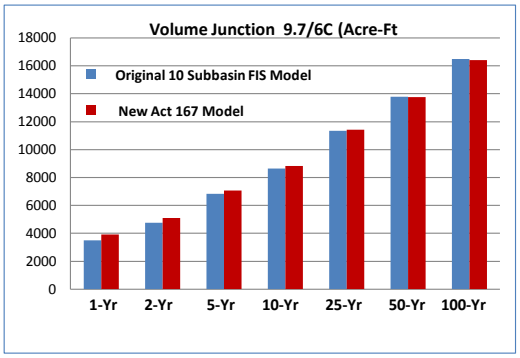
		Peak discharge (cfs)	
Storm	**Original Model**	**New Model**	**% Difference**
1-Yr	3107.10	3335.70	7.36
2--Yr	4207.00	4271.00	1.52
5-Yr	5961.80	6078.80	1.96
10-Yr	7481.20	7700.40	2.93
25-Yr	9716.10	10166.30	4.63
50-Yr	11689.40	12323.50	5.42
100-Yr	13883.20	14839.00	6.88

		Volume (Acre-Ft)	
Storm	**Original Model**	**New Model**	**% Difference**
1-Yr	1766.80	1915.90	8.44
2-Yr	2358.50	2473.00	4.85
5-Yr	3317.20	3378.60	1.85
10-Yr	4157.20	4176.80	0.47
25-Yr	5401.00	5364.00	-0.69
50-Yr	6504.60	6423.70	-1.24
100-Yr	7736.70	7611.80	-1.61

Figure 4.3.C Model Test Results – Lower Portion of Pennypack Creek

Comparison for Pennypack Creek at Rhawn Street Stream Gage





	Junction 9.7/6C	Peak Discharge (CFS)	
Storm	Original Model	New Model	% Difference
1-Yr	4320.1	4346.5	0.61
2-Yr	5720.2	5702.3	-0.31
5-Yr	8073	8150.4	0.96
10-Yr	10331.80	10437	1.02
25-Yr	13478.5	13895.9	3.10
50-Yr	16478.40	17668.9	7.22
100-Yr	21164.30	22273.3	5.24

	Junction 9.7/6C	Volume (Acre-FT)	
Storm	Original Model	New Model	% Difference
1-Yr	3508.6	3907.9	11.38
2-Yr	4762.8	5108.7	7.26
5-Yr	6820.2	7072.7	3.70
10-Yr	8639.20	8819.3	2.08
25-Yr	11354.7	11425.8	0.63
50-Yr	13775.20	13768.4	-0.05
100-Yr	16489.70	16403.1	-0.53

4.4 Modeling Assumptions

Assumptions included in the hydrologic modeling affect the representation of the rainfall-runoff process and the potential applications of the model. The key modeling assumptions include:

- Subbasin properties are averaged for each subbasin area. Subbasin areas ranged from 0.35 to 2.36 square miles.
- The hydrologic impact of stormwater piping is not included in the modeling. Tc for the subbasins was calculated based on surface features.
- For the design events, the same volume and temporal distribution of rainfall is applied uniformly over each of the 68 subbasins.
- Design storm precipitation totals were obtained from NOAA Atlas 14 using the upper limit of the 90 percent confidence interval values.
- Design storm precipitation timing was assigned a Type II distribution.
- The maximum distance for sheet flow was assumed to be 100 feet based on NRCS recommendations.
- For representing existing conditions, all impervious area was assumed to be connected to the stream via runoff over other impervious areas or inlets to storm sewers.
- The aggregate total of existing detention storage in each subbasin was considered additional potential storage. The Curve Number in the permeable portion of each subbasin was adjusted downward to account for this using the NRCS Curve Number equation.

- Tc was used to represent subbasin lag time, and was calculated as the sum of sheet flow, shallow concentrated flow and channel flow.

The resulting model produces higher peak flow values for the design storm events than would be obtained by applying regression equations based on gauged flow record.[5] This is primarily due to the simultaneous application of design storm precipitation conditions over each of the subbasins. It is also important to note that the model scale, while considered adequate for purposes of the Act 167 study, is not suitable for site level analysis or design.

4.5 Model Applications

The hydrologic model was applied to several components of the study. Each of the applications is summarized in this section.

- Comparison of existing vs. "undeveloped" runoff conditions
- Evaluation of hydrologic impacts of land use change scenarios
- Determination of peak flow rates for identifying frequently flooded bridges and culverts
- Determination of peak rate control management districts included in the model ordinance
- Evaluation of runoff impacts of improved stormwater control through BMP applications

Comparison of Existing vs. "Undeveloped" Runoff Conditions

The hydrology of the Pennypack Watershed has been altered by land conversion and increased impervious cover, particularly during smaller storm events. As original forest cover was converted to agricultural and residential use, and later when asphalt, concrete and roof surfaces increased, the ability to retain precipitation decreased. This led to both increased runoff volume and quicker runoff response from precipitation. The highest densities of impervious cover are generally found in the upper and lower thirds of the watershed, with the middle third consisting mostly of residential and open space uses. As an urban watershed, the Pennypack has benefited from stream corridor protection provided by Fairmount Park in Philadelphia, and by lands donated and preserved through the Pennypack Ecological Restoration Trust. In addition, portions of the Meadow Run and, to a lesser extent, the Huntington Creek watersheds include wetland areas that help reduce flood velocities.

The hydrologic model was applied to help describe the current runoff characteristics of the watershed as presented in Section 2. Figure 4.5.A compares modeled peak discharge and runoff volume for existing land use conditions to modeled results for forest cover in "good" and "fair" condition for seven different design storm events. The hydrograph comparison for the 1-year storm is also shown. In addition to impacting the 1-year storm, the model results indicate development has increased the peak discharge and runoff volume for larger floods. The model results for forested conditions were generated by eliminating connected impervious cover, by assigning Curve Number values representative of the two forest cover conditions, and by calculating subbasin lag times based on the NRCS lag equation.[6]

---

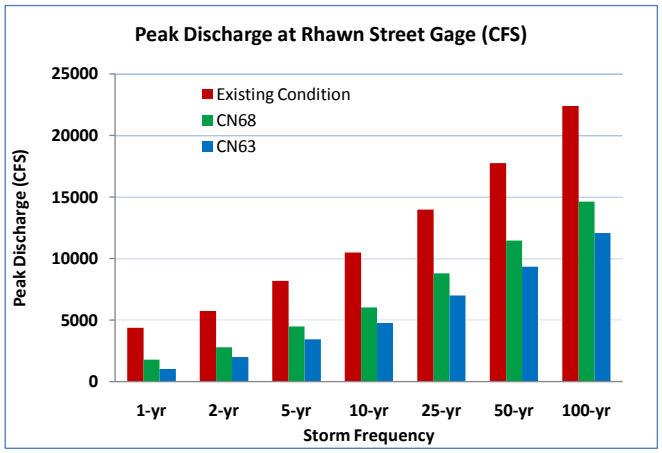
[5] Roland, Mark A.; Stuckey, Marla H., Regression Equations for Estimating Flood Flows at Selected Recurrence Intervals for Ungaged Streams in Pennsylvania, Scientific Investigations Report, U.S. Geological Survey, 2008.

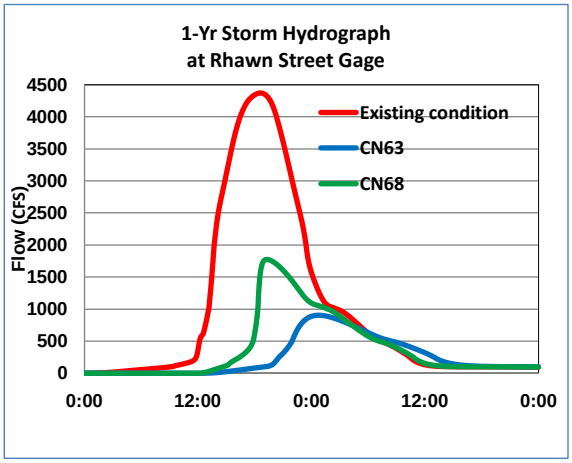
[6] *Bedient, P.B., Huber, W.C., Vieux, B.E., Hydrology and Floodplain Analysis, Fourth Edition, Pearson/Prentice Hall, 2008, p. 135.*

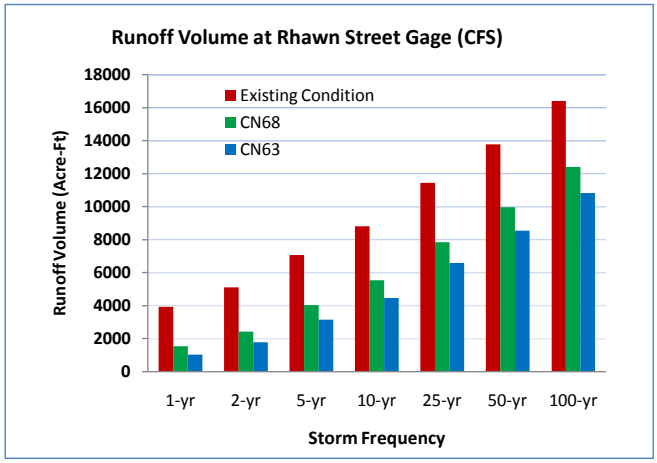
Figure 4.5.A Modeling Comparison of Existing and "Undeveloped" Runoff Conditions

Existing vs. "Undeveloped" Conditions

- Location: Pennypack Creek at Rhawn Street
- Total Precipitation for 1-Yr Storm = 2.98 inches
- Comparison is to NRCS Curve Numbers of 63 and 68.
- A curve number of 63 represents forest cover in good condition averaged for hydrologic soil groups B and C.



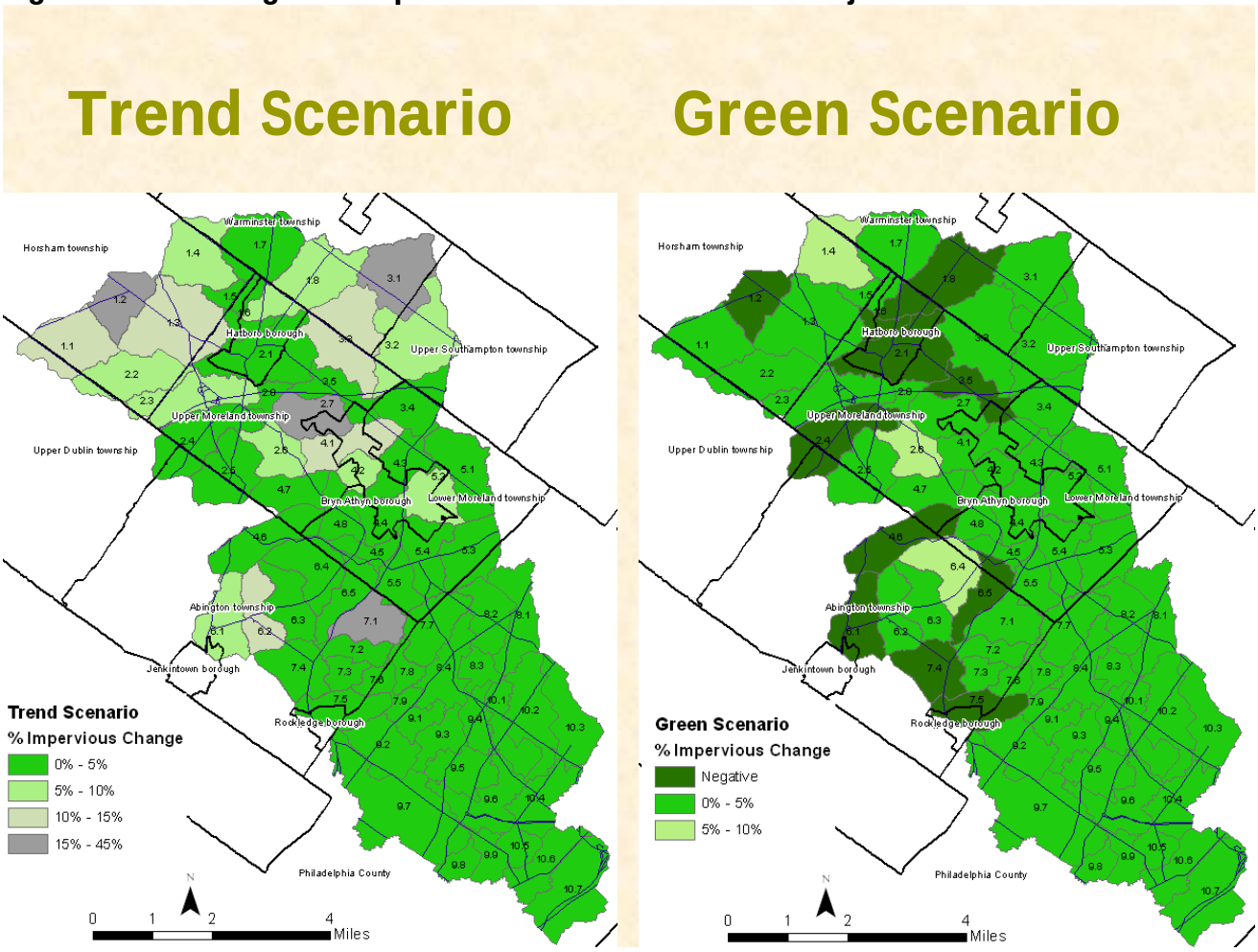




Evaluation of the Hydrologic Impacts of Future Land Use Change Scenarios

As described in Section 2, two future land use scenarios were projected for the Pennypack Watershed for this study – one based on recent trends (Trend), and a second based on land suitability criteria (Green). The hydrologic model was applied to compare the scenarios' peak flow and volumes for different storm events to those for existing land use conditions. Peak rate control associated with future development was not included in the modeling. Although this would most likely lead to over-prediction of the peak flows, volume increase is considered a stronger indicator of the impact of land use change. The model results were generated by calculating the change in impervious cover for the future conditions and subsequently adjusting the Curve Number for the pervious portion of each subbasin. Figure 4.5.B shows the relative increase in impervious cover in the Pennypack subbasins for each of the two scenarios, based on the projected distribution of land use change. The comparison illustrates the effectiveness of the Green scenario in limiting the increase in impervious cover resulting from projected growth.

Figure 4.5.B Changes in Impervious Cover for Land Use Projections

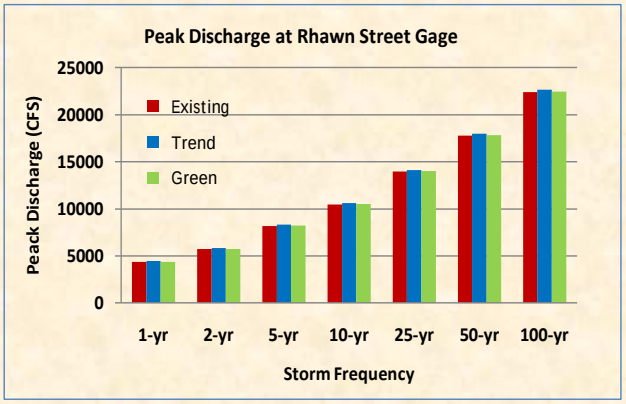


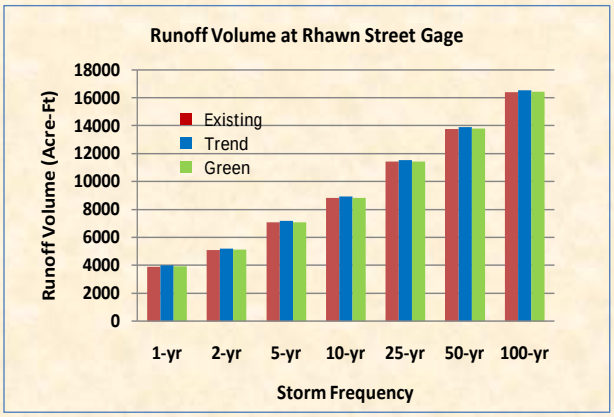
The modeling results shown in Figure 4.5.C show the aggregate effect of the two land use projections on peak discharge and runoff in the lower portion of the main stem of the Pennypack at Rhawn Street. Peak discharge and runoff volume would increase two percent or less for the Trend scenario and less than one percent for the Green scenario. Increases in peak discharge and volume would be more significant in the areas with the greatest projected change in impervious cover. Figures 4.5.D and 4.5.E indicate the subbasins with the largest increases in 1-year storm peak flow and runoff volume for each scenario. For the Trend scenario, volume increases for the 1-year storm range from 7 to 13 percent in the circled subbasins. For the Green scenario, volume increases are limited to 4 percent or less. This result supports the concept that land use management based on suitability criteria offer means of control for future runoff volume that supplements the use of extended detention and other BMPs.

Figure 4.5.C Hydrologic Impact of Projections for Pennypack Creek at Rhawn Street

Existing vs. Trend vs. Green Modeling Comparison

- Suitability projection based on medium density residential and open space preservation.
- Location: Pennypack Creek at Rhawn Steet near lower end of watershed. Drainage Area ~ 50 sq. mi.





	Peak Discharge (CFS)				
Storm	Existing	Trend	Green	% Change Trend	% Change Green
1-yr	4368.00	4462.50	4379.70	2.16	0.27
2-yr	5737.30	5862.40	5754.10	2.18	0.29
5-yr	8198.90	8343.20	8220.00	1.76	0.26
10-yr	10485.90	10626.70	10507.80	1.34	0.21
25-yr	13971.10	14140.40	13999.10	1.21	0.20
50-yr	17772.40	17978.10	17807.30	1.16	0.20
100-yr	22403.10	22646.20	22448.10	1.09	0.20

	Volume (Acre-FT)				
Storm	Existing	Trend	Green	% Change Trend	% Change Green
1-yr	3908.80	3989.80	3916.50	2.07	0.20
2-yr	5107.20	5196.70	5116.80	1.75	0.19
5-yr	7072.90	7172.40	7085.20	1.41	0.17
10-yr	8818.60	8924.60	8832.80	1.20	0.16
25-yr	11427.50	11541.10	11444.20	0.99	0.15
50-yr	13768.00	13886.60	13786.00	0.86	0.13
100-yr	16399.40	16523.00	16419.60	0.75	0.12

Figure 4.5.D Subbasins with Highest Volume Increases – Trend Scenario

At the sub-watershed scale, significant impacts on volume are indicated by the modeling.

Increases range from 7 to 13 percent for these Subbasins for the 1-YR storm.

Peak rate control would require infiltration or detention of the increased volume.

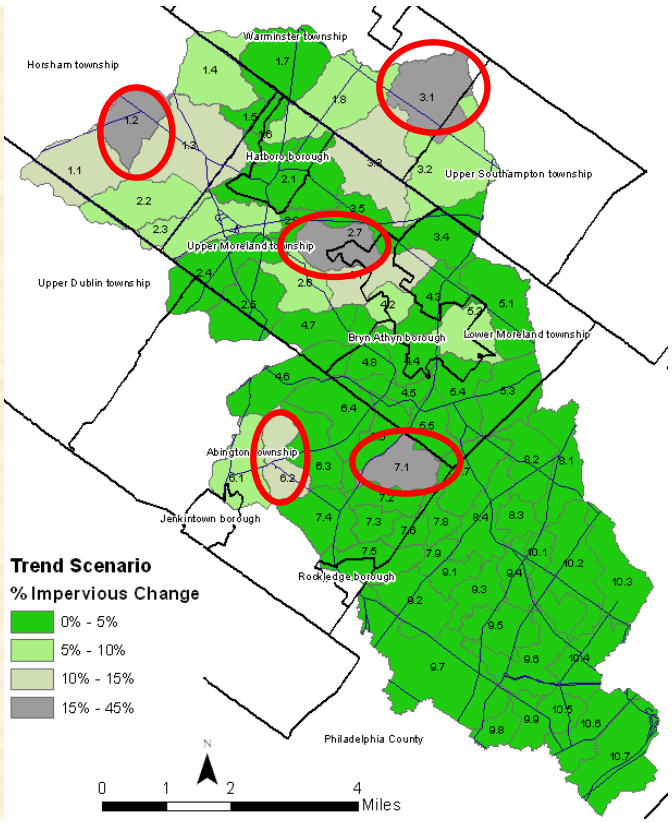
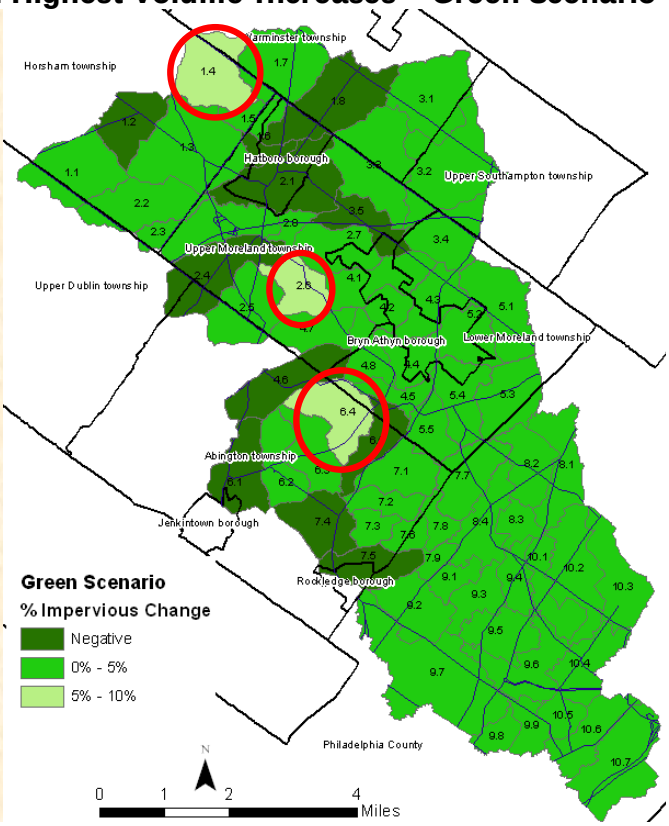


Figure 4.5.E Subbasins with Highest Volume Increases – Green Scenario

The Green scenario results in substantially less runoff volume.

Volume increases are less than 4 percent in the most affected subbasins for the 1-Yr storm.



Determination of Peak Flow Rates for Identifying Flood-Prone Bridges and Culverts

The hydrologic model was applied to determine obstructions (bridges and culverts) where capacities are most likely to be exceeded by flooding. PWD provided the CSC with a GIS shape file including over 700 bridges and culverts located in the Pennypack Watershed, based on survey work performed during 2009 and 2010. PWD then used the SWMM model to calculate the full flow capacity of most of these structures and provided the results to the CSC. The hydrologic model was used to calculate peak discharges at each obstruction for the 1-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year storms. The discharges were then compared to the calculated obstruction capacity. Due to the scale of the hydrologic modeling, the peak discharge versus capacity comparison was limited to those locations where the contributing drainage area is 0.5 square miles or more. The results of the comparison were presented in Figure 3.1.F as part of the description of flood problems in the watershed. The method applied does not take into account the increased backwater required to overtop a given structure, or backwater depth that may affect upstream properties prior to overtopping. It is a screening tool to identify structures where the free flow capacity to convey flooding is most limited.

Outputs from the hydrologic model were also used in combination with the HEC-RAS model (from the flood insurance study) to determine structures vulnerable to overtopping in the suburban portion of the Pennypack Watershed. Peak discharges at the mouths of streams were adjusted for upstream reaches based on drainage area and the HEC-RAS model was run to generate flood profiles for the design storms. Figure 3.1.G shows those bridges most likely to be overtopped based on this analysis.

Determination of Peak Rate Control Management Districts Included in the Model Ordinance

Stormwater management criteria include peak rate control in order to prevent post development flood discharge from exceeding pre-development discharge and worsening downstream flooding. Because detention basins used to control increased peak flows and runoff volumes from development also slow the timing of outflow, an understanding of runoff timing throughout the watershed is needed to establish peak rate criteria. Under some conditions, delaying runoff at a site can cause the peak from the site to better coincide with the peak from other parts of the watershed at downstream locations. This may occur even when the detention basin limits outflow so that there is no increase in the runoff rate from the site after development. This can worsen downstream flooding and increase erosion for a given storm. Because it accounts for the timing of flow through the subbasins and stream reaches, a hydrologic model is useful for defining post-development runoff rates that will prevent this situation from occurring.

The objective of modeling for peak rate control is to determine the flow contribution of different subareas in the watershed (model subbasins) to the peak discharge at various locations downstream, and then determine which subbasins can potentially worsen flooding at the downstream location if runoff is detained. The method follows the procedures presented by DeBarry for establishing stormwater management districts.[7] For this analysis, the downstream locations or "Points of Interest" are shown in Figure 4.5.F. The 10-year storm event was used in the modeling to determine routing time and flow contributions for a Type II storm event. The time required for discharge from each upstream subbasin to reach a given point of interest was

[7] *DeBarry, P.A., Watersheds, Processes, Assessment, and Management, John Wiley & Sons, Inc., 2004, Section 18.5.*

determined on order to “lag” the subbasin hydrograph, and see how it actually contributes to the peak flow at the point of interest as it flows past the location. If the lagged peak flow from the subbasin occurs after the peak flow at the point of interest, then detention in that subbasin would not worsen flooding at that location. If it occurs before the peak, detention can worsen flooding and a peak rate control is necessary to protect the point of interest. In general, for the Pennypack Watershed, headwater subbasins fall into the first category, while subbasins in the middle and lower portions of the watershed fall into the second group. For subbasins where detention could worsen flooding, the ratio of the contributing discharge at the time of peak flow at the point of interest, to the peak flow of the subbasin, is taken as the “release rate” and can be expressed as a percentage. For example, a release rate of 70 percent means that the lagged subbasin flow at the time of the peak discharge at the point of interest is 70 percent of the subbasin peak flow. To prevent worsened flooding at the point of interest, detention to control new runoff volume should limit discharge to 70 percent of the pre-development peak. Release rates for all upstream subbasins were calculated for each point of interest shown in Figure 4.5.F, and the minimum release rate for each subbasin was then determined. The calculated release rates were then used to establish the stormwater management districts shown in Figure 4.5.G, which is incorporated with the recommended stormwater management criteria in Section 5.

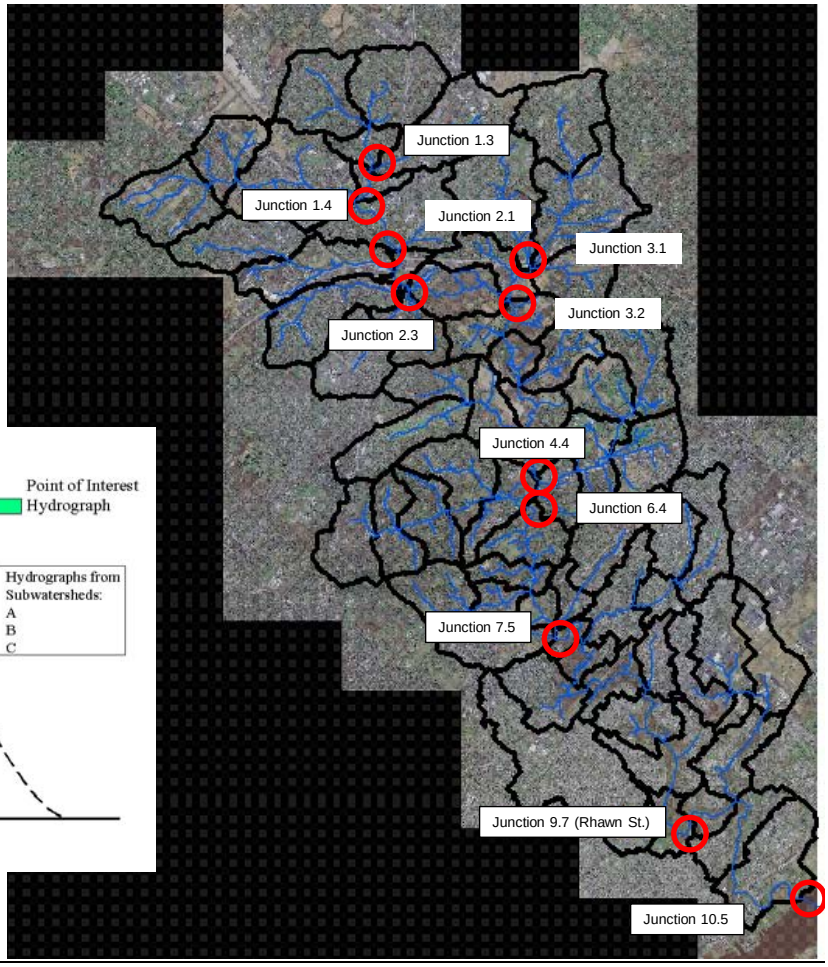
Figure 4.5.F Points of Interest Used for Modeling to Determine Release Rates

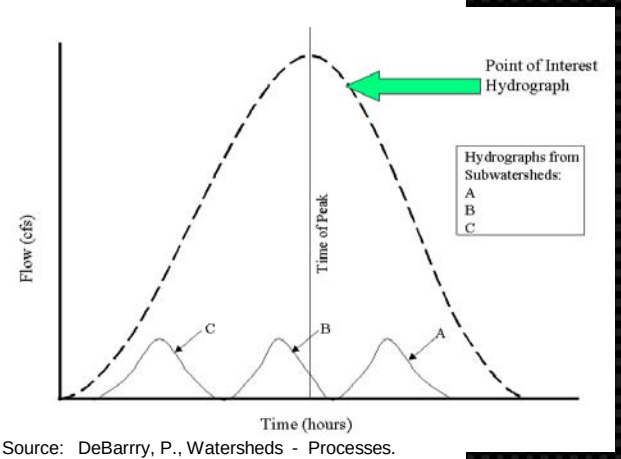
Circles show Point of Interest and Corresponding Hydrologic Model Junction

Determination of Release Rates for New and Expanded Development

The model was used to determine the contributions to flood flows from different portions of the watershed.

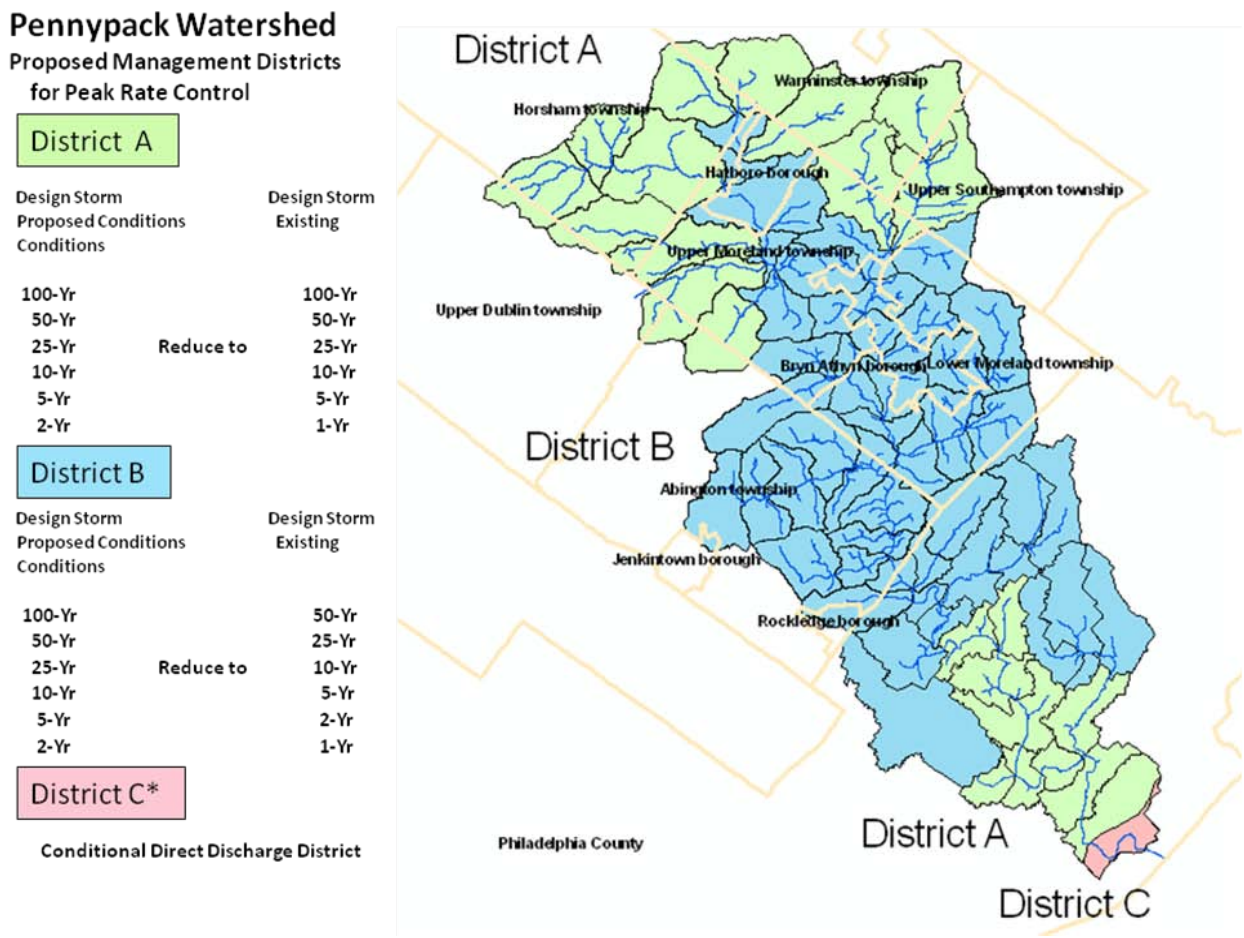
This shows where rate controls should be applied to prevent detention at new development sites from increasing flood flows





Source: DeBarrry, P., Watersheds - Processes. Assessment, and Management, Wiley, 2004, Figure 18.4

Figure 4.5.G Proposed Peak Rate Control Management Districts



Evaluation of Runoff Impacts of Improved Stormwater Control through BMP Applications

The hydrologic model was applied to evaluate the hydrologic impact of implementing identified opportunities for installation and/or retrofitting of stormwater BMPs. These potential improvements are presented in Section 6 of this report. Three categories of BMP applications were considered: new or expanded detention, infiltration, and restoration of riparian buffers along stream corridors. The potential additional storage for each type of improvement was aggregated by subbasin. For detention facilities, the total storage was considered additional potential storage available during the course of a given storm event, and the Curve Number for the subbasin was adjusted downward using the NRCS Curve Number equation.[8] The total additional infiltration storage in each subbasin was modeled as initial abstraction, with one inch of storage assumed for the site areas. Restored riparian buffer acreage was also assumed to provide an inch of additional storage and was modeled as initial abstraction.

[8] *Urban Hydrology for Small Watersheds, TR55, Natural Resources Conservation Service, 1986*

The modeling of existing conditions represented impervious cover as being connected to the drainage system. However, for this analysis, the aggregate storage from the improvements was not directly applied to this model, since the improvements could affect runoff from both impervious and non-impervious areas. Instead, a model with each subbasin represented by a single composite Curve Number (including both pervious and impervious land uses) was run both with and without the improvements to determine the percent change in peak discharge and runoff volume at each model point. The resulting percent change was then applied to the model output for the existing conditions run. Figure 4.5.H shows the modeled percentage change in peak discharge and runoff volume for two locations in the Pennypack Watershed with the improvements in place. Section 6 presents additional model results for this analysis. While the modeling is not site-specific to the improvements, it indicates that cumulative flow and volume reductions would accrue to the watershed, with the largest impacts in the upstream portion of the watershed.

Figure 4.5.H Impact on Peak Discharge and Runoff Volume of Proposed Improvements

Effects of Improvements in Lower Watershed (Rhawn Street)

J	% Difference Peak discharge
Storm	Additional Potential Storage Method
1-yr	-5.44
2-yr	-5.23
5-yr	-4.43
10-yr	-3.62
25-yr	-3.05
50-yr	-2.95
100-yr	-2.79

	% Difference in Runoff Volume
Storm	Additional Potential Storage Method
1-yr	-4.84
2-yr	-4.06
5-yr	-3.26
10-yr	-2.82
25-yr	-2.36
50-yr	-2.07
100-yr	-1.82

Effects of Improvements in Upper Watershed (Upper Moreland/Bryn Athyn)

	% Difference Peak discharge
Storm	Additional Potential Storage Method
1-yr	-7.87
2-yr	-6.72
5-yr	-5.74
10-yr	-4.88
25-yr	-3.82
50-yr	-3.32
100-yr	-3.42

	% Difference in Runoff Volume
Storm	Additional Potential Storage Method
1-yr	-6.93
2-yr	-5.90
5-yr	-4.84
10-yr	-4.22
25-yr	-3.57
50-yr	-3.15
100-yr	-2.80

In addition to the hydrologic modeling, the HEC-RAS model for the suburban portion of the watershed was used to determine potential reductions in water surface elevations resulting from the improvements. Peak flows at the mouth of each stream were proportioned by drainage area in order to assign flows to stream reaches and water surface elevations were compared for the cases with and without the improvements. Results at selected locations are provided in Section 6.

Section 5: Criteria and Standards for New Development and Redevelopment in the Pennypack Watershed

This section provides a summary of the model stormwater management ordinance for the Pennypack Creek Watershed as presented in Appendix A. The standards and criteria for the model ordinance were developed based on information from the following sources:

- The recently completed ordinance for the Tookany-Tacony-Frankford Watershed
- The approved ordinance for the Darby-Cobbs Watershed
- Discussions with representatives from Philadelphia, Bucks, and Montgomery counties
- Hydrologic modeling results used to establish management districts for peak rate control
- Experience and professional judgment of the study team regarding effectiveness of stormwater requirements.

The objective of the model ordinance is to minimize the hydrologic and water quality impacts of future development and redevelopment in the watershed. As described in Section 3, most stream reaches in the watershed are classified as impaired by the Pennsylvania Department of Environmental Protection (DEP) and the cause of the impairment for 78 percent of the impaired stream reaches is attributed to urban runoff. [1] While adoption and enforcement of the ordinance would address the impacts of future development, the improvements in Section 7 are also recommended to address the current level of impairment by reducing stormwater flows and runoff volumes.

5.1 Model Ordinance Summary

The standards and criteria included in the model ordinance apply to regulated activities defined in Article I and vary based on the county of jurisdiction. The standards pertain to the following areas of potential impact as defined in Tables 106.1 of the Ordinance:

- Site Design and Drainage Plan Requirements
- Groundwater Recharge
- Water Volume Control
- Stream Bank Erosion (Channel Protection)
- Peak Rate Control

Article I, Section 103 requires that all legal water quality requirements under state law, including regulations at 25 Pennsylvania Code Chapter 93.4.a requiring protection and maintenance of “existing uses” and maintenance of the level of water quality to support those uses in all streams, and the protection and maintenance of water quality in “special protection” streams, be met.

Applicability and Exemptions (Article I, Sections 105 and 106) for Regulated Activities defined in Section 105 of the Ordinance are based on the area of land disturbance and the area of

[1] *Table 2.12 and Figure 2.10 of the Comprehensive Characterization Report for the Pennypack Creek Watershed – Philadelphia Water Department, 2009.*

impervious cover included in the project. The exemption thresholds vary by county. Exemptions may be denied by municipalities based on identified downstream problem areas, based on High Quality, or Exceptional Value stream designations, or based on known source water protection areas.

Article II, Section 202 of the Ordinance defines terms used in the Ordinance provisions.

Article III specifies stormwater management site plan requirements that must be addressed prior to issuance of land development plans, building or occupancy permits or land disturbance. Plan contents, including stormwater management and erosion and sedimentation plans, and submission requirements are specified.

Article IV contains the stormwater management criteria and provides additional details on the scope of application of these standards to regulated activities. Requirements for determining design storms, for groundwater recharge, water volume control, streambank erosion control, and peak runoff rate control, including acceptable calculation methodologies for determining runoff peaks and volumes, are provided.

Articles V thru IX cover inspections, fees and expenses, maintenance responsibilities, prohibitions, and enforcement and penalties, respectively.

The following two sections highlight the Applicability and Exemptions, and Stormwater Management Criteria provisions of the Ordinance.

Section 5.2 Applicability and Exemptions

Tables 5.2.A and 5.2.B were taken from Section 106 of the ordinance and summarize its applicability to the Bucks and Montgomery counties portion of the watershed and the Philadelphia portion of the watershed.

Table 5.2.A Eligibility for Exemptions for the Bucks and Montgomery County Portions of the Watershed

Ordinance Article or Section	Type of Project	Proposed Impervious Surface					Earth Disturbance	
		0-500 sq. ft.	501-1,499 sq. ft.	1,500- 5,000 sq. ft.	5,000 sq. ft. – 1 acre	> 1 acre	5,000 sq. ft. – 1 acre	> 1 acre
Article III SWM Site Plan Requirements	Development	Exempt	Modified	Partial	No	No	Modified	No
	Redevelopment	Exempt	Modified	Partial	No	No	Modified	No
Section 404 Nonstructural Project Design	Development	Yes	Yes	No	No	No	No	No
	Redevelopment	Yes	Yes	No	No	No	No	No
Section 405 Groundwater Recharge	Development	Yes	Yes	No	No	No	No	No
	Redevelopment	Yes	Yes	No	No	No	No	No
Section 406 WaterVolume Control Requirements	Development	Yes	Yes	No	No	No	No	No
	Redevelopment	Yes	Yes	No	No	No	No	No
Section 407 Stream Bank Erosion Requirements	Development	Yes	Yes	No	No	No	No	No
	Redevelopment	Yes	Yes	Exempt	No	No	Exempt	No
Section 408 Stormwater Peak Rate Control and Management Districts	Development	Exempt	Exempt	Exempt	No	No	No	No
	Redevelopment	Exempt	Exempt	Exempt	No	No	No	No
Erosion and Sediment Pollution Control Plan	Earth Disturbance	See Earth Disturbance Requirements	See Earth Disturbance Requirements	See Earth Disturbance Requirements	See Earth Disturbance Requirements	See Earth Disturbance Requirements	No	No
		(Refer to municipal earth disturbance requirements, as applicable)						

Notes:
No – Drainage plan required with associated section provision.
Exempt – Exempt from indicated provision – SWM Site Plan submission may still be required by other sections or provisions.
Modified – Modified SWM Site Plan required
- Sites with less than one thousand five hundred (1,500) square feet of new impervious surface, but between five thousand (5,000) square feet and one (1) acre of earth disturbance must submit a SWM Site Plan to the Municipality which need consist only of the items in Sections 301.A.2 and 4; 301.B.7, 8, 11, and 22; and 301.D.1 and 3, and related supportive material needed to determine compliance with Sections 404 and 408.

Partial – Standard Grading Permit is required.
- Sites with more than one thousand five hundred (1,500) square feet, but less than five thousand (5,000) square feet of new impervious surface must submit a SWM Site Plan; however, it need not address the items in Sections 407 and 408.

Table 5.2.B Eligibility for Exemptions for the Philadelphia County Portion of the Watershed

Ordinance Article or Section	Type of Project	Earth Disturbance Associated with Development		
		0-5,000 sq. ft.	5,000 sq. ft.-1 acre	> 1 acre
Article III SWM Site Plan Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	No	No
Section 405 Groundwater Recharge Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	No	No
Section 406 Water Volume Control Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	No	No
Section 407 Streambank Erosion (Channel Protection) Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	Exempt	Yes (Alternate Criteria)
Section 408 Flood Control / Stormwater Peak Rate Control and Management Districts Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	No	Yes (Alternate Criteria)

Yes (Alternate Criteria) – Redevelopment disturbing one acre or more that reduces the DCIA from predevelopment conditions by at least 20% is exempt from the Channel Protection/Streambank Erosion (Section 407) and Flood Control/Peak Rate Control (Section 408) Requirements of this Ordinance; and redevelopment that results in an area of earth disturbance equal to or greater than 5,000 square feet, but less than one (1) acre, is exempt from the Channel Protection/Streambank Erosion Requirements of this Ordinance (See Section 106, Exemptions, Philadelphia County Portion of the Watershed).

N/A – Not Applicable, development project is not subject to requirements of the indicated sections of this Ordinance. Voluntary controls are encouraged.

Exempt – Development project is not subject to requirements of indicated section of this Ordinance.

** – If the proposed development results in stormwater discharge that exceeds stormwater system capacity, increases the FEMA regulated water surface elevation, causes a combined sewer overflow, or degrades receiving waters, the design specifications presented in this Ordinance may be applied to proposed development activities as warranted to protect public health, safety, or property.

Section 5.3 Stormwater Management Criteria

Article IV, Section 401 of the Ordinance sets forth General Requirements.

Sections 402, 403, and 404, pertain respectively to Permit Requirements of Other Governmental Entities, Erosion and Sediment Control During Regulated Earth Disturbance Activities, and Nonstructural Project Design.

Section 405.A.1 contains minimum requirements for Infiltration Best Management Practices (BMPs), and Section 405.A.2 establishes volume criteria for the infiltration facilities, which are computed differently for Bucks and Montgomery counties, and for Philadelphia County, as follows:

Bucks County and Montgomery County Portions of the Watershed

Where practicable and appropriate the recharge volume shall be infiltrated on site. The recharge volume shall be equal to one (1.0) inch of runoff (I) over all proposed impervious surfaces.

The Re_v required shall be computed as:

$$Re_v = (1/12) * (I)$$

Where:
Re_v = Recharge Volume (cubic feet)
I = Impervious Area within the limits of earth disturbance (square feet)

An asterisk (*) in equations denotes multiplication.

Philadelphia County Portion of the Watershed

The recharge volume shall be equal to one (1.0) inch of rainfall over all **DCIA within the limits of Earth Disturbance**.

$$Re_v = (1/12) * (I)$$

Where:
Re_v = Recharge Volume (cubic feet)
I = DCIA within the limits of earth disturbance (square feet)

An asterisk (*) in equations denotes multiplication.

Section 405.B sets forth the required soils evaluations on project sites to determine the suitability of proposed infiltration facilities.

Section 406 states the Water Volume Control Requirements, which are excerpted from Section 303 of the Pennsylvania Model Stormwater Ordinance [2] *(Note: Philadelphia County, Bucks County, and Montgomery County will follow different Water Volume Control requirements.)*

Bucks County and Montgomery County Portions of the Watershed:

The low impact development practices provided in the BMP Manual shall be utilized for all regulated activities to the maximum extent practicable. Water Volume Controls shall be implemented using the *Design Storm Method* in Subsection A or the *Simplified Method* in Subsection B below. For regulated activity areas equal to or less than one (1) acre that do not require hydrologic routing to design the stormwater facilities, this Ordinance establishes no preference for either methodology; therefore, the applicant may select either methodology on the basis of economic considerations, the intrinsic limitations on applicability of the analytical procedures associated with each methodology, and other factors. All regulated activities greater than one (1) acre must use the Design Storm Method.

A. The *Design Storm Method* (CG-1 in the BMP Manual) is applicable to any size of regulated activity. This method requires detailed modeling based on site conditions.

1. The post-development total runoff volume for all storms equal to or less than the
2-year, 24-hour storm event shall not be increased.

2. For modeling purposes:
   a. Existing (predevelopment) non-forested pervious areas must be considered meadow.
   b. 20% of existing impervious area, when present, shall be considered meadow in the model for existing conditions.

B. The *Simplified Method* (CG-2 in the BMP Manual) provided below is independent of site conditions and should be used if the *Design Storm Method* is not followed. This method is not applicable to regulated activities greater than one (1) acre, or for projects that require design of stormwater storage facilities. For new impervious surfaces:

1. Stormwater facilities shall capture at least the first two (2) inches of runoff from all new impervious surfaces. *(Note: An asterisk (*) in equations denotes multiplication.)*

Volume (cubic feet) = (2/12) * Impervious Surfaces (square feet)

[2] *Department of Environmental Protection, Bureau of Watershed Management, Document Number 363-03000-003, September 2, 2010.*

2. At least the first one (1) inch of runoff from new impervious surfaces shall be permanently removed from the runoff flow-- i.e., it shall not be released into the surface waters of the Commonwealth. Removal options include reuse, evaporation, transpiration, and infiltration.

   Volume (cubic feet) = (1/12) * Impervious Surfaces (square feet)

3. Wherever possible, infiltration facilities should be designed to accommodate infiltration of the entire permanently removed runoff; however, in all cases at least the first half (0.5) inch of the permanently removed runoff should be infiltrated.

4. This method is exempt from the requirements of Section 408, Peak Rate Controls.

Philadelphia County Portion of the Watershed:

The following equation is to be used to determine the Water Volume Control storage requirement in cubic feet for regulated activities within the Pennypack Creek Watershed in Philadelphia County:

Water Volume Control (cubic feet) = (1/12) * (I)

Where: I = DCIA within the limits of earth disturbance (square feet)

Section 407 sets forth the requirements for the control of Stream Bank Erosion. Philadelphia County, Bucks County, and Montgomery County will follow different requirements. If a municipality has adopted a riparian corridor ordinance, the more restrictive requirement shall apply.

Section 408 sets forth Stormwater Peak Rate Control Standards by Management Districts in the table below. The districts are shown in Figure 5.3.A, Proposed Peak Rate Control Management Districts, on the next page, the map is also provided in Section 4.5 as Figure 4.5.G and in the model ordinance as Figure 1.

Section 409 specifies calculation methodologies that shall be used for the design of stormwater management facilities.

TABLE 5.3.A PEAK RATE CONTROL STANDARDS BY STORMWATER MANAGEMENT DISTRICT IN THE PENNYPACK CREEK WATERSHED

District	Proposed Condition Design Storm		Existing Condition Design Storm
A	2-year	Reduce to	1-year
	5-year		5-year
	10-year		10-year
	25-year		25-year
	50-year		50-year
	100-year		100-year
B	2-year	Reduce to	1-year
	5-year		2-year
	10-year		5-year
	25-year		10-year
	50-year		25-year
	100-year		50-year
C*	Conditional Direct Discharge District		

In District C, development sites that can discharge directly to the Pennypack Creek Main Channel (east of I-95) and to the Delaware River main channel without use of City infrastructure may do so without control of proposed conditions peak rate of runoff.

Projects that are required to obtain a NPDES Permit for stormwater discharges associated with construction activities are required to show no increase in peaks from existing conditions.

When adequate capacity in the downstream system does not exist and will not be provided through improvements, the proposed conditions peak rate of runoff must be controlled to the Predevelopment Conditions peak rate as required in District A provisions for the specified Design Storms. The Predevelopment Condition for new development is the existing condition. For redevelopment purposes in Philadelphia County, the Predevelopment Condition is determined according to the procedures found in the Philadelphia Stormwater Guidance Manual.

Figure 5.3.A Proposed Peak Rate Control Management Districts

Pennypack Watershed

Proposed Management Districts for Peak Rate Control

District A

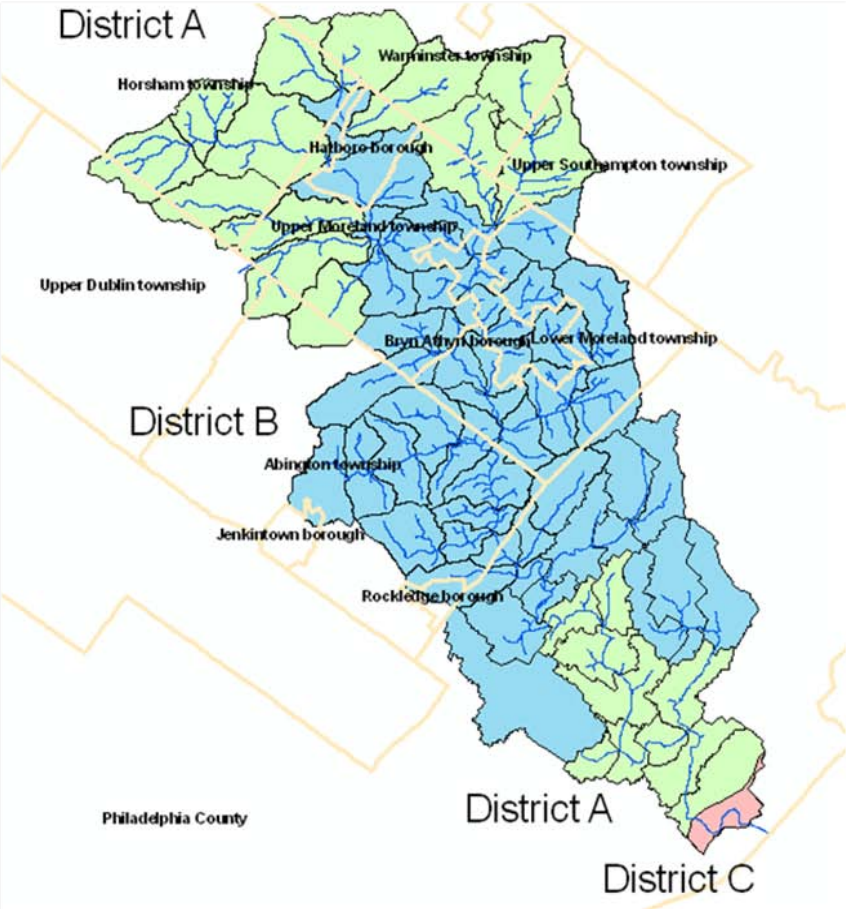
Design Storm Proposed Conditions Conditions		Design Storm Existing
100-Yr		100-Yr
50-Yr		50-Yr
25-Yr	Reduce to	25-Yr
10-Yr		10-Yr
5-Yr		5-Yr
2-Yr		1-Yr

District B

Design Storm Proposed Conditions Conditions		Design Storm Existing
100-Yr		50-Yr
50-Yr		25-Yr
25-Yr	Reduce to	10-Yr
10-Yr		5-Yr
5-Yr		2-Yr
2-Yr		1-Yr

District C*

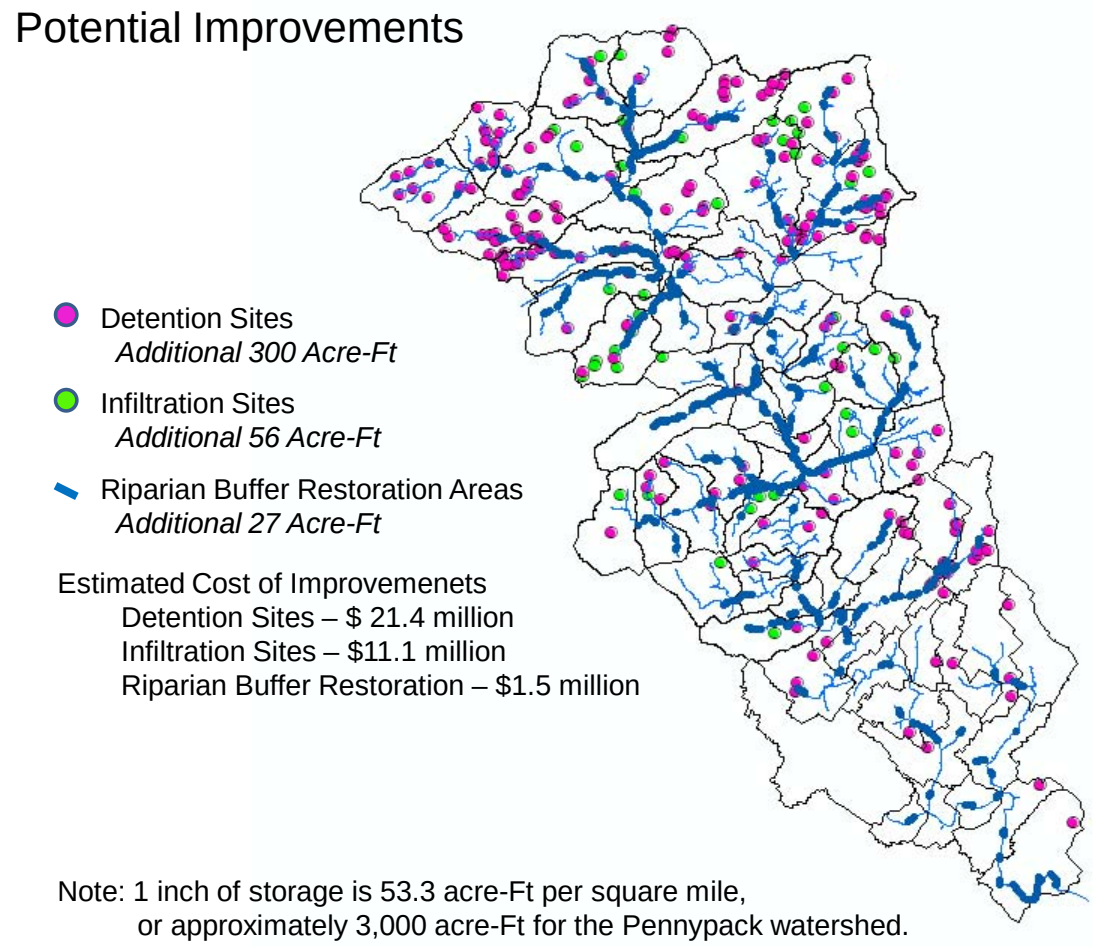
Conditional Direct Discharge District



Section 6: Stormwater Improvements

A major objective of this study was to identify opportunities for improvements to address the widespread water quality impairments caused by stormwater runoff in the Pennypack Creek Watershed. This work built upon the field inspection and site identification conducted during the 2006 Pennypack Creek Watershed Study.[1] Three classes of sites were evaluated for their potential to provide expanded or new storage. These included detention basins, potential infiltration sites, and stream reaches for potential restoration of riparian buffers. The distribution of these sites in the watershed is shown in Figure 6.A, along with the aggregate total storage volume and estimated total cost for each category. Appendix C provides the estimated storage and costs for the improvements at the identified facilities. The following sections summarize the evaluation steps and present results of hydrologic modeling of the impact on peak flow and volume in different parts of the watershed. The facilities were also ranked based on factors including catchment area, cost, and watershed location. The ranking method allows for cross-comparison of all sites.

Figure 6.A Distribution of potential improvements in the Pennypack Watershed



[1] *Temple University, Center for Sustainable Communities, Pennypack Creek Watershed Study, August 2006.*

6.1 Detention Storage Facilities

A total of 208 existing and potential detention sites were inventoried. GIS files with the locations, estimated storage, and catchment areas for 141 of these facilities were provided by the Philadelphia Water Department (PWD). The remaining sites were added based on field inspections by the Center for Sustainable Communities (CSC). Existing sites with surface areas greater than a quarter of an acre were field inspected. Factors considered for evaluating potential expansion included:

- Property access
- Drainage or flood risk to nearby properties if berm height were increased
- Water table with respect to the floor of the facility if the floor were lowered
- Availability of adjacent property for expansion

Sites where increased berm height or lowered floors appeared feasible were considered for expansion. For most sites with areas less than a quarter of an acre, a recommendation was made to both increase berm height and lower the basin floor by one foot. In some cases, increased floodplain storage was recommended as a means of providing additional detention, rather than construction of a detention facility in the floodplain. Generally, such areas are recommended as constructed wetlands. A total of 172 sites were recommended for new or expanded detention, including floodplain storage sites. Recommendations were also made to improve outlet structures and revegetate basin floors to increase extended detention. The Detention Spreadsheet in Appendix C lists the existing and potential increased storage at each of the detention sites, and provides estimated costs of the improvements. Cost estimates include 35% for design and contingency, and assumed union labor rates. A ranking based on the catchment area (a measure of the potential for extended detention during small storms), cost, and watershed locations is also included to provide a possible means of prioritizing sites. A GIS shape file is also included for detailed mapping of the improvement location, such as that shown in Figure 6.1.A. The spreadsheet includes the following fields:

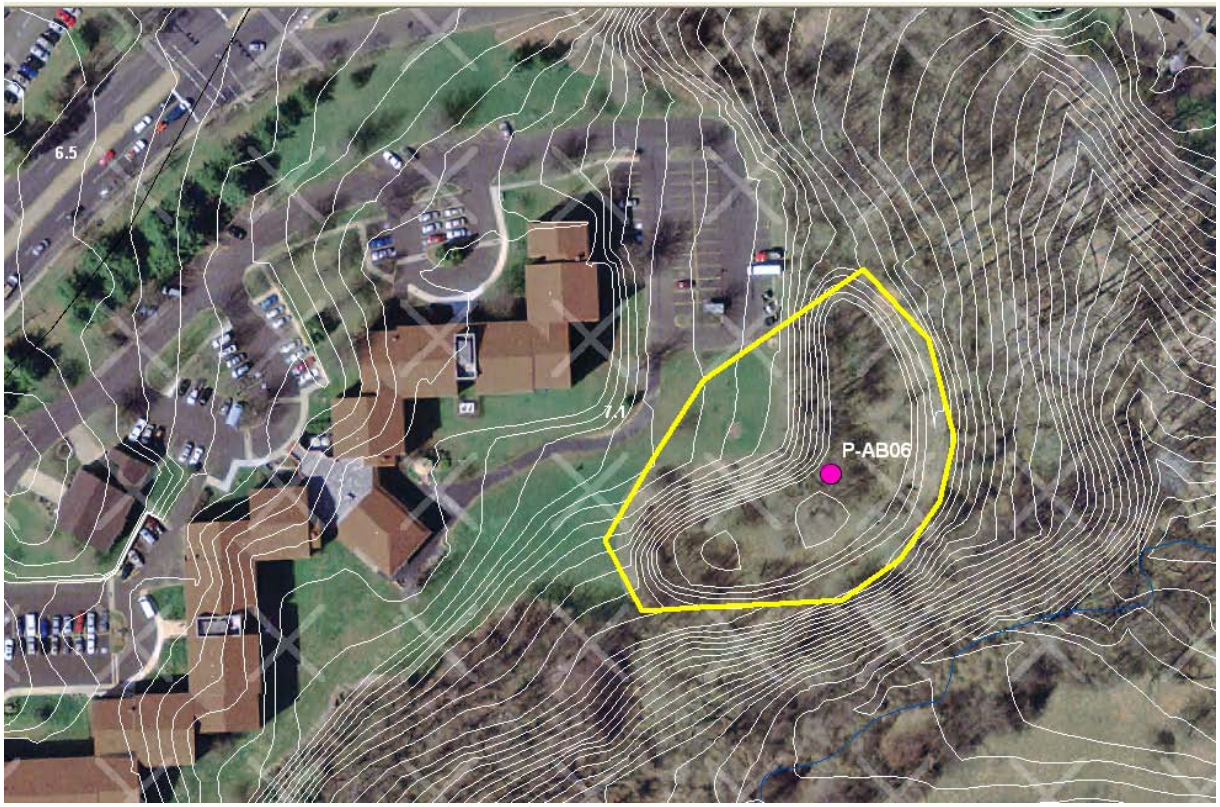
- Site ID
- Subbasin
- Municipality
- Cross reference to Site ID used in original Pennypack study where applicable
- Location or nearby intersection
- Public or Private Ownership
- Current Land Use
- Receiving Watershed
- Existing Depth
- Existing Area
- Existing Volume
- Potential Additional Volume
- Estimated Cost
- Notes regarding the improvement
- Priority ranking assigned to the facility

Figure 6.1.A Sample Detention Basin Site Map

Site P-AB06: Holy Redeemer Village – Abington Township

Recommendation- Raise berm 1 ft. Lower floor 2 ft. Modify outlet and piping.

Estimated cost = $108,000 Additional Volume = 1.80 Acre-Ft



The total of existing storage from detention basins and ponds in the Pennypack Watershed is estimated at 300 acre-feet. Potential additional storage would provide an additional 300 acre-feet of storage. Detention storage opportunities, if fully implemented, would provide more than four times the total potential storage from identified infiltration and riparian buffer restoration sites.

6.2 Potential Infiltration Sites

Opportunities for additional infiltration were based on field inspections of 43 sites where installation of stone-filled trenches could provide storage for runoff from large rooftops, parking areas, or athletic fields. Cost estimates were based on the design of infiltration to provide storage for one inch of runoff from the site. A 40% void ratio was assumed for the stone fill, and a hauling cost of $9 per cubic yard was applied. The total combined area of the identified sites is 709 acres, and the estimated infiltration volume would be 56 acre-feet. The inventory focused on larger sites rather than individual residential properties where the installation of such measures as pervious paving or rain gardens could also increase infiltration. The Infiltration Spreadsheet in Appendix B lists the infiltration sites and includes the following data fields:

- Site ID
- Municipality
- Cross reference to Site ID used in original Pennypack study where applicable
- Location/Intersection
- Public or Private Ownership
- Current Land Use
- Watershed receiving largest share of site runoff
- Notes
- Infiltration Area
- Potential Infiltration Volume
- Estimated Cost
- Site Ranking

A GIS file for the infiltration sites is also provided in Appendix B and sample mapping for one of the sites is shown in Figure 6.2.A.

Figure 6.2.A Sample Infiltration Site Map

Site P-AB04: Penn State Abington Campus

Recommendation- Install infiltration trenches for roof and parking drainage. 1" infiltration

Estimated cost = $109,000 Volume = 0.57 Acre-Ft

6.3 Riparian Buffer Restoration

An inventory conducted by the Heritage Conservancy in 2000 identified over 300 stream reaches where riparian stream buffers could be restored on either one or both sides of streams in the Pennypack watershed. The distribution of these locations is shown in Figure 6.A. To estimate the potential additional storage available, the CSC assumed an average buffer width of 75 feet for each side of the stream and an average runoff volume reduction of one inch. The estimated acreage and cost of re-establishing the buffers by municipality is presented in Table 6.3.A. The total additional storage volume provided to the watershed would be 27 acre-feet. Riparian buffer restoration has the lowest average cost of the three improvement categories. It should be noted however, that land use conditions have changed in some areas since the survey was completed in 2000. Actual buffer width would vary significantly from site to site, and buffers may no longer be feasible at some locations. The lack of acceptance by property owners can also limit re-establishing buffers. GIS file with the locations of the identified buffer restoration locations is provided in Appendix C, and a sample site map is shown in Figure 6.3.A.

Table 6.3.A Potential Total Riparian Buffer Restoration Areas by Municipality

Municipality	*Acreage Requiring Riparian Buffers	**Cost Assuming $4,500 per acre	Rounded-Up Cost	Primary Affected Streams	***Average Volume Reduction per event (Acre-feet)
Abington	51.27	230,712	$231,000	Harper's Run, Meadow Brook	4.3
Bryn Athyn	14.40	63,470	$64,000	Robinhood Brook, Rockledge Brook	1.2
Hatboro	14.54	65,428	$66,000	Pennypack Creek	1.2
Horsham	25.74	115,851	$116,000	Pennypack Creek, Blair Mill Run	2.2
Lower Moreland	51.50	231,728	$232,000	Huntington Valley Creek, Pennypack Creek, Axe Factory Run, Benton Brook, Darlington Run, Paul's Run	4.3
Philadelphia	59.56	268,015	$269,000	Wooden Bridge Run	5.0
Upper Dublin	1.81	8,131	$9,000	Pennypack Creek Tributaries	0.2
Upper Moreland	81.57	367,049	$368,000	Meadow Run, Southampton Creek	6.8
Upper Southampton	14.85	66,837	$67,000	Southampton Creek	1.2
Warminster	10.55	47,490	$48,000	Blair Mill Run, Southampton Creek	0.9

*Base data on riparian buffer needs were obtained from the Heritage Conservancy. These data indicate stream lengths requiring a riparian buffer, either on one side or both sides of the stream. The CSC assumed an average buffer width of 75 feet, recognizing that 50 feet may be appropriate for some locations and 100 feet for others. Acreage was derived using GIS analysis.

**Cost assumes 430 three- to four- foot high trees per acre, protective tubes, stakes, and labor, including some replacement in the second year.

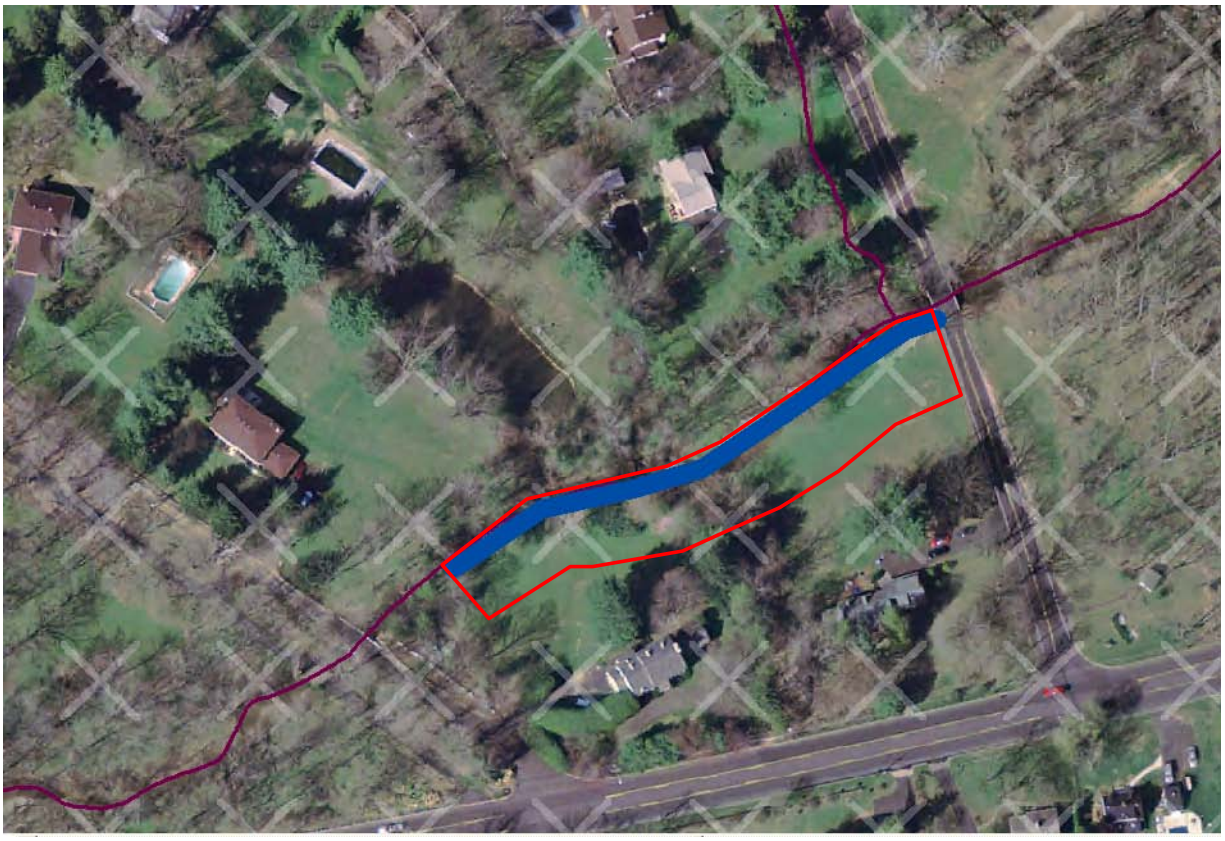
*** Average volume reduction is an average value per event and assumed to be an inch of water per acre. The reduction would be the greater in the summer during dry periods, and substantially less in the winter during wet periods.

Figure 6.3.A Sample Riparian Buffer Restoration Site Map

Riparian Buffer Restoration Based on Survey by Heritage Conservancy

Location: Meadow Brook in Abington Township

Restoration for one side of stream. Width = 75 ft.



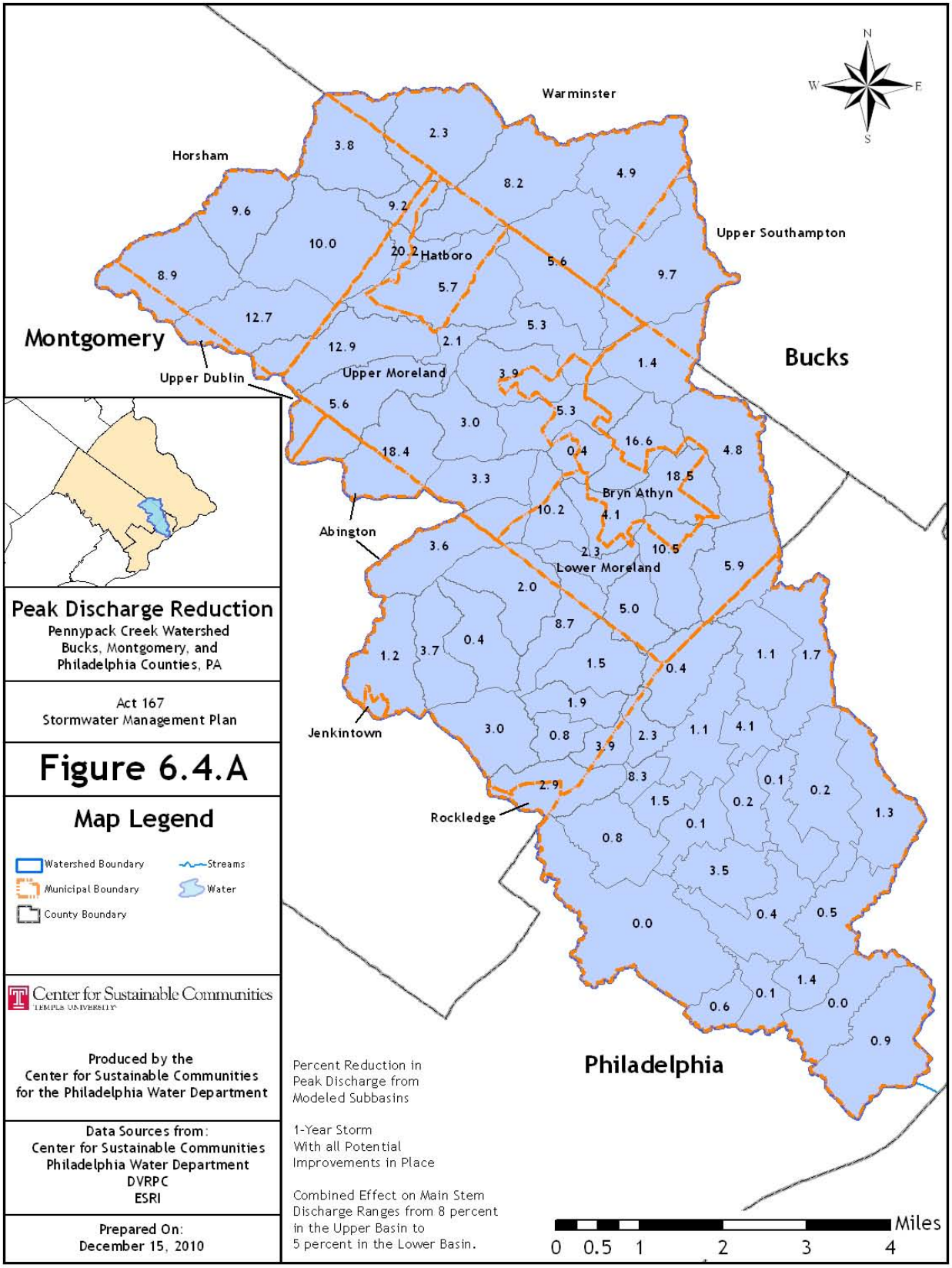
6.4 Hydrologic and Water Quality Impact of the Proposed Improvements

The modeling to evaluate the effect of the proposed improvements is summarized in Section 4.5 of this report. The combined potential additional storage provided by the three categories of improvements is estimated at 383 acre-feet, or 128 million gallons. This volume of storage is equivalent to 0.13 inches of runoff from the 56 square mile watershed, compared to 2,987 acre-feet of storage that would be needed to capture a full inch of stormwater runoff for the entire watershed. The modeling shows that the storage reduces peak flows and runoff volumes for the 1-year storm, with smaller reductions for the larger events. The distribution of the proposed improvements is most concentrated in the headwaters of the upper part of the watershed, where peak flow and runoff volume reductions would have the most far-reaching effects and benefit the greatest number of stormwater problem areas along the Pennypack Creek and tributaries. Figures 6.4.A and 6.4.B provide maps showing the modeled percent reduction in peak discharge

and runoff volume from each subbasin predicted by the hydrologic model with the recommended improvements in place during the 1-year storm. The aggregate reductions for two locations along the main stem of the Pennypack Creek in the upper and lower portions of the watershed were shown in Figure 4.5.H. The change in peak discharge ranges from eight percent in the upper basin to five percent in the lower basin, with the respective change in runoff volume ranging from seven percent in the upper basin to five percent in the lower basin.

The reductions in peak flow and volume would help reduce scour and erosion potential along stream reaches, and would be helpful where stream restoration is planned or has been completed. For example Upper Southampton Township is serving as the local sponsor for a proposed stream restoration project along a two-mile reach of Southampton Creek where the stream is seriously degraded. The project has been developed by the Corps of Engineers, U.S. Fish and Wildlife Service, and the University of New Hampshire in coordination with the township, and would extend from Davisville Road, downstream to County Line Road.[2] Several of the improvements recommended in this Act 167 study are located in the drainage area contributing to this reach, and any peak flow reductions would lower erosion potential in the restoration stream segment. In addition to reducing erosion rates, the facilities recommended by this study would provide for settling and storage of sediment in runoff and reduce sediment loading in the watershed. To estimate the effect of the improvements on water surface elevations, the HEC-RAS model for the suburban portion of the watershed was used to compare the before and after-improvements cases for the 2-year storm event, and HEC-GEORAS was used to prepare floodplain maps for the two scenarios. Modeling results show that the improvements would lower water surface elevations, but not enough to cause significant reduction in the aerial extent of the 2-year floodplain. Elevation differences at selected locations along three of the tributaries within the watershed are shown in Figures 6.4.C thru 6.4.E.

[2] *U.S. Army Corps of Engineers, Finding of No Significant Impact, Southampton Creek Ecological Restoration Project, July, 2010, http://www.nap.usace.army.mil/Projects/screek/Southampton%20Final%20EA.pdf.*


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
S
E
W
Peak Discharge Reduction
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 6.4.A
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Percent Reduction in
Peak Discharge from
Modeled Subbasins
1-Year Storm
With all Potential
Improvements in Place
Combined Effect on Main Stem
Discharge Ranges from 8 percent
in the Upper Basin to
5 percent in the Lower Basin.
Miles
0 0.5 1 2 3 4

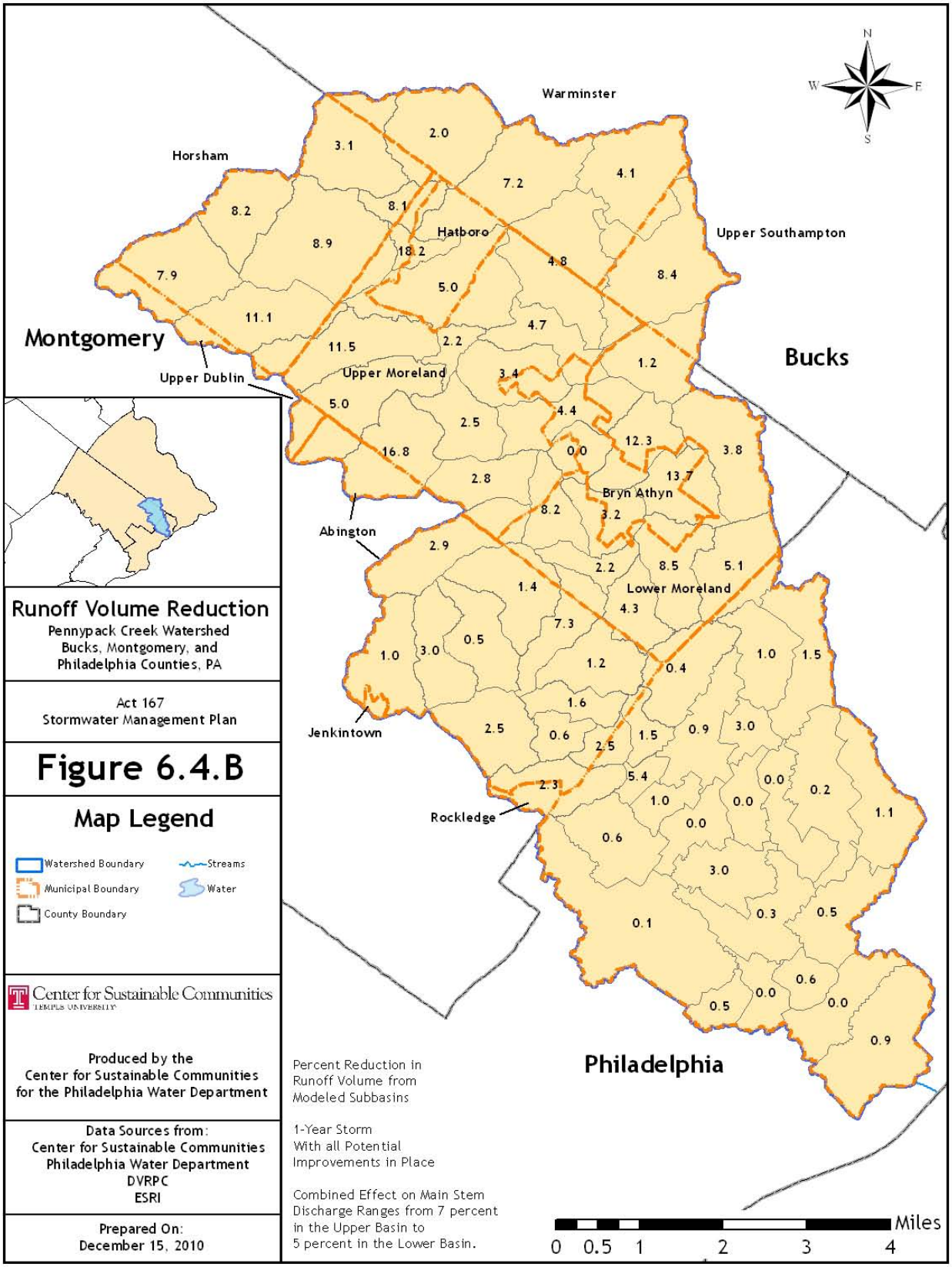

Warminster
Horsham
Hatboro
Upper Southampton
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
S
E
W
Runoff Volume Reduction
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 6.4.B
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Percent Reduction in
Runoff Volume from
Modeled Subbasins
1-Year Storm
With all Potential
Improvements in Place
Combined Effect on Main Stem
Discharge Ranges from 7 percent
in the Upper Basin to
5 percent in the Lower Basin.
Miles
0 0.5 1 2 3 4

Figure 6.4.C
Huntington Valley Creek near Philmont Road, Lower Moreland Twp., Bucks County, PA
Modeled Elevation Change with All Improvements in Place = 0.9 ft for 2-Yr Storm Event

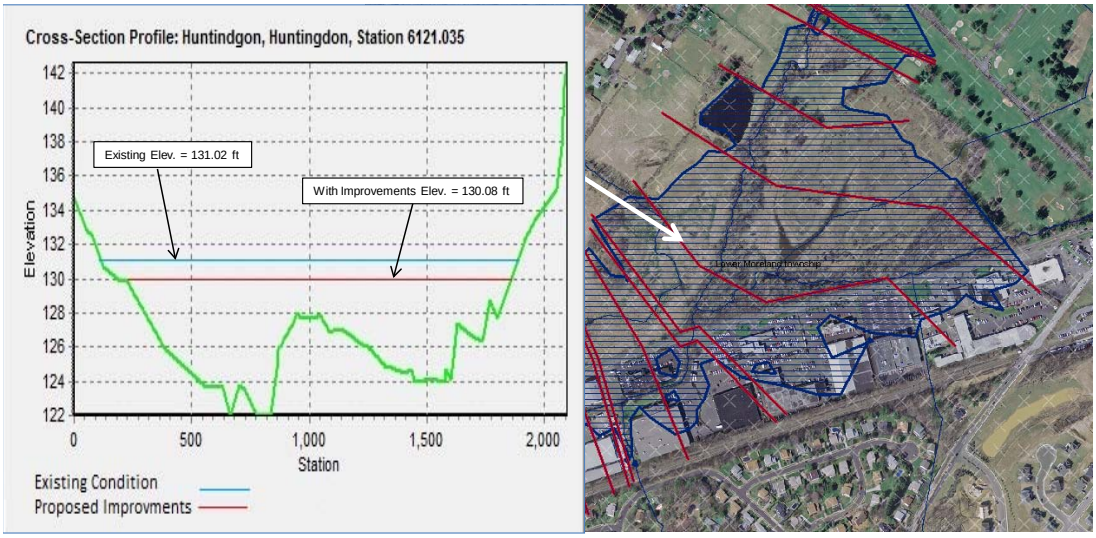


Figure 6.4.D
Southampton Creek at County Line Road, Bucks/Montgomery Counties, PA
Modeled Elevation Change with All Improvements in Place = 0.5 ft for 2-Yr Storm Event

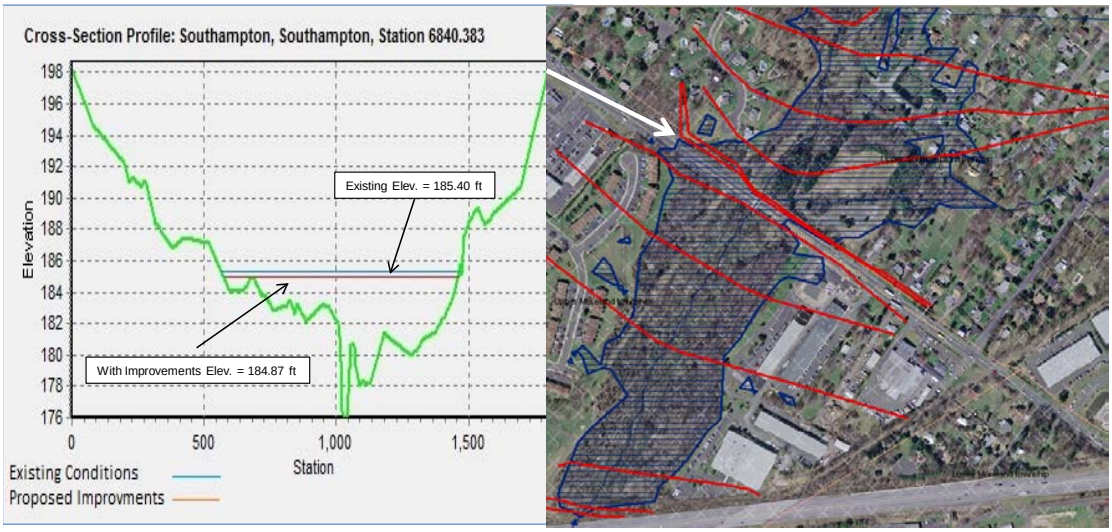
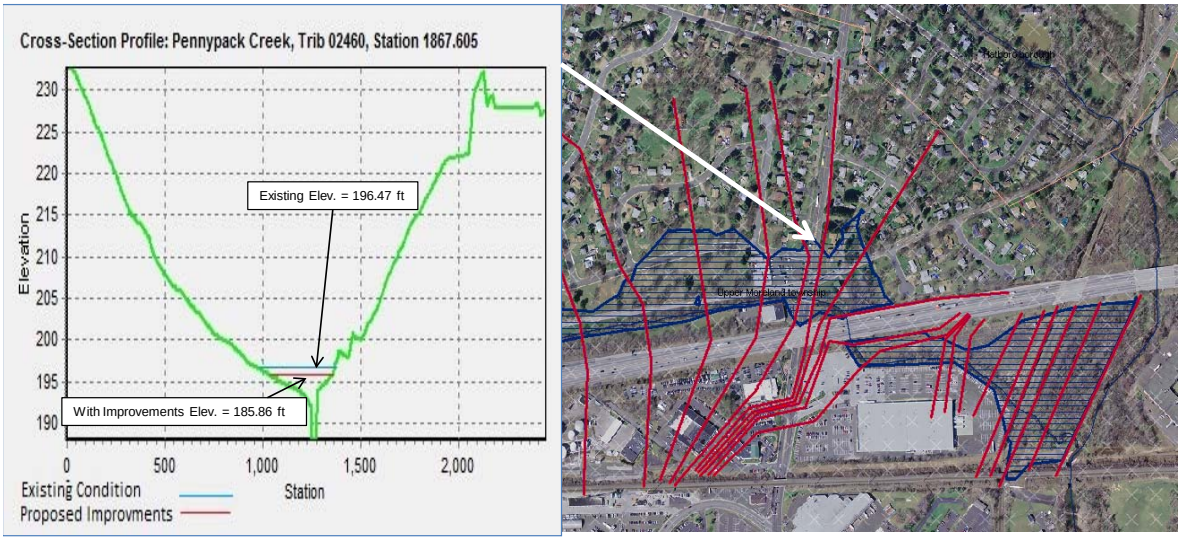


Figure 6.4.E
Tributary to Pennypack Creek at York &Mill Roads, Upper Moreland Twp, Montgomery Co.
Modeled Elevation Change with All Improvements in Place = 0.6 ft for 2-Yr Storm Event

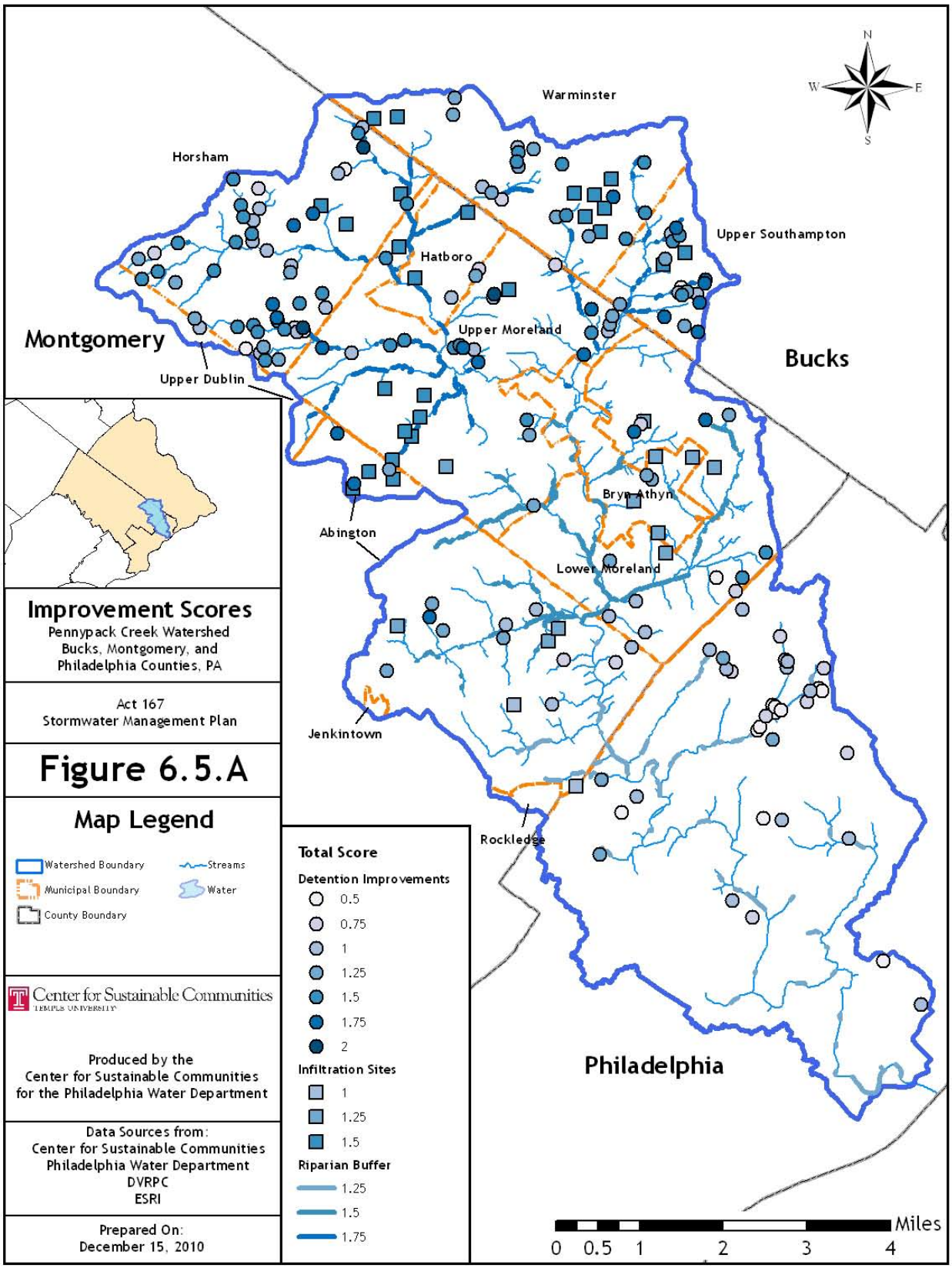


6.5 Improvement Site Ranking

To provide a means of prioritizing further investigation of the proposed improvements, each site was rated based on three factors:

- Effective use of additional storage during small storms. This was assigned a weight of 50 percent of the total ranking. Storage at infiltration and riparian buffer restoration sites was assumed to be fully used during small storms. Use of detention storage during small storms was assumed to vary based on the ratio of the catchment area to the existing detention volume. Those detention basins where sufficient runoff would be available for additional detention during the 1-year storm received the highest score.
- Cost per acre-foot of storage provided by the site- this was assigned a weight of 25 percent of the total score.
- Location in the watershed, with the upstream portion of the watershed receiving the highest score- this was assigned a weight of 25 percent of the total score.

Figure 6.5.A shows the ratings of the detention and infiltration sites using the criteria described above. Based on this preliminary screening sites with the higher score should receive first consideration for further site evaluation and funding.


Warminster
Horsham
Upper Southampton
Hatboro
Upper Moreland
Montgomery
Bucks
Upper Dublin
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
W
E
S
Improvement Scores
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 6.5.A
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC
ESRI
Prepared On:
December 15, 2010
Total Score
Detention Improvements
0.5
0.75
1
1.25
1.5
1.75
2
Infiltration Sites
1
1.25
1.5
Riparian Buffer
1.25
1.5
1.75
Miles
0 0.5 1 2 3 4

SECTION 7: Plan Implementation

The existing institutional arrangements for the management of stormwater include state and county governments, as well as the twelve municipalities within the Pennypack watershed. All agencies are required to comply with the standards and criteria set forth in the Plan. This section outlines specific actions to be undertaken by those agencies.

Upon adoption of the Plan by the counties, the Plan will be submitted to the Pennsylvania Department of Environmental Protection (DEP). The DEP review process involves a determination that the Plan is consistent with the policies and requirements of Act 167. The DEP will also review the Plan for consistency with floodplain management requirements and other state programs, including those pertaining to dams, encroachments and other water obstructions.

After DEP approval, the Philadelphia Water Department will publish the Plan and provide copies of the Plan to Bucks and Montgomery counties and the remaining eleven municipalities.

7.1 Municipal Adoption of Ordinance to Implement the Plan

As set forth in Act 167, within six months following the adoption and approval of the Plan, each municipality shall adopt or amend, and shall implement such ordinances and regulations, including zoning, subdivision and land development (SALDO), building code, and erosion and sedimentation ordinances, as are necessary to regulate development within the municipality in a manner consistent with the Plan. Table 7.1.A summarizes the status of zoning and SALDO provisions for the watershed municipalities.[1] This table was included in the Pennypack Creek River Conservation Plan and reviewed in 2011 as part of this study.

The project team recommends that the municipalities adopt the model ordinance in its entirety as part of its zoning regulations. If the municipality lies in more than one watershed, the applicable release rates should be identified for the different watersheds.

[1] Philadelphia Water Department. Pennypack Creek River Conservation Plan. December, 2005.

Table 7.1.A Status of Ordinances

Category	*Bryn Athyn Borough*	*Hatboro Borough*	*Abington Township*	*Horsham Township*	*Lower Moreland Township*	*Upper Moreland Township*	*Upper Southampton Township*	*Warminster Township*	*Philadelphia*
Ordinance reviewed	SALDO Zoning	SALDO Zoning	SALDO Zoning	SALDO Zoning	SALDO Zoning	SALDO Zoning	SALDO Zoning Stormwater management ordinance	SALDO Zoning	Stormwater Zoning
Riparian Buffer	No	100 ft. Stormwater management	No	Riparian Corridor Conservation District 75ft.	No	No	No	No	Yes
Wetland Protection	No	100% and 50ft. buffer	Yes	100% and 25-50ft. buffer	No	No	Yes	Yes	Yes
Water course, lake, pond protection	No	Intermittent stream protection	Intermittent stream protection	Intermittent stream protection, lands and ponds	Intermittent stream protection	No	All DEP regulated watercourses	Intermittent stream protection, lands and ponds	Yes
Floodplain regulation	Floodplain Conservation District	Floodplain Conservation District	Floodplain Conservation District	Floodplain Conservation District	Floodplain Conservation District	Floodplain Conservation District	Yes	Floodplain Conservation District	Yes
Percent protected for 100-yr floodplain	100%	100%	100%	100%	100%	100%	100%	100%	100%
Limit development on 100-yr floodplain fringe	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stormwater ordinance	No	SALDO Act 167 standards	Yes	SALDO Act 167 standards	SALDO	SALDO	SALDO Stormwater management ordinance	SALDO Act 167 standards	Act 167 Standards
Runoff equals pre and post development	No	Yes	Yes	Yes, requires groundwater recharge	Yes	Yes	Yes	Yes	Yes
Erosion and sediment control	Yes SALDO Clean Streams Law	Yes SALDO	Yes SALDO Clean Streams Law	Yes SALDO Clean Streams Law	Yes SALDO	Yes SALDO	Yes SALDO	Yes SALDO Clean Streams Law	Yes
Restrictive soils	100% on alluvial soils	100% on alluvial soils	100% on alluvial soils	100% on alluvial soils	100% on alluvial soils	100% on alluvial soils	100% on alluvial soils	100% on alluvial soils	100% on alluvial soils

7.2 Municipal Implementation of Stormwater Improvements

While not required by Act 167, the municipalities are encouraged to construct the stormwater improvements identified in Appendix C. This can be done by increasing each municipality's capital improvement program funding. The various improvements are assigned a priority according to their location, cost-effectiveness and capture potential, and municipalities can use this ranking as a basis for funding projects over a long-term period, for example 10 years. PennVEST funding can be sought to jump start a stormwater improvement program.

With respect to drainage problems, the project team recommends the construction of stormwater improvements to increase storage and reduce stormwater flows and volumes as the first consideration in addressing such problems. For cases where increased culvert capacity is the only viable means for solving a drainage problem, an evaluation of potential increases in downstream flood peaks should be performed to prevent adverse flooding or stream channel impacts. In addition, such actions might require municipalities to modify their flood insurance rate maps to outline additional areas subject to inundation during more extreme flood events.

An alternative approach for funding stormwater improvements and culvert capacity projects is to implement them through existing municipal water or wastewater authorities, which can collect parcel-based stormwater fees similar to those collected by the Philadelphia Water Department as part of its Green City Clean Waters Program. The Sunbury Municipal Authority in central Pennsylvania includes stormwater fees as part of its water and wastewater infrastructure maintenance program. A recent survey identified 1,112 stormwater utilities located in 38 states and the District of Columbia. The average monthly single family residential fee was $4.12 and the median fee was $3.50. [2] A similar program could be instituted by the municipal authorities in the Pennypack watershed.

Municipalities also can consider a pooled watershed approach for constructing stormwater improvements given that improvements vary according to their effectiveness. Section 6 and Appendix C outline 383 acre-feet of additional storage reduction potential in the watershed. Using land area within the basin as baseline criterion, volume reduction targets can be established and used as credits towards achieving this overall reduction amount. Potential volume reduction targets are set forth on Table 7.2.A.

[2] Stormwater Utility Survey 2010. Western Kentucky University, Bowling Green, Kentucky.

Table 7.2.A Reduced Volume Reduction Targets

Municipality	Land Area %	Volume Reduction (acre/feet)
Abington	13.9	53.2
Bryn Athyn	3.5	13.4
Hatboro	2.6	10.0
Horsham	10.1	38.7
Jenkintown	0.1	0.4
Lower Moreland	11.3	43.3
Philadelphia	31.7	121.4
Rockledge	0.3	1.2
Upper Dublin	0.9	3.4
Upper Moreland	14.2	54.4
Upper Southampton	3.3	12.6
Warminster	8.1	31.0

As noted in Section 3.2, the EPA approved a TMDL for the Southampton Creek watershed to address nutrients, organic enrichment/low dissolved oxygen, pathogens, and siltation contaminants from nonpoint sources. This TMDL is established for sediments (1,075,668 lbs/ year) and allocated among five municipalities (Bryn Athyn, Lower Moreland, Upper Moreland, Upper Southampton, and Warminster). The stormwater improvements recommended in Appendix C for the Southampton Creek subwatershed can provide a starting point for addressing these impairments.

7.3 County-Wide Coordination

The Bucks and Montgomery county planning commissions will be available upon request to assist municipalities in the adoption of the model ordinance provisions to fit particular municipal ordinance structures. The primary county level activity will be the establishment of review procedures for evaluating stormwater management proposals for development sites and erosion and sediment control plans, the latter being the responsibility of the county conservation districts.

The counties are the primary local contact for stormwater management programs. County personnel provide the needed linkage between federal and state programs and local implementation. For example, counties can ensure that the requirements of federal wetland regulatory programs have been incorporated into land development decisions. The counties should maintain a database of information to assist the municipalities in their regulation of stormwater.

7.4 Commonwealth of Pennsylvania Actions

As set forth in Act 167: “After adoption and approval of a watershed stormwater plan in accordance with this act, the location, design and construction within the watershed of stormwater management systems, obstructions, flood control projects, subdivisions and major land developments, highways and transportation facilities, facilities for the provision of public utility services and facilities owned or financed in whole or in part by funds from the Commonwealth shall be conducted in a manner consistent with the watershed stormwater plan.” Therefore, with the support of the DEP, state agencies constructing roads, highways,

buildings and other facilities shall comply with the standards and criteria within the Plan as they pertain to stormwater management.

The PennVEST Act of 1988, as amended, provides low interest loans to governmental entities for the construction, improvement or rehabilitation of stormwater projects including the transport, storage, and infiltration of stormwater, and best management practices to address non-point source pollution associated with stormwater. In order to qualify for a loan under PennVEST, the municipality or county must be located in a watershed in which there is an existing county-adopted and DEP-approved stormwater plan with enacted stormwater ordinances consistent with the plan, or have enacted a stormwater control ordinance consistent with the Stormwater Management Act. With the adoption of the Plan, all local agencies will be eligible for low interest loans through PennVEST.

7.5 Landowners' and Developers' Responsibilities

As noted in Act 167, "Any landowner and any person engaged in the alteration or development of land which may affect stormwater runoff characteristics shall implement such measures consistent with the provisions of the applicable watershed stormwater plan as are reasonably necessary to prevent injury to health, safety or other property. Such measures shall include such actions as are required:

(1) to assure that the maximum rate of stormwater runoff is no greater after development than prior to development activities; or
(2) to manage the quantity, velocity and direction of resulting stormwater runoff in a manner which otherwise adequately protects health and property from possible injury."

7.6 Plan Review

The City of Philadelphia and Bucks and Montgomery county planning commissions shall monitor the administration and enforcement of the Plan and meet at least annually to coordinate the results of this monitoring. The Plan should be updated in five years.

7.7 Milestones

Table 7.7.A presents the primary milestones for implementing the Pennypack Creek Watershed Act 167 Plan.

Table 7.7.A Milestones for Implementing the Pennypack Creek Watershed Act 167 Plan

Milestone Action	Time Frame	Lead Agency
Conduct Public Hearing	Spring 2011	PWD
Adopt Plan	Summer 2011	Counties, DEP
Adopt and Enforce Ordinances	Six Months after DEP Adoption	Municipalities
Construct Improvements	2011-2016	Municipalities
Monitor Plan and Ordinances	Annual	Counties
Update Plan	2016	Counties

Appendix A
Model Ordinance

PENNYPACK CREEK WATERSHED STORMWATER MANAGEMENT ORDINANCE

Implementing the Requirements of the Pennypack Creek Watershed Stormwater Management Plan

ORDINANCE NO._____ OF _____

_[*Municipality*], __[*County*]_ COUNTY,

PENNSYLVANIA

Adopted at a Public Meeting held on

_____, 20__

TABLE OF CONTENTS

ARTICLE I - GENERAL PROVISIONS **A-3**

ARTICLE II - DEFINITIONS **A-13**

ARTICLE III - STORMWATER MANAGEMENT (SWM) SITE PLAN REQUIREMENTS **A-27**

ARTICLE IV - STORMWATER MANAGEMENT **A-32**

ARTICLE V - INSPECTIONS **A-45**

ARTICLE VI - FEES AND EXPENSES **A-46**

ARTICLE VII - MAINTENANCE RESPONSIBILITIES **A-47**

ARTICLE VIII - PROHIBITIONS **A-50**

ARTICLE IX - ENFORCEMENT AND PENALTIES **A-52**

SIGNATORY PAGE **A-55**

SUBAPPENDIX 1 – SMALL PROJECT STORMWATER MANAGEMENT (SWM) SITE PLAN **A-56**
SUBAPPENDIX 2 – NONSTRUCTURAL PROJECT DESIGN CHECKLIST **A-70**
SUBAPPENDIX 3 – RIPARIAN BUFFER TRAIL GUIDELINES **A-71**

ARTICLE I - GENERAL PROVISIONS

Section 101. Short Title

This Ordinance shall be known and cited as the "Pennypack Creek Stormwater Management Ordinance".

Section 102. Statement of Findings

The governing body of the Municipality finds that:

A. Inadequate management of accelerated stormwater runoff resulting from development throughout a watershed increases flood flows and velocities, contributes to erosion and sedimentation, overtaxes the carrying capacity of existing streams and storm sewers, greatly increases the cost of public facilities to convey and manage stormwater, undermines floodplain management and flood reduction efforts in upstream and downstream communities, reduces groundwater recharge, and threatens public health and safety.

B. Inadequate planning and management of stormwater runoff resulting from land development throughout a watershed can also harm surface water resources by changing the natural hydrologic patterns, accelerating stream flows (which increase scour and erosion of streambeds and streambanks, thereby increasing sedimentation), destroying aquatic habitat, and increasing aquatic pollutant concentrations and loadings such as sediments, nutrients, heavy metals, and pathogens. Groundwater resources are also impacted through loss of recharge.

C. A comprehensive program of stormwater management, including minimization of impacts of development, redevelopment, and activities causing accelerated erosion and loss of natural infiltration, is fundamental to the public health, safety, welfare, and the protection of the people of the Municipality and all of the people of the Commonwealth, their resources, and the environment.

D. Stormwater is an important resource by providing groundwater recharge for water supplies and baseflow of streams, which also protects and maintains surface water quality.

E. Impacts from stormwater runoff can be minimized by using project designs that maintain the natural hydrologic regime and sustain high water quality, groundwater recharge, stream baseflow, and aquatic ecosystems. The most cost-effective and environmentally advantageous way to manage stormwater runoff is through nonstructural project design that minimizes impervious surfaces and sprawl, avoids sensitive areas (i.e., stream buffers, floodplains, steep slopes), and considers topography and soils to maintain the natural hydrologic regime.

F. Public education on the control of pollution from stormwater is an essential component in successfully addressing stormwater.

G. Federal and state regulations require certain municipalities to implement a program of stormwater controls. These municipalities are required to obtain a permit for stormwater discharges from their separate storm sewer systems under the National Pollutant Discharge Elimination System (NPDES).

H. Nonstormwater discharges to municipal separate storm sewer systems can contribute to pollution of waters of the Commonwealth by the Municipality.

Section 103. Purpose

The purpose of this Ordinance is to promote the public health, safety, and welfare within the Pennypack Creek Watershed by maintaining the natural hydrologic regime and by minimizing the harms and maximizing the benefits described in Section 102 of this Ordinance, through provisions designed to:

A. Promote alternative project designs and layouts that minimize the impacts on surface and groundwater.

B. Promote stormwater Best Management Practices (BMPs).

C. Minimize increases in runoff stormwater volume.

D. Minimize impervious surfaces.

E. Manage accelerated stormwater runoff, erosion and sedimentation problems, and stormwater runoff impacts at their source by regulating activities that cause these problems.

F. Provide review procedures and performance standards for stormwater planning and management.

G. Utilize and preserve existing natural drainage systems as much as possible.

H. Manage stormwater impacts close to the runoff source, requiring a minimum of structures and relying on natural processes.

I. Focus on infiltration of stormwater to maintain groundwater recharge, prevent degradation of surface and groundwater quality, and protect water resources.

J. Maintain existing baseflows and quality of streams and watercourses.

K. Meet legal water quality requirements under state law, including regulations at 25 Pennsylvania Code Chapter 93.4.a requiring protection and maintenance of “existing uses” and maintenance of the level of water quality to support those uses in all streams, and the protection and maintenance of water quality in “special protection” streams.

L. Address the quality and quantity of stormwater discharges from the development site.

M. Provide standards necessary to meet NPDES permit requirements.

N. Implement an illegal discharge detection and elimination program that addresses non-stormwater discharges into the Municipality’s separate storm sewer system.

O. Preserve the flood-carrying capacity of streams.

P. Prevent scour and erosion of streambanks and streambeds.

Q. Provide performance standards and design criteria based on watershed-wide stormwater management and planning.

R. Provide proper operation and maintenance of all stormwater management facilities and BMPs that are implemented in the Municipality.

Section 104. Statutory Authority

The Municipality is empowered to regulate land use and activities that may affect runoff and surface and groundwater quality and quantity by the authority of:

A. Primary Authority.

The Municipality is empowered to regulate land use activities that affect runoff and surface and groundwater quality and quantity by the authority of the Act of October 4, 1978, P.L. 864 (Act 167), 32 P.S. Section 680.1, et seq., as amended, the "Storm Water Management Act" and the (appropriate municipal code). In addition, the City of Philadelphia's stormwater regulations prescribe stormwater management requirements for development and post-development stormwater management control. These regulations are available online at: http://www.phillyriverinfo.org/programs/subprogrammain.aspx?Id=Regulations

B. Secondary Authority.

The municipality also is empowered to regulate land use activities that affect runoff by the authority of the Act of July 31, 1968, P.L. 805, No. 247, The Pennsylvania Municipalities Planning Code, as amended.

Section 105. Applicability

All Regulated Activities and all activities that may affect stormwater runoff, including Land Development and Earth Disturbance Activities, are subject to regulation by this Ordinance. This Ordinance shall apply to those portions of the Municipality that lie within the Pennypack Creek Watershed, in accordance with the Stormwater Management Districts established in Section 408, and shall apply only to stormwater BMPs constructed as part of any of the regulated activities listed in this section.

In addition, all applicable development in Philadelphia County must comply with The City of Philadelphia's stormwater regulations, which are available online at http://www.phillyriverinfo.org/programs/subprogrammain.aspx?Id=Regulations.

Furthermore, all applicable development in Philadelphia County must comply with the latest version of the "Stormwater Management Guidance Manual" (currently Version 2.0), prepared by the Philadelphia Water Department Office of Watersheds. This manual is available online at: http://www.phillyriverinfo.org/PWDDevelopmentReview/RequirementsLibrary.aspx?. The site contains several checklists that have been developed to assist the user in complying with the City of Philadelphia's regulations.

Regulated Activities include the following:
a) Land development,
b) Subdivisions,
c) Alteration of the natural hydrologic regime,
d) Construction or reconstruction (see definition in Section 202.B) of or addition of new impervious or semi-pervious surfaces (i.e., driveways, parking lots, roads, etc.),
e) Construction of new buildings or additions to existing buildings,
f) Redevelopment,
g) Diversion piping or encroachments in any natural or man-made channel,
h) Stormwater BMPs or appurtenances thereto,
i) Earth disturbance activities of equal to or greater than five thousand (5,000) square feet,
j) Any of the above regulated activities which were approved more than five (5) years prior to the effective date of this Ordinance and resubmitted for municipal approval.
k) *(The following note applies to those portions of the Pennypack Creek Watershed that lie within Bucks and Montgomery Counties.)*
This Ordinance applies to any earth disturbance activity equal to or greater than five thousand (5,000) square feet that is associated with a development or redevelopment project. Earth disturbance activities of between 5,000 square feet and one (1) acre that are associated with either development or redevelopment projects have modified drainage plan requirements per Table 106.1, and those that are associated with redevelopment are exempt from the Section 407 stream bank erosion requirements. Earth disturbance activities and associated stormwater management controls are also regulated under existing state law and implementing regulations.

Section 106. Exemptions

A. Tables 106.1 summarize the eligibility for exemptions from certain requirements in this Ordinance. "Proposed Impervious Surface" in Table 106.1 includes new, additional, or replacement impervious surface/cover. "Repaving" existing surfaces without reconstruction (see Section 202) does not constitute replacement.

Table 106.1
Eligibility for Exemptions for the Bucks and Montgomery County Portions of the Watershed

Ordinance Article or Section	Type of Project	Proposed Impervious Surface					Earth Disturbance	
		0-500 sq. ft.	501-1,499 sq. ft.	1,500- 5,000 sq. ft.	5,000 sq. ft. – 1 acre	> 1 acre	5,000 sq. ft. – 1 acre	> 1 acre
Article III SWM Site Plan Requirements	Development	Exempt	Modified	Partial	No	No	Modified	No
	Redevelopment	Exempt	Modified	Partial	No	No	Modified	No
Section 404 Nonstructural Project Design	Development	Yes	Yes	No	No	No	No	No
	Redevelopment	Yes	Yes	No	No	No	No	No
Section 405 Groundwater Recharge	Development	Yes	Yes	No	No	No	No	No
	Redevelopment	Yes	Yes	No	No	No	No	No
Section 406 WaterVolume Control Requirements	Development	Yes	Yes	No	No	No	No	No
	Redevelopment	Yes	Yes	No	No	No	No	No
Section 407 Stream Bank Erosion Requirements	Development	Yes	Yes	No	No	No	No	No
	Redevelopment	Yes	Yes	Exempt	No	No	Exempt	No
Section 408 Stormwater Peak Rate Control and Management Districts	Development	Exempt	Exempt	Exempt	No	No	No	No
	Redevelopment	Exempt	Exempt	Exempt	No	No	No	No
Erosion and Sediment Pollution Control Plan	Earth Disturbance	See Earth Disturbance Requirements	See Earth Disturbance Requirements	See Earth Disturbance Requirements	See Earth Disturbance Requirements	See Earth Disturbance Requirements	No	No
		(Refer to municipal earth disturbance requirements, as applicable)						

Notes:
No – Drainage plan required with associated section provision.
Exempt – Exempt from indicated provision – SWM Site Plan submission may still be required by other sections or provisions.
Modified – Modified SWM Site Plan required
- Sites with less than one thousand five hundred (1,500) square feet of new impervious surface, but between five thousand (5,000) square feet and one (1) acre of earth disturbance must submit a SWM Site Plan to the Municipality which need consist only of the items in Sections 301.A.2 and 4; 301.B.7, 8, 11, and 22; and 301.D.1 and 3, and related supportive material needed to determine compliance with Sections 404 and 408.

Partial – Standard Grading Permit is required.
- Sites with more than one thousand five hundred (1,500) square feet, but less than five thousand (5,000) square feet of new impervious surface must submit a SWM Site Plan; however, it need not address the items in Sections 407 and 408.

Table 106.1
Eligibility for Exemptions for the Philadelphia County Portion of the Watershed

Ordinance Article or Section	Type of Project	Earth Disturbance Associated with Development		
		0-5,000 sq. ft.	5,000 sq. ft.-1 acre	> 1 acre
Article III SWM Site Plan Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	No	No
Section 405 Groundwater Recharge Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	No	No
Section 406 Water Volume Control Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	No	No
Section 407 Streambank Erosion (Channel Protection) Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	Exempt	Yes (Alternate Criteria)
Section 408 Flood Control / Stormwater Peak Rate Control and Management Districts Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	No	Yes (Alternate Criteria)

Yes (Alternate Criteria) – Redevelopment disturbing one acre or more that reduces the DCIA from predevelopment conditions by at least 20% is exempt from the Channel Protection/Streambank Erosion (Section 407) and Flood Control/Peak Rate Control (Section 408) Requirements of this Ordinance; and redevelopment that results in an area of earth disturbance equal to or greater than 5,000 square feet, but less than one (1) acre, is exempt from the Channel Protection/Streambank Erosion Requirements of this Ordinance (See Section 106, Exemptions, Philadelphia County Portion of the Watershed).

N/A – Not Applicable, development project is not subject to requirements of the indicated sections of this Ordinance. Voluntary controls are encouraged.

Exempt – Development project is not subject to requirements of indicated section of this Ordinance.

** – If the proposed development results in stormwater discharge that exceeds stormwater system capacity, increases the FEMA regulated water surface elevation, causes a combined sewer overflow, or degrades receiving waters, the design specifications presented in this Ordinance may be applied to proposed development activities as warranted to protect public health, safety, or property.

B. Exemptions for Land Use Activities

Note: In addition to the Exemptions for Eligibility summarized in the respective Tables 106.1, Philadelphia County, Bucks County, and Montgomery County will follow different Exemption Criteria, as stated below.

Bucks County and Montgomery County Portions of the Watershed:

(Note: Subappendix 1 contains guidance for preparation of Small Project SWM Site Plans for small regulated activities that create impervious surface areas of between 1,000 and 5,000 square feet. This guidance provides property owners who propose such small regulated activities the opportunity to submit SWM Site Plans without having to hire Qualified Persons.)

1. Disconnected Regulated Activities (Regulated Activities that create Disconnected Impervious Areas) smaller in area than 500 square feet are exempt from the SWM Site Plan (Section 301) preparation requirements of this Ordinance.

2. Disconnected Regulated Activities (Regulated Activities that create Disconnected Impervious Areas) less than 1,500 sq. ft. are exempt only from the peak rate control (Section 408) requirements of this Ordinance.

3. Agricultural plowing and tilling are exempt from the rate control and SWM Site Plan preparation requirements of this Ordinance provided the activities are performed according to the requirements of 25 Pa. Code Chapter 102.

4. Forest management and timber operations are exempt from the rate control and SWM Site Plan preparation requirements of this Ordinance provided the activities are performed according to the requirements of 25 Pa. Code Chapter 102.

5. For a development taking place in stages, the entire development plan must be used in determining compliance with these exemption criteria. The starting point from which to consider tracts as "parent tracts" in which future subdivisions and respective impervious area computations are cumulatively considered shall be the date of the municipality's adoption of the original Pennypack Creek Watershed Stormwater Management Plan Ordinance [Watershed Plan Date].

   For example: If a property owner in Bucks County or Montgomery County proposes a 300-square-foot shed after adoption of the municipal stormwater management ordinance, that property owner would be exempt from site plan and peak rate control requirements. If, at a later date, the property owner proposes to construct a garage and driveway adding an additional 1,100 square feet of impervious surface, the applicant would be required to submit a Modified SWM Site Plan demonstrating the stormwater control requirements for the total impervious surface of 1,400 square feet.

<u>Philadelphia County Portion of the Watershed:</u>

1. Development, including new development and redevelopment, that results in an area of Earth Disturbance less than five thousand (5,000) square feet is exempt from certain requirements as outlined in Table 106.1. Applicants must still meet Erosion and Sediment (E&S) Control requirements (Section 403) and coastal water quality

requirements from other programs if applicable as described in Philadelphia County's Table 106.1.

2. Redevelopment that results in an area of Earth Disturbance equal to or greater than five thousand (5,000) sq. ft., but less than one (1) acre, is exempt from the Channel Protection/Streambank Erosion (Section 407) Requirements of this Ordinance.

3. Redevelopment that results in an area of Earth Disturbance equal to or greater than one (1) acre and reduces the predevelopment DCIA (Directly Connected Impervious Areas) on the site by at least 20% is exempt from the Channel Protection/Streambank Erosion (Section 407) and Flood Control/Peak Rate Control (Section 408) Requirements of this Ordinance.

4. In District C, development sites that can discharge directly to the Pennypack Creek Main Channel (east of I-95) and to the Delaware River main channel major tributary without use of City infrastructure may do so without control of proposed conditions peak rate of runoff. When adequate capacity in the downstream system does not exist and will not be provided through improvements, the proposed conditions peak rate of runoff must be controlled to the Predevelopment Conditions peak rate as required in District A provisions for the specified Design Storms. The Predevelopment Condition for new development is the existing condition. For redevelopment purposes, the Predevelopment Condition is determined according to the procedures found in the Philadelphia Stormwater Guidance Manual.

C. Infiltration Exemptions (Note: Section 106.C applies to Bucks, Montgomery, and Philadelphia Counties.)

1. Depth to Limiting Zone

A minimum of two (2) feet of soil suitable for infiltration must exist between the invert of the infiltration BMP and the top of the nearest limiting zone. Otherwise, the Re_v requirement shall not be applied to the development site, and the entire WQ_v must be treated.

2. Hotspots

Stormwater Hotspots – Below is a list of types of hotspots recognized by the municipality. If a site is a potential hotspot, it has important implications for how stormwater is managed. First and foremost, untreated stormwater runoff from hotspots concentrated into a collection system, shall not be recharged into groundwater where it may contaminate water supplies. Therefore, the Re_v requirement shall NOT be applied to development sites that fit in a hotspot (the entire WQ_v must still be treated). Second, a greater level of stormwater treatment shall be applied at hotspot sites to prevent pollutant washoff after construction. The Environmental Protection Agency's (EPA) National Pollutant Discharge Elimination System (NPDES) stormwater program requires some industrial sites to prepare and implement a stormwater pollution prevention plan.

List of potential hotspots:

- Vehicle salvage yards and recycling facilities
- Vehicle fueling stations
- Vehicle service and maintenance facilities
- Vehicle and equipment cleaning facilities
- Fleet storage areas (bus, truck, etc.)
- Industrial sites based on Standard Industrial Codes
- Marinas (service and maintenance)
- Outdoor liquid container storage
- Commercial/industrial facilities
- Public works storage areas
- Facilities that generate, transfer, store, or dispose hazardous materials
- Commercial container nursery

The following land uses and activities are not normally considered hotspots:

- Residential streets and rural highways
- Residential development
- Institutional development
- Office developments
- Nonindustrial rooftops
- Pervious areas, except golf courses and nurseries (which may need an integrated pest management (IPM) plan).

3. Rate of Infiltration:

When infiltration is not feasible due to poor infiltration rates, the water quality volume must be treated by an approved SMP.

D. Additional Exemption Criteria:

1. Exemption Responsibilities - An exemption shall not relieve the Applicant from implementing such measures as are necessary to protect public health, safety, property, water quality, and the environment.

2. Drainage Problems - Where drainage problems exist downstream of the proposed activity, then the Municipality may deny exemptions.

3. Exemptions are limited to specific portions of this Ordinance.

4. HQ and EV Streams – The municipalities may deny exemptions in High Quality (HQ) or Exceptional Value (EV) waters and Source Water Protection Areas (SWPA).

5. For a development taking place in stages, the entire development plan must be used in determining compliance with these exemption criteria. The starting point from which to consider tracts as "parent tracts" in which future subdivisions and respective impervious area computations are cumulatively considered shall be the date of the municipal ordinance adoption of the original Pennypack Creek Watershed Stormwater Management Plan Ordinance [Watershed Plan Date].

For example: If a property owner in Bucks County or Montgomery County proposes a 300-square-foot shed after adoption of the municipal stormwater management ordinance, that property owner would be exempt from site plan and peak rate control requirements. If, at a later date, the property owner proposes to construct a garage and driveway adding an additional 1,300 square feet of impervious surface, the applicant would be required to submit a SWM Site Plan demonstrating the stormwater control requirements for the total impervious surface of 1,600 square feet.

E. The municipality may deny or revoke any exemption pursuant to this Section at any time for any project that the municipality believes may pose a threat to public health, safety, property or the environment.

Section 107. Repealer

Any other Ordinances, provisions or regulations of the Municipality inconsistent with any of the provisions of this Ordinance are hereby repealed to the extent of the inconsistencies only.

Section 108. Severability

In the event that a court of competent jurisdiction declares any section or provision of this Ordinance invalid, such decision shall not affect the validity of any of the remaining provisions of this Ordinance.

Section 109. Compatibility with Other Ordinances or Legal Requirements

Approvals issued pursuant to this Ordinance do not relieve the Applicant of the responsibility to secure required permits or approvals for activities regulated by any other applicable code, rule, act, or Ordinance, including Title 25PA Code, Chapter 92, 102 & 105.

Section 110. Duty of Persons Engaged in the Development of Land

Notwithstanding any provision(s) of this Ordinance, including exemptions, any landowner or any person engaged in the alteration or development of land that may affect stormwater runoff characteristics shall implement such measures as are reasonably necessary to prevent injury to health, safety, or other property. Such measures also shall include actions as are required to manage the rate, volume, direction, and quality of resulting stormwater runoff in a manner that otherwise adequately protects health, safety, property, and water quality.

ARTICLE II - DEFINITIONS

Section 201. Interpretation

For the purposes of this Ordinance, certain terms and words used herein shall be interpreted as follows:

A. Words used in the present tense include the future tense; the singular number includes the plural, and the plural number includes the singular; words of masculine gender include feminine gender; and words of feminine gender include masculine gender.

B. The word "includes" or "including" shall not limit the term to the specific example, but is intended to extend its meaning to all other instances of like kind and character.

C. The words "shall" and "must" are mandatory; the words "may" and "should" are permissive.

Section 202. Definitions

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

Agricultural Activities – Activities associated with agriculture such as agricultural cultivation, agricultural operation, and animal heavy use areas. This includes the work of producing crops including tillage, land clearing, plowing, disking, harrowing, planting, harvesting crops, or pasturing and raising of livestock and installation of conservation measures. Construction of new buildings or impervious area is not considered an agricultural activity.

Alteration – As applied to land, a change in topography as a result of the moving of soil and rock from one location or position to another; also the changing of surface conditions by causing the surface to be more or less impervious; land disturbance.

Applicant – A landowner, developer or other person who has filed an application to the Municipality for approval to engage in any Regulated Activity at a project site in the Municipality.

As-built Drawings – Engineering or site drawings maintained by the contractor as he constructs the project and upon which he documents the actual locations of the building components and changes to the original contract documents. These documents, or a copy of same, are turned over to the Municipality at the completion of the project.

Bankfull – The channel at the top-of-bank or point from where water begins to overflow onto a floodplain.

Baseflow – Portion of stream discharge derived from groundwater; the sustained discharge that does not result from direct runoff or from water diversions, reservoir releases, piped discharges, or other human activities.

Bioretention – A stormwater retention area that utilizes woody and herbaceous plants and soils to remove pollutants before infiltration occurs.

BMP (Best Management Practice) – Activities, facilities, designs, measures or procedures used to manage stormwater impacts from Regulated Activities, to meet State Water Quality Requirements, to promote groundwater recharge and to otherwise meet the purposes of this Ordinance. Stormwater BMPs are commonly grouped into one of two broad categories or measures: "structural" or "non-structural." In this Ordinance, non-structural BMPs or measures refer to operational and/or behavior-related practices that attempt to minimize the contact of pollutants with stormwater runoff, or to provide other environmental or aesthetic benefits such as low impact designs, riparian or forested buffers; whereas structural BMPs or measures are those that consist of a physical device or practice that is installed to capture and treat stormwater runoff. Structural BMPs include, but are not limited to, a wide variety of practices and devices, from large-scale retention ponds and constructed wetlands, to small-scale underground treatment systems, infiltration facilities, filter strips, bioretention, wet ponds, permeable paving, grassed swales, sand filters, detention basins, and manufactured devices. Structural Stormwater BMPs are permanent appurtenances to the project site.

BMP Manual - *Pennsylvania Stormwater Best Management Practices Manual*, No. 363-0300-002 (December 2006).

Buffer – The area of land immediately adjacent to any stream, measured perpendicular to and horizontally from the top-of-bank on both sides of a stream (see Top-of-bank).

Channel – An open drainage feature through which stormwater flows. Channels include, but shall not be limited to, natural and man-made drainageways, swales, streams, ditches, canals, and pipes flowing partly full.

Channel Erosion – The widening, deepening, or headward cutting of channels and waterways caused by stormwater runoff or bankfull flows.

Cistern – An underground reservoir or tank for storing rainwater.

Conservation District – A conservation district, as defined in section 3(c) of the Conservation District Law (3 P. S. § 851(c)), that has the authority under a delegation agreement executed with DEP to administer and enforce all or a portion of the regulations promulgated under 25 Pa. Code 102.

Conveyance – A facility or structure used for the transportation or transmission of something from one place to another.

Culvert – A structure with its appurtenant works which carries water under or through an embankment or fill.

Dam – A man-made barrier, together with its appurtenant works, constructed for the purpose of impounding or storing water or another fluid or semifluid. A dam may include a refuse bank, fill, or structure for highway, railroad, or other purposes that impounds or may impound water or another fluid or semifluid.

DEP (or PADEP) - The Pennsylvania Department of Environmental Protection.

Design Storm – The magnitude and temporal distribution of precipitation from a storm event measured in probability of occurrence that such magnitude will be equaled or exceeded in any one year (e.g., the 20% chance, or so-called 5-year (recurrence interval) storm), and duration (e.g., twenty-four (24) hours), used in the design and evaluation of stormwater management systems. Also see Return Period.

Detention Volume - The volume of runoff that is captured and released into the waters of this Commonwealth at a controlled rate.

Detention Basin – An impoundment designed to collect and retard stormwater runoff by temporarily storing the runoff and releasing it at a predetermined rate. Detention basins are designed to drain completely soon after a rainfall event, and to become dry until the next rainfall event.

Developer – A person who seeks to undertake any regulated earth disturbance activities at a project site in the Municipality.

Development – Any human-induced change to improved or unimproved real estate, whether public or private, including, but not limited to, land development, construction, installation, or expansion of a building or other structure, land division, street construction, and site alteration such as embankments, dredging, grubbing, grading, paving, parking or storage facilities, excavation, filling, stockpiling, or clearing. As used in this Ordinance, development encompasses both new development and redevelopment.

Development Site (Site) – See Project Site.

Diameter at Breast Height (DBH) – The outside bark diameter at breast height which is defined as four and one half (4.5) feet (1.37m) above the forest floor on the uphill side of the tree.

Diffused Drainage Discharge – Drainage discharge that is not confined to a single point location or channel, including sheet flow or shallow concentrated flow.

Directly Connected Impervious Area (DCIA) – An impervious or impermeable surface that is directly connected to a stormwater drainage or conveyance system, leading to direct runoff, decreased infiltration, decreased filtration, and decreased time of concentration.

Disconnected Impervious Area (DIA) – An impervious or impermeable surface that is disconnected from any stormwater drainage or conveyance system, and is redirected or directed to a pervious area, which allows for infiltration, filtration, and increased time of concentration.

Disturbance – See Earth Disturbance.

Disturbed Area – An unstabilized land area where an earth disturbance activity is occurring or has occurred.

Ditch – A man-made waterway constructed for irrigation or stormwater conveyance purposes.

Downslope Property Line – That portion of the property line of the lot, tract, or parcels of land being developed, located such that overland or pipe flow from the project site would be directed towards it by gravity.

Drainage Conveyance Facility – A stormwater management facility designed to transport stormwater runoff that includes channels, swales, pipes, conduits, culverts, and storm sewers.

Drainage Easement – A right granted by a landowner to a grantee allowing the use of private land for stormwater management purposes.

Drainage Plan – See Stormwater Management Site Plan.

Earth Disturbance Activity– A construction or other human activity which disturbs the surface of land including, but not limited to, clearing and grubbing, grading, filling, excavations, embankments, land development, agricultural plowing or tilling, timber harvesting activities, road maintenance activities, mineral or fluid extraction, and the moving, depositing, stockpiling, or storing of soil, rock, or earth materials.

Emergency Spillway – A conveyance area that is used to pass peak discharge greater than the maximum design storm controlled by the stormwater facility.

Encroachment – A structure or activity that changes, expands, or diminishes the course, current, or cross-section of a watercourse, floodway, or body of water.

Erosion – The natural process by which the surface of the land is worn away by water, wind or chemical action.

Erosion and Sediment Control Plan – A plan that is designed to minimize accelerated erosion and sedimentation.

Exceptional Value Waters – Surface waters having quality that satisfy one (1) or more of the conditions established in Pennsylvania Code Title 25 Environmental Protection, Chapter 93, Water Quality Standards, §93.4b(b).

Existing Condition – The dominant land cover during the 5-year period immediately preceding a proposed Regulated Activity. If the initial condition of the site is undeveloped land, the land use shall be considered as "meadow" unless the natural land cover is proven to generate a lower curve number (CN) or Rational "c" value, such as forested lands.

FEMA – Federal Emergency Management Agency.

Flood – A temporary condition of partial or complete inundation of land areas from the overflow of streams, rivers, and other waters of this Commonwealth.

Floodplain – Any land area susceptible to inundation by water from any natural source or delineated by applicable FEMA maps and studies as being a special flood hazard area. Included are lands adjoining a river or stream that have been or may be expected to be inundated by a 100-year flood, i.e., the flood of magnitude that has a one (1) percent chance of being equaled or exceeded in any given year. Also included are areas that comprise Group 13 Soils, as listed in Appendix A of the Pennsylvania DEP Technical Manual for Sewage Enforcement Officers (as amended or replaced from time to time by DEP).

Floodway – The channel of a watercourse and those portions of the adjoining floodplains that are reasonably required to carry and discharge the 100-year frequency flood. Unless otherwise specified, the boundary of the floodway is as indicated on Flood Insurance Rate Maps (FIRMs) and flood insurance studies provided by FEMA. In an area where no FEMA maps or studies have defined the boundary of the 100-year frequency floodway, it is assumed, absent evidence to the contrary, that the floodway extends fifty (50) feet from the top-of-bank on each side of the stream.

Fluvial Geomorphology – The study of landforms associated with river channels and the processes that form them.

Forest Management/Timber Operations – Planning and associated activities necessary for the management of forest lands. These include timber inventory and preparation of forest management plans, silvicultural treatment, cutting budgets, logging road design and construction, timber harvesting, site preparation, and reforestation.

Freeboard – A vertical distance between the elevation of the design high-water and the top of a dam, levee, tank, basin, swale, or diversion berm. The space is required as a safety margin in a pond or basin.

Grade – 1. (noun) A slope, usually of a road, channel, or natural ground specified in percent and shown on plans as specified herein. 2. (verb) To finish the surface of a roadbed, the top of an embankment, or the bottom of an excavation.

Grassed Waterway – A natural or man-made waterway, usually broad and shallow, covered with erosion-resistant grasses used to convey surface water.

Groundwater – Water beneath the earth's surface that supplies wells and springs and is within the saturated zone of soil and rock.

Groundwater Recharge – The replenishment of existing natural underground water supplies from precipitation or overland flow.

HEC-HMS – The U.S. Army Corps of Engineers, Hydrologic Engineering Center (HEC) - Hydrologic Modeling System (HMS). This model was used to model the Pennypack Creek Watershed during the Act 167 plan development and is the basis for the standards and criteria of this Ordinance.

High Quality Waters – Surface waters having quality that satisfy one (1) or more of the conditions established by Pennsylvania Code Title 25 Environmental Protection, Chapter 93, Water Quality Standards, § 93.4b(a).

Hotspots – Areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

Hydrograph – A graph representing the discharge of water versus time at a selected point in the drainage system.

Hydrologic Regime – The hydrologic cycle or balance that sustains quality and quantity of stormwater, baseflow, storage, and groundwater supplies under natural conditions.

Hydrologic Soil Group (HSG) – Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four HSGs (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting. The NRCS defines the four groups and provides a list of most of the soils in the United States and their group classifications. The soils in the area of the development site may be identified from a soil survey report that can be obtained from local NRCS offices or conservation district offices. Soils become less pervious as the HSG varies from A to D (NRCS).

Impervious Surface (Impervious Area) – A surface that prevents the infiltration of water into the ground. Impervious surfaces (or areas) shall include, but not be limited to, roofs, additional indoor living spaces, patios, garages, storage sheds and similar structures, swimming pools, and any new streets or sidewalks. Decks, parking areas, and driveway areas are not counted as impervious areas if they do not prevent infiltration.

Impoundment – A retention or detention basin designed to retain stormwater runoff and release it at a controlled rate.

Infill – Development that occurs on smaller parcels that remains undeveloped but is within or in very close proximity to urban or densely developed areas. Infill development usually relies on existing infrastructure and does not require an extension of water, sewer, or other public utilities.

Infiltration – Movement of surface water into the soil, where it is absorbed by plant roots, evaporated into the atmosphere, or percolated downward to recharge groundwater.

Infiltration basin - A shallow impoundment that is designed to infiltrate stormwater into the soil. Infiltration basins are believed to have a high pollutant removal efficiency, and can also help recharge the groundwater, thus restoring baseflows to stream systems. Infiltration basins can be problematic at many sites because of stringent soil requirements.

Infiltration Structures – A structure designed to direct runoff into the underground water (e.g., French drains, seepage pits, seepage trenches, or infiltration galleries).

Inflow – The flow entering the stormwater management facility and/or BMP.

Inlet – The upstream end of any structure through which water may flow.

Intermittent Stream – A stream that flows only part of the time. Flow generally occurs for several weeks or months in response to seasonal precipitation or groundwater discharge.

Invert – The lowest surface, the floor or bottom of a culvert, drain, sewer, channel, basin, BMP, or orifice.

Karst - A type of topography or landscape characterized by surface depressions, sinkholes, rock pinnacles/uneven bedrock surface, underground drainage and caves. Karst is formed on carbonate rocks, such as limestone or dolomite.

Land Development (Development) – Any of the following activities:

(i) The improvement of one (1) lot or two (2) or more contiguous lots, tracts, or parcels of land for any purpose involving:
   a. A group of two (2) or more residential or nonresidential buildings, whether proposed initially or cumulatively, or a single nonresidential building on a lot or lots regardless of the number of occupants or tenure, or
   b. The division or allocation of land or space, whether initially or cumulatively, between or among two (2) or more existing or prospective occupants by means of, or for the purpose of, streets, common areas, leaseholds, condominiums, building groups, or other features;

(ii) A subdivision of land;

(iii) Development in accordance with Section 503(1.1) of the PA Municipalities Planning Code.

Limiting Zone – A soil horizon or condition in the soil profile or underlying a stratum that includes one of the following:

(i) A seasonal high water table, whether perched or regional, determined by direct observation of the water table or indicated by soil mottling.

(ii) A rock with open joints, fracture or solution channels, or masses of loose rock fragments, including gravel, with sufficient fine soil to fill the voids between the fragments.

(iii) A rock formation, other stratum, or soil condition that is so slowly permeable that it effectively limits downward passage of water.

Lot – A designated parcel, tract, or area of land established by a plat or otherwise as permitted by law and to be used, developed, or built upon as a unit.

Main Stem (Main Channel) – Any stream segment or other runoff conveyance used as a reach in the Pennypack Creek Watershed hydrologic model.

Manning Equation (Manning Formula) – A method for calculation of velocity of flow (e.g., feet per second) and flow or discharge rate (e.g., cubic feet per second) in open channels based upon channel shape, roughness, depth of flow, and slope. "Open channels" may include closed conduits so long as the flow is not under pressure.

Maximum Design Storm – The maximum (largest) design storm that is controlled by the stormwater facility.

Municipal Engineer – A professional engineer (PE) licensed as such in the Commonwealth of Pennsylvania, duly appointed as the Engineer for a Municipality, planning agency, or joint planning commission.

Municipality – [*Municipal Name*], [*County Name*] County, Pennsylvania.

Natural Condition – Pre-development condition.

Natural Hydrologic Regime – See Hydrologic Regime.

Natural Recharge Area – Undisturbed surface area or depression where stormwater collects and a portion of which infiltrates and replenishes the underground and groundwater.

Nonpoint Source Pollution – Pollution that enters a waterbody from diffuse origins in the watershed and does not result from discernible, confined, or discrete conveyances.

Nonstormwater Discharges – Water flowing in stormwater collection facilities, such as pipes or swales, which are not the result of a rainfall event or snowmelt.

Nonstructural Best Management Practice (BMPs) – Methods of controlling stormwater runoff quantity and quality, such as innovative site planning, impervious area and grading reduction, protection of natural depression areas, temporary ponding on site, and other techniques.

NPDES – National Pollutant Discharge Elimination System, the federal government's system for issuance of permits under the Clean Water Act, which is delegated to DEP in Pennsylvania.

NRCS – Natural Resource Conservation Service of the U.S. Department of Agriculture (previously the Soil Conservation Service (SCS)).

Open Channel – A conveyance channel that is not enclosed.

Outfall – "Point source" as described in 40 CFR § 122.2 at the point where the Municipality's storm sewer system discharges to Surface Waters of the Commonwealth.

Outflow – The flow exiting the stormwater management facility and/or BMP.

Outlet – Points of water disposal to a stream, river, lake, tidewater, or artificial drain.

Parent Tract – The parcel of land from which a land development or subdivision originates, determined from the date of municipal adoption of this Ordinance.

Parking Lot Storage – Involves the use of parking areas as temporary impoundments with controlled release rates during rainstorms.

Peak Discharge – The maximum rate of stormwater runoff from a specific storm event.

Pipe – A culvert, closed conduit, or similar structure (including appurtenances) that conveys stormwater.

Point Source – Any discernible, confined, and discrete conveyance including, but not limited to, any pipe as defined in state regulations at 25 Pennsylvania Code § 92.1.

Post-construction – Period after construction during which disturbed areas are stabilized, stormwater controls are in place and functioning, and all proposed improvements in the approved land development plan are completed.

Pre-construction – Prior to commencing construction activities.

Pre-development Condition – Undeveloped/natural condition.

Pretreatment – Techniques employed in stormwater BMPs to provide storage or filtering to trap coarse materials and other pollutants before they enter the system, but not necessarily designed to meet the water quality volume control requirements (WQ_v) of Section 406. For example, any inlets draining to an infiltrating system should be sumped and trapped to prevent the system from becoming clogged with excess sediment.

Project Site – The specific area of land where any regulated activities in the Municipality are planned, conducted, or maintained.

Qualified Person - Any person licensed by the Pennsylvania Department of State or otherwise qualified by law to perform the work required by the Ordinance.

Rational Formula – A rainfall-runoff relation used to estimate peak flow.

Reach – Any stream segment or other runoff conveyance used in the Pennypack Creek Watershed hydrologic model.

Recharge – The replenishment of groundwater through the infiltration of rainfall, other surface waters, or land application of water or treated wastewater.

Recharge Volume (Re_v) – The volume of stormwater, in cubic feet, required to be infiltrated on site, where practicable and appropriate.

Reconstruction – Demolition and subsequent rebuilding of impervious surface.

Record Drawings – Original documents revised to suit the as-built conditions and subsequently provided by the Engineer to the client. The Engineer reviews the contractor's as-builts against his/her own records for completeness, then either turns these over to the client or transfers the information to a set of reproducibles, in both cases for the client's permanent records.

Recurrence Interval – See Return Period.

Redevelopment – Any development that requires demolition or removal of existing structures or impervious surfaces at a site and replacement with new impervious surfaces. Maintenance activities such as top-layer grinding and re-paving are not considered to be redevelopment. Interior remodeling projects and tenant improvements are also not considered to be redevelopment.

Regulated Activities – Any Earth Disturbance Activities or any activities that involve the alteration or development of land in a manner that may affect stormwater runoff.

Regulated Earth Disturbance Activity – Defined under NPDES Phase II regulations as earth disturbance activity of one (1) acre or more with a point source discharge to surface waters or the Municipality's storm sewer system or five (5) acres or more with or without a point source discharge. This includes earth disturbance on any portion of, or during any stage of, a larger common plan of development. Activity involving earth disturbance subject to regulation under 25 PA Code 92, 25 PA Code 102, or the Clean Streams Law.

Release Rate – The percentage of existing conditions peak rate of runoff from a site or subarea to which the proposed conditions peak rate of runoff must be reduced to protect downstream areas.

Repaving – Replacement of an impervious surface that does not involve reconstruction of an existing paved (impervious) surface (e.g., addition of a new layer of asphalt over an existing paved surface).

Replacement Paving – Reconstruction of and full replacement of an existing paved (impervious) surface (e.g., demolition and removal of surface layer, foundation, and base course; and subsequent reconstruction of the entire sequence).

Retention Volume/Removed Runoff - The volume of runoff that is captured and not released directly into the surface waters of this Commonwealth during or after a storm event.

Return Period – The average interval, in years, within which a storm event of a given or greater magnitude can be expected to recur. For example, the 25-year return period rainfall would be expected to recur on the average of once every twenty-five (25) years, or conversely would have a four (4) percent chance of occurrence or exceedance in any given year.

Riparian Buffer – An area of land adjacent to a body of water and managed to maintain the integrity of stream channels and shorelines to 1) reduce the impact of upland sources of pollution by trapping, filtering, and converting sediments, nutrients, and other chemicals, and 2) supply food, cover and thermal protection to fish and other wildlife.

Riser – A vertical pipe extending from the bottom of a pond that is used to control the discharge rate from the pond for a specified design storm.

Road Maintenance – Earth disturbance activities within the existing road cross-section, such as grading and repairing existing unpaved road surfaces, cutting road banks, cleaning or clearing drainage ditches, and other similar activities.

Roof Drains – A drainage conduit or pipe that collects water runoff from a roof and leads it away from the structure.

Rooftop Detention – The temporary ponding and gradual release of stormwater falling directly onto flat roof surfaces using controlled-flow roof drains in building designs.

Runoff – Any part of precipitation that flows over the land surface.

SALDO – Subdivision and Land Development Ordinance.

Sediment - Soils or other materials transported by surface water as a product of erosion.

Sediment Basin – A barrier, dam, or retention or detention basin located and designed in such a way as to retain rock, sand, gravel, silt, or other material transported by water during construction.

Sediment Pollution – The placement, discharge, or any other introduction of sediment into the waters of the Commonwealth.

Sedimentation – The process by which mineral or organic matter is accumulated or deposited by the movement of water or air.

Seepage Pit/Seepage Trench – An area of excavated earth filled with loose stone or similar coarse material into which surface water is directed for infiltration into the underground water.

Separate Storm Sewer System – A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) primarily used for collecting and conveying stormwater runoff.

Shallow Concentrated Flow – Stormwater runoff flowing in shallow, defined ruts prior to entering a defined channel or waterway.

Sheet Flow – A flow process associated with broad, shallow water movement on sloping ground surfaces that is not channelized or concentrated.

Soil Cover Complex Method – A method of runoff computation developed by NRCS that is based on relating soil type and land use/cover to a runoff parameter called curve number (CN).

Source Water Protection Areas (SWPA) – The zones through which contaminants, if present, are likely to migrate and reach drinking water wells or surface water intakes.

Spillway – A conveyance that is used to pass the peak discharge of the maximum design storm that is controlled by the stormwater facility.

Standard Grading Permit - The permit required to be issued by the Municipality before any grading activities are allowed to commence on a site within the Municipality. Such permits typically require information including, but not limited to, a contour map of the site showing existing and proposed contours, a plot plan showing streams and drainage courses on or within fifty (50) feet of the site, drainage structures, neighboring streets and alleys, trees, and floodplain zones on or within fifty (50) feet of the site, soil classifications.

State Water Quality Requirements – The regulatory requirements to protect, maintain, reclaim, and restore water quality under Title 25 of the Pennsylvania Code and the Clean Streams Law.

Storage Indication Method – A reservoir routing procedure based on solution of the continuity equation (inflow minus outflow equals the change in storage) with outflow defined as a function of storage volume and depth.

Storm Frequency – The number of times that a given storm "event" occurs or is exceeded on average in a stated period of years (see Return Period).

Storm Sewer – A system of pipes and/or open channels that convey intercepted runoff and stormwater from other sources but exclude domestic sewage and industrial wastes.

Stormwater – Drainage runoff from the surface of the land resulting from precipitation or snow or ice melt.

Stormwater Management District – Those subareas of a watershed in which some type of detention is required to meet the plan requirements and the goals of Act 167.

Stormwater Management Facility (SMF) – Any structure, natural or man-made, that, due to its condition, design, or construction, conveys, stores, or otherwise affects stormwater runoff quality, rate, or quantity. Typical stormwater management facilities include, but are not limited to, detention and infiltration basins, open channels, storm sewers, pipes, and infiltration structures.

Stormwater Management Plan – The watershed plan, known as the "Pennypack Creek Watershed Act 167 Stormwater Management Plan," for managing those land use activities that will influence stormwater runoff quality and quantity, and that would impact the Pennypack Creek Watershed adopted by Bucks, Montgomery, and Philadelphia Counties as required by the Act of October 4, 1978, P.L. 864 (Act 167).

Stormwater Management Site Plan (SWM Site Plan) – The plan prepared by the Applicant or his representative indicating how stormwater runoff will be managed at the particular site of interest to meet the requirements of this Ordinance.

Stream – A natural watercourse.

Stream Buffer – The land area adjacent to each side of a stream essential to maintaining water quality (see Buffer).

Stream Enclosure – A bridge, culvert, or other structure in excess of one hundred (100) feet in length upstream to downstream, which encloses a regulated water of the Commonwealth.

Subarea (Subwatershed) – The smallest drainage unit of a watershed for which stormwater management criteria have been established in the stormwater management plan.

Subdivision – The division or redivision of a lot, tract, or parcel of land by any means into two (2) or more lots, tracts, parcels, or other divisions of land including changes in existing lot lines for the purpose, whether immediate or future, of lease, partition by the court for distribution to heirs or devisees, transfer of ownership, or building or lot development; provided, however, that the subdivision by lease of land for agricultural purposes into parcels of more than ten (10) acres not involving any new street or easement of access or any residential dwelling shall be exempted. As defined in The Pennsylvania Municipalities Planning Code, Act of July 31, 1968, P.L. 805, No. 247.

Surface Waters of the Commonwealth – Any and all rivers, streams, creeks, rivulets, ditches, watercourses, storm sewers, lakes, dammed water, wetlands, ponds, springs, and all other bodies or channels of conveyance of surface waters, or parts thereof, whether natural or artificial, within or on the boundaries of the Commonwealth.

Swale – A low-lying stretch of land that gathers or carries surface water runoff.

Timber Operations – See Forest Management.

Time-of-concentration (Tc) – The time required for surface runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed. This time is the combined total of overland flow time and flow time in pipes or channels, if any.

Top-of-bank – Highest point of elevation in a stream channel cross-section at which a rising water level just begins to flow out of the channel and over the floodplain.

Undeveloped Condition – Natural condition (see also Pre-development Condition).

USDA - United States Department of Agriculture.

Vernal Pond – Seasonal depressional wetlands that are covered by shallow water for variable periods from winter to spring but may be completely dry for most of the summer and fall.

Watercourse – A channel or conveyance of surface water having a defined bed and banks, whether natural or artificial, with perennial or intermittent flow.

Water Volume Control (see Section 406) – The storage capacity, in acre-feet, required to capture and treat a portion of stormwater runoff from the developed or redeveloped areas of the site.

Waters of the Commonwealth – Rivers, streams, creeks, rivulets, impoundments, ditches, watercourses, storm sewers, lakes, dammed water, wetlands, ponds, springs and other bodies or channels of conveyance of surface and underground water, or parts thereof, whether natural or artificial, within or on the boundaries of this Commonwealth.

Watershed – Region or area drained by a river, watercourse or other surface water of the Commonwealth.

Wellhead – 1. A structure built over a well, 2. The source of water for a well.

Wellhead Protection Area – The surface and subsurface area surrounding a water supply well, well field, or spring supplying a public water system through which contaminants are reasonably likely to move toward and reach the water source.

Wet Basin – Pond for urban runoff management that is designed to detain urban runoff and always contains water.

Wetland – Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, fens, and similar areas.

Woods – A natural groundcover with more than one (1) viable tree of a DBH of six (6) inches or greater per fifteen hundred (1,500) square feet which existed within three (3) years of application; a cover condition for which SCS curve numbers have been assigned or to which equivalent Rational Method runoff coefficients have been assigned.

ARTICLE III - STORMWATER MANAGEMENT (SWM) SITE PLAN REQUIREMENTS

Section 301. SWM Site Plan Contents

The SWM Site Plan shall consist of a general description of the project, including calculations, maps, and plans. A note on the maps shall refer to the associated computations and Erosion and Sediment (E&S) Control Plan by title and date. The cover sheet of the computations and E&S Control Plan shall refer to the associated maps by title and date. All SWM Site Plan materials shall be submitted to the Municipality in a format that is clear, concise, legible, neat, and well organized; otherwise, the SWM Site Plan shall not be accepted for review and shall be returned to the Applicant.

The following items shall be included in the SWM Site Plan:

A. General

1. General description of the project.

2. General description of proposed stormwater management techniques, including construction specifications of the materials to be used for stormwater management facilities. *(Required for modified SWM Site plan, per Table 106.1 for Bucks and Montgomery Counties.)*

3. Complete hydrologic, hydraulic, and structural computations for all stormwater management facilities.

4. An erosion and sediment control plan, including all reviews and letters of adequacy from the Conservation District. *(Required for modified SWM Site plan, per Table 106.1 for Bucks and Montgomery Counties.)*

5. A general description of proposed nonpoint source pollution controls.

6. The SWM Site Plan Application and completed fee schedule form and associated fee.

7. The SWM Site Plan Checklist.

B. Maps

Prepare an Existing Resource and Site Analysis Map (ERSAM) showing environmentally sensitive areas including, but not limited to, steep slopes, ponds, lakes, streams, wetlands, hydric soils, vernal pools, stream buffers, floodplains and hydrologic soil groups. Land development, existing recharge areas, and any other requirements specifically outlined in the municipal SALDO also shall be included.

Map(s) of the project area shall be submitted on 24-inch x 36-inch sheets and/or shall be prepared in a form that meets the requirements for recording at the offices of the Recorder of Deeds of [*County Name*] County. If the SALDO has more stringent criteria than this Ordinance, then the more stringent criteria shall apply. The contents of the map(s) shall include, but not be limited to:

1. The location of the project relative to highways, municipal boundaries, or other identifiable landmarks.

2. Existing contours at intervals of two (2) feet or less. In areas of slopes greater than [10] percent, 5-foot contour intervals may be used.

3. Existing streams, lakes, ponds, or other waters of the Commonwealth within the project area.

4. Other physical features including flood hazard boundaries, stream buffers, existing drainage courses, areas of natural vegetation to be preserved, and the total extent of the upstream area draining through the site.

5. The locations of all existing and proposed utilities, sanitary sewers, and water lines within fifty (50) feet of property lines.

6. A map, which may be done as an overlay, showing soil names and boundaries.

7. Limits of earth disturbance, including the type and amount of impervious area that is proposed. *(Required for modified SWM Site plan, per Table 106.1 for Bucks and Montgomery Counties.)*

8. Proposed structures, roads, paved areas, and buildings. *(Required for modified SWM Site plan, per Table 106.1 for Bucks and Montgomery Counties.)*

9. Final contours at intervals of two (2) feet or less. In areas of steep slopes (greater than ten [10] percent), 5-foot contour intervals may be used.

10. The name of the development, the name and address of the owner of the property, and the name of the individual or firm preparing the plan.

11. The date of submission. *(Required for modified SWM Site plan, per Table 106.1 for Bucks and Montgomery Counties.)*

12. A graphic and written scale of one (1) inch equals no more than fifty (50) feet; for tracts of twenty (20) acres or more, the scale shall be one (1) inch equals no more than one hundred (100) feet.

13. A north arrow.

14. The total tract boundary and size with distances marked to the nearest foot and bearings to the nearest degree.

15. Existing and proposed land use(s).

16. A key map showing all existing man-made features beyond the property boundary that would be affected by the project.

17. Location of all open channels.

18. Overland drainage patterns and swales.

19. A 15-foot wide access easement around all stormwater management facilities to provide ingress to and egress from a public right-of-way.

20. The location of all erosion and sediment control facilities.

21. A note on the plan indicating the location and responsibility for maintenance of stormwater management facilities that would be located off site. All off-site facilities shall meet the performance standards and design criteria specified in this Ordinance.

22. A statement, signed by the Applicant, acknowledging that any revision to the approved drainage plan must be approved by the Municipality, and that a revised erosion and sediment control plan must be submitted to the Municipality or Conservation District for approval. *(Required for modified SWM Site plan, per Table 106.1 for Bucks and Montgomery Counties.)*

23. The following signature block for the Design Engineer:

    "I, (Design Engineer), on this date (date of signature), hereby certify that the drainage plan meets all requirements of the Department of Environmental Protection's (DEP's) regulations and this Ordinance."

C. Supplemental Information to be Submitted to the Municipality

1. The following information shall be submitted by the Applicant and shall include:

    a. The overall stormwater management concept for the project designed.
    b. Stormwater runoff computations required by this Ordinance.
    c. Stormwater management techniques to be applied both during and after development.
    d. Expected project time schedule.
    e. Development stages or project phases, if so proposed.
    f. An Operations and Maintenance (O&M) Plan in accordance with Section 702 of this Ordinance.

2. An E&S Control Plan

3. A description of the effect of the project (in terms of runoff volumes and peak flows) on adjacent properties and on any existing municipal stormwater collection system that may receive runoff from the project site.

4. An Approved Highway Occupancy Permit from the Pennsylvania Department of Transportation (PennDOT) District office when drainage towards PennDOT property is proposed.

D. Stormwater Management Facilities

1. All stormwater management facilities must be located on a plan and described in detail. *(Required for modified SWM Site plan, per Table 106.1 for Bucks and Montgomery Counties.)*

2. When infiltration measures such as seepage pits, beds, or trenches are used, the locations of existing and proposed septic tank infiltration areas and wells must be shown.

3. All calculations, assumptions, and criteria used in the design of the stormwater management facilities must be shown. *(Required for modified SWM Site plan, per Table 106.1 for Bucks and Montgomery Counties.)*

Section 302. Plan Submission

The Municipality requires submission of a complete SWM Site Plan, as specified in this Ordinance.

A. Proof of application or documentation of required permit(s) or approvals for the programs listed below shall be part of the plan:

1. National Pollutant Discharge Elimination System (NPDES) Permit for Stormwater Discharges from Construction Activities

2. Any other permit under applicable state or federal regulations

B. Six (6) copies of the SWM Site Plan shall be submitted and distributed as follows:

1. Three (3) copies to the Municipality accompanied by the requisite fees, as specified in this Ordinance.

2. Two (2) copies to the County Conservation District.

3. One (1) copy to the County Planning Commission/Department.

C. Any submissions to the agencies listed above that are found to be incomplete may not be accepted for review and may be returned to the Applicant with a notification in writing of the manner in which the submission is incomplete.

D. Additional copies shall be submitted as requested by the Municipality, County Conservation District, or DEP.

Section 303. SWM Site Plan Review

A. The SWM Site Plan must be consistent with this Ordinance. Any SWM Site Plan found incomplete may be returned to the Applicant.

B. The Municipality will notify the applicant in writing within (___) days whether the SWM Site Plan is approved or disapproved. If the SWM Site Plan involves a Subdivision and Land Development Plan, the notification period is (___) days. If a longer notification period is provided by other statute, regulation, or ordinance, the applicant will be so notified by the Municipality. If the Municipality disapproves the SWM Site Plan, the Municipality shall cite the reasons for disapproval in writing.

Section 304. Modification of SWM Site Plans

A modification to a submitted SWM Site Plan that involves a change in BMPs or techniques, or that involves the relocation or redesign of BMPs, or that is necessary because soil or other conditions are not as stated on the SWM Site Plan as determined by the Municipality shall require modification and resubmission of the SWM Site Plan in accordance with this Article.

Section 305. Resubmission of Inconsistent or Noncompliant SWM Plans

A disapproved SWM Site Plan may be resubmitted, with the revisions addressing the municipality's concerns, to the municipality in accordance with this Article. The applicable review fees must accompany a resubmission of a disapproved SWM Site Plan.

ARTICLE IV - STORMWATER MANAGEMENT

Section 401. General Requirements

A. For any of the activities regulated by this Ordinance, unless preparation of a Stormwater Management (SWM) Site Plan is specifically exempted, the preliminary or final approval of subdivision and/or land development plans, the issuance of any building or occupancy permit, the commencement of any earth disturbance activity may not proceed until the Property Owner or Applicant or his/her agent has received written approval from the Municipality of a SWM Site Plan that demonstrates compliance with the requirements of this Ordinance, and a written approval of an adequate Erosion and Sediment (E&S) Control Plan from the Municipality or County Conservation District when required.

B. SWM Site Plan approved by the municipality shall be on-site throughout the duration of the regulated activity.

C. The municipality may, after consultation with the Department of Environmental Protection (DEP), approve measures for meeting the state water quality requirements other than those in this Ordinance, provided that they meet the minimum requirements of, and do not conflict with, state law including but not limited to the Clean Streams Law.

D. For all regulated earth disturbance activities, E&S control Best Management Practices (BMPs) shall be designed, implemented, operated and maintained during the Regulated Earth Disturbance activities (e.g., during construction) to meet the purposes and requirements of this Ordinance and to meet all requirements under Title 25 of the Pennsylvania Code and the Clean Streams Law. DEP regulations require an erosion and sediment control plan for any earth disturbance activity of five thousand (5,000) square feet or more, under 25 Pennsylvania Code § 102.4(b). In addition, under 25 Pennsylvania Code Chapter 92, a DEP "NPDES Construction Activities" Permit is required for regulated earth disturbance activities. A copy of the erosion and sediment control plan and any required permit, as required by DEP regulations, shall be available on the project site at all times. Various BMPs and their design standards are listed in the *Erosion and Sediment Pollution Control Program Manual* (E&S Manual), No. 363-2134-008 (April 15, 2000), as amended and updated. However, the municipality may require E&S controls for projects with lesser areas of earth disturbance (e.g., the Bucks County Conservation District requires E&S controls for projects with 1,000 square feet or more of earth disturbance.)

E. For all Regulated Activities, implementation of the water volume controls in Section 406 is required.

F. Impervious areas:

1. The measurement of impervious areas shall include all of the impervious areas in the total proposed development even if development is to take place in stages.

2. For development taking place in stages, the entire development plan must be used in determining conformance with this Ordinance.

3. For projects that add impervious area to a parcel, Sections 403 through 408 shall apply to the total impervious area within the limits of earth disturbance.

G. Stormwater discharges onto adjacent property shall not be created, increased, decreased, relocated, or otherwise altered without written notification of the adjacent property owner(s). Such stormwater discharges shall be subject to the requirements of this Ordinance.

H. All Regulated Activities shall include such measures as necessary to:

1. Protect health, safety and property;

2. Meet the water quality goals of this Ordinance by implementing measures to:

a. Minimize disturbance to floodplains, wetlands, and wooded areas.

b. Maintain or extend riparian buffers.

c. Avoid erosive flow conditions in natural flow pathways.

d. Minimize thermal impacts to waters of this Commonwealth.

e. Disconnect impervious surfaces by directing runoff to pervious areas, wherever possible.

3. To the maximum extent practicable, incorporate the techniques for Low Impact Development Practices described in the *Pennsylvania Stormwater Best Management Practices Manual* (BMP Manual) or the Philadelphia Stormwater Management Guidance Manual.

I. The design of all facilities over karst shall include an evaluation of measures to minimize adverse effects.

J. Infiltration BMPs should be dispersed on site, made as shallow as practicable, and located to maximize use of natural onsite infiltration features while still meeting the other requirements of this Ordinance.

K. Storage facilities should completely drain both the volume control and rate control capacities over a period of time not less than 24 and not more than 72 hours from the end of the design storm.

L. The design storm precipitation amounts to be used in the analysis of peak rates of discharge shall be those from the upper limits of the 90% confidence intervals for the 24-hour precipitation events in the Precipitation-Frequency Atlas of the United States, Atlas 14,

Volume 2, Version 3.0, U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS), Hydrometeorological Design Studies Center (HDSC), Silver Spring, Maryland. NOAA's Atlas 14 can be accessed at http://hdsc.nws.noaa.gov/hdsc/pfds/.

M. For all regulated activities, SWM BMPs shall be designed, implemented, operated, and maintained to meet the purposes and requirements of this Ordinance and to meet all requirements under Title 25 of the Pennsylvania Code, the Clean Streams Law, and the Storm Water Management Act.

N. Various BMPs and their design standards are listed in the BMP Manual[1.]

Section 402. Permit Requirements by Other Governmental Entities

Approvals issued and actions taken under this Ordinance do not relieve the Applicant of the responsibility to secure required permits or approvals for activities regulated by any other code, law, regulation or ordinance.

Section 403. Erosion and Sediment Control During Regulated Earth Disturbance Activities

A. Evidence of any necessary permit(s) for regulated earth disturbance activities from the appropriate DEP regional office or County Conservation District must be provided to the Municipality.

B. Additional erosion and sediment control design standards and criteria are recommended to be applied where infiltration BMPs are proposed. They shall include the following:

1. Areas proposed for infiltration BMPs shall be protected from sedimentation and compaction during the construction phase to maintain maximum infiltration capacity.

2. Infiltration BMPs shall not be constructed nor receive runoff until the entire drainage area contributory to the infiltration BMP has achieved final stabilization.

Section 404. Nonstructural Project Design to Minimize Stormwater Impacts

The design of all regulated activities should include the following to minimize stormwater impacts: *(See Subappendix 2 for a Nonstructural Project Design Checklist.)*

1.The Applicant should find practicable alternatives to the surface discharge of stormwater, the creation of impervious surfaces, and the degradation of waters of the Commonwealth and must maintain as much as possible the natural hydrologic regime of the site.

2. An alternative is practicable if it is available and capable of implementation after taking into consideration existing technology and logistics in light of overall project purposes and other municipal requirements.

3. All practicable alternatives to the discharge of stormwater are presumed to have less adverse impact on quantity and quality of waters of the Commonwealth unless otherwise demonstrated.

Section 405. Groundwater Recharge Requirements

Note: Philadelphia County, Bucks County, and Montgomery County will follow different Groundwater Recharge criteria.

A. Infiltration Best Management Practices (BMPs) shall meet the following minimum requirements unless the site qualifies for an exemption from the infiltration requirements of this ordinance as listed in Section 106:

1. Infiltration BMPs intended to receive runoff from developed areas shall be selected based on suitability of soils and site conditions and shall be constructed on soils that have the following characteristics:

   a. A minimum soil depth of twenty-four (24) inches between the bottoms of the infiltration BMPs and bedrock or other limiting zones.

   b. An infiltration rate sufficient to accept the additional stormwater load and dewater completely as determined by field tests conducted by the Applicant's Qualified Person.

   c. All open-air infiltration facilities shall be designed to completely infiltrate the recharge (infiltration) volume (Re_v) within three (3) days (72 hours) from the end of the design storm.

   d. All subsurface and contained facilities such as capture-and-reuse systems must have storage available equivalent to the Water Volume Control amount within three (3) days (72 hours) from the end of the design storm.

   e. Pretreatment (See Section 202) shall be provided prior to infiltration.

2. The size of the infiltration facility shall be based upon the following volume criteria:

<u>Bucks County and Montgomery County Portions of the Watershed:</u>

Where practicable and appropriate the recharge volume shall be infiltrated on site. The recharge volume shall be equal to one (1.0) inch of runoff (I) over all proposed impervious surfaces.

The Re_v required shall be computed as:

$$\mathbf{Re_v = (1/12) * (I)}$$

Where:
Re_v = Recharge Volume (cubic feet)
I = Impervious Area within the limits of earth disturbance (square feet)

An asterisk (*) in equations denotes multiplication.

Philadelphia County Portion of the Watershed:

The recharge volume shall be equal to one (1.0) inch of runoff over all **DCIA within the limits of Earth Disturbance**.

$$\mathbf{Re_v = (1/12) * (I)}$$

Where:
Re_v = Recharge Volume (cubic feet)
I = DCIA within the limits of earth disturbance (square feet)

An asterisk (*) in equations denotes multiplication.

B. Soils - A detailed soils evaluation of the project site shall be required to determine the suitability of infiltration facilities. The evaluation shall be performed by a Qualified Person, and at a minimum address soil permeability, depth to bedrock, and subgrade stability. The general process for designing the infiltration BMP shall be:

1. Analyze hydrologic soil groups as well as natural and man-made features within the site to determine general areas of suitability for infiltration practices. In areas where development on fill material is under consideration, conduct geotechnical investigations of sub-grade stability; infiltration may not be ruled out without conducting these tests.

2. Provide field tests such as double ring infiltrometer or hydraulic conductivity tests (at the level of the proposed infiltration surface) to determine the appropriate hydraulic conductivity rate. Percolation tests are not recommended for design purposes.

3. Design the infiltration structure for the required recharge volume (Re_v) based on field determined capacity at the level of the proposed infiltration surface.

4. If on-lot infiltration structures are proposed by the Applicant's Qualified Person, it must be demonstrated to the Municipality that the soils are conducive to infiltrate on the lots identified.

5. An impermeable liner will be required in detention basins where the possibility of groundwater contamination exists. A detailed hydrogeologic investigation may be required by the Municipality.

Section 406. Water Volume Control Requirements
(Note: Philadelphia County, Bucks County, and Montgomery County will follow different Water Volume Control requirements.)

<u>Bucks County and Montgomery County Portions of the Watershed:</u>

The low impact development practices provided in the BMP Manual shall be utilized for all regulated activities to the maximum extent practicable. Water Volume Controls shall be implemented using the *Design Storm Method* in Subsection A or the *Simplified Method* in Subsection B below. For regulated activity areas equal to or less than one (1) acre that do not require hydrologic routing to design the stormwater facilities, this Ordinance establishes no preference for either methodology; therefore, the applicant may select either methodology on the basis of economic considerations, the intrinsic limitations on applicability of the analytical procedures associated with each methodology, and other factors. All regulated activities greater than one (1) acre must use the Design Storm Method.

A. The *Design Storm Method* (CG-1 in the BMP Manual) is applicable to any size of regulated activity. This method requires detailed modeling based on site conditions.

1. The post-development total runoff volume for all storms equal to or less than the 2-year, 24-hour storm event shall not be increased.

2. For modeling purposes:
   a. Existing (predevelopment) nonforested pervious areas must be considered meadow.
   b. 20% of existing impervious area, when present, shall be considered meadow in the model for existing conditions.

B. The *Simplified Method* (CG-2 in the BMP Manual) provided below is independent of site conditions and should be used if the *Design Storm Method* is not followed. This method is not applicable to regulated activities greater than one (1) acre, or for projects that require design of stormwater storage facilities. For new impervious surfaces:

1. Stormwater facilities shall capture at least the first two (2) inches of runoff from all new impervious surfaces. *(Note: An asterisk (*) in equations denotes multiplication.)*

   Volume (cubic feet) = (2/12) * Impervious Surfaces (square feet)

2. At least the first one (1) inch of runoff from new impervious surfaces shall be permanently removed from the runoff flow-- i.e., it shall not be released into the surface waters of the Commonwealth. Removal options include reuse, evaporation, transpiration, and infiltration.

   Volume (cubic feet) = (1/12) * Impervious Surfaces (square feet)

3. Wherever possible, infiltration facilities should be designed to accommodate infiltration of the entire permanently removed runoff; however, in all cases at least the first half (0.5) inch of the permanently removed runoff should be infiltrated.

4. This method is exempt from the requirements of Section 408, Peak Rate Controls.

Philadelphia County Portion of the Watershed:

The following equation is to be used to determine the Water Volume Control storage requirement in cubic feet for regulated activities within the Pennypack Creek Watershed in Philadelphia County:

Water Volume Control (cubic feet) = (1/12) * (I)

Where: I = DCIA within the limits of earth disturbance (square feet)

Section 407. Stream Bank Erosion Requirements (Channel Protection)

Note: Philadelphia County, Bucks County, and Montgomery County will follow different Stream Bank Erosion Requirements. If the Municipality has adopted a riparian corridor ordinance, the more restrictive requirement shall apply.

If a perennial or intermittent stream passes through the site, the Applicant shall create a stream buffer extending a minimum of fifty (50) feet to either side of the top-of-bank of the channel. The buffer area shall be established and maintained with appropriate native vegetation (refer to Appendix B of the BMP Manual for plant lists). If the applicable rear or side yard setback is less than fifty (50) feet, the buffer width may be reduced to twenty-five (25) percent of the setback to a minimum of ten (10) feet. If an existing buffer is legally prescribed (i.e., deed, covenant, easement, etc.) and it exceeds the requirements of this Ordinance, the existing buffer shall be maintained. *[Note: The Municipality may select a smaller buffer width (above) if desired, but the selected buffer may not be less than ten (10) feet]*. This does not include lakes or wetlands.

Bucks County and Montgomery County Portions of the Watershed:

Applicants shall adhere to the following Stream Bank Erosion/Channel Protection Requirements:

A. In addition to the control of water quality volume (in order to minimize the impact of stormwater runoff on downstream stream bank erosion), the primary requirement is to design a BMP to detain the proposed conditions 2-year, 24-hour storm event to the existing conditions 1-year flow using the SCS Type II distribution. Additionally, provisions shall be made (such as adding a small orifice at the bottom of the outlet structure or a sand filter) so that the proposed conditions 1-year, 24-hour storm event takes a minimum of twenty-four (24) hours to drain from the facility from a point when the maximum volume of water from the 1-year, 24-hour storm event is captured (i.e., the maximum water surface elevation is

achieved in the facility). Release of water can begin at the start of the storm (i.e., the invert of the water volume control orifice is at the invert of the facility).

B. The minimum orifice size in the outlet structure to the BMP shall be three (3) inches in diameter where possible, and a trash rack shall be installed to prevent clogging. On sites with small drainage areas contributing to this BMP that do not provide enough runoff volume to allow a 24-hour attenuation with the 3-inch orifice, the calculations shall be submitted showing this condition. Orifice sizes less than three (3) inches can be utilized, provided that the design will prevent clogging of the intake. It is recommended that the design, to accommodate maintenance, include a sand or porous media filter.

Philadelphia County Portion of the Watershed:

Redevelopment sites with less than one (1) acre of Earth Disturbance or redevelopment sites that demonstrate a 20% reduction in DCIA from predevelopment conditions are exempt from this requirement.

Applicants shall adhere to the following Stream Bank Erosion/Channel Protection Requirements:

A. To meet the requirement, Stormwater Management Practices shall retain or detain the runoff from all DCIA within the limits of Earth Disturbance from a 1-year, 24-hour Natural Resources Conservation Service (NRCS) Type II storm event in the proposed site condition such that the runoff takes a minimum of 24 hours and a maximum of 72 hours from the end of the storm event to drain the management facility.

B. The infiltration and water quality volumes may be incorporated into the channel protection portion of the design provided the design meets all requirements concurrently.

C. In "Conditional Direct Discharge Districts" (District C) only (see Section 408), the objective is not to attenuate the 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.

Section 408. Stormwater Peak Rate Control and Management Districts

A. The Pennypack Creek Watershed has been divided into stormwater management districts as shown on the Management District Map (Figure 408.1).

In addition to the requirements specified in Table 408.1 below, the erosion and sedimentation control (Section 403), the nonstructural project design (Section 404), the groundwater recharge (Section 405), the water volume control (Section 406), and the stream bank erosion (Section 407) requirements shall be implemented.

Standards for managing runoff from each subarea in the Pennypack Creek Watershed for the 2-, 5-, 10-, 25-, 50-, and 100-year storm events are shown in Table 408.1. Development sites located in each of the management districts must control proposed condition runoff rates to existing condition runoff rates for the design storms in accordance with Table 408.1.

TABLE 408.1

PEAK RATE CONTROL STANDARDS BY STORMWATER MANAGEMENT DISTRICT IN THE PENNYPACK CREEK WATERSHED

District	Proposed Condition Design Storm		Existing Condition Design Storm
A	2-year	Reduce to	1-year
	5-year		5-year
	10-year		10-year
	25-year		25-year
	50-year		50-year
	100-year		100-year
B	2-year	Reduce to	1-year
	5-year		2-year
	10-year		5-year
	25-year		10-year
	50-year		25-year
	100-year		50-year
C*	Conditional Direct Discharge District		

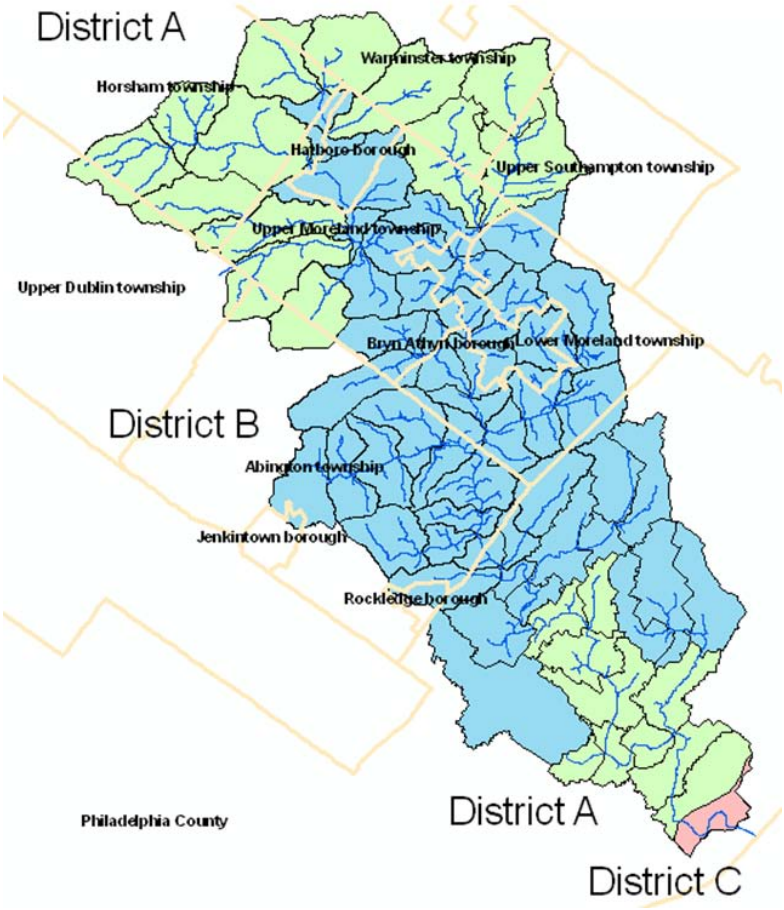
In District C, development sites that can discharge directly to the Pennypack Creek Main Channel (east of I-95) and to the Delaware River main channel without use of City infrastructure may do so without control of proposed conditions peak rate of runoff.

Projects that are required to obtain a NPDES Permit for stormwater discharges associated with construction activities are required to show no increase in peaks from existing conditions.

When adequate capacity in the downstream system does not exist and will not be provided through improvements, the proposed conditions peak rate of runoff must be controlled to the Predevelopment Conditions peak rate as required in District A provisions for the specified Design Storms. The Predevelopment Condition for new development is the existing condition. For redevelopment purposes in Philadelphia County, the Predevelopment Condition shall be determined according to the procedures found in the Philadelphia Stormwater Guidance Manual.

B. General - Proposed condition rates of runoff from any regulated activity shall not exceed the peak release rates of runoff from existing conditions for the design storms specified on the Stormwater Management District Watershed Map (Figure 408.1).

FIGURE 408.1
MANAGEMENT DISTRICT WATERSHED MAP



C. District Boundaries - The boundaries of the stormwater management districts are shown on an official map that is available for inspection at the municipal and County Planning offices. A copy of the official map at a reduced scale is included as Figure 408.1. The exact location of the stormwater management district boundaries as they apply to a given development site shall be determined by mapping the boundaries using the 2-foot topographic contours (or most accurate data required) provided as part of the drainage plan.

D. Sites Located in More than One (1) District - For a proposed development site located within two (2) or more stormwater management districts, the peak discharge rate from any subarea shall meet the management district criteria in which the discharge is located.

E. Off-site Areas - Off-site areas that drain through a proposed development site are not subject to release rate criteria when determining allowable peak runoff rates. However, on-site drainage facilities shall be designed to safely convey off-site flows through the development site.

F. Site Areas - Where the site area to be impacted by a proposed development activity differs significantly from the total site area, only the proposed impact area utilizing stormwater

management measures shall be subject to the management district criteria. In other words, unimpacted areas bypassing the stormwater management facilities would not be subject to the management district criteria.

G. Alternate Criteria for Redevelopment Sites - For redevelopment sites, one of the following minimum design parameters shall be accomplished, whichever is most appropriate for the given site conditions as determined by [*Municipality*];

1. Meet the full requirements specified by Table 408.1 and Sections 408.A through 408.F.

   or

2. Reduce the total impervious surface on the site by at least twenty (20) percent based upon a comparison of existing impervious surface to proposed impervious surface.

Section 409. Calculation Methodology

A. Stormwater runoff from all development sites with a drainage area of greater than 200 acres shall be calculated using a generally accepted calculation technique that is based on the NRCS soil cover complex method. The Qualified Person must consult with the municipality to gain approval of design methods prior to design.

Table 409-1 summarizes acceptable computation methods and the method selected by the Qualified Person shall be based on the individual limitations and suitability of each method for a particular site. The Municipality may allow the use of the Rational Method to estimate peak discharges from drainage areas that contain less than 200 acres. The Soil Complex Method shall be used for drainage areas greater than 200 acres.

TABLE 409.1
Acceptable Computation Methodologies For
Stormwater Management Plans

Bucks County and Montgomery County Portions of the Watershed

METHOD	METHOD DEVELOPED BY	APPLICABILITY
WINTR-20	USDA NRCS	Applicable where use of full hydrology computer model is desirable or necessary.
WINTR-55	USDA NRCS	Applicable for land development plans within limitations described in TR-55.
HEC-HMS	US Army Corps of Engineers	Applicable where use of full hydrologic computer model is desirable or necessary.
Rational Method or commercial computer package based on Rational Method)	Emil Kuichling (1889)	For sites less than 200 acres and with time of concentration less than 60 minutes (tc< 60 min), or as approved by the Municipality and/or Municipal Engineer
Other Methods	Varies	Other computation methodologies approved by the Municipality and/or Municipal Engineer.

Philadelphia County Portion of the Watershed

METHOD	METHOD DEVELOPED BY	APPLICABILITY
WINTR-20	USDA NRCS	Applicable where use of full hydrology computer model is desirable or necessary.
WINTR-55	USDA NRCS	Applicable for land development plans within limitations described in TR-55.
HEC-HMS	US Army Corps of Engineers	Applicable where use of full hydrologic computer model is desirable or necessary.
SWMM 5	EPA	For single event or continuous simulation of runoff quantity and quality from primarily urban areas.

**Note: Successors to the above methods are also acceptable. These successors include WinTR55 for TR-55 and WinTR20 for TR-20.*

B. If a hydrologic computer model such as HydroCAD or HEC-HMS is used for stormwater runoff calculations, then the duration of rainfall shall be 24 hours. The rainfall distribution should reference NRCS Type II.

C. For the purposes of existing conditions flow rate determination, undeveloped land shall be considered as "meadow" in good condition, unless the natural ground cover generates a lower curve number or Rational 'C' value (i.e., forest).

D. For Montgomery County only, all calculations using the Rational Method shall use rainfall intensities from the NOAA 14 Precipitation-Frequency Atlas of the United States (2004, revised 2006). Times-of-concentration for overland flow shall be calculated using the methodology presented in Chapter 3 of Urban Hydrology for Small Watersheds, NRCS, TR-55 (as amended or replaced from time to time by NRCS). Times-of-concentration for channel and pipe flow shall be computed using flow velocities as determined by Manning's equation.

E. The Manning equation is preferred for 1-D, gradually-varied, open channel flow. In other cases, appropriate, applicable methods should be applied, however, early coordination with the municipality is necessary.

F. Outlet structures for stormwater management facilities shall be designed to meet the performance standards of this Ordinance using the generally accepted hydraulic analysis technique or method of the Municipality.

G. The design of any stormwater detention facilities intended to meet the performance standards of this Ordinance shall be verified by routing the design storm hydrograph through these facilities using the Storage-Indication Method. For drainage areas greater than 200 acres in size, the design storm hydrograph shall be computed using a calculation method that produces a full hydrograph. The Municipality may approve the use of any generally accepted full hydrograph approximation technique that shall use a total runoff volume that is consistent with the volume from a method that produces a full hydrograph.

ARTICLE V - INSPECTIONS

Section 501. Inspections

A. The Municipality may inspect all phases of the installation of the Best Management Practices (BMPs) and/or stormwater management facilities as deemed appropriate by the Municipality.

B. During any stage of the work, if the Municipality determines that the BMPs and/or stormwater management (SWM) facilities are not being installed in accordance with the approved SWM plan, the Municipality, may suspend or revoke, in whole or in part, any existing permits or other approvals and issue a cease and desist order until a revised SWM Site Plan is submitted and approved, as specified in this Ordinance, and until the deficiencies are corrected.

C. A final inspection of all BMPs and/or SWM facilities may be conducted by the Municipality to confirm compliance with the approved Stormwater Management Site Plan prior to the issuance of any occupancy permit.

D. The developer shall be responsible for providing as-built plans of all SWM BMPs included in the approved SWM Site Plan. The as-built plans and an explanation of any discrepancies, which were reviewed and received approval by the Municipality, shall be submitted to the Municipality.

E. The as-built submission shall include a certification of completion signed and sealed by a Qualified Professional verifying that all permanent SWM BMPs have been constructed according to the approved plans and specifications. If any licensed Qualified Persons contributed to the construction plans, they must sign and seal the completion certificate.

F. Final plans based upon the as-builts (Record Drawings) must be received by the Municipality prior to the issuance of the Certificate of Occupancy.

ARTICLE VI - FEES AND EXPENSES

Section 601. Municipality SWM Site Plan Review and Inspection Fees

Fees may be established by the Municipality to defray costs incurred by the Municipality. All fees shall be paid by the Applicant. A fee schedule shall be established by resolution of the municipal Governing Body, which may be based on the size of the Regulated Activity or the Municipality's costs for processing SWM Site Plans and conducting inspections. The Municipality may periodically update the fee schedule to ensure that its costs are adequately reimbursed.

Section 602. Expenses Covered by Fees

The fees authorized by this Ordinance may at a minimum cover:

A. Administrative costs.

B. Review of the SWM Site Plan by the Municipality.

C. Site inspections.

D. Inspection of SWM facilities and drainage improvements during construction.

E. Final inspection at the completion of the construction of the SWM facilities and drainage improvements presented in the SWM Site Plan.

F. Any additional work required to enforce any permit provisions, correct violations, and assure proper completion of necessary remedial actions.

ARTICLE VII - MAINTENANCE RESPONSIBILITIES

Section 701. Performance Guarantee

A. For subdivisions and land developments, the Applicant shall provide a financial guarantee to the Municipality for the timely installation and proper construction of all stormwater management facilities as required by the approved SWM Site Plan. The amount of the guarantee shall be equal to or greater than the full construction cost of the required controls.

B. For other regulated activities, the Municipality may require a financial guarantee from the Applicant.

Section 702. Responsibilities for Operation and Maintenance (O&M) of Stormwater Facilities and Best Management Practices (BMPs)

A. The owner of any land upon which stormwater facilities and BMPs will be placed, constructed, or implemented, as described in an O&M Plan, shall record the following documents in the Office of the Recorder of Deeds for _____ County, within _____ (__) days of approval of the O&M plan by the Municipality:

1. The O&M Plan, or a summary thereof,
2. O&M Agreements under Section 704, and
3. Easements under Section 705.

B. The Municipality may suspend or revoke any approvals granted for the project site upon discovery of failure on the part of the owner to comply with this Ordinance.

C. The following items shall be included in the O&M Plan:

1. Map(s) of the project area, in a form that meets the requirements for recording at the offices of the Recorder of Deeds of _____County, shall be submitted on_____-inch x-_____inch sheets. The contents of the map(s) shall include, but not be limited to:

   a. Clear identification of the location and nature of stormwater controls and BMPs,
   b. The location of the project site relative to highways, municipal boundaries or other identifiable landmarks,
   c. Existing and final contours at intervals of two (2) feet, or others as appropriate,
   d. Existing streams, lakes, ponds, or other bodies of water within the project site area,
   e. Other physical features including flood hazard boundaries, sinkholes, streams, existing drainage courses, and areas of natural vegetation to be preserved,
   f. The locations of existing and proposed utilities, sanitary sewers, and water lines within fifty (50) feet of property lines of the project site,

g. Proposed final changes to the land surface and vegetative cover, including the type and amount of impervious area that would be added,
h. Proposed final structures, roads, paved areas, and buildings, and
i. A 15 feet wide access easement around all stormwater controls and BMPs that would provide ingress to and egress from a public right-of-way.

2. A description of how each stormwater facility and BMP will be operated and maintained, and the identity and contact information associated with the person(s) responsible for operations and maintenance,

3. The name of the project site, the name and address of the owner of the property, and the name of the individual or firm preparing the plan, and

4. A statement, signed by the landowner, acknowledging that the stormwater facilities and BMPs are fixtures that cannot be altered or removed without prior approval by the Municipality.

D. The O&M Plan for the project site shall establish responsibilities for the continuing O&M of all stormwater facilities and BMPs, as follows:

1. If a plan includes structures or lots that are to be separately owned and in which streets, sewers, and other public improvements are to be dedicated to the Municipality, associated stormwater controls and BMPs also may be dedicated to and maintained by the Municipality;

2. If a plan includes operation and maintenance by a single ownership or if sewers and other public improvements are to be privately owned and maintained, the O&M of stormwater controls and BMPs, and inspections required by permits, shall be the responsibility of the owner.

E. The Municipality will make the final determination on the continuing operation and maintenance responsibilities prior to final approval of the Stormwater Management Site Plan. The Municipality reserves the right to accept or reject the O&M responsibility for any or all portions of the stormwater controls and BMPs.

F. The O&M Plan shall be recorded as a restrictive deed covenant that runs with the land.

G. The municipality may take enforcement actions against an owner for any failure to satisfy the provisions of this Article and this Ordinance.

Section 703. Municipal Review of an O&M Plan

A. O&M plans shall be consistent with the requirements of this Ordinance.

B. The Municipality will notify Applicants in writing whether or not O&M plans are approved.

C. The Municipality's approval letter will indicate whether or not "record drawings" of all stormwater controls and BMPs are required, including a final "as-built" O&M Plan.

Section 704. Operation and Maintenance (O&M) Agreement for Privately Owned Stormwater Controls and BMPs

A. The owner shall sign an O&M agreement with the Municipality covering all stormwater facilities and BMPs that are to be privately owned. The O&M agreement shall be transferred with transfer of ownership.

B. Other items may be included in the agreement where determined necessary to guarantee the satisfactory operation and maintenance of all stormwater facilities and BMPs. The O&M Agreement shall be subject to the review and approval of the Municipality.

C. The owner is responsible for O&M of the SWM BMPs. If the owner fails to adhere to the O&M Agreement, the Municipality may perform the services required and charge the owner appropriate fees. Nonpayment of fees may result in a lien against the property.

Section 705. Stormwater Management Easements

A. The owner must obtain all necessary real estate rights to install, operate, and maintain all stormwater facilities in the SWM Site Plan and the O&M Plan.

B. The owner must provide the municipal easements, or other appropriate real estate rights, to perform inspections and maintenance or the preservation of stormwater runoff conveyance, infiltration, and detention areas.

ARTICLE VIII - PROHIBITIONS

Section 801. Prohibited Discharges and Connections

A. Any drain or conveyance, whether on the surface or subsurface, that allows any non-stormwater discharge, including sewage, process wastewater, or wash water to enter the separate storm sewer system, or otherwise to enter the waters of the Commonwealth is prohibited. Any connections to the storm drain system from indoor drains and sinks also are prohibited.

B. No person shall allow, or cause to allow, discharges into surface waters of this Commonwealth which are not composed entirely of stormwater, except (1) as provided in subsection C below, and (2) discharges allowed under a state or federal permit.

C. The following discharges are authorized unless they are determined to be significant contributors to pollution to the waters of this Commonwealth:

- Discharges from fire fighting activities	- Flows from riparian habitats and wetlands
- Potable water sources including water line flushing	- Uncontaminated water from foundations or from footing drains
- Irrigation drainage	- Lawn watering
- Air conditioning condensate	- Dechlorinated swimming pool discharges
- Springs	- Uncontaminated groundwater
- Water from crawl space pumps	- Water from individual residential car washing
- Pavement wash waters where spills or leaks of toxic or hazardous materials have not occurred (unless all spill material has been removed) and where detergents are not used	- Routine external building wash down (which does not use detergents or other compounds)

D. In the event that the Municipality or DEP determines that any of the discharges identified in Subsection C significantly contribute to pollution of the waters of this Commonwealth, the Municipality or DEP will notify the responsible person(s) to cease the discharge.

Section 802. Roof Drains

A. In Philadelphia, roof drains shall comply with Section P-1001 of the Philadelphia Plumbing Code.

B. In Bucks County and Montgomery County, roof drains shall not be connected to streets, sanitary or storm sewers, or roadside ditches, and shall discharge to infiltration areas or vegetative BMPs to the maximum extent practicable.

Section 803. Alteration of BMPs

A. No person shall modify, remove, fill, landscape, or alter any existing stormwater facility or BMP unless it is part of an approved maintenance program and written approval of the Municipality has been obtained.

B. No person shall place any structure, fill, landscaping, or vegetation into a stormwater control or BMP or within a drainage easement which would limit or alter the functioning of the stormwater control or BMP without the written approval of the Municipality.

ARTICLE IX - ENFORCEMENT AND PENALTIES

Section 901. Right-of-Entry

The Municipality, or its authorized agents and employees, will provide forty-eight (48) hours written notice when appropriate, at its sole discretion, and may then enter upon any part of the property within the Municipality to inspect and determine the compliance of the implementation, condition, or operation and maintenance (O&M) of the stormwater facilities or Best Management Practices (BMPs) in regard to any aspect governed by this Ordinance. Inspection includes monitoring and sampling to determine proper operation of stormwater facilities and BMPs. The Municipality shall have the right to temporarily locate on any stormwater control or BMP in the Municipality such devices as are necessary to conduct monitoring and/or sampling of the discharges from such stormwater control or BMP.

Section 902. Inspection

BMPs should be inspected for proper operation by the landowner, or the owner's designee (including the municipality for dedicated and owned facilities), according to the following list of minimum frequencies:

1. Annually for the first 5 years.

2. Once every 3 years thereafter.

3. During or immediately after the cessation of a 10-year, 24-hour, or greater storm event.

4. As specified in the O&M agreement,

Section 903. Enforcement

All inspections regarding compliance with the Stormwater Management (SWM) Site Plan and this Ordinance shall be the responsibility of the Municipality.

A. Whenever the Municipality finds that a person has violated a prohibition or failed to meet a requirement of this Ordinance, the Municipality may order compliance by notifying the responsible person. Such notice may include the following remedies:

1. Performance of monitoring, analyses, and reporting;

2. Elimination of prohibited connections or discharges;

3. Cessation of any violating discharges, practices, or operations;

4. Abatement or remediation of stormwater pollution or contamination hazards and the restoration of any affected property;

5. Payment of a fine to cover administrative and remediation costs;

6. Implementation of stormwater controls and BMPs; and

7. O&M of stormwater facilities and BMPs.

B. Such notification shall set forth the nature of the violation(s) and establish a time limit for correction of those violations(s). If the violator fails to take the required action within the established deadline, the work may be done by the Municipality and the expenses may be charged to the violator.

C. Failure to comply within the time specified may subject a violator to the penalty provisions of this Ordinance. All such penalties shall be deemed cumulative and shall not prevent the Municipality from pursuing other remedies available in law or equity.

Section 904. Suspension and Revocation

A. Any approval or permit issued by the municipality pursuant to this Ordinance may be suspended or revoked for:

1. Non-compliance with or failure to implement any provision of the approved SWM Site Plan or O&M Agreement.

2. A violation of any provision of this Ordinance or any other applicable law, ordinance, rule, or regulation relating to the Regulated Activity.

3. The creation of any condition or the commission of any act during the Regulated Activity which constitutes or creates a hazard, nuisance, pollution, or endangers the life or property of others.

B. A suspended approval may be reinstated by the municipality when:

1. The municipality has inspected and approved the corrections to the violations that caused the suspension.

2. The municipality is satisfied that the violation has been corrected.

C. An approval that has been revoked by the municipality cannot be reinstated. The applicant may apply for a new approval under the provisions of this Ordinance.

D. If a violation causes no immediate danger to life, public health or safety, or property, at its sole discretion, the municipality may provide a limited time period for the owner to correct the violation. In these cases, the municipality will provide the owner, or the owner's designee, with a written notice of the violation and the time period allowed for the owner to

correct the violation. If the owner does not correct the violation within the allowed time period, the municipality may revoke or suspend any, or all, applicable approvals and permits pertaining to any provision of this Ordinance.

Section 905. Penalties
(Municipalities should ask their solicitors to provide appropriate wording for this section.)

A. Anyone violating the provisions of this Ordinance shall be guilty of a summary offense, and upon conviction, shall be subject to a fine of not more than $_____ for each violation, recoverable with costs. Each day that the violation continues shall be a separate offense and penalties shall be cumulative.

B. In addition, the municipality may institute injunctive, mandamus, or any other appropriate action or proceeding at law or in equity for the enforcement of this Ordinance. Any court of competent jurisdiction shall have the right to issue restraining orders, temporary or permanent injunctions, mandamus, or other appropriate forms of remedy or relief.

Section 906. Appeals

A. Any person aggrieved by any action of the municipality or its designee, relevant to the provisions of this Ordinance, may appeal to the municipality within 30 days of that action.

B. Any person aggrieved by any decision of the municipality, relevant to the provisions of this Ordinance, may appeal to the County Court of Common Pleas in the county where the activity has taken place within 30 days of the municipality's decision.

ENACTED and ORDAINED at a regular meeting of the _____ _____ on the _____ of _____, 20__. This Ordinance shall take effect immediately.

_____
[Name]

_____
[Title]

_____
[Name]

_____
[Title]

_____
[Name]

_____
[Title]

_____
[Name]

_____
[Title]

_____
[Name]

_____
[Title]

ATTEST:

_____
Secretary

I hereby certify that the foregoing Ordinance was advertised in the _____ on _____, 20__, a newspaper of general circulation in the Municipality and was duly enacted and approved as set forth at a regular meeting of the Municipality's Governing Body held on _____, 20__.

_____
Secretary

SUBAPPENDIX 1
SMALL PROJECT STORMWATER MANAGEMENT (SWM) SITE PLAN

This Small Project SWM Site Plan is included as an option for municipalities to adopt to give small regulated activities the opportunity to submit a non-engineered stormwater management plan. The requirements of this site plan alternative are consistent with the volume control requirements of the *Neshaminy Creek Watershed Stormwater Management Plan (SMP)*. The Bucks County Planning Commission recommends that this site plan be applied only to residential development activities proposing less than or equal to 5,000 square feet of impervious surface and less than 1 acre of earth disturbance. These recommendations are the result of a multi-municipal roundtable discussion and guidance from PADEP and the Bucks and Montgomery County Conservation Districts. The following table is an example of how the exemption criteria of the Neshaminy Creek Watershed SMP Model Ordinance could change as the result of adopting this site plan alternative into the municipal stormwater management regulations.

Table 1.1 Small Project Exemptions

Ordinance Article or Section	Type of Project	Proposed Impervious Surface		
		0 – 1,000 sq. ft.	**1,001 – 5,000 sq. ft.**	**5,000 + sq. ft.**
Article IV SWM Site Plan Requirements	All Development	Exempt	Not Exempt (except residential activity following Appendix I)	Not Exempt
Non-Engineered Small Project Site Plan	Only Residential Development Applicable	Exempt	Not Exempt	N/A
Section 303 Volume Control Requirements	All Development	Not Exempt	Not Exempt	Not Exempt
Section 304 Peak Rate Control Requirements	All Development	Exempt	Exempt	Not Exempt
Erosion and Sediment Pollution Control Requirements	Must comply with Title 25, Chapter 102 of the PA Code and any other applicable state, county and municipal codes. PADEP requires an engineered post-construction SWM Plan with projects proposing earth disturbance greater than 1 acre.			

Small Project Stormwater Management Site Plan

This small project stormwater site plan has been developed to assist those proposing residential projects to meet the requirements of the *Neshaminy Creek Watershed Stormwater Management Plan* Model Ordinance without having to hire professional services to draft a formal stormwater management plan. This small project site plan is only permitted for residential projects proposing less than or equal to 5,000 square feet of impervious surface and less than 1 acre of earth disturbance.

A. What is an applicant required to submit?

A brief description of the proposed stormwater facilities, including types of materials to be used, total square footage of proposed impervious areas, volume calculations, and a simple sketch plan showing the following information:

- Location of proposed structures, driveways, or other paved areas with approximate surface area in square feet.
- Location of any existing or proposed onsite septic system and/or potable water wells showing proximity to infiltration facilities.
- Bucks or Montgomery County Conservation District erosion and sediment control "Adequacy" letter as required by Municipal, County or State regulations.

B. Determination of Required Volume Control and Sizing Stormwater Facilities

By following the simple steps outlined below in the provided example, an applicant can determine the runoff volume that is required to be controlled and how to choose the appropriate stormwater facility to permanently remove the runoff volume from the site. Impervious area calculations must include all areas on the lot proposed to be covered by roof area or pavement which would prevent rain from naturally percolating into the ground, including impervious surfaces such as sidewalks, driveways, parking areas, patios or swimming pools. Sidewalks, driveways or patios that are designed and constructed to allow for infiltration are not included in this calculation.

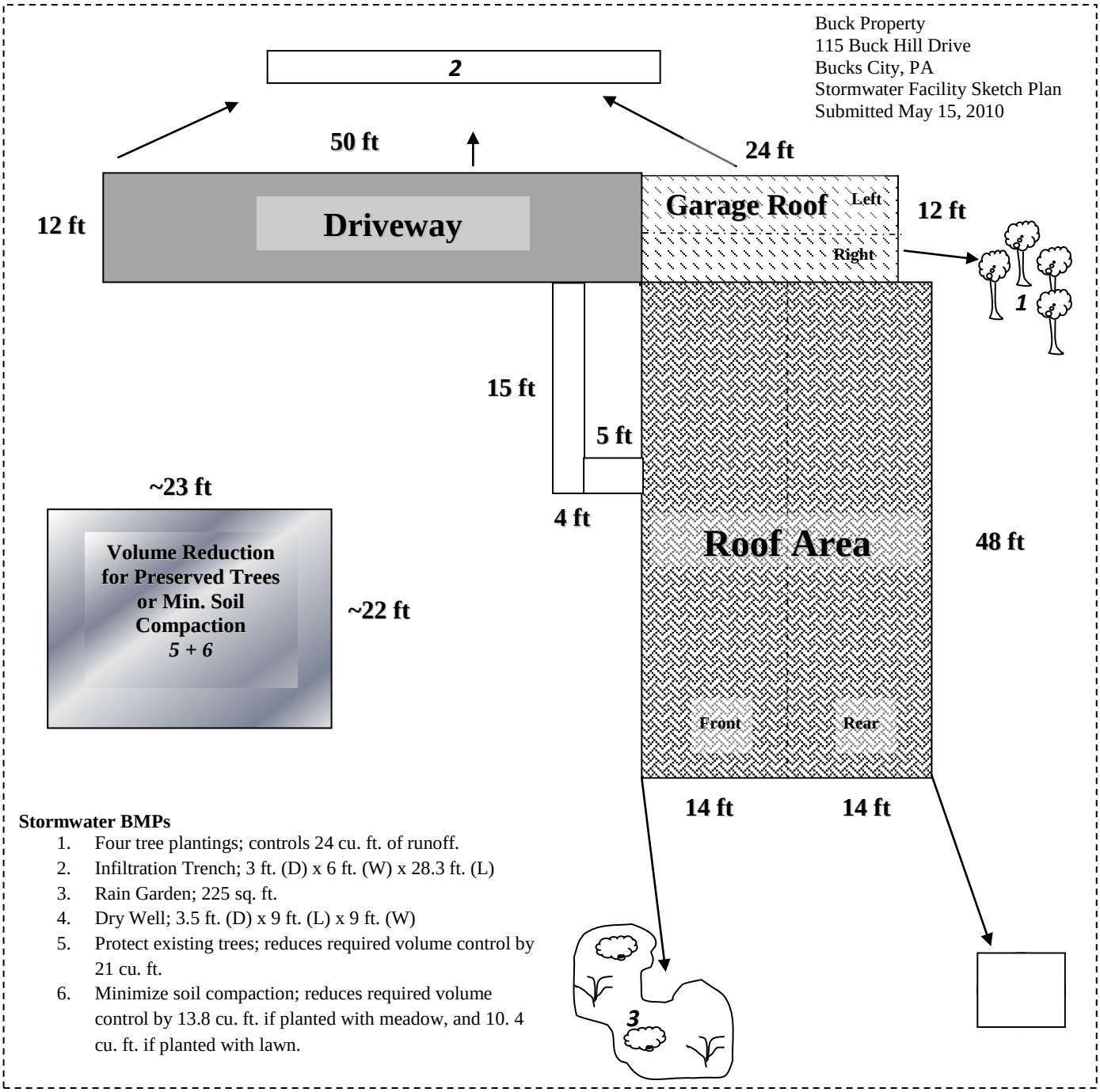
Site Plan Example: Controlling runoff volume from a proposed home site

Step 1: Determine Total Impervious Surfaces

Impervious Surface			Area (sq. ft.)
House Roof (Front)	14 ft. x 48 ft.	=	672 sq. ft.
House Roof (Rear)	14 ft. x 48 ft.	=	672 sq. ft.
Garage Roof (Left)	6ft. x 24 ft.	=	144 sq. ft.
Garage Roof (Right)	6 ft. x 24 ft.	=	144 sq. ft.
Driveway	12 ft. x 50 ft.	=	1000 sq. ft.
Walkway	4 ft. x 20 ft.	=	80 sq. ft.

	Total Impervious		3000 sq ft

Figure 1: Sample Site Sketch Plan



Stormwater BMPs

1. Four tree plantings; controls 24 cu. ft. of runoff.
2. Infiltration Trench; 3 ft. (D) x 6 ft. (W) x 28.3 ft. (L)
3. Rain Garden; 225 sq. ft.
4. Dry Well; 3.5 ft. (D) x 9 ft. (L) x 9 ft. (W)
5. Protect existing trees; reduces required volume control by 21 cu. ft.
6. Minimize soil compaction; reduces required volume control by 13.8 cu. ft. if planted with meadow, and 10. 4 cu. ft. if planted with lawn.

Step 2: Determine Required Volume Control (cubic feet) using the following equation:

Volume (cu. ft.) = (Total impervious area in square feet x 2 inches of runoff) /12 inches

(3,000 sq. ft. x 2 inches of runoff) /12 inches = 500 cu. ft.

Step 3: Sizing the Selected Volume Control BMP

Several Best Management Practices (BMPs), as described below, are suitable for small stormwater management projects. However, their application depends on the volume required to be controlled, how much land is available, and the site constraints. Proposed residential development activities can apply both non-structural and structural BMPs to control the volume of runoff from the site. A number of different volume control BMPs are described below. Note that Figure 1 is an example of how these BMPs can be utilized in conjunction to control the total required volume on one site.

Structural BMPs

1. Infiltration Trench

An Infiltration Trench is a linear stormwater BMP consisting of a continuously perforated pipe at a minimum slope in a stone-filled trench. During small storm events, infiltration trenches can significantly reduce volume and serve in the removal of fine sediments and pollutants. Runoff is stored between the stones and infiltrates through the bottom of the facility and into the soil matrix. Runoff should be pretreated using vegetative buffer strips or swales to limit the amount of coarse sediment entering the trench which can clog and render the trench ineffective. In all cases, an infiltration trench should be designed with a positive overflow.

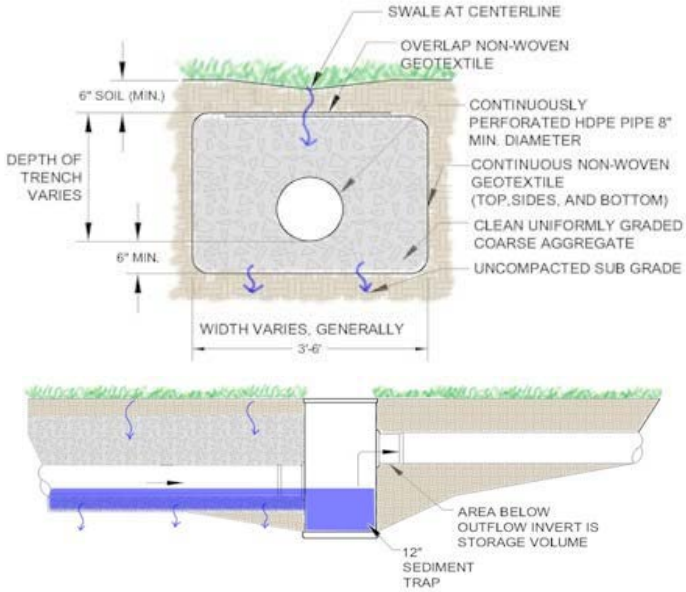
Design Considerations:

- Although the width and depth can vary, it is recommended that Infiltration Trenches be limited in depth to not more than six (6) feet of stone.
- Trench is wrapped in nonwoven geotextile (top, sides, and bottom).
- Trench needs to be placed on uncompacted soils.
- Slope of the Trench bottom should be level or with a slope no greater than 1%.
- A minimum of 6" of topsoil is placed over trench and vegetated.
- The discharge or overflow from the Infiltration Trench should be properly designed for anticipated flows.
- Cleanouts or inlets should be installed at both ends of the Infiltration Trench and at appropriate intervals to allow access to the perforated pipe.
- Volume of facility = Depth x Width x Length x Void Space of the gravel bed (assume 40%).

Maintenance:

- Catch basins and inlets should be inspected and cleaned at least two times a year.
- The vegetation along the surface of the infiltration trench should be maintained in good condition and any bare spots should be re-vegetated as soon as possible.
- Vehicles should not be parked or driven on the trench and care should be taken to avoid soil compaction by lawn mowers.

Figure 2: Infiltration Trench Diagram



Source: PA BMP Guidance Manual, Chapter 6, page 42.

Figure 3: Example of Infiltration Trench Installation

Source: PA BMP Guidance Manual, Chapter 6, Page 46.

Sizing Example for Infiltration Trench

1. Determine Total Impervious Surface to drain to Infiltration Trench:

Garage Roof (Left)	6 ft. x 24 ft.	=	144 sq ft
Driveway	12 ft. x 50 ft.	=	1000 sq ft
Walkway	4 ft. x 20 ft.	=	80 sq ft

2. Determine the required infiltration volume:

   (1224 sq. ft. x 2 inches of runoff)/12 ft. = 204 cu. ft. / 0.4* = 510 cu. ft.
   (*0.4 assumes 40% void ratio in gravel bed)

3. Sizing the infiltration trench facility:

   Volume of Facility = Depth x Width x Length

   Set Depth to 3 feet and determine required surface area of trench.

   510 cu. ft / 3 ft = 170 sq ft.

   The width of the trench should be greater than 2 times its depth (2 x D), therefore in this example the trench width of 6 feet selected.

   Determine trench length: L = 170 sq. ft. / 6 ft. = 28.3 ft.

   Final infiltration trench dimensions: 3 ft. (D) x 6 ft. (W) x 28.3 ft. (L)

2. Rain Garden

A Rain Garden is a planted shallow depression designed to catch and filter rainfall runoff. The garden captures rain from a downspout or a paved surface. The water sinks into the ground, aided by deep rooted plants that like both wet and dry conditions. The ideal location for a rain garden is between the source of runoff (roofs and driveways) and the runoff destination (drains, stream, low spots, etc).

Design Considerations:

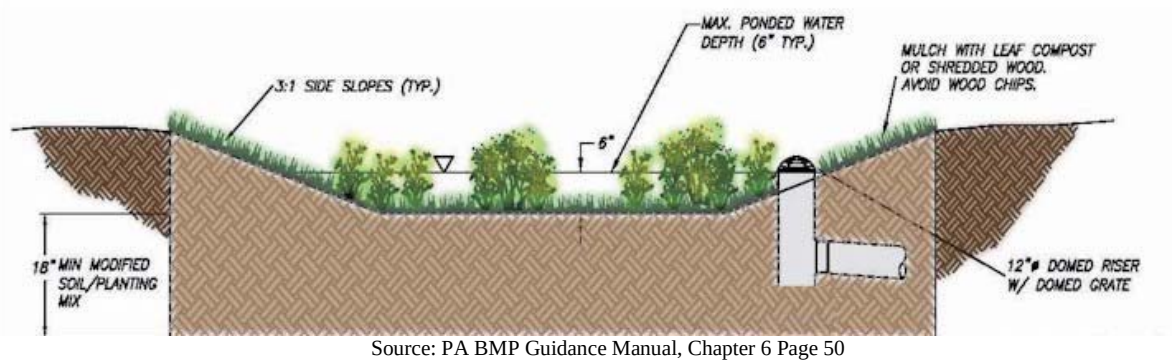
- A maximum of 3:1 side slope is recommended.
- The depth of a rain garden can range from 6 - 8 inches. Ponded water should not exceed 6 inches.
- The rain garden should drain within 72 hours.
- The garden should be at least 10-20 feet from a building's foundation and 25 feet from septic system drainfields and wellheads.
- If the site has clay soils, soil should be amended with compost or organic material.
- Choose native plants. See http://pa.audubon.org/habitat/PDFs/RGBrochure_complete.pdf for a native plant list. To find native plant sources go to www.pawildflower.org.

- At the rain garden location, the water table should be at least 2' below the soil level. If water stands in an area for more than one day after a heavy rain you can assume it has a higher water table and is not a good choice for a rain garden.

Maintenance:

- Water plants regularly until they become established.
- Inspect twice a year for sediment buildup, erosion and vegetative conditions.
- Mulch with hardwood when erosion is evident and replenish annually.
- Prune and remove dead vegetation in the spring season.
- Weed as you would any garden.
- Move plants around if some plants would grow better in the drier or wetter parts of the garden.

Figure 4: Rain Garden Diagram



Source: PA BMP Guidance Manual, Chapter 6 Page 50

Sizing Example for Rain Garden

1. Pick a site for the rain garden between the source of runoff and between a low lying area, a.k.a., a drainage area.

2. Perform an infiltration test to determine the depth of the rain garden:
   - Dig a hole 8″ x 8″
   - Fill with water and put a popsicle stick at the top of the water level.
   - Measure how far it drains down after a few hours (ideally 4).
   - Calculate the depth of water that will drain out over 24 hours.

3. Determine total impervious surface area to drain to rain garden:

House Roof (Front)	14 ft. x 48 ft.	=	672 sq ft

4. Sizing the rain garden:

   For this example the infiltration test determined 6″ of water drained out of a hole in 24 hours. The depth of the rain garden should be set to the results of the infiltration test so 6″ is the depth of the rain garden. The sizing calculation below is based on controlling 1″ of runoff. First divide the impervious surface by the depth of the rain garden.

   (672 sq ft / 6 ft.) = 112 sq. ft.

   In order to control 2″ of runoff volume, the rain garden area needs to be multiplied by 2.

   112 sq. ft. * 2 = 224 sq. ft.

   The rain garden should be about 225 sq. ft. in size and 6″ deep.

3. Dry Well (a.k.a., Seepage Pit)

A Dry Well, sometimes called a Seepage Pit, is a subsurface storage facility that temporarily stores and infiltrates stormwater runoff from the roofs of structures. By capturing runoff at the source, Dry Wells can dramatically reduce the increased volume of stormwater generated by the roofs of structures. Roof leaders connect directly into the Dry Well, which may be either an excavated pit filled with uniformly graded aggregate wrapped in geotextile, or a prefabricated storage chamber or pipe segment. Dry Wells discharge the stored runoff via infiltration into the surrounding soils. In the event that the Dry Well is overwhelmed in an intense storm event, an overflow mechanism (surcharge pipe, connection to a larger infiltration are, etc.) will ensure that additional runoff is safely conveyed downstream.

Design Considerations:

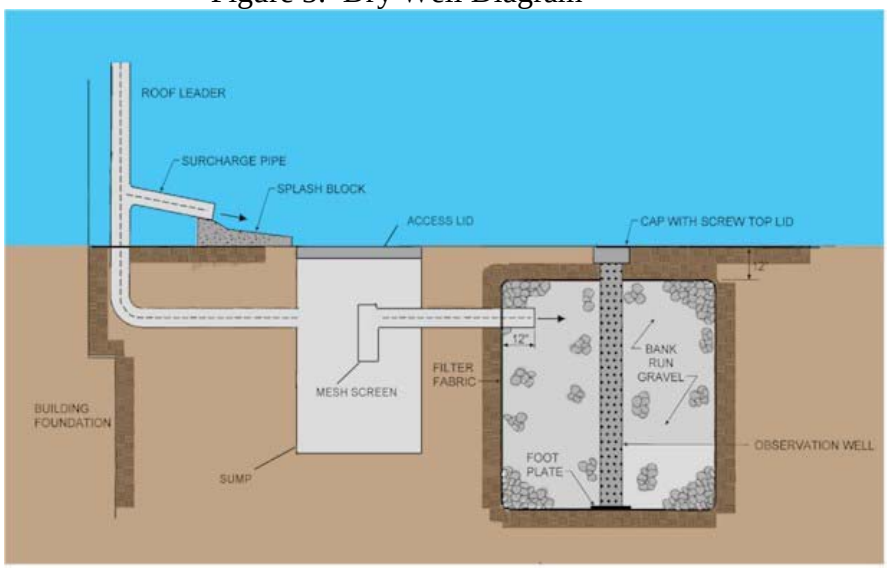
- Dry Wells typically consist of 18 to 48 inches of clean washed, uniformly graded aggregate with 40% void capacity (AASHTO No. 3, or similar). “Clean” gravel fill should average one and one-half to three (1.5 – 3.0) inches in diameter.
- Dry Wells are not recommended when their installation would create a significant risk for basement seepage or flooding. In general, 10 - 20 feet of separation is recommended between Dry Wells and building foundations.
- The facility may be either a structural prefabricated chamber or an excavated pit filled with aggregate.
- Depth of dry wells in excess of three-and-a-half (3.5) feet should be avoided unless warranted by soil conditions.
- Stormwater dry wells must never be combined with existing, rehabilitated, or new septic system seepage pits. Discharge of sewage to stormwater dry wells is strictly prohibited.

Maintenance:

- Dry wells should be inspected at least four (4) times annually as well as after large storm events.
- Remove sediment, debris/trash, and any other waste material from a dry well.
- Regularly clean out gutters and ensure proper connections to the dry well.

- Replace the filter screen that intercepts the roof runoff as necessary.

Figure 5: Dry Well Diagram



Source: PA BMP Guidance Manual, Chapter 6, Page 65.

Sizing Example for Dry Wells:

1. Determine contributing impervious surface area:

House Roof (Rear)	14 ft. x 48 ft.	=	672 sq. ft.

2. Determine required volume control:

   (672 sq. ft. * 2 inches of runoff) / 12 inches = 112 cu. ft.

   112 cu ft / 0.4 = 280 cu. ft. (assuming the 40% void ratio in the gravel bed)

3. Sizing the dry well:

   Set depth to 3.5 ft; Set width equal to length for a square chamber.

   280 cu. ft. = 3.5 ft. x L x L; L = 9 ft.

   Dimensions = 3.5 ft. (D) x 9 ft. (L) x 9 ft. (W)

Non-Structural BMPs

1. Tree Plantings and Preservation

Trees and forests reduce stormwater runoff by capturing and storing rainfall in the canopy and releasing water into the atmosphere through evapotranspiration. Tree roots and leaf litter also create soil conditions that promote the infiltration of rainwater into the soil. In addition, trees and forests reduce pollutants by taking up nutrients and other pollutants from soils and water through their root systems. A development site can reduce runoff volume by planting new trees or by preserving trees which existed on the site prior to development. The volume reduction calculations either determine the cubic feet to be directed to the area under the tree canopy for infiltration or determine a volume reduction credit which can be used to reduce the size of any one of the planned structural BMPs on the site.

Tree Considerations**:**

- Existing trees must have at least a 4″ trunk caliper or larger.
- Existing tree canopy must be within 100 ft. of impervious surfaces.
- A tree canopy is classified as the continuous cover of branches and foliage formed by a single tree or collectively by the crowns of adjacent trees.
- New tree plantings must be at least 6 ft. in height and have a 2″ trunk caliper.
- All existing and newly planted trees must be native to Pennsylvania. See http://www.dcnr.state.pa.us/forestry/commontr/commontrees.pdf for a guide book titled *Common Trees of Pennsylvania* for a native tree list.
- When using trees as volume control BMPs, runoff from impervious areas should be directed to drain under the tree canopy.

Determining the required number of planted trees to reduce the runoff volume:

1. Determine contributing impervious surface area:

Garage Roof (Right)	6 ft. x 24 ft.	=	144 ft

2. Calculate the required control volume:

   (144 sq. ft. x 2 inches of runoff) / 12 inches = 24 cu. ft.

3. Determine the number of tree plantings:

   - A newly planted deciduous tree can reduce runoff volume by 6 cu. ft.
   - A newly planted evergreen tree can reduce runoff volume by 10 cu. ft.

   24 cu. ft./ 6 cu. ft. = 4 Deciduous Trees

Determining the volume reduction for preserving existing trees:

1. Calculate approximate area of the existing tree canopy:

~22 sq. ft. x ~23 sq. ft = 500 sq. ft.

2. Measure distance from impervious surface to tree canopy: 35 ft.

3. Calculate the volume reduction credit by preserving existing trees:

   - For Trees within 20 feet of impervious cover:
     Volume Reduction cu. ft. = (Existing Tree Canopy sq. ft. x 1 inch) / 12
   - For Trees beyond 20 feet but not farther than 100 feet from impervious cover:
     Volume Reduction cu. ft. = (Existing Tree Canopy sq. ft. x 0.5 inch) / 12

   (500 sq. ft. x 0.5 inches) / 12 = 21 cu. ft.

   This volume credit can be utilized in reducing the size of any one of the structural BMPs planned on the site. For example, the 21 cu. ft. could be subtracted from the required infiltration volume when sizing the infiltration trench;

   510 cu. ft – 21 cu. ft. = 489 cu. ft.

   489 cu. ft. / 3 ft (Depth) = 163 / 6 ft. (Width) = 27.1 ft (Length)

   Using the existing trees for a volume credit would decrease the length of the infiltration trench to 27.1 ft. instead of 28.3 ft.

2. Minimize Soil Compaction and Replant with Lawn or Meadow

When soil is overly compacted during construction it can cause a drastic reduction in the permeability of the soil and rarely is the soil profile completely restored. Runoff from vegetative areas with highly compacted soils similarly resembles runoff from an impervious surface. Minimizing soil compaction and re-planting with a vegetative cover like meadow or lawn, not only increases the infiltration on the site, but also creates a friendly habitat for a variety of wildlife species.

Design Considerations:

- Area shall not be stripped of topsoil.
- Vehicle movement, storage, or equipment/material lay down shall not be permitted in areas preserved for minimum soil compaction.
- The use of soil amendments and additional topsoil is permitted.
- Meadow should be planted with native grasses. Refer to *Meadows and Prairies: Wildlife-Friendly Alternatives to Lawn* at http://pubs.cas.psu.edu/FreePubs/pdfs/UH128.pdf for reference on how to properly plant the meadow and for a list of native species.

Determining the volume reduction by minimizing soil compaction and planting a meadow:

1. Calculate approximate area of preserved meadow:

   ~22 sq. ft. x ~23 sq. ft = 500 sq. ft.

2. Calculate the volume reduction credit by minimizing the soil compaction and planting a lawn/meadow:

   - For Meadow Areas: Volume Reduction (cu. ft.) = (Area of Min. Soil Compaction (sq. ft.) x 1/3 inch of runoff) / 12

     (500 sq. ft. x 1/3 inch of runoff) / 12 = 13.8 cu. ft.

   - For Lawn Areas: Volume Reduction (cu. ft.) = (Area of Min. Soil Compaction (sq. ft.) x 1/4 inch of runoff) / 12

     (500 sq. ft. x 1/4 inch of runoff) / 12 = 10.4 cu. ft.

This volume credit can be used to reduce the size of any one of the structural BMPs on the site. See explanation under the volume credit for preserving existing trees for details.

Alternative BMP to Capture and Reuse Stormwater

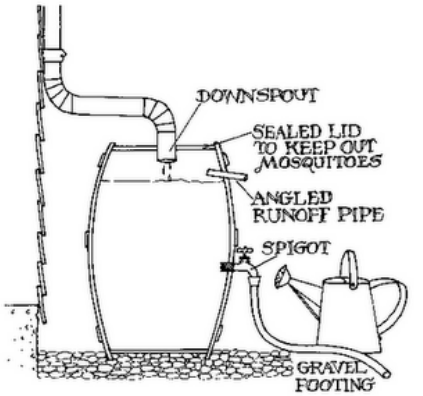
Rain Barrels

Rain barrels are large containers that collect drainage from roof leaders and temporarily store water to be released to lawns, gardens, and other landscaped areas after the rainfall has ended. Rain barrels are typically between 50 and 200 gallons in size. It is not recommended for rain barrels to be used as a volume control BMP because infiltration is not guaranteed after each storm event. For this reason, a rain barrel is not utilized in the site plan example. However, the information is included to provide an alternative for a homeowner to utilize when considering capture and reuse stormwater methods.

Design Considerations:

- Rain barrels should be directly connected to the roof gutter/spout.
- There must be a means to release the water stored between storm events to provide the necessary storage volume for the next storm.
- When calculating rain barrel size, rain barrels are typically assumed to be 25% full because they are not always emptied before the next storm.
- Use screens to filter debris and cover lids to prevent mosquitoes.
- An overflow outlet should be placed a few inches below the top with an overflow pipe to divert flow away from structures.
- It is possible to use a number of rain barrels jointly for an area.

Figure 6: Rain Barrel Diagram and Examples



Sources: (top picture) http://www.citywindsor.ca/DisplayAttach.asp?AttachID=12348
(bottom picture on left) http://repurposinglife.blogspot.com/2009/05/rainwater-harvesting.html
(bottom picture on right) http://www.floridata.com/tracks/transplantedgardener/Rainbarrels.cfm

Sizing Example for a Rain Barrel

1. Determine contributing impervious surface area:

Garage Roof (Right)	6 ft. x 24 ft.	=	144 sq ft

2. Determine the amount of rainfall to be captured by the Rain Barrel. A smaller storm, no more than 2″, is recommended to calculate the runoff to be captured. This example chose the 1″ storm event.

3. Calculate the volume to be captured and reused:

   (144 sq. ft. x 1 inch of runoff) / 12 inches = 12 cu. ft.

4. Size the rain barrel:

1 cu. ft. = 7. 48 gallons

12 cu. ft. x 7.48 = 90 gallons
90 gallons x (0.25*) = 22.5 gallons (*assuming that the rain barrel is always at least 25% full)

90 gallons + 22.5 gallons = 112 gallons

The rain barrel or barrels should be large enough to hold at least 112 gallons of water.

REFERENCES:

Center for Watershed Protection and US Forest Service. (2008). *Watershed Forestry Resource Guide*. Retrieved on May 26, 2010 from http://www.forestsforwatersheds.org/reduce-stormwater/.

Department of Environmental Protection. (2006). *Pennsylvania Stormwater Best Management Practices Manual.*

Wissahickon Watershed Partnership. *Pennsylvania Rain Garden Guide*. Retrieved on May 4, 2010 from http://pa.audubon.org/habitat/PDFs/RGBrochure_complete.pdf.

Building a Backyard Rain Garden. North Carolina Cooperative Extension. Retrieved on May 4, 2010 from http://www.bae.ncsu.edu/topic/raingarden/Building.htm

Delaware County Planning Commission. (2010). *Draft Crum Creek Watershed Act 167 Stormwater Management Plan. Ordinance Appendix B. Simplified Approach to Stormwater Management for Small Projects.*

Solebury Township. (2008). *Solebury Township Stormwater Management Ordinance. "Appendix J Simplified Stormwater Management Procedures for Existing Single Family Dwelling Lots*"

SUBAPPENDIX 2
NONSTRUCTURAL PROJECT DESIGN CHECKLIST

The goal of this checklist is to minimize the increases in stormwater runoff and impacts to water quality resulting from the proposed regulated activity:

1. Prepare an Existing Resource and Site Analysis Map (ERSAM, see Section 301.B.)
2. Establish a stream buffer according to Section 407.
3. Prepare a draft project layout avoiding sensitive areas identified in Section 301.
4. Identify site-specific existing conditions drainage areas, discharge points, recharge areas, and hydrologic soil groups A and B (areas conducive to infiltration).
5. Evaluate nonstructural stormwater management alternatives:
    a) Minimize earth disturbance.
    b) Minimize clearing operations (vegetation removal)
    c) Minimize impervious surfaces.
    d) Break up large impervious surfaces.
6. Satisfy the groundwater recharge (infiltration) objective (Section 405) and provide for stormwater pretreatment prior to infiltration.
7. Provide for water quality protection in accordance with Section 406 water volume control requirements.
8. Provide stream bank erosion protection in accordance with Section 407 stream bank erosion requirements.
9. Determine into what management district the site falls (Section 408) and conduct an existing conditions runoff analysis.
10. Prepare final project design to maintain existing conditions drainage areas and discharge points, to minimize earth disturbance and impervious surfaces, and, to the maximum extent possible, to ensure that the remaining site development has no surface or point discharge.
11. Conduct a proposed conditions runoff analysis based on the final design that meets the management district requirements (Section 408).
12. Manage any remaining runoff prior to discharge through detention, bioretention, direct discharge, or other structural control.

SUBAPPENDIX 3
RIPARIAN BUFFER TRAIL GUIDELINES

[Note to Municipality: The following riparian buffer trail guidelines may be modified provided that the buffer meets all minimum width and vegetation requirements detailed in Section 407 of the ordinance as well as all federal, state and local, stormwater, floodplain, and other requirements and regulations.]

Introduction

Riparian buffers are used as non-structural best management practices (BMPs) for protecting and enhancing water quality. Depending on their size, location, and design, riparian buffers often supply additional environmental, economic, aesthetic, and recreational value. Passive recreational trails can be a compatible use within riparian buffers if the trails are sized and placed appropriately. The trail guidelines below are meant to supplement Section 406, Water Volume Control Requirements, and do not alter or modify the regulations set forth in Section 401, General Requirements. All other applicable rules and requirements should be followed, including all federal, state, permitting, and local stormwater and floodplain ordinances.

Installing a trail does not relieve a developer or municipality of the minimum buffer and vegetation requirements described in Section 407, or infiltration and peak rate controls in Sections 405 and 408. Effort shall be made to mitigate water quality and peak rate adjacent the trail structure to avoid collecting runoff in a large facility and creating a point discharge. This can be accomplished by trail-side stone filtration trenches, vegetative filter strips, small bio-retention facilities, and other mechanisms subject to site constraints and municipal engineer approval. See Figure 2-1. In situations where site constraints negate the feasibility of trail-side mitigation methods, effort shall be made to collect runoff in multiple stormwater facilities for segmented portions of the trail, in place of detaining stormwater in one large facility. Level spreaders shall be constructed at facility outlets to decrease point-source discharges.

As with all trails, adequate land acquisition, easements, and/or landowner permission should be obtained in advance of any trail placement. Care should be given when designing and installing trails so as not to compromise the buffer's ability to protect water quality. Many factors such as slope, vegetation, and soil type will determine the type, size, and placement of the trail within the riparian buffer. Heavily used trails and trails with wide impervious surfaces should be set back farther from the stream edge to help mitigate the effects of any associated increase in runoff. Note: failure to comply with these guidelines (Installing a trail with inadequate setback from the stream bank) could result in increased stormwater runoff, decreased water quality, stream bank degradation, and damage to the buffer or trail.

Trail Recommendations

Location, Size, and Orientation

All trails should be a reasonable width appropriate for the site conditions. It is not recommended that the width of any paved trail exceed twenty five (25) percent of the total buffer width. All trail designs and specifications are subject to approval by the municipality.

Natural vegetation must be present throughout the buffer as described in Section 306 of the ordinance. Grassy areas should be managed as meadows or be reforested and should not be mowed as lawn in any part of the buffer. Where existing vegetation is insufficient to protect water quality, additional native species should be planted to enhance the buffer.

Paved trails, if appropriate to the site, are permitted and must be located at least twenty-five (25) feet from the top of the stream bank. In limited instances, paved trails be placed closer to a stream due to topography, or in order to accommodate passive educational and recreational activities, but must always be at least ten (10) feet from the top of the stream bank. Although this can be achieved by diverting the entire trail closer to the stream, more conservative methods should be considered, such as smaller spur trails or loop trails. These smaller trails provide access to the stream, but reduce the total traffic along the sensitive stream bank.

In rare instances where the buffer width is reduced due to zoning setback or geographical constraints, the municipality should strongly consider whether the benefits of a trail outweigh the benefits of a wider buffer.

Signage

The installation of interpretive and educational signage is strongly encouraged along the trail. Signs should point out local natural resources and educate the public on how riparian buffers protect the watershed. There should be minimum disturbance in the vegetated buffer between the trail and the stream. Therefore, all appurtenances (e.g. benches, educational signs, kiosks, fountains, etc.) should be installed on the landward side of the trail, if possible. All appurtenances shall be installed in compliance with federal, state, local, stormwater, floodplain, and other regulations and permitting requirements (e.g. anchoring, etc.)

Parking Areas

New trailheads and trail parking areas shall meet all the infiltration, rate control, and minimum setback requirements of this ordinance. Every effort should be made to coordinate trail access with existing parking areas. Any new parking areas and trailhead clearings should not encroach on the riparian buffer in any way.

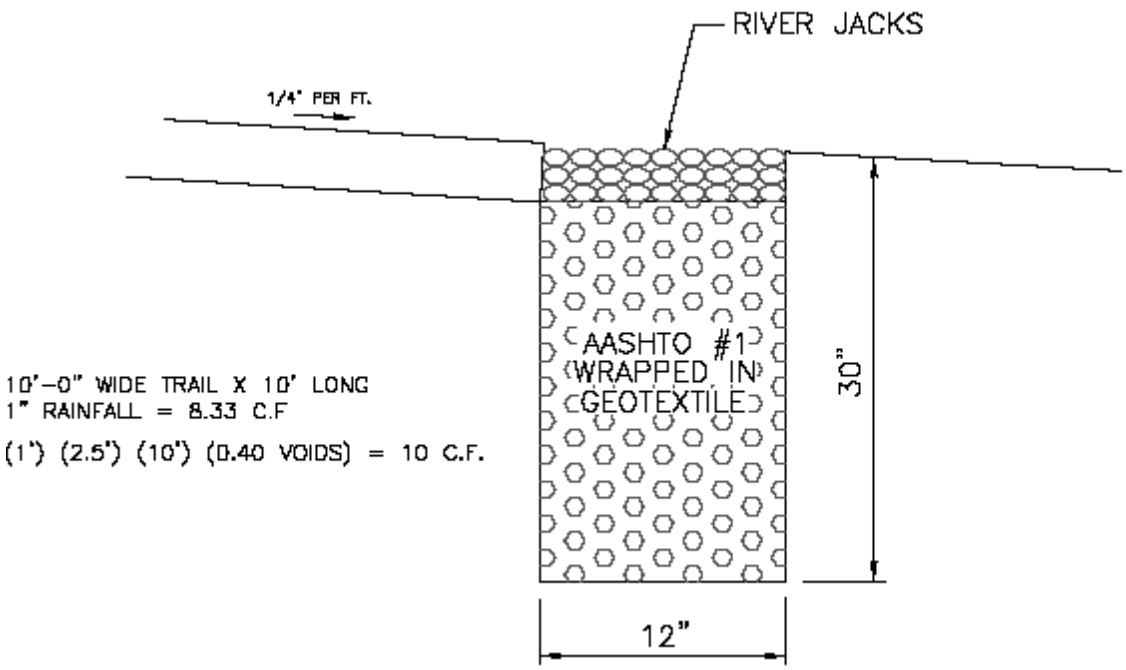
Trail Maintenance

The installation and maintenance of all trails should be performed in a manner that minimizes site disturbance and prevents runoff and erosion. Soil disturbance should be avoided if possible. The

removal of native trees and other native vegetation should also be kept to a minimum. If large or heavy equipment is required for trail installation, special care should be given not to damage existing trees and tree roots.

FIGURE 3-1

EXAMPLE DESIGN OF A TRAIL-SIDE STONE FILTRATION TRENCH



Source:
James MacCombie, H*erbert E. MacCombie Jr. P.E. Consulting Engineers & Surveyors Inc.*