Pennypack Creek Watershed
Act 167 Plan

Prepared by the

Center for Sustainable Communities
TEMPLE UNIVERSITY®

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

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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

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Section 1: Watershed Location and Setting

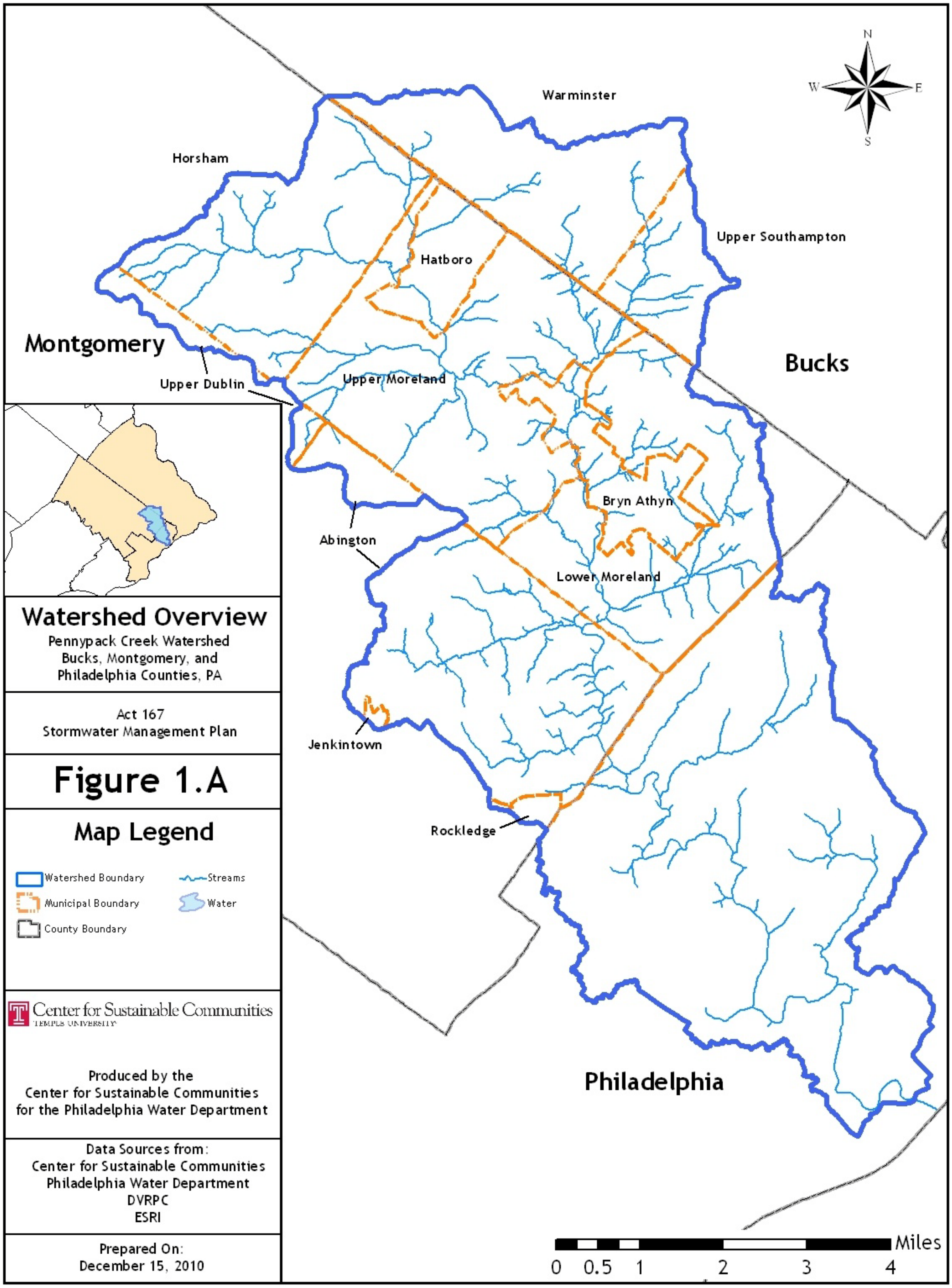
The Pennypack Creek Watershed is located in southeastern Pennsylvania. It covers 56 square miles and includes a population of approximately 300,000 people (2000 Census). The watershed includes the 1,334 acre Pennypack Park, part of the Fairmount Park system; Lorimer Park in Montgomery County; the Pennypack 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
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Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
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Produced by the
Center for Sustainable Communities
for the Philadelphia Water Department
Data Sources from:
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Philadelphia Water Department
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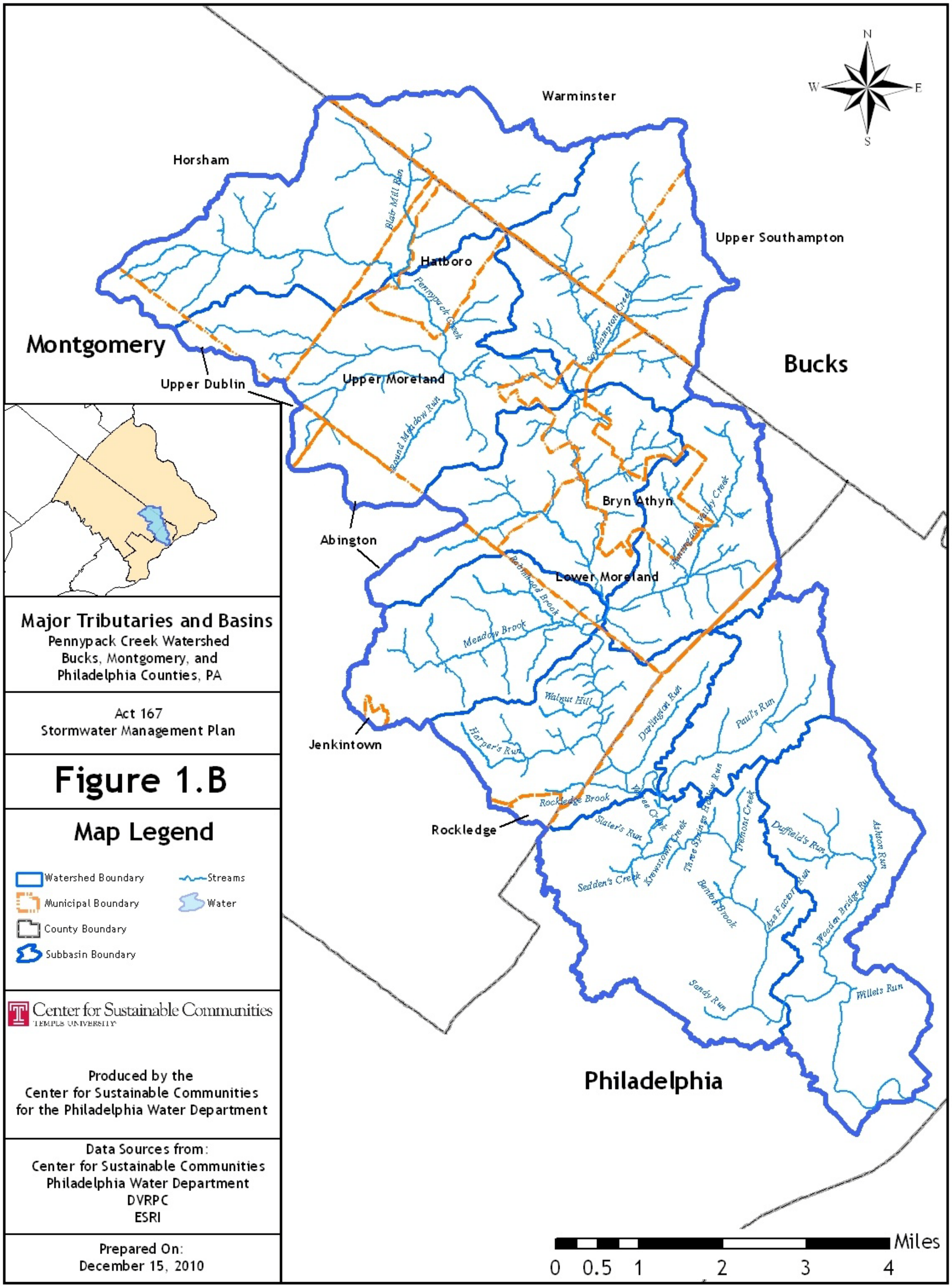
Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Abington
Bryn Athyn
Lower Moreland
Jenkintown
Rockledge
Philadelphia
Blair Mill Run
Pennypack Creek
Southampton Creek
Round Meadow Run
Huntingdon Valley Creek
Meadow Brook
Walnut Hill
Harper's Run
Darlington Run
Paul's Run
Rockledge Brook
Slater's Run
Sedden's Creek
Krewstown Creek
Three Springs Hollow Run
Tremont Creek
Benton Brook
Duffield's Run
Ashton Run
Axe Factory Run
Wooden Bridge Run
Sandy Run
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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

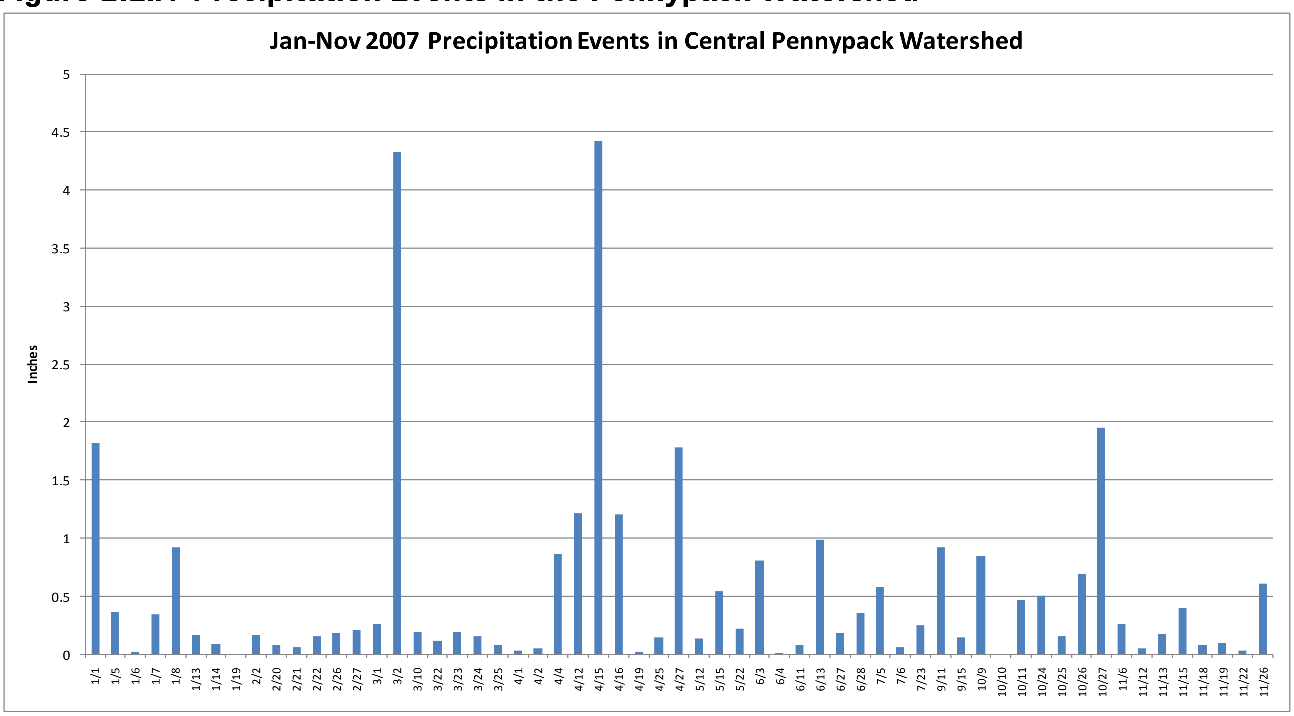
Based on the upper limit of the 90% confidence interval from NOAA Atlas 14 for the 24 hour storm.

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.

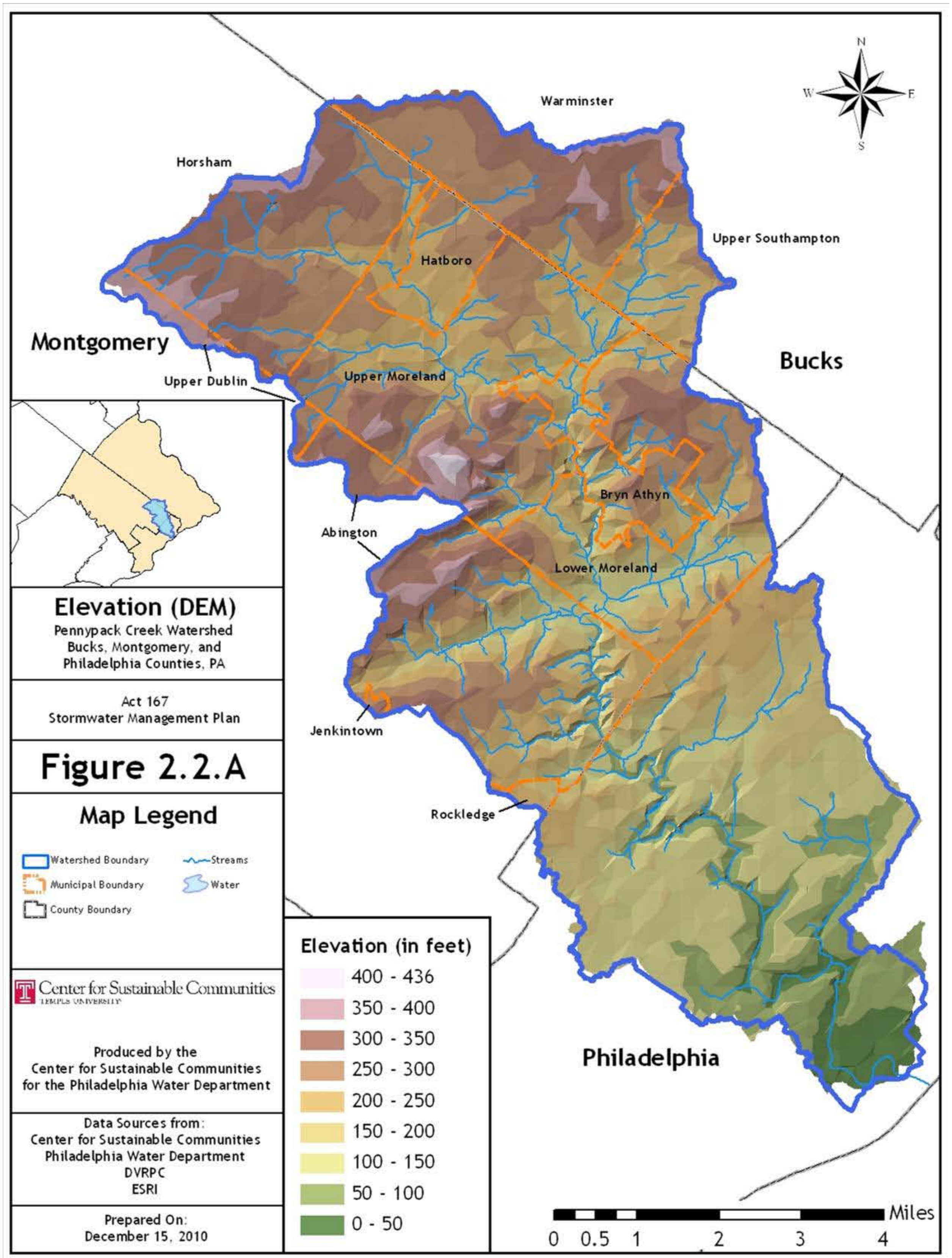
Taken together, the surface features of the Pennypack Watershed, along with antecedent soil moisture conditions, define how it responds to rainfall. In order to provide more precise information about potential for flash flooding in small watersheds, the National Weather Services' Mount Holly Weather 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.

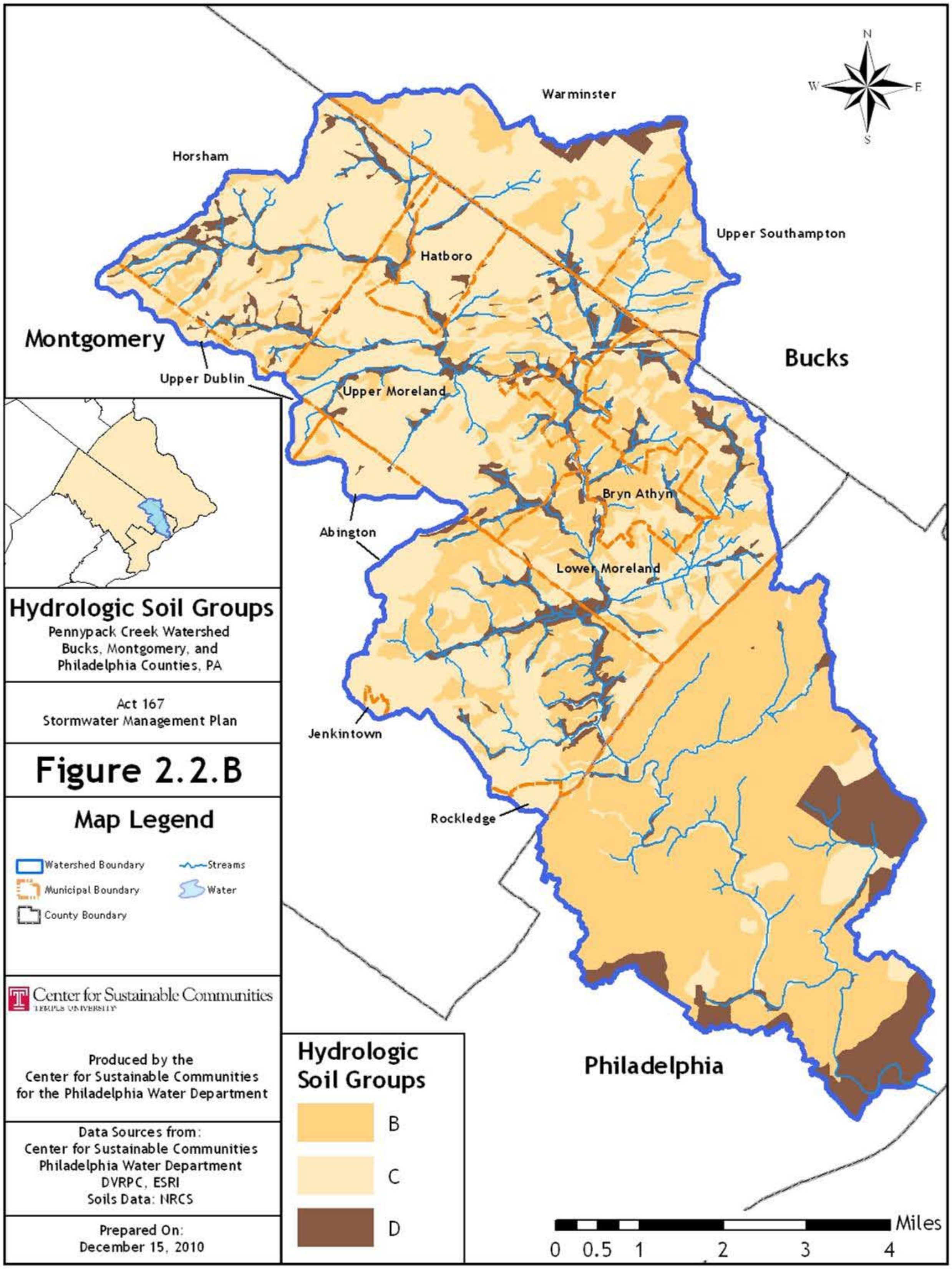
Stormwater collection, piping, and discharge through outfalls affect the pathway and timing of runoff in developed watersheds such as the Pennypack. Stormwater collection systems are located in each of the municipalities in the Pennypack Watershed. The collection systems are located primarily in the 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.

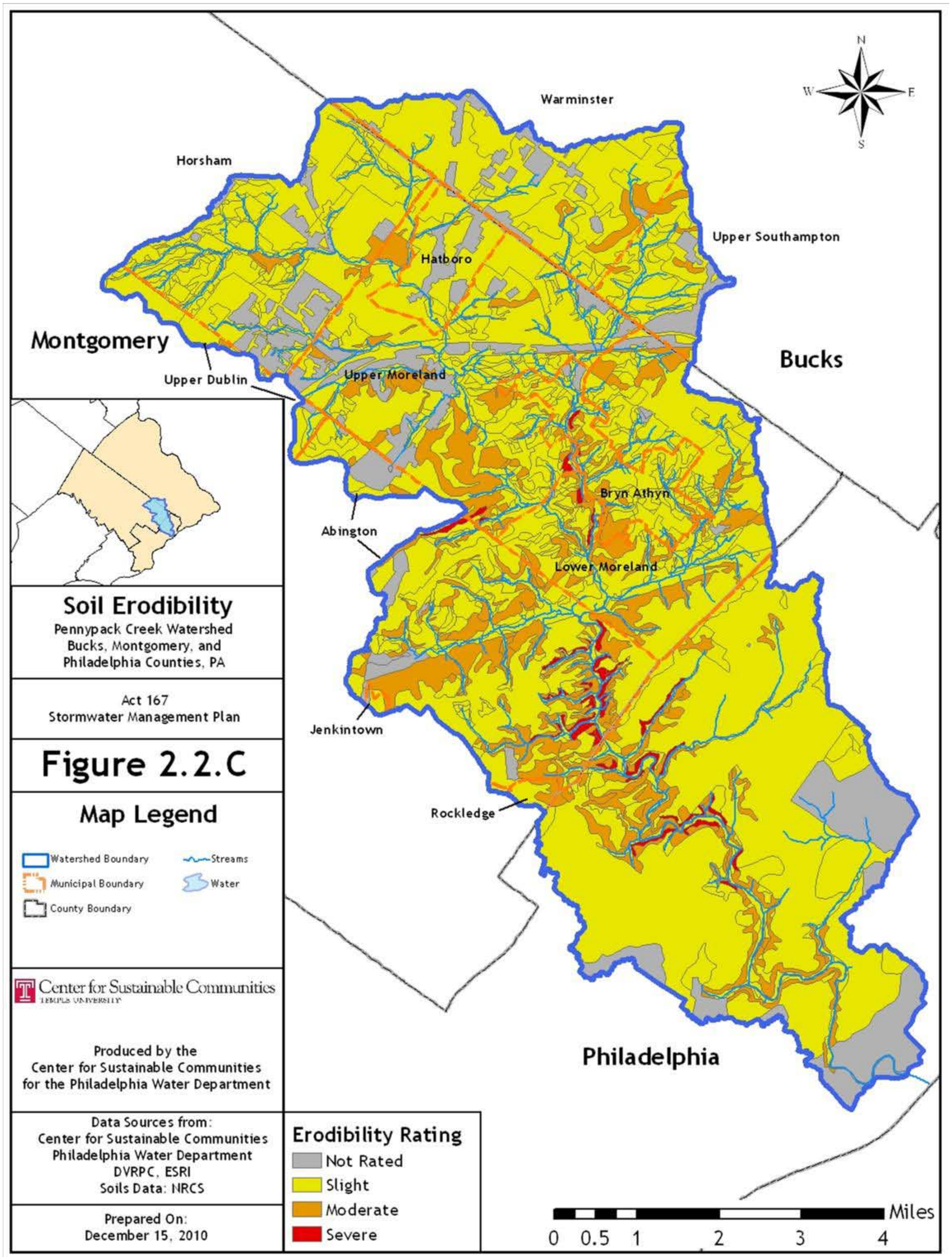
Based on the analysis of future land use presented in Section 2.3, areas with the most potential for growth are located in Montgomery County in Horsham, Upper Moreland, and Abington townships and Hatboro Borough, and in Bucks County in Warminster and Upper Southampton townships. Future stormwater collection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

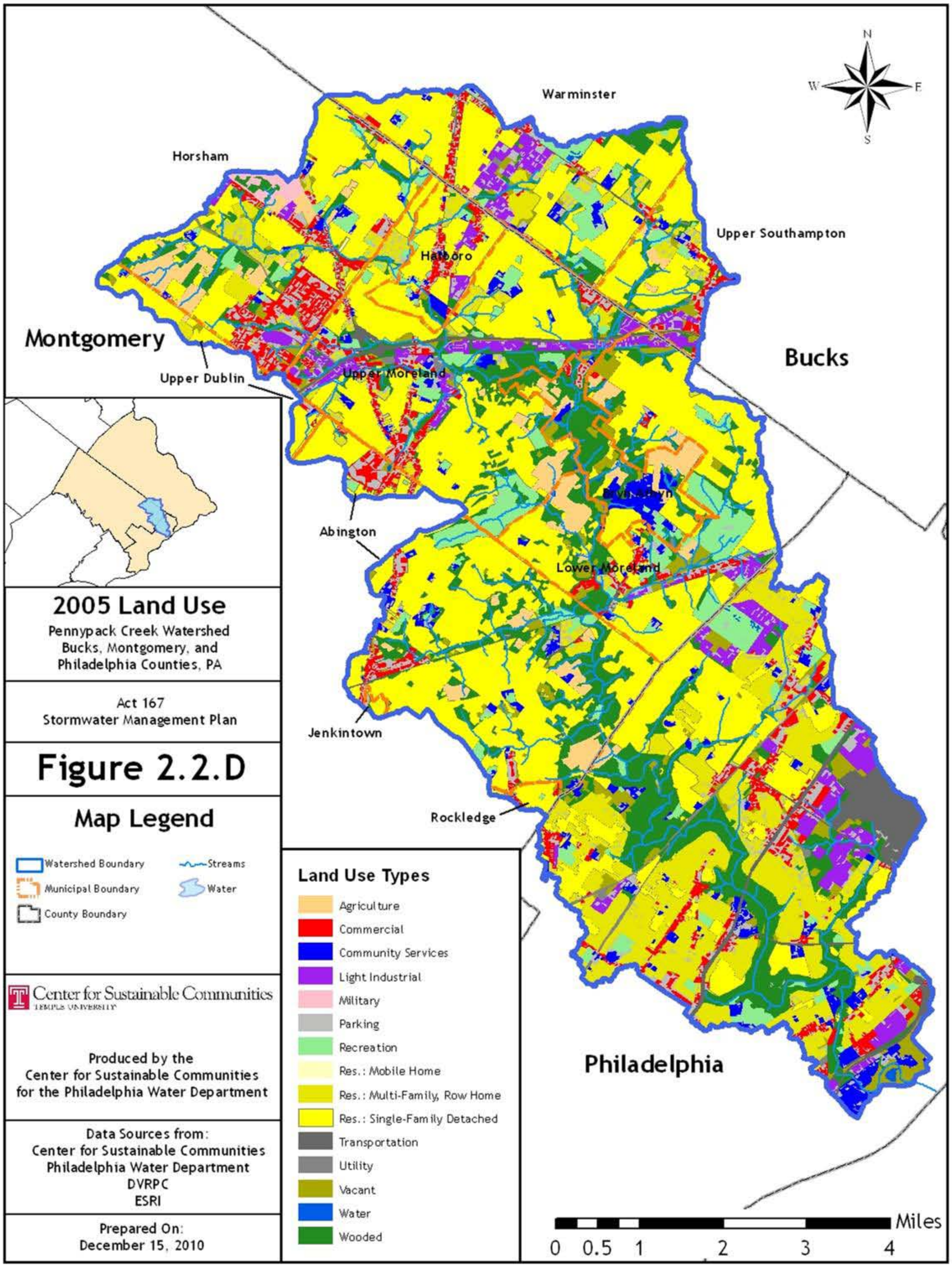


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Abington
Bryn Athyn
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
S
E
W
Elevation (DEM)
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.A
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

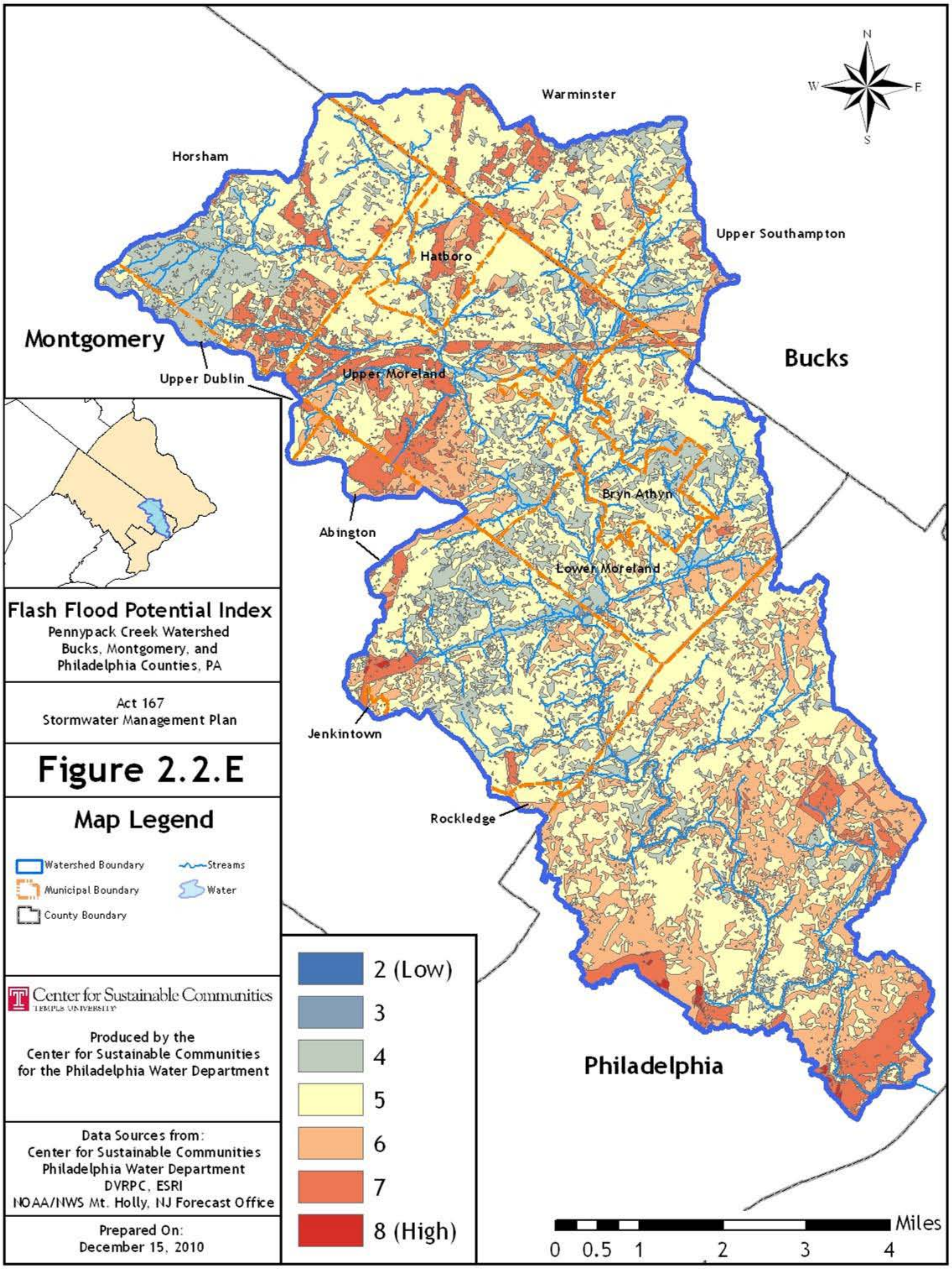


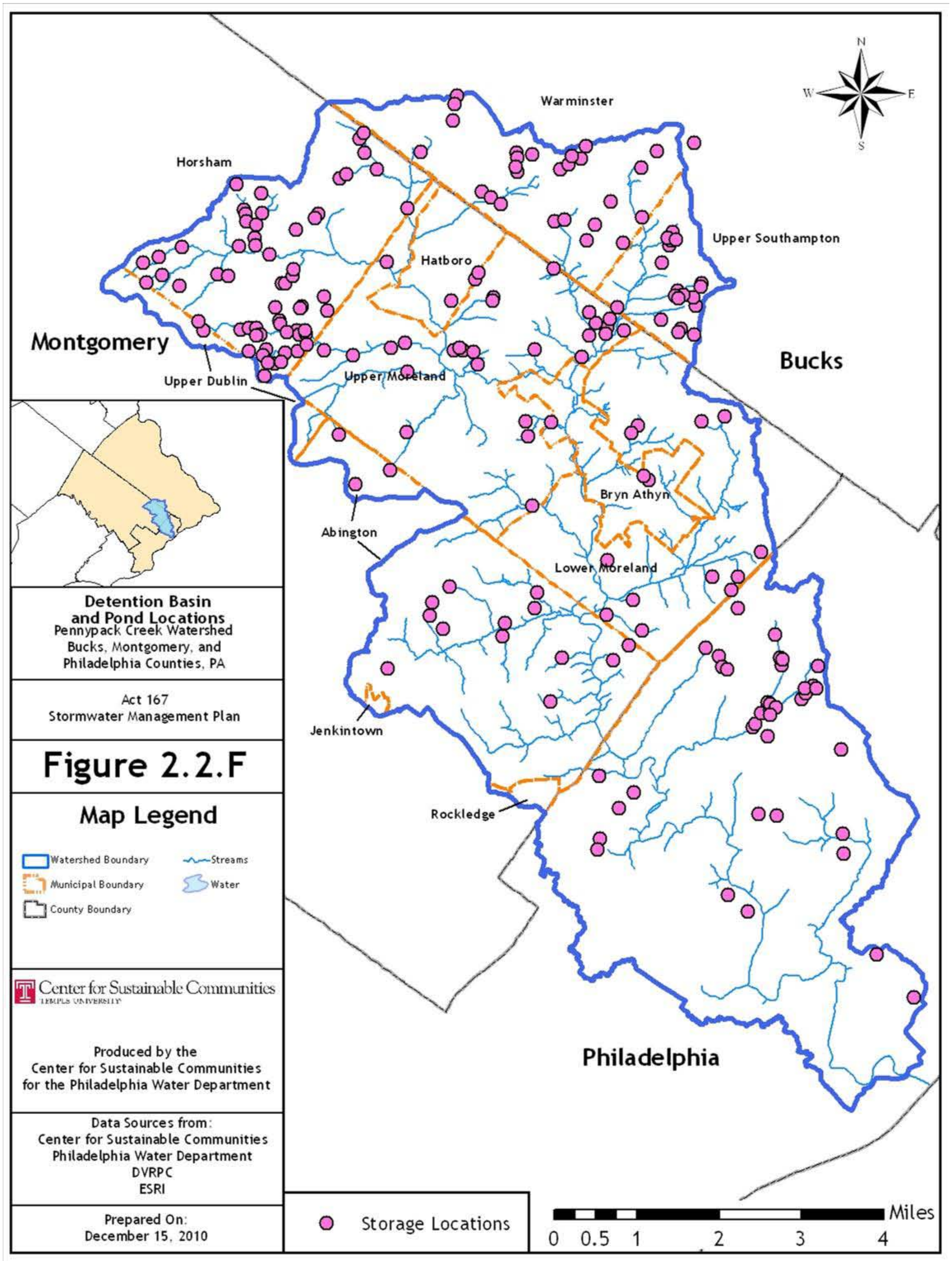
N
S
W
E
Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
Hydrologic Soil Groups
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.B
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
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
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
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
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
N
S
E
W



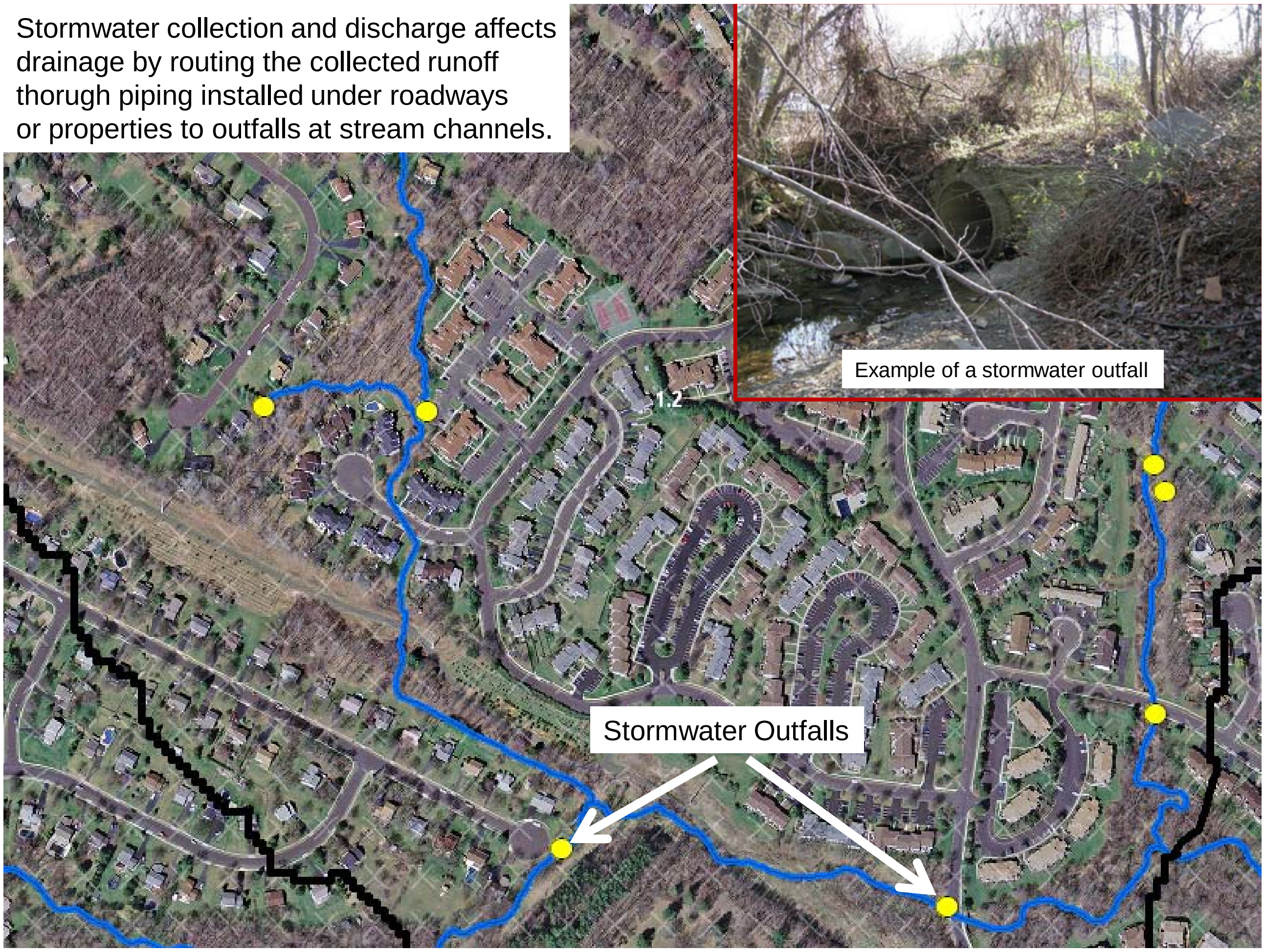
Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
2005 Land Use
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.D
Map Legend
Watershed 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
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
2 (Low)
3
4
5
6
7
8 (High)
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
NOAA/NWS Mt. Holly, NJ Forecast Office
Prepared On:
December 15, 2010
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
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
N
S
E
W

Figure 2.2.G Stormwater Collection and Outfalls



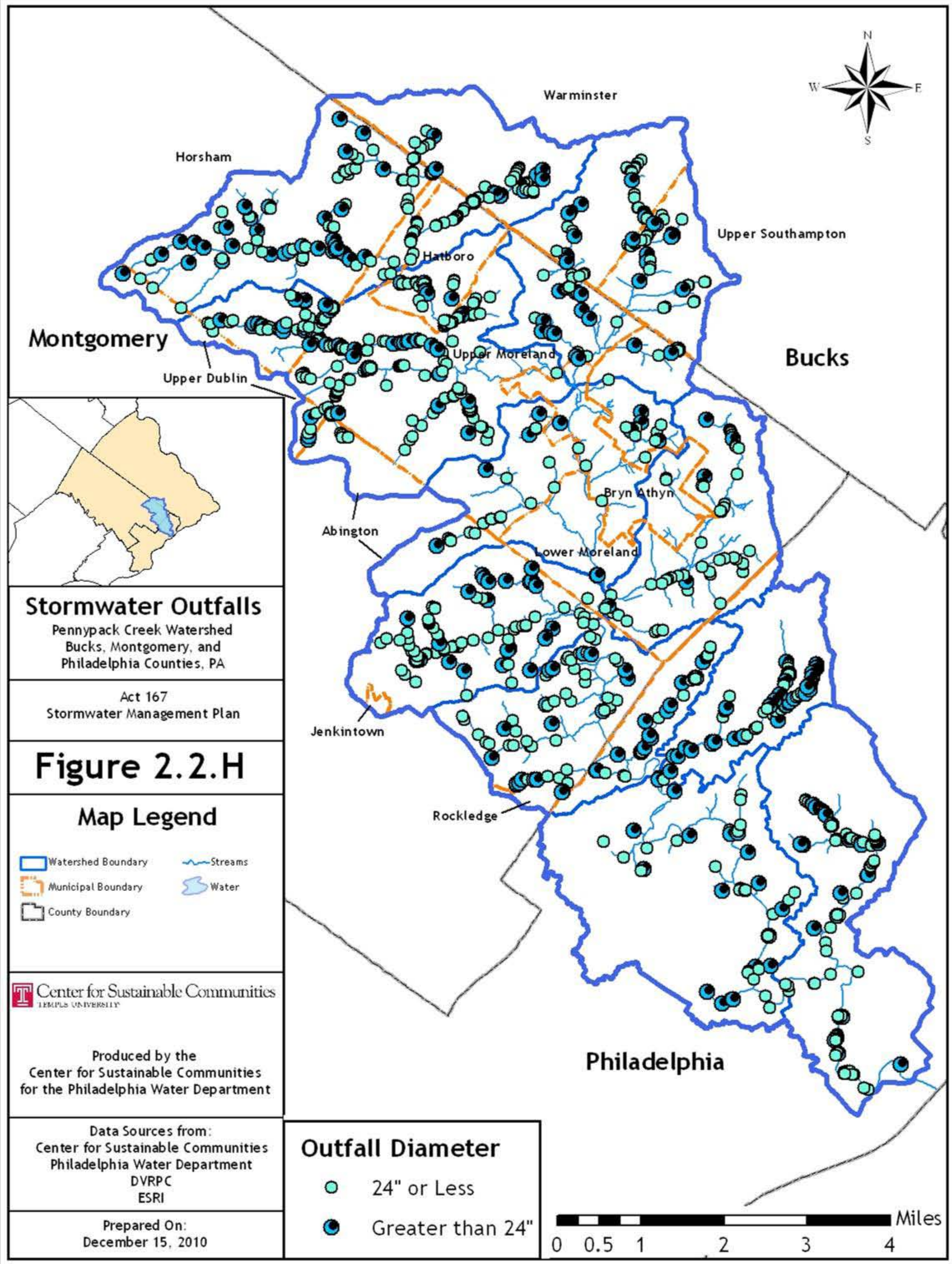
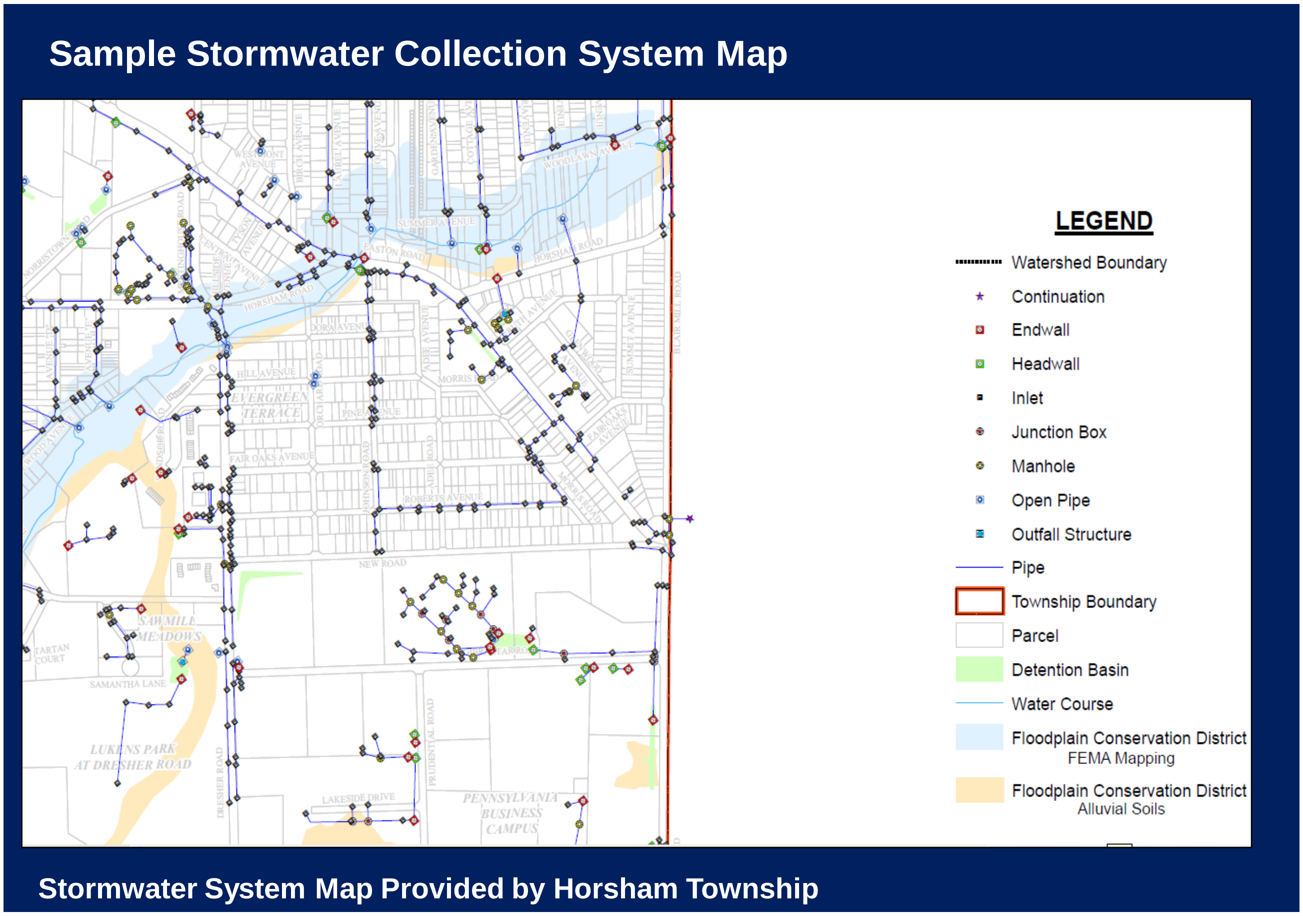

Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Upper Moreland
Bucks
Upper Dublin
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
Stormwater Outfalls
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.H
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
N
E
S
W

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:

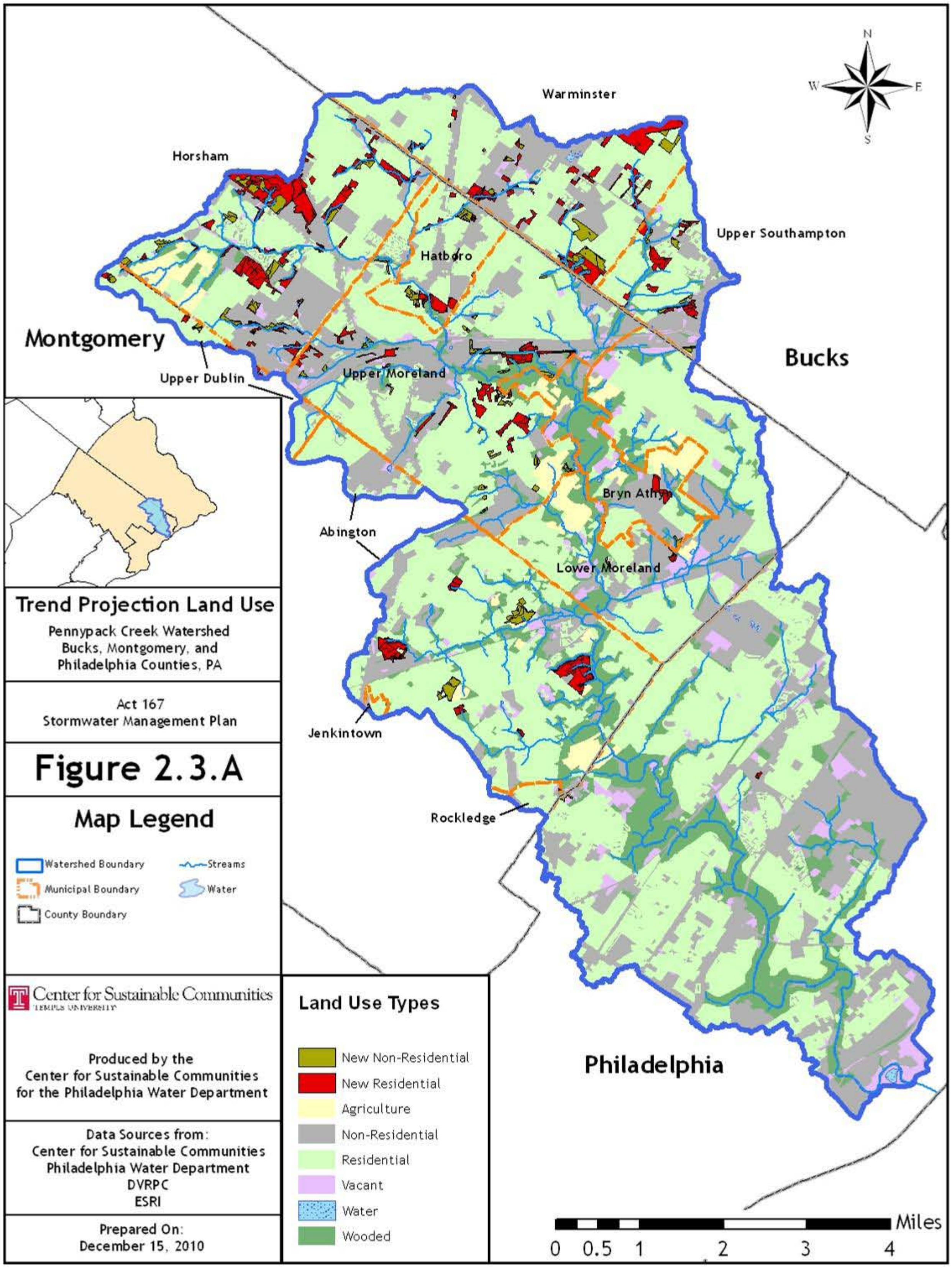
- 10%: Roads
- 10%: Rail Stations
- 2%: Institutions (schools, hospitals, employment centers, religious sites)
- 4%: Open Space (includes trails)

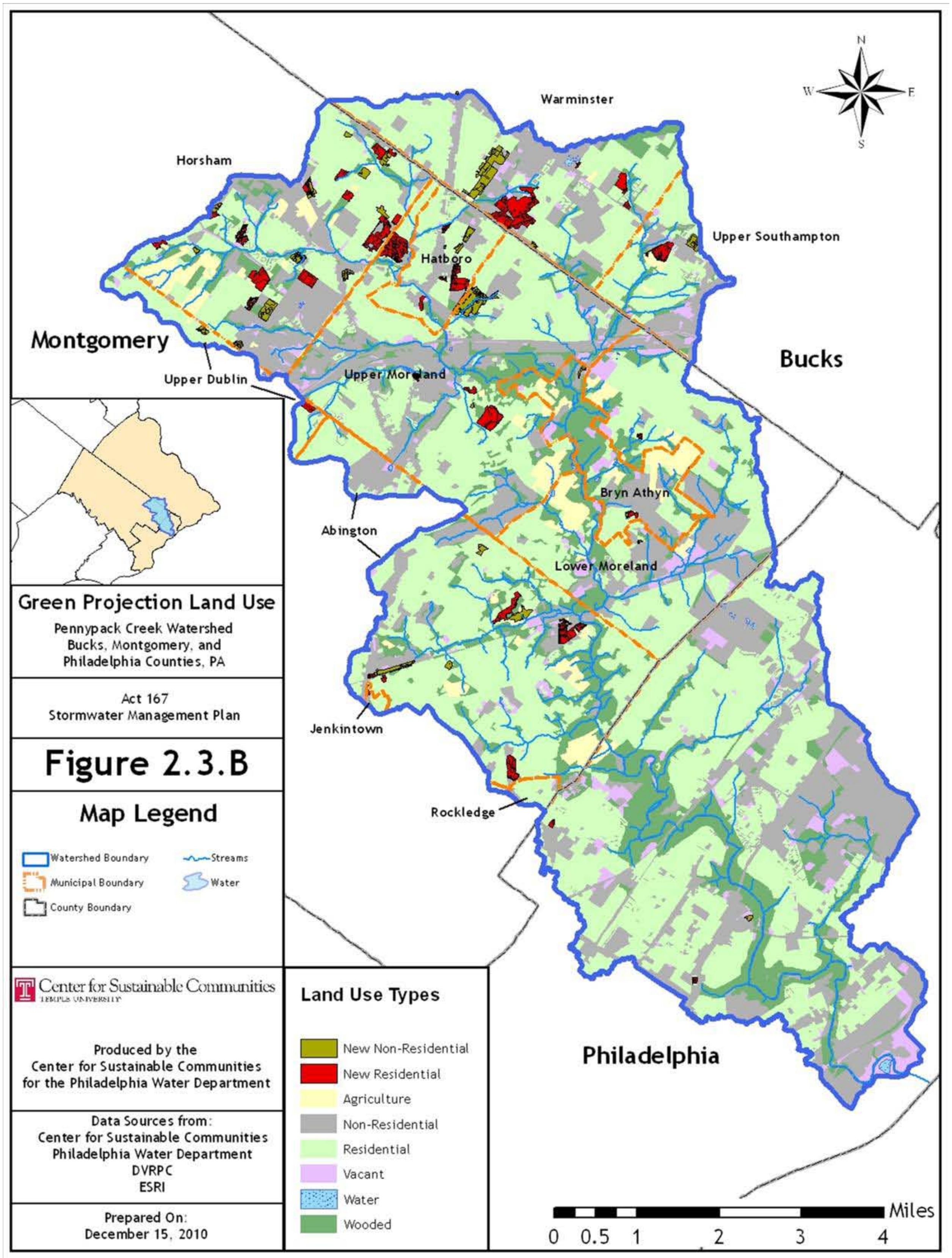
These factors were combined into a single score out of 10. Table 2.3.E shows how the development required for each municipality was allocated among the suitability scores.

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
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
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
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
Land Use Types
New Non-Residential
New Residential
Agriculture
Non-Residential
Residential
Vacant
Water
Wooded
Miles
0 0.5 1 2 3 4
N
S
E
W

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

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[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

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[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.

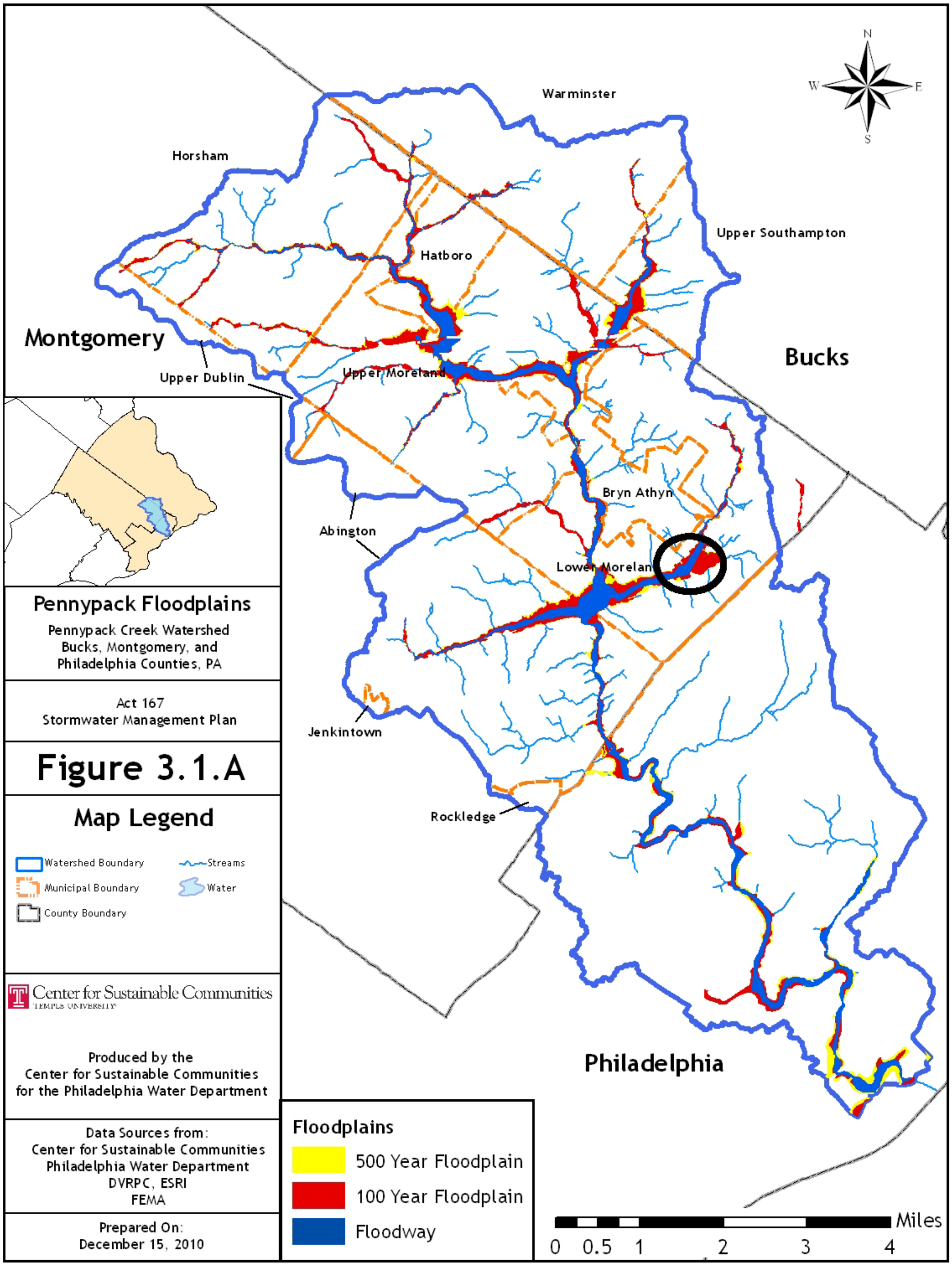
As noted in Section 3.1, bridges and culverts with drainage areas of one-half square mile or more in the Pennypack Watershed were evaluated to determine flood events that would exceed their flow capacity. The results are shown in Figure 3.1.F. Figure 3.1.G shows bridges that are most prone to overtopping 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

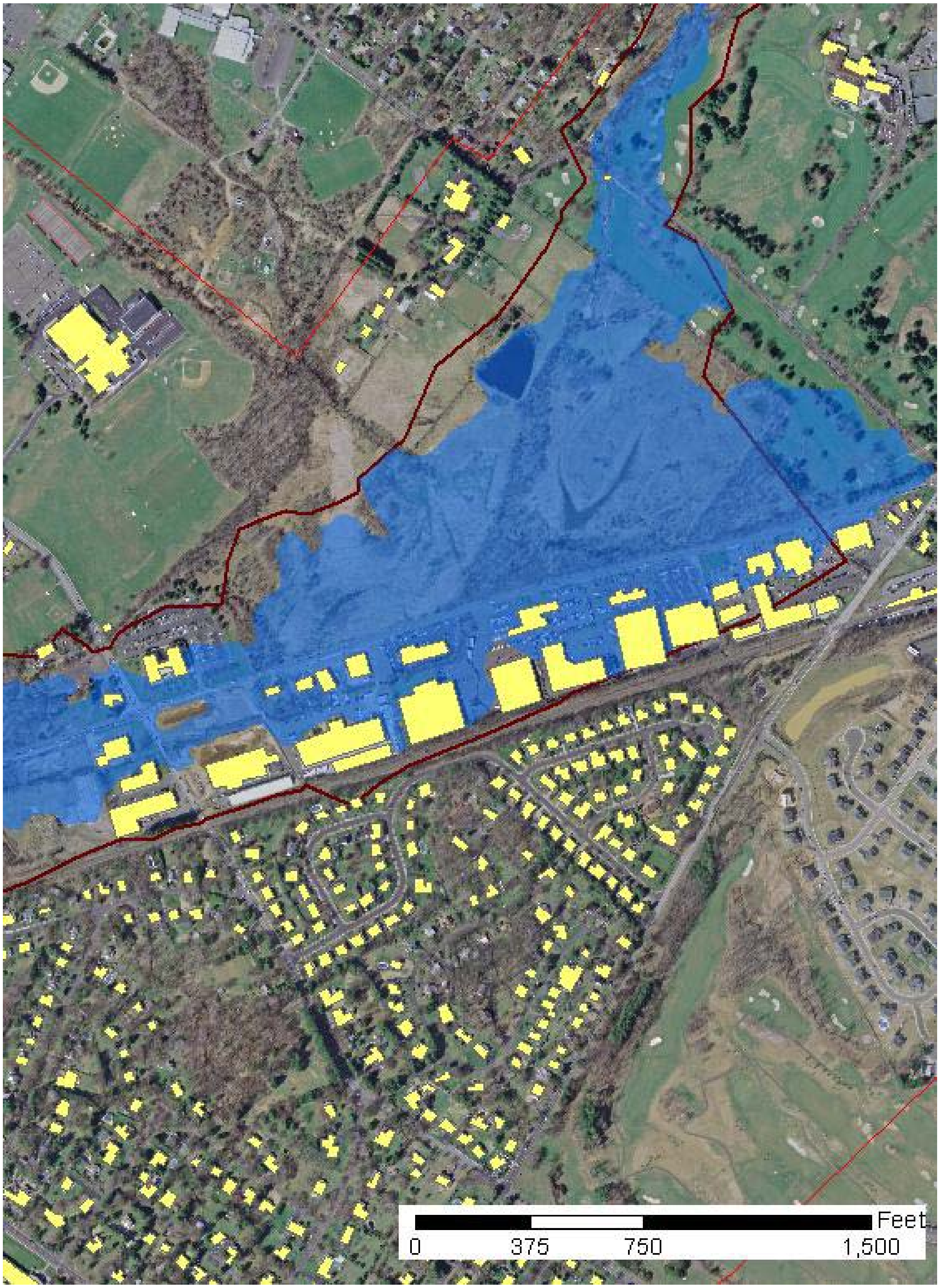
Municipality	Building Footprints in Flood Zones		
	Floodway	100-Year	500-Year
Abington	7	22	29
Bryn Athyn	0	5	16
Hatboro	28	80	102
Horsham	17	61	87
Lower Moreland	42	94	117
Upper Dublin	0	4	4
Upper Moreland	27	131	170
Upper Southampton	4	38	54
Warminster	0	8	9
Total	**125**	**443**	**588**

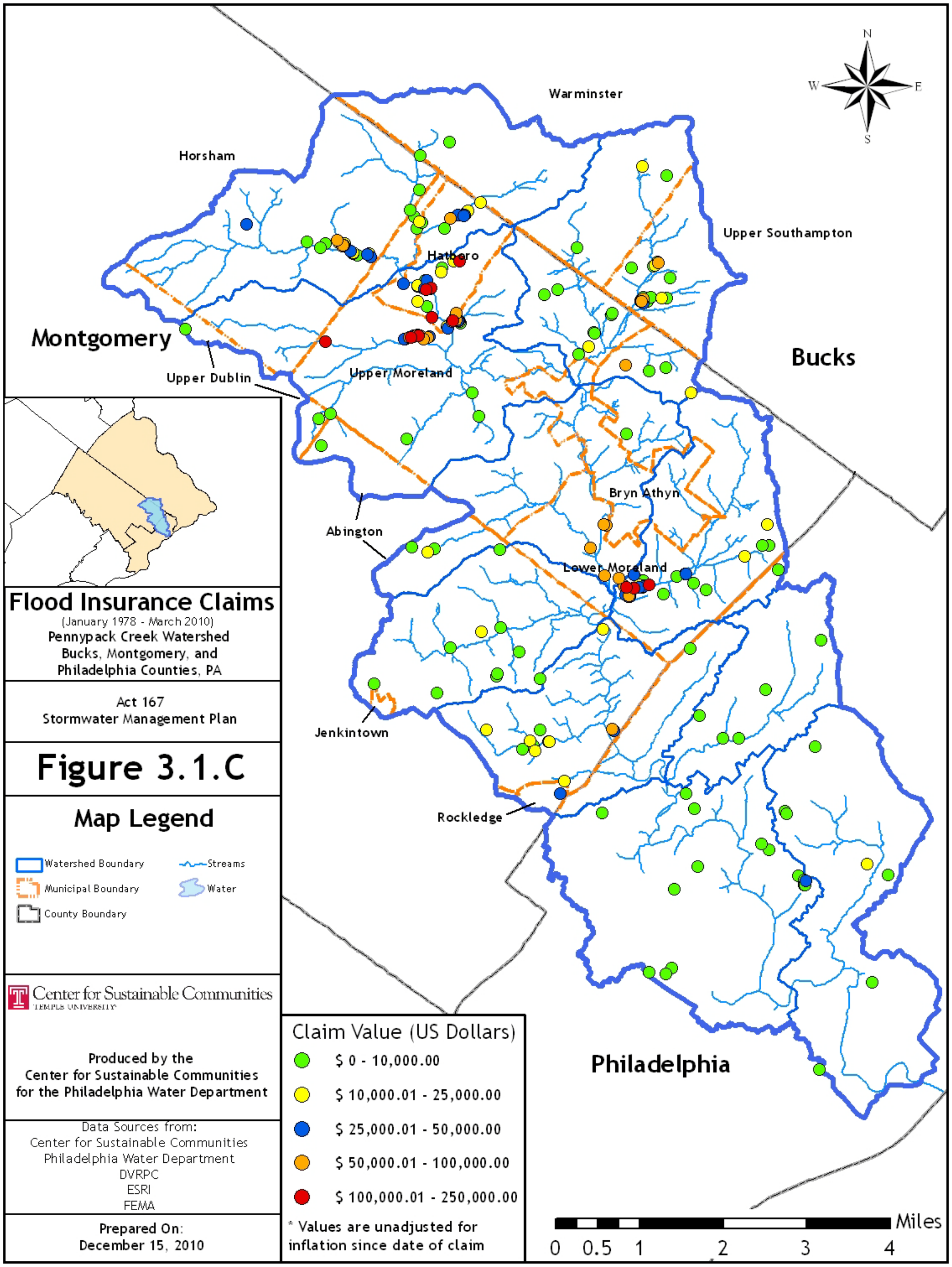
Source: FEMA

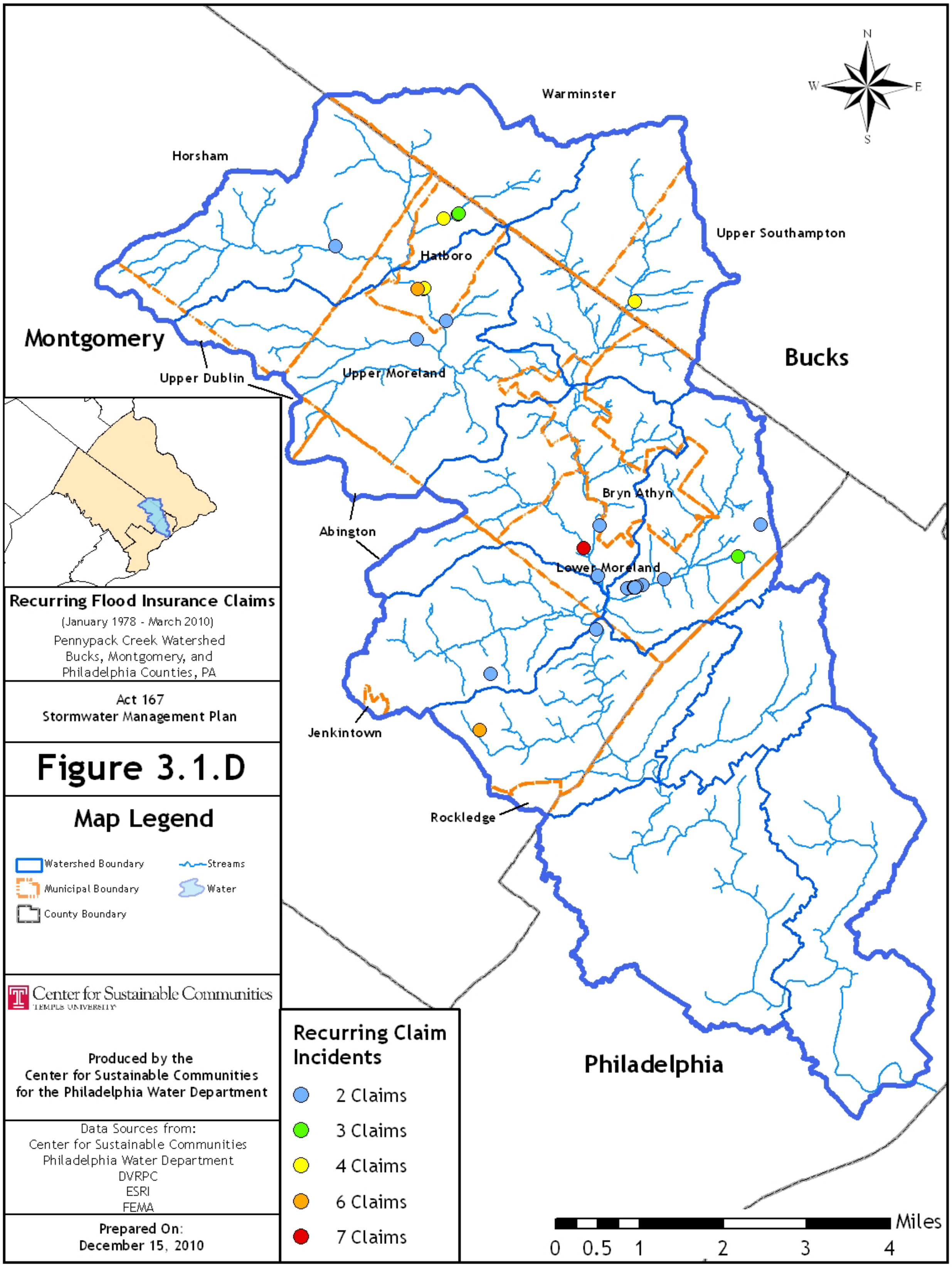


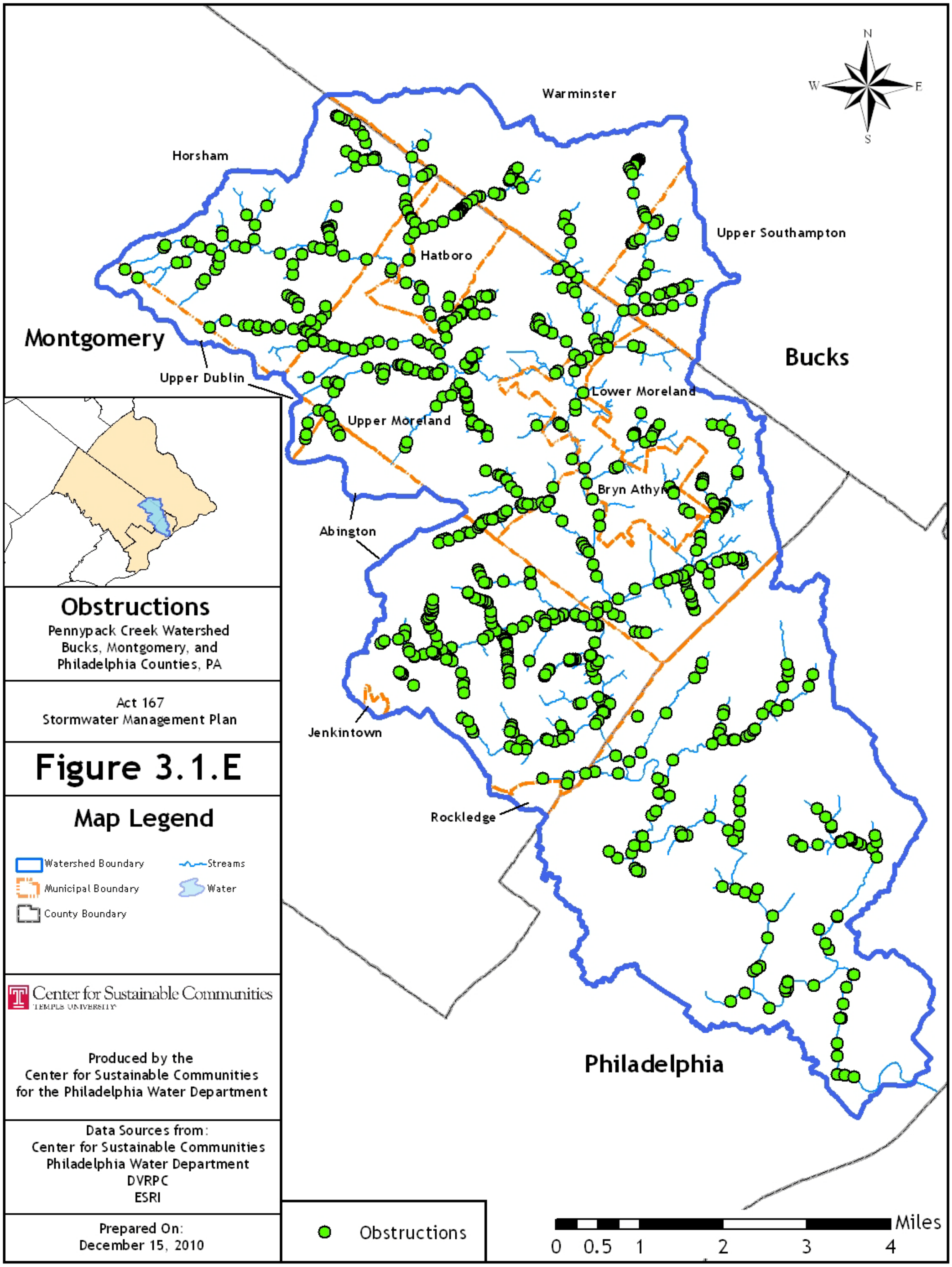
Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
Pennypack Floodplains
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 3.1.A
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
N
W
E
S

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

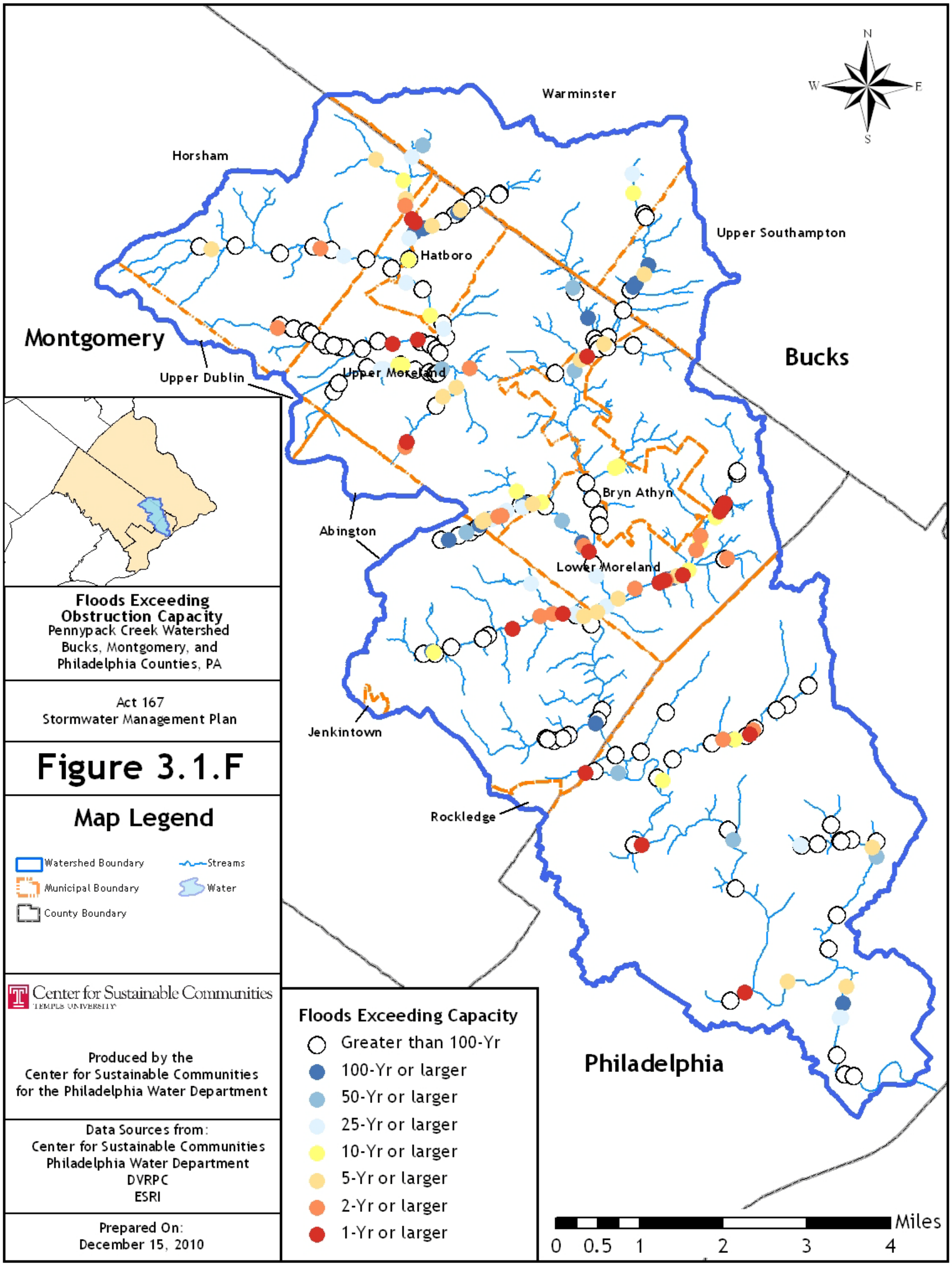


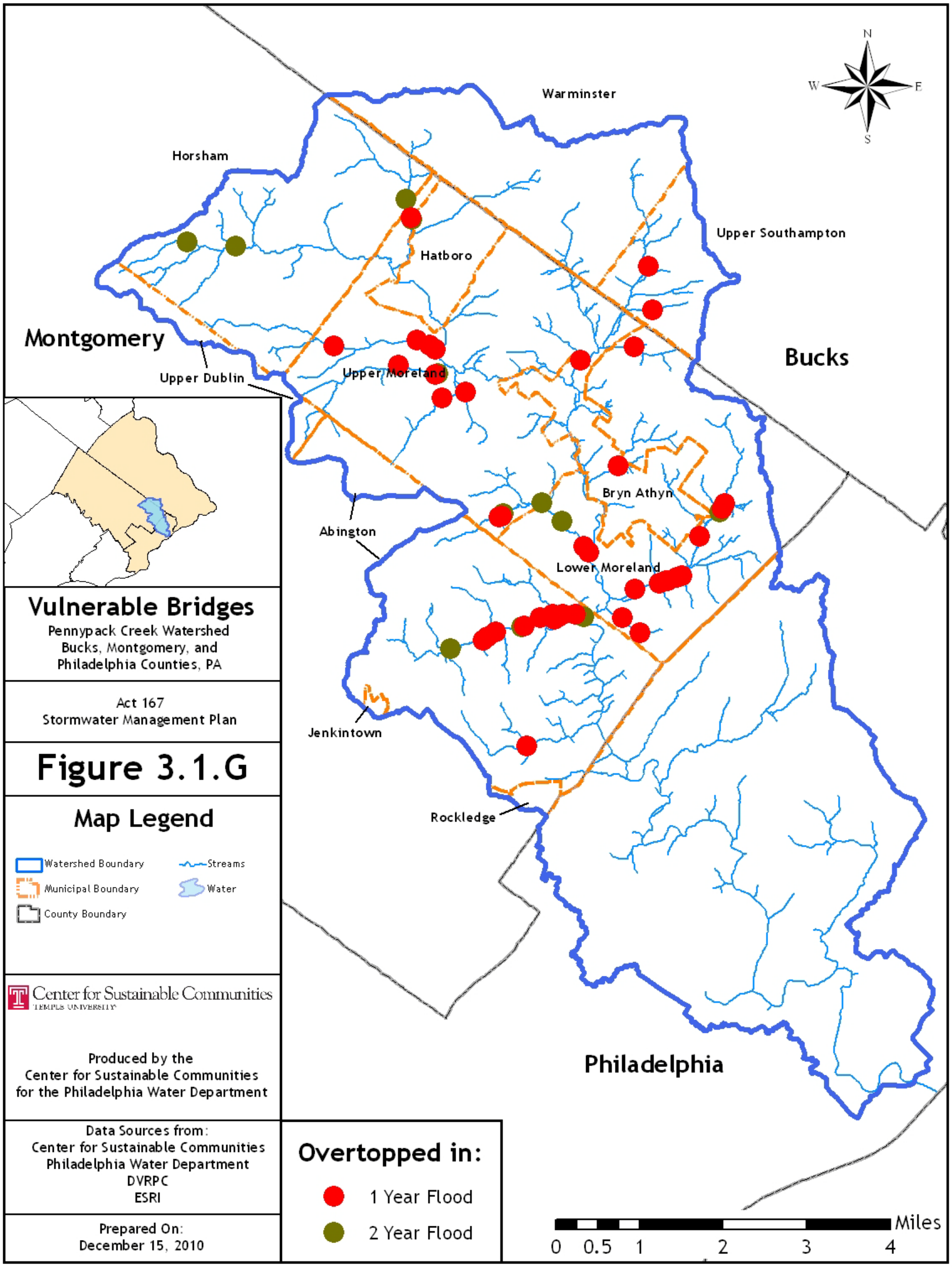

Flood Insurance Claims
(January 1978 - March 2010)
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 3.1.C
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
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
N
S
E
W
Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia


Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
S
E
W
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
S
E
W
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
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
N
E
S
W


Warminster
Horsham
Hatboro
Upper Southampton
Montgomery
Bucks
Upper Dublin
Upper Moreland
Abington
Bryn Athyn
Lower Moreland
Jenkintown
Rockledge
Philadelphia
N
S
E
W
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
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
0 0.5 1 2 3 4
Miles

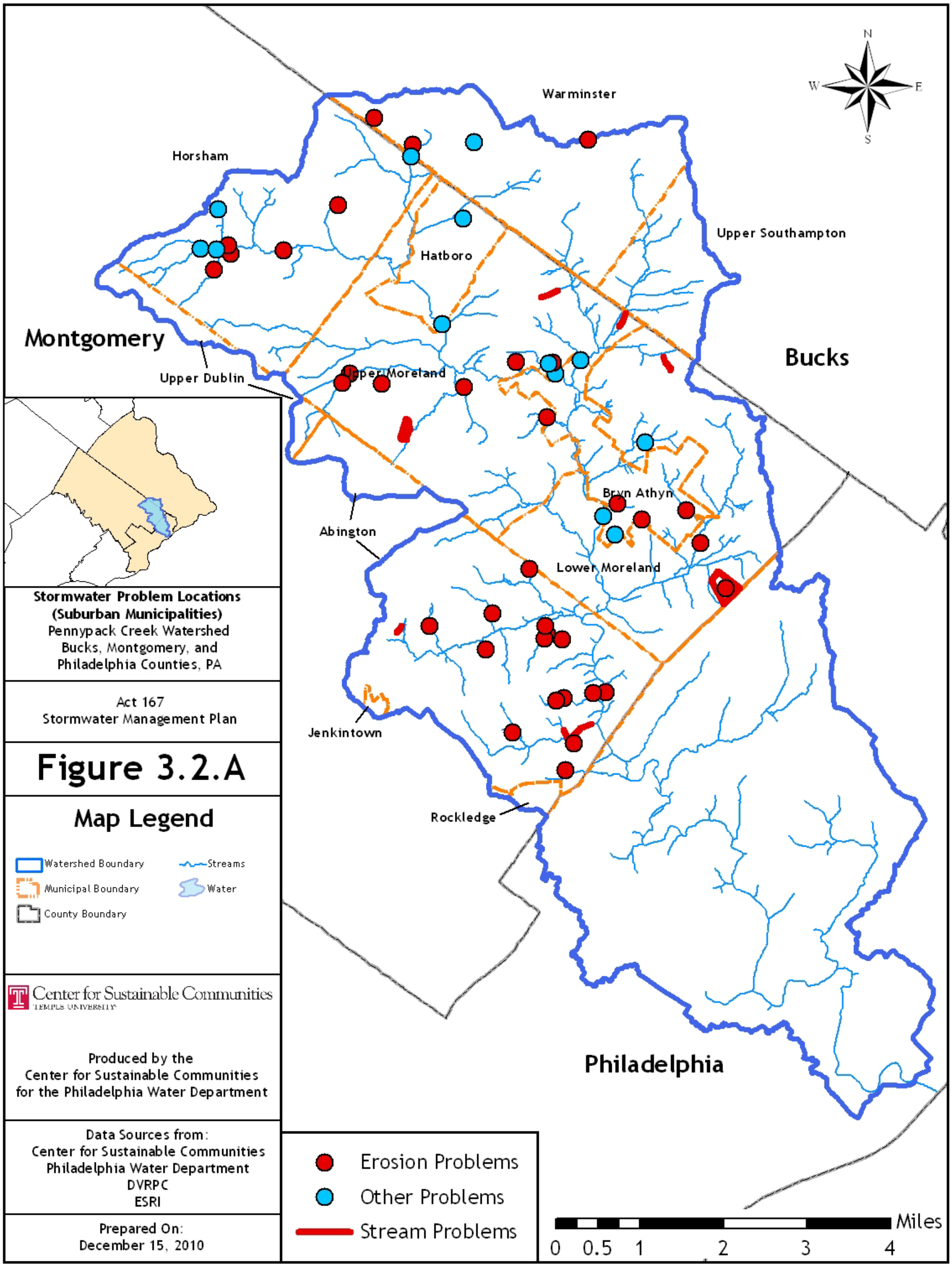

Stormwater Problem Locations
(Suburban Municipalities)
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 3.2.A
Map Legend
Watershed Boundary
Streams
Municipal Boundary
Water
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
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
N
W
E
S
Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia

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

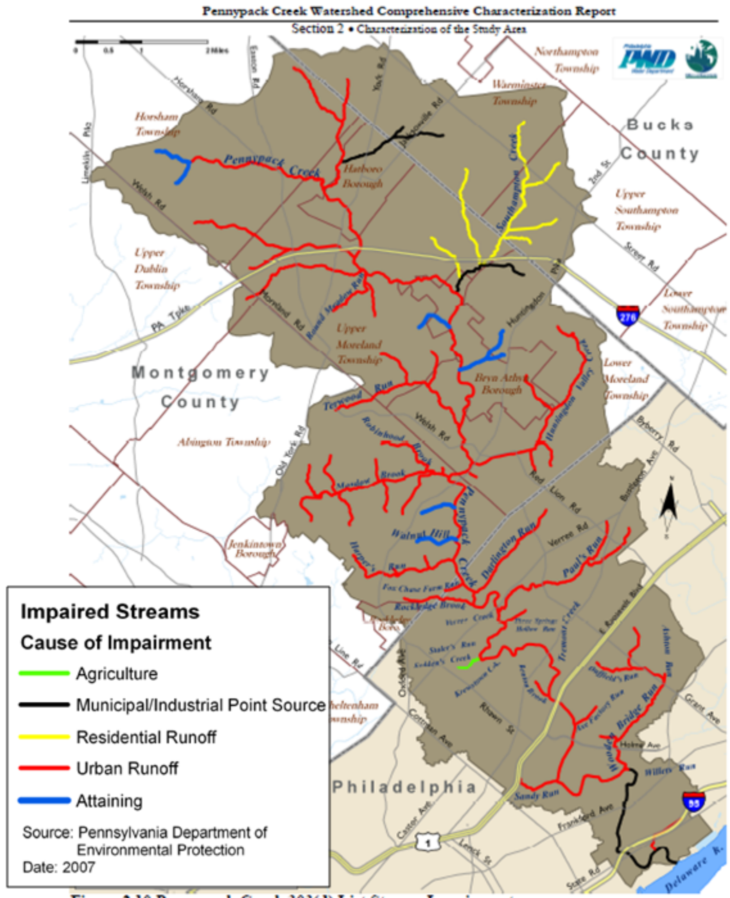


Figure 2.10 Pennypack Creek 303(d) List Stream Impairments

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

Section 4: Model Development and Application

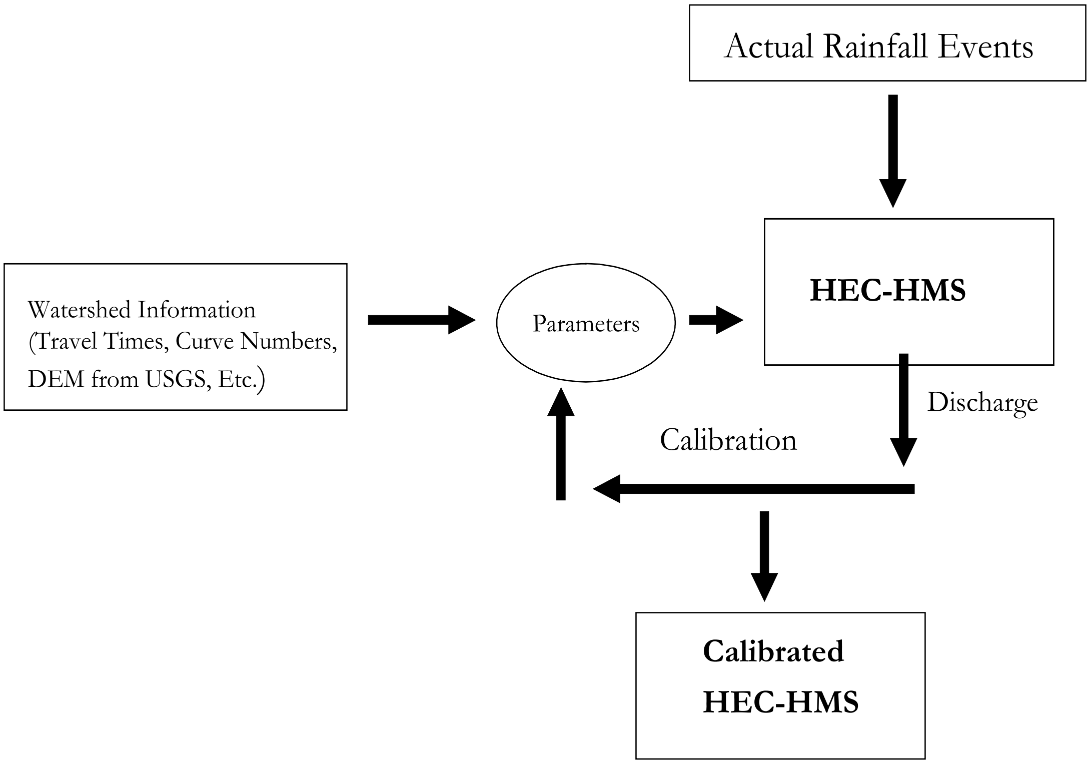
The modeling for the Act 167 study was built upon hydrologic and hydraulic modeling completed for the recent flood insurance study of the suburban Pennypack Watershed. The modeling for the flood insurance study has been approved by the Federal Emergency Management Agency (FEMA) and the associated flood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

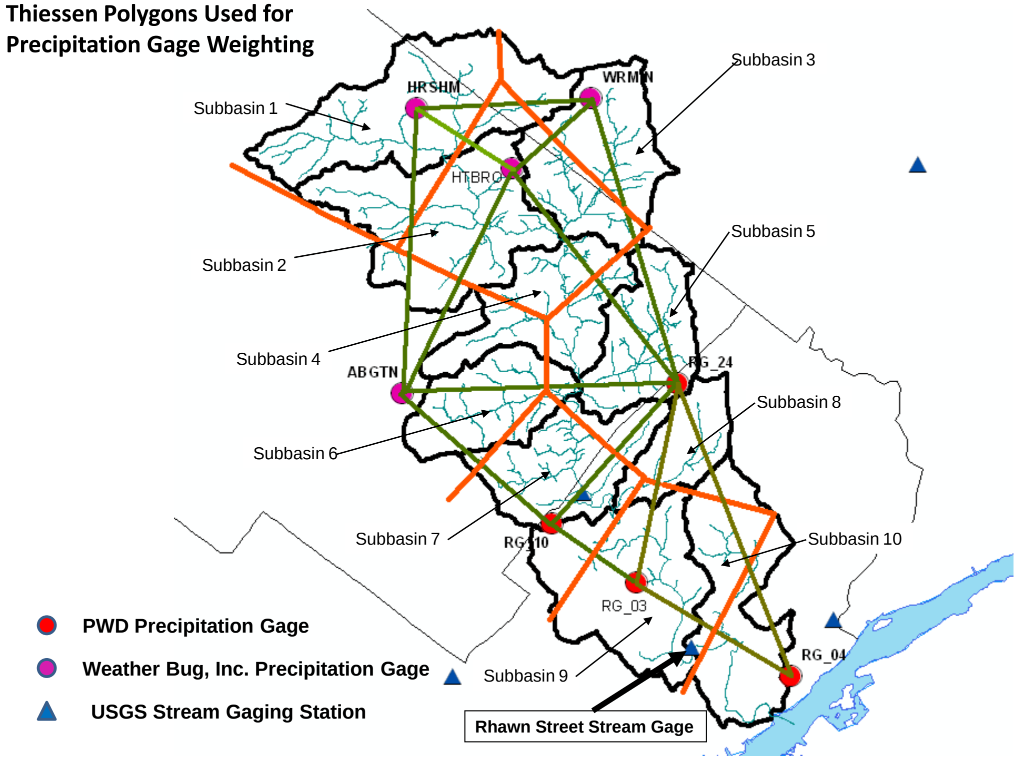
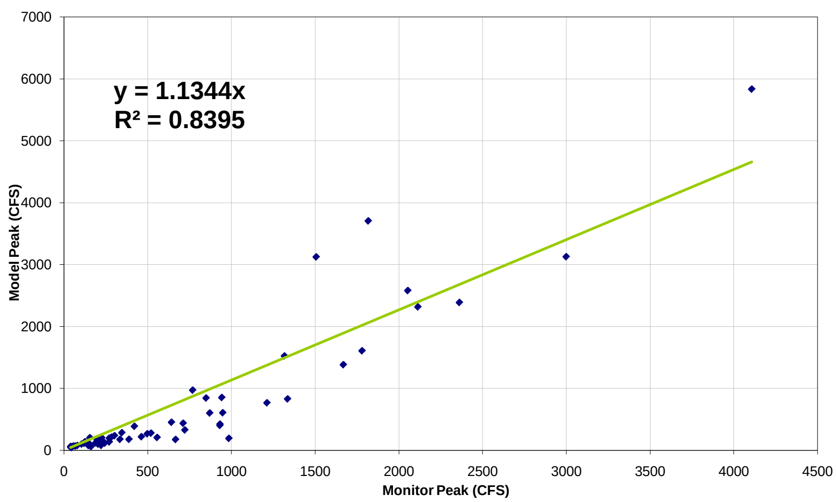


Figure 4.1.D Observed vs. Modeled Peak Flows – Original 10-Subbasin Model

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

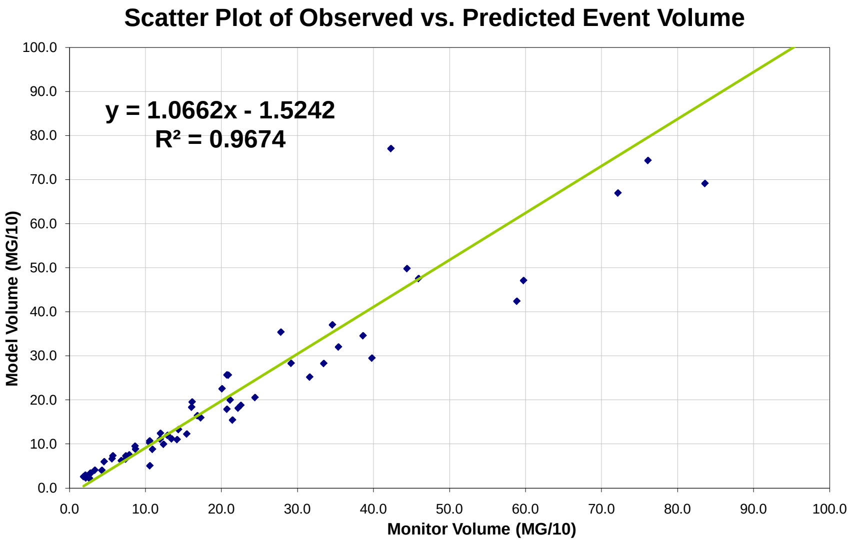


Observed flow at USGS Stream Gage at Rhawn Street

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



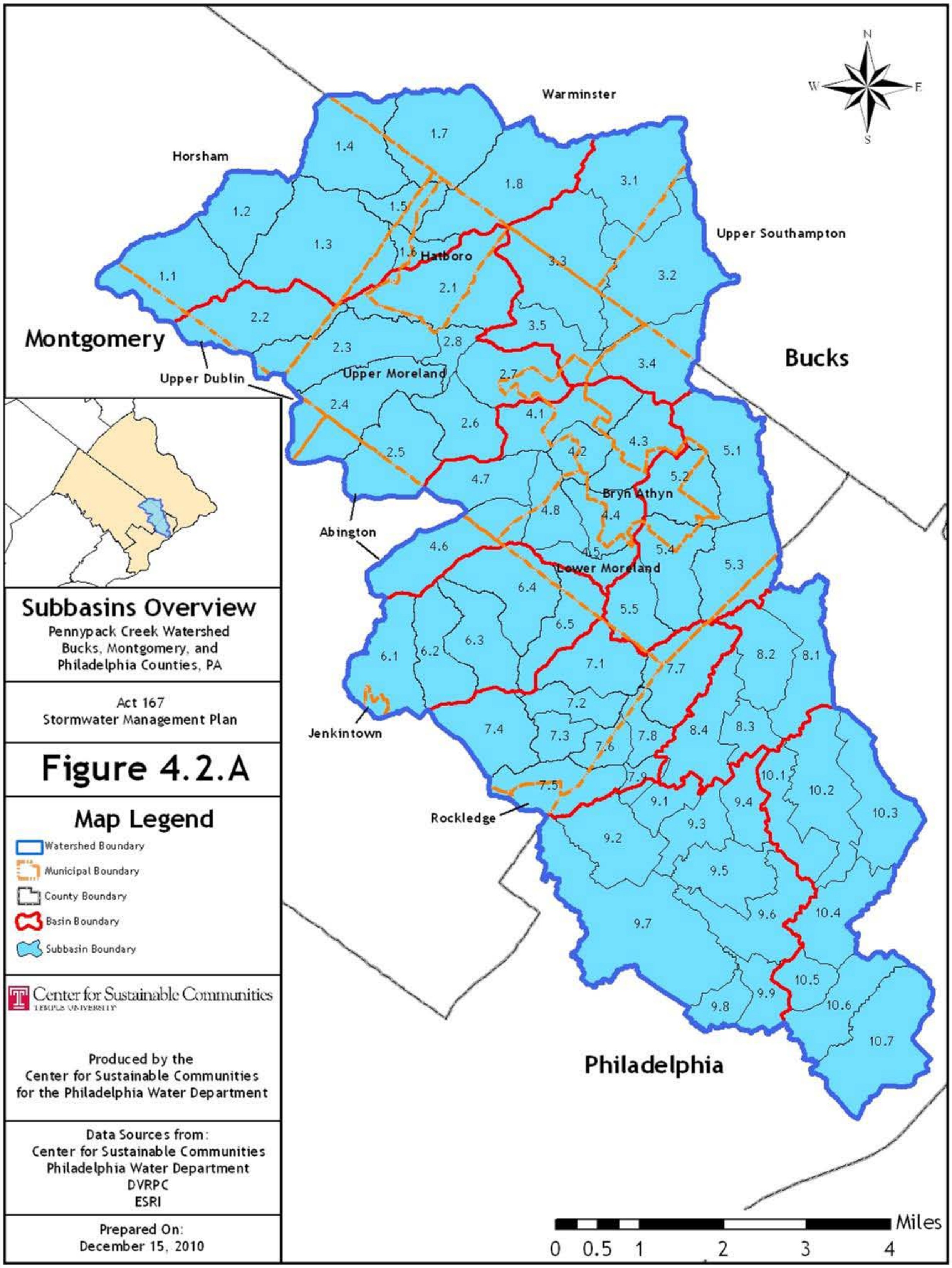
Observed volume at USGS Stream Gage at Rhawn Street

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
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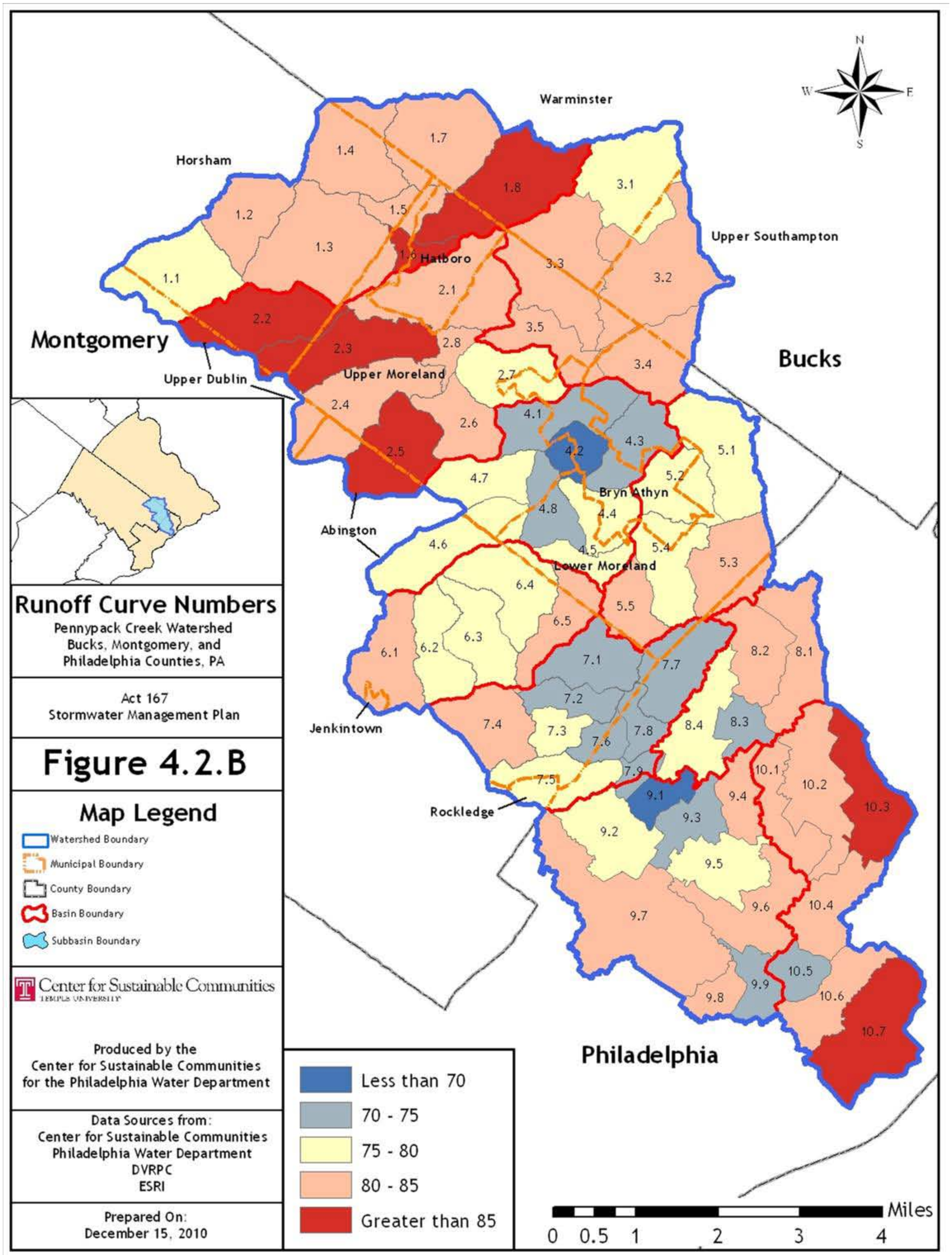
W
Subbasins Overview
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 4.2.A
Map Legend
Watershed Boundary
Municipal Boundary
County Boundary
Basin Boundary
Subbasin Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced 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



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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
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
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80 - 85
Greater than 85
Miles
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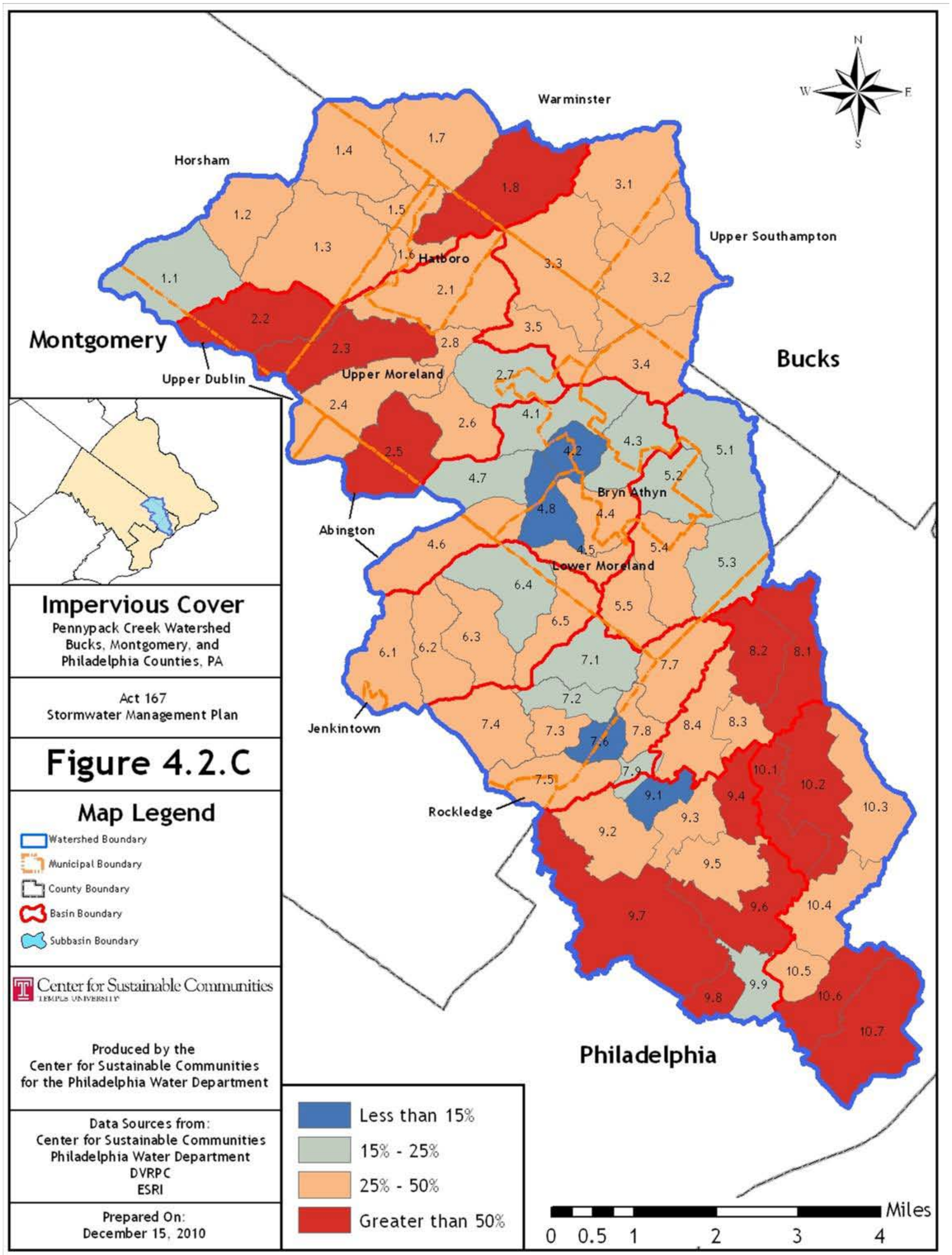
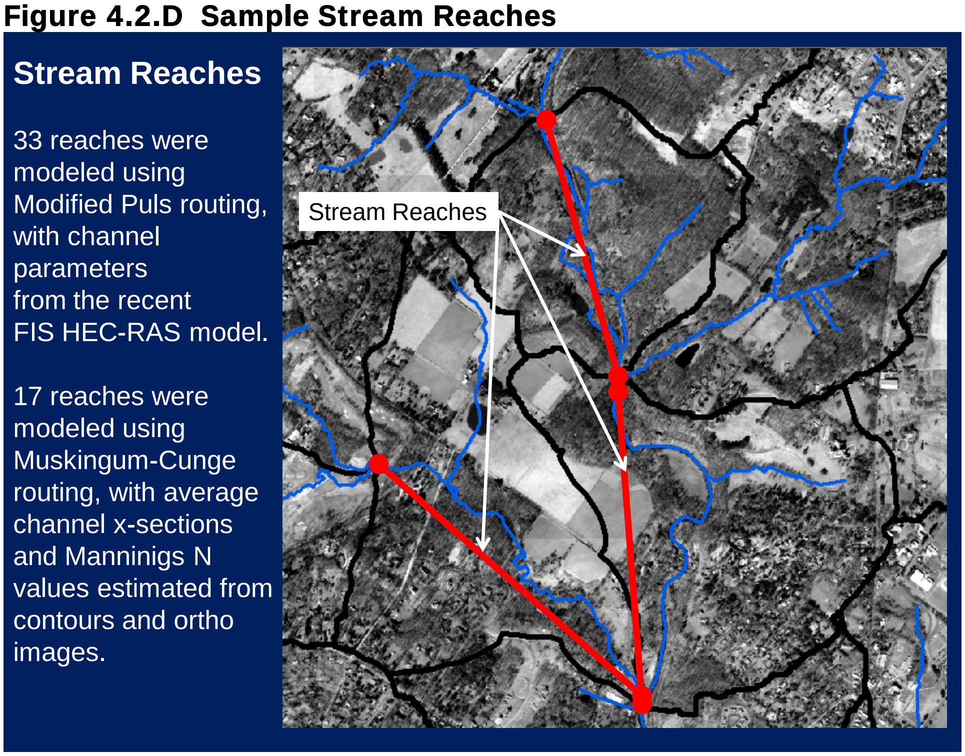

Warminster
Horsham
Upper Southampton
Hatboro
Montgomery
Bucks
Upper Dublin
Upper Moreland
Bryn Athyn
Abington
Lower Moreland
Jenkintown
Rockledge
Philadelphia
Impervious Cover
Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 4.2.C
Map Legend
Watershed Boundary
Municipal Boundary
County Boundary
Basin Boundary
Subbasin Boundary
Center for Sustainable Communities
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

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



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[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.

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[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**

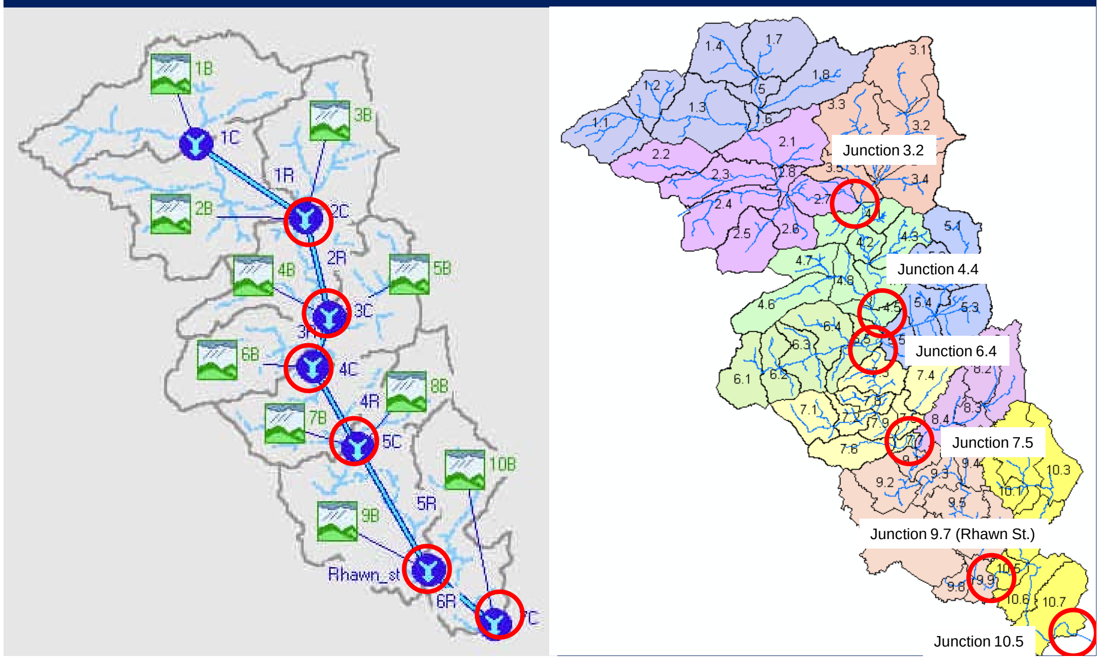
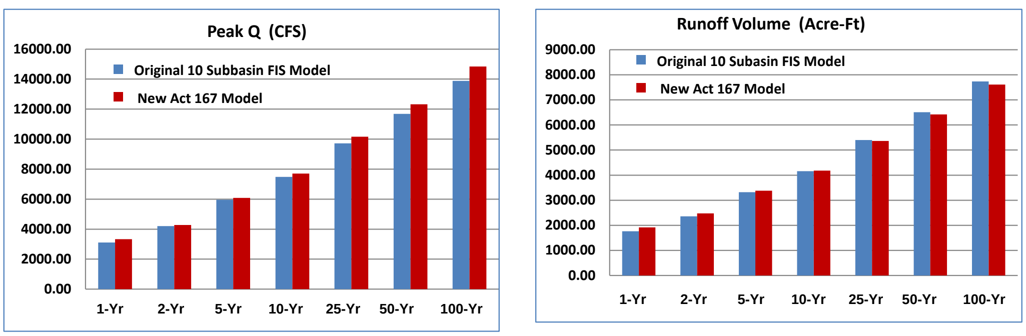


Figure 4.3.B Model Test Results – Upper Portion of Pennypack Creek

Comparison for Pennypack Creek below Confluence with Southampton Creek

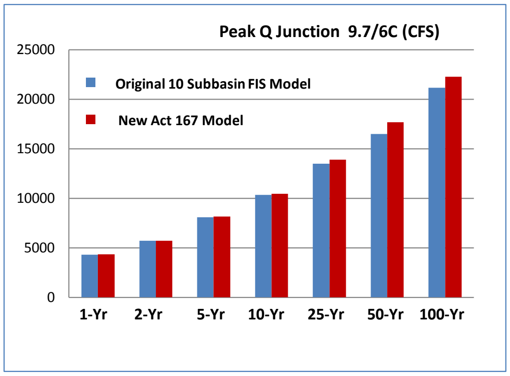


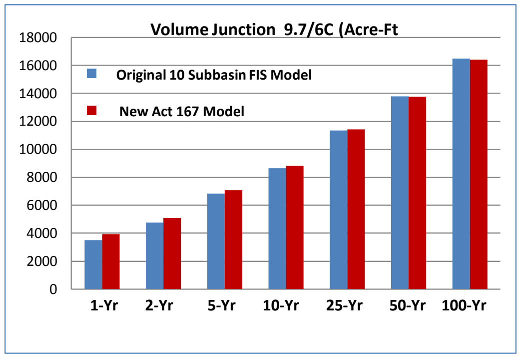
		Peak discharge (cfs)	
Storm	Original Model	New Model	% Difference
1-Yr	3107.10	3335.70	7.36
2--Yr	4207.00	4271.00	1.52
5-Yr	5961.80	6078.80	1.96
10-Yr	7481.20	7700.40	2.93
25-Yr	9716.10	10166.30	4.63
50-Yr	11689.40	12323.50	5.42
100-Yr	13883.20	14839.00	6.88

		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.

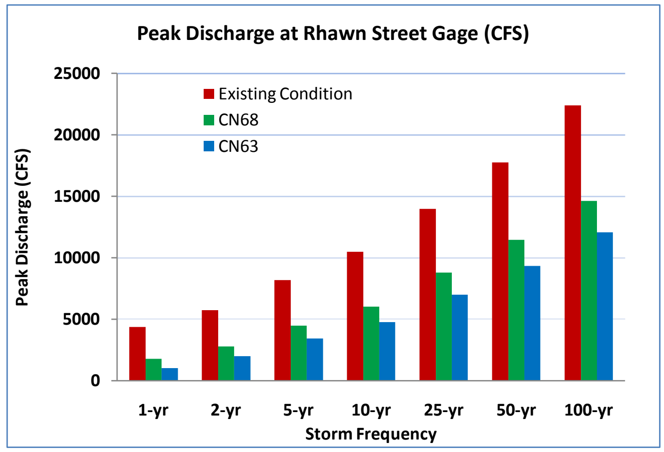
The hydrologic model was applied to help describe the current runoff characteristics of the watershed as presented in Section 2. Figure 4.5.A compares modeled peak discharge and runoff volume for existing land use conditions to modeled results for forest cover in "good" and "fair" condition for seven 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]

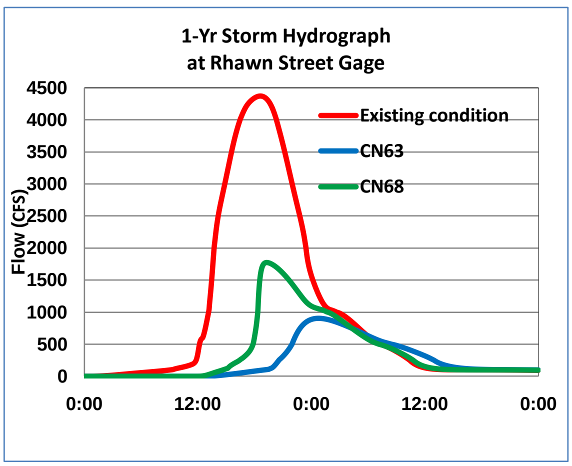
[5] Roland, Mark A.; Stuckey, Marla H., Regression Equations for Estimating Flood Flows at Selected Recurrence Intervals for Ungaged Streams in Pennsylvania, Scientific Investigations Report, U.S. Geological Survey, 2008.
[6] *Bedient, P.B., Huber, W.C., Vieux, B.E., Hydrology and Floodplain Analysis, Fourth Edition, Pearson/Prentice Hall, 2008, p. 135.*

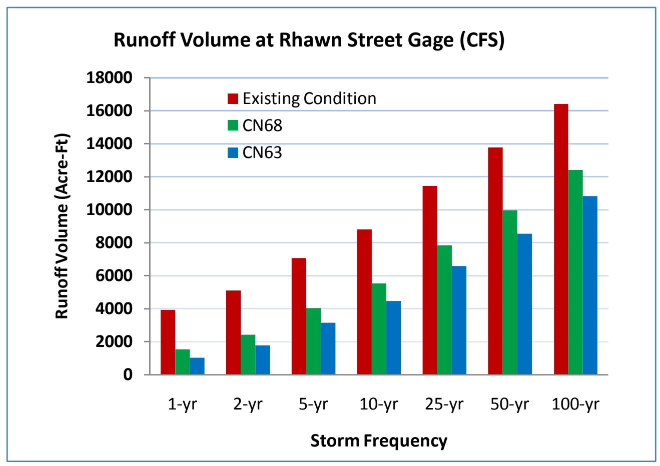
Figure 4.5.A Modeling Comparison of Existing and "Undeveloped" Runoff Conditions

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.



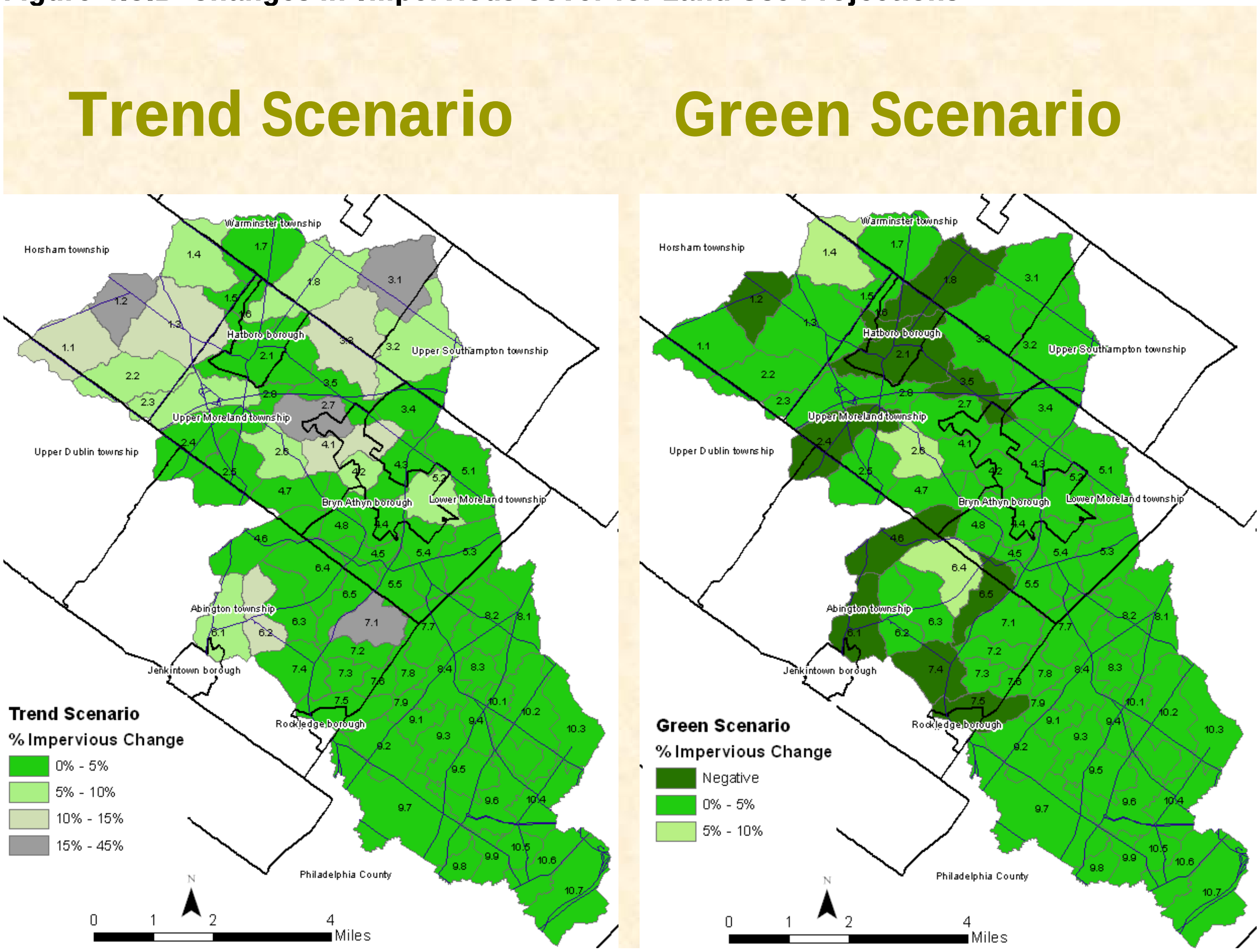




Evaluation of the Hydrologic Impacts of Future Land Use Change Scenarios

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

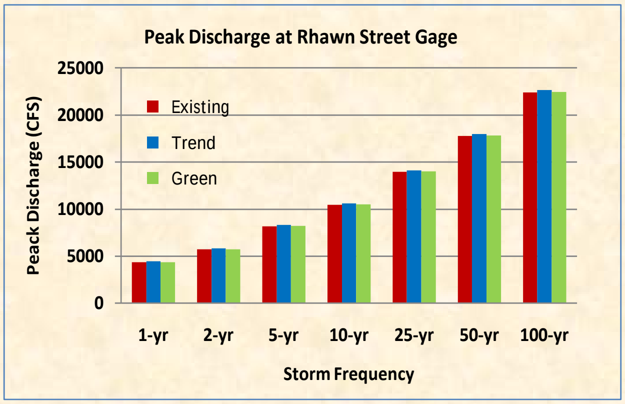


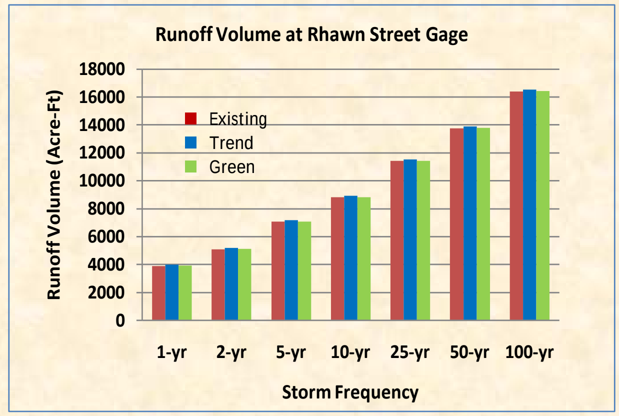
The modeling results shown in Figure 4.5.C show the aggregate effect of the two land use projections on peak discharge and runoff in the lower portion of the main stem of the Pennypack at Rhawn Street. Peak discharge and runoff volume would increase two percent or less for the Trend scenario and less 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.

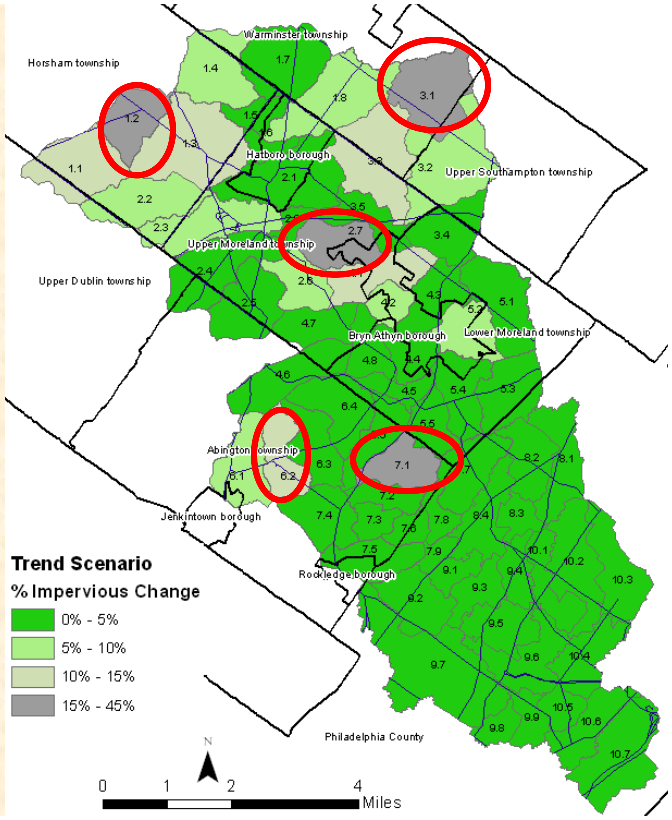
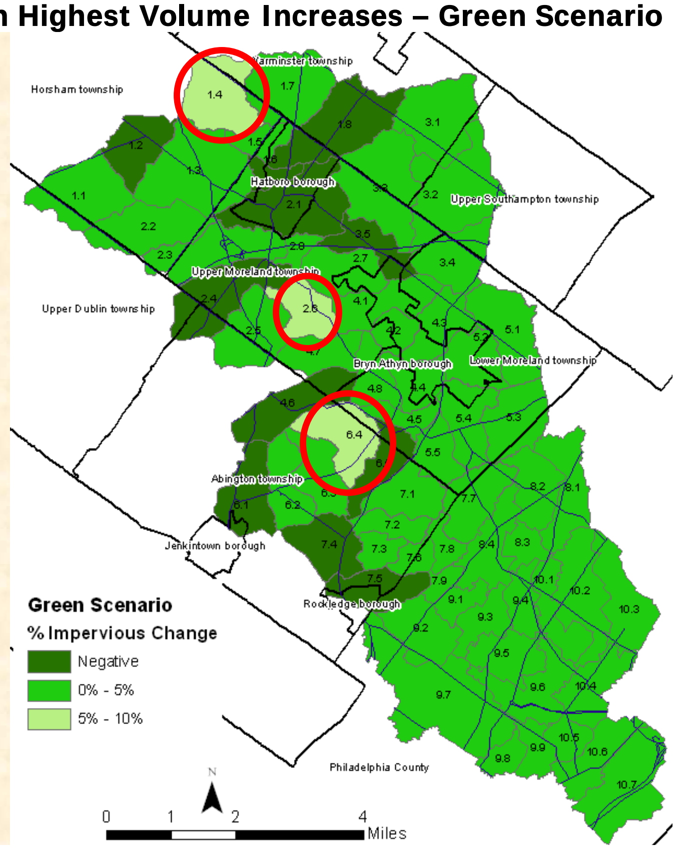


Figure 4.5.E Subbasins with Highest Volume Increases – Green Scenario

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.

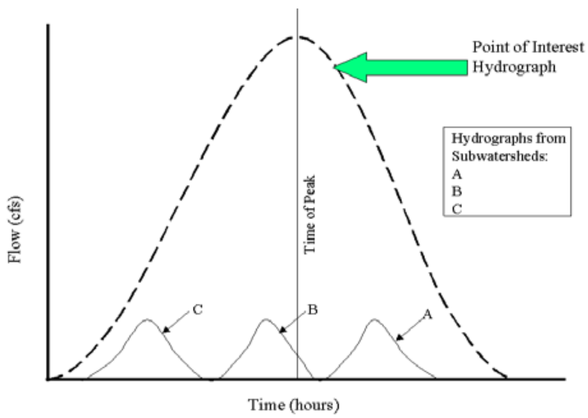
Figure 4.5.F Points of Interest Used for Modeling to Determine Release Rates

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

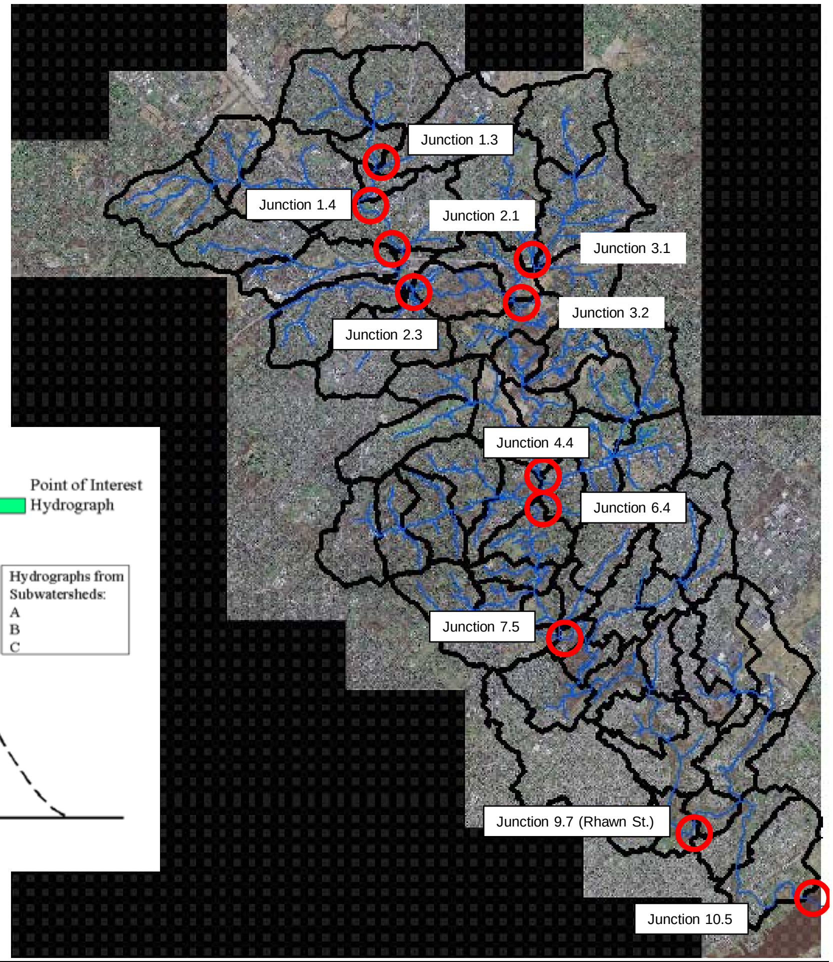
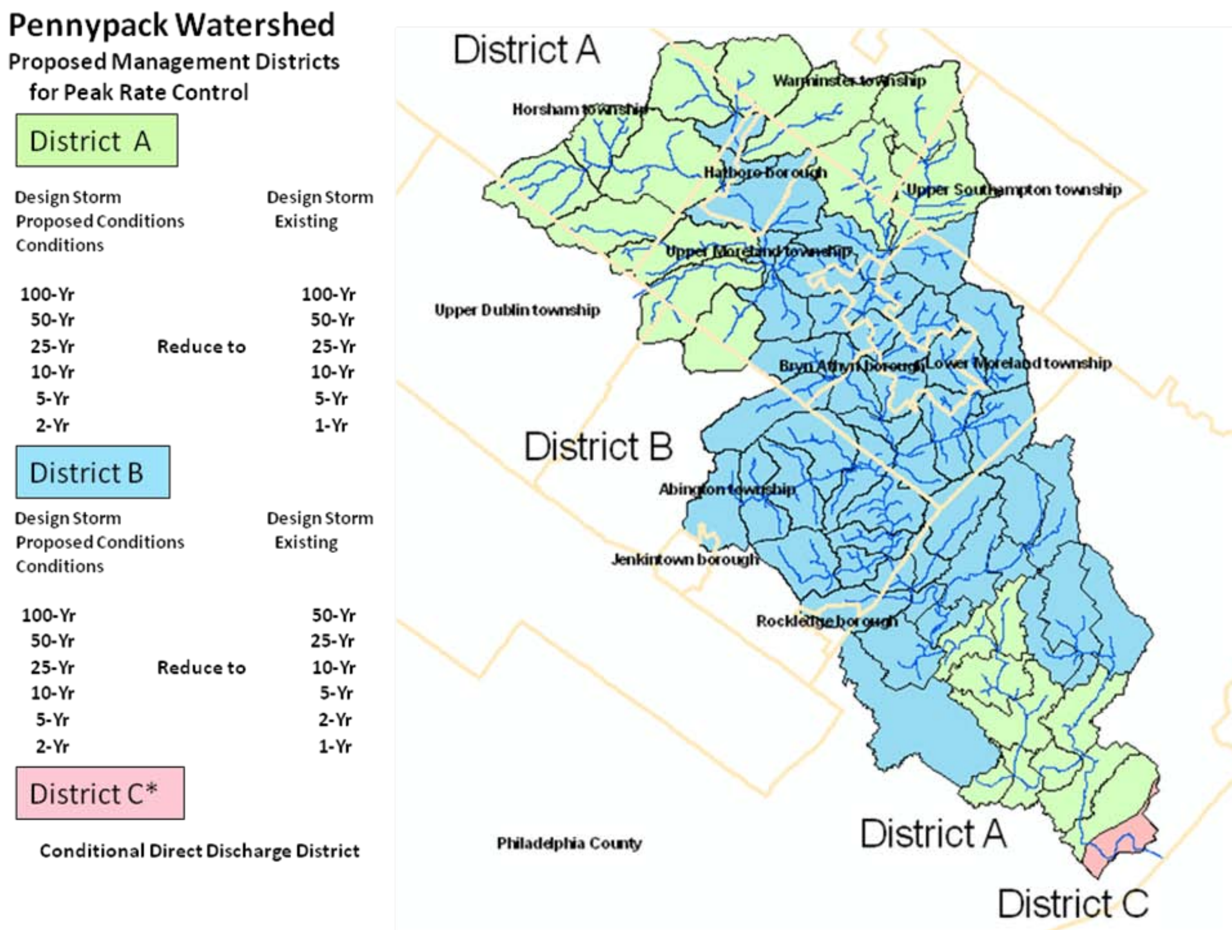


Figure 4.5.G Proposed Peak Rate Control Management Districts



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 New Impervious Cover						
		< 1,000 sq. ft.			≥ 1,000 to < 5,000 sq. ft.			≥ 5,000 sq. ft.
		Earth Disturbance <5,000 sq. ft.	Earth Disturbance ≥5,000 sq. ft. - 1 acre	Earth Disturbance > 1 acre	Earth Disturbance <5,000 sq. ft.	Earth Disturbance ≥5,000 sq. ft. - 1 acre	Earth Disturbance > 1 acre	All Earth Disturbance Categories
<u>Article III</u> SWM Site Plan Requirements	Development and Redevelopment	Yes	No*	No	No*	No*	No	No
<u>Section 404</u> Nonstructural Project Design	Development and Redevelopment	Yes	No*	No	No*	No*	No	No
<u>Section 405</u> Groundwater Recharge	Development and Redevelopment	Yes	No*	No	No*	No*	No	No
<u>Section 406</u> WaterVolume Control Requirements	Development and Redevelopment	Yes	No*	No	No*	No*	No	No
<u>Section 407</u> Stream Bank Erosion Requirements	Development	Yes	No*	No	No*	No*	No	No
	Redevelopment		Yes		Yes	Yes		
<u>Section 408</u> Stormwater Peak Rate Control and Management Districts	Development and Redevelopment	Yes	No*	No	Yes	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	See Earth Disturbance Requirements	See Earth Disturbance Requirements
		(Refer to municipal earth disturbance requirements, as applicable)						

Notes:
Yes – Exempt unless a determination is made by the municipality that the project is subject to Section 106.C. SWM Site Plan may still be required by other sections or provisions.
No – Not exempt. All provisions apply.
No* – Modified SWM Site Plan required, Small Project Site Plan possible.
- Sites with less than one thousand (1,000) 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 through 408. The applicant can use the protocols in the Small Project SWM Site Plan if Municipality has adopted Subappendix A1.

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		
		< 5,000 sq. ft.	≥ 5,000 sq. ft. but < 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**	Yes	Yes (Alternate Criteria)
Section 408 Flood Control / Stormwater Peak Rate Control and Management Districts Requirements	New Development	N/A**	No	No
	Redevelopment	N/A**	Yes (Alternate Criteria)	Yes (Alternate Criteria)

Yes (Alternate Criteria) – Redevelopment sites with one acre or more of earth disturbance and can demonstrate a twenty percent reduction in DCIA from predevelopment conditions are exempt from the Channel Protection/Streambank Erosion (Section 407) Requirements of this Ordinance. All redevelopment sites that can demonstrate a twenty percent reduction in DCIA from predevelopment conditions are exempt the Flood Control/Peak Rate Control (Section 408) Requirements of this Ordinance.

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

Yes – 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.)*

<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) 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

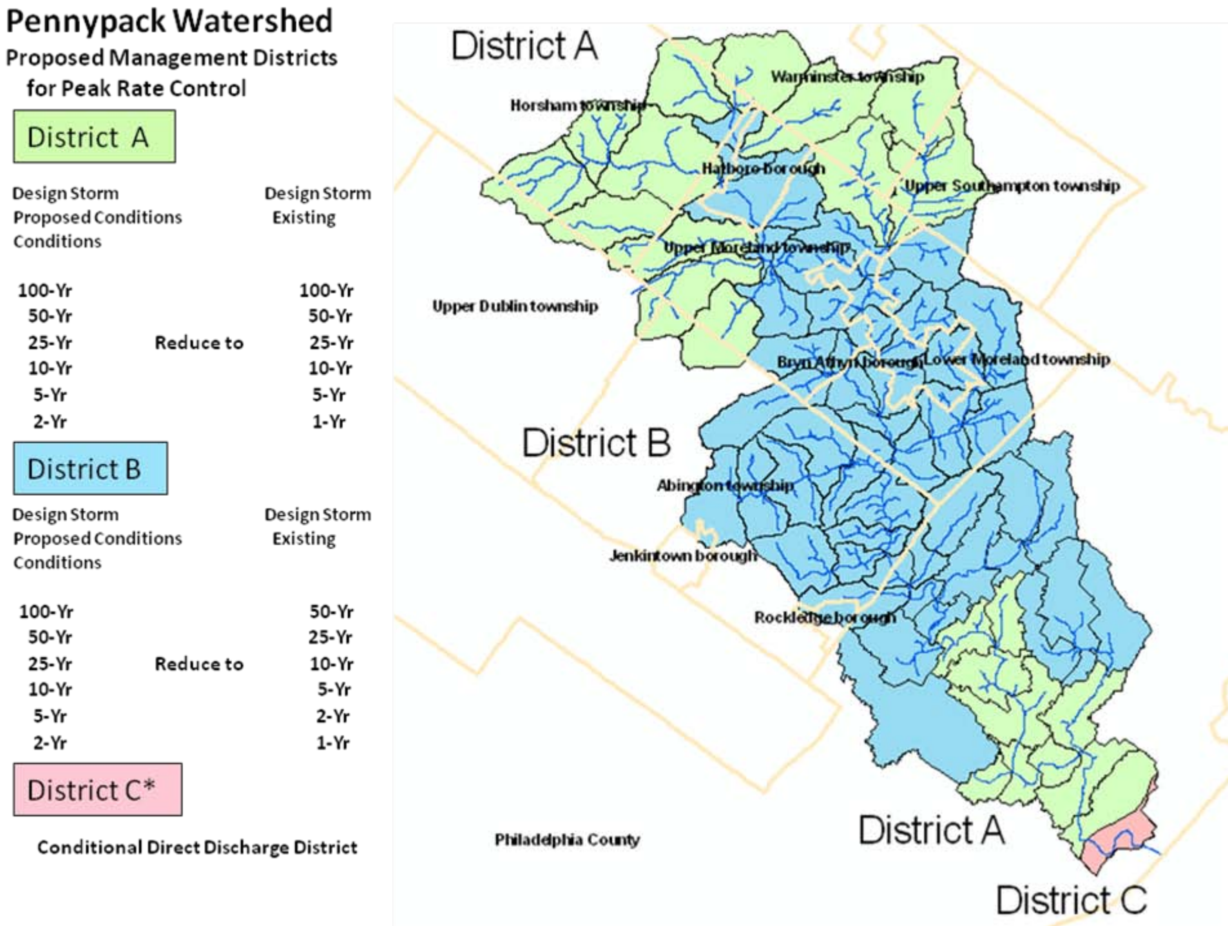
District	Proposed Condition Design Storm		Existing Condition Design Storm
A	2-year	Reduce to	1-year
	5-year		5-year
	10-year		10-year
	25-year		25-year
	50-year		50-year
	100-year		100-year
B	2-year	Reduce to	1-year
	5-year		2-year
	10-year		5-year
	25-year		10-year
	50-year		25-year
	100-year		50-year
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.

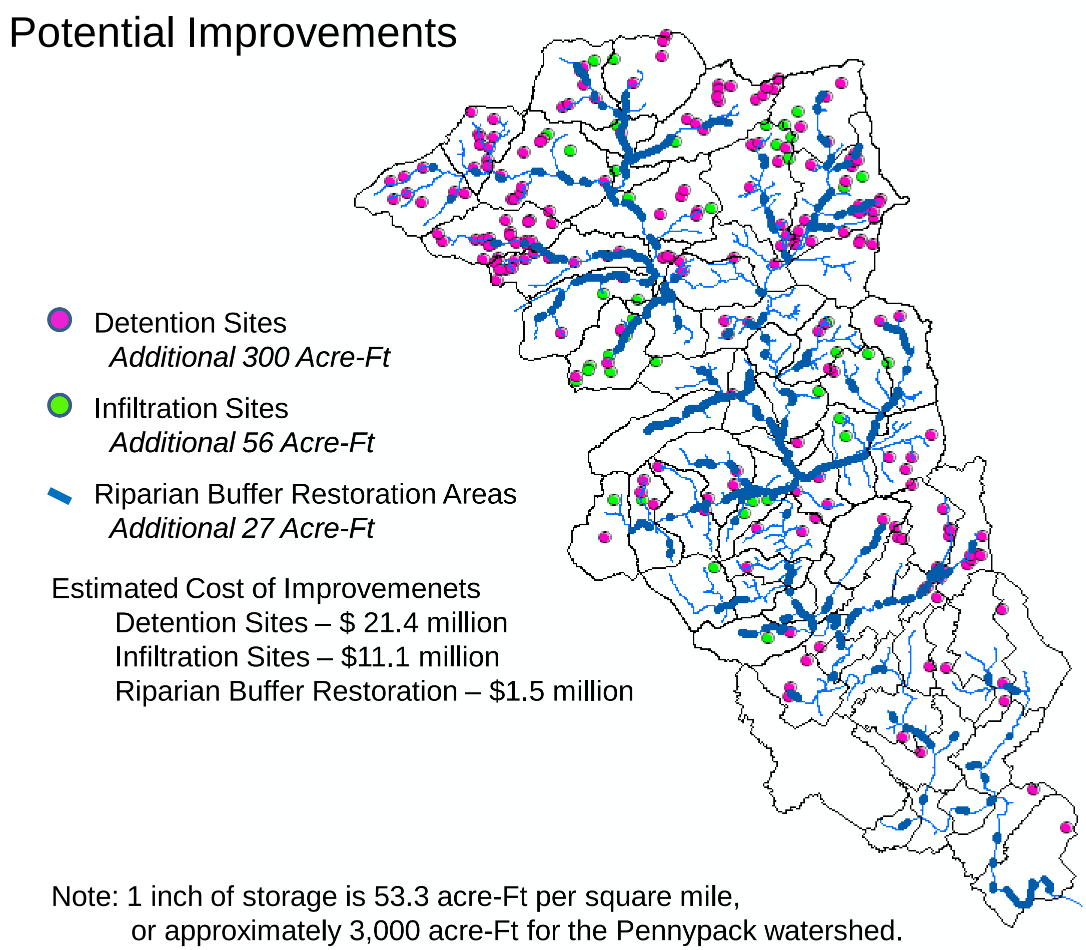
Figure 5.3.A Proposed Peak Rate Control Management Districts



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:

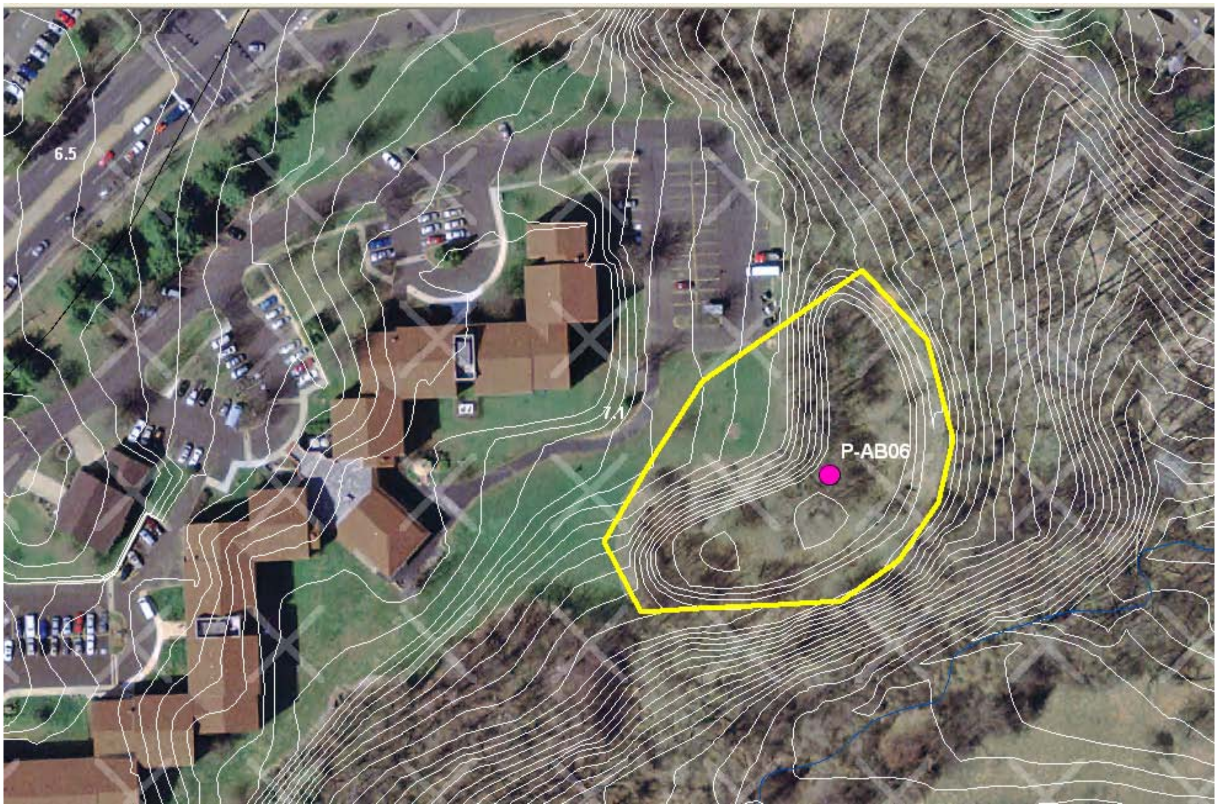
- Site ID
- Subbasin
- Municipality
- Cross reference to Site ID used in original Pennypack study where applicable
- Location or nearby intersection
- Public or Private Ownership
- Current Land Use
- Receiving Watershed
- Existing Depth
- Existing Area
- Existing Volume
- Potential Additional Volume
- 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

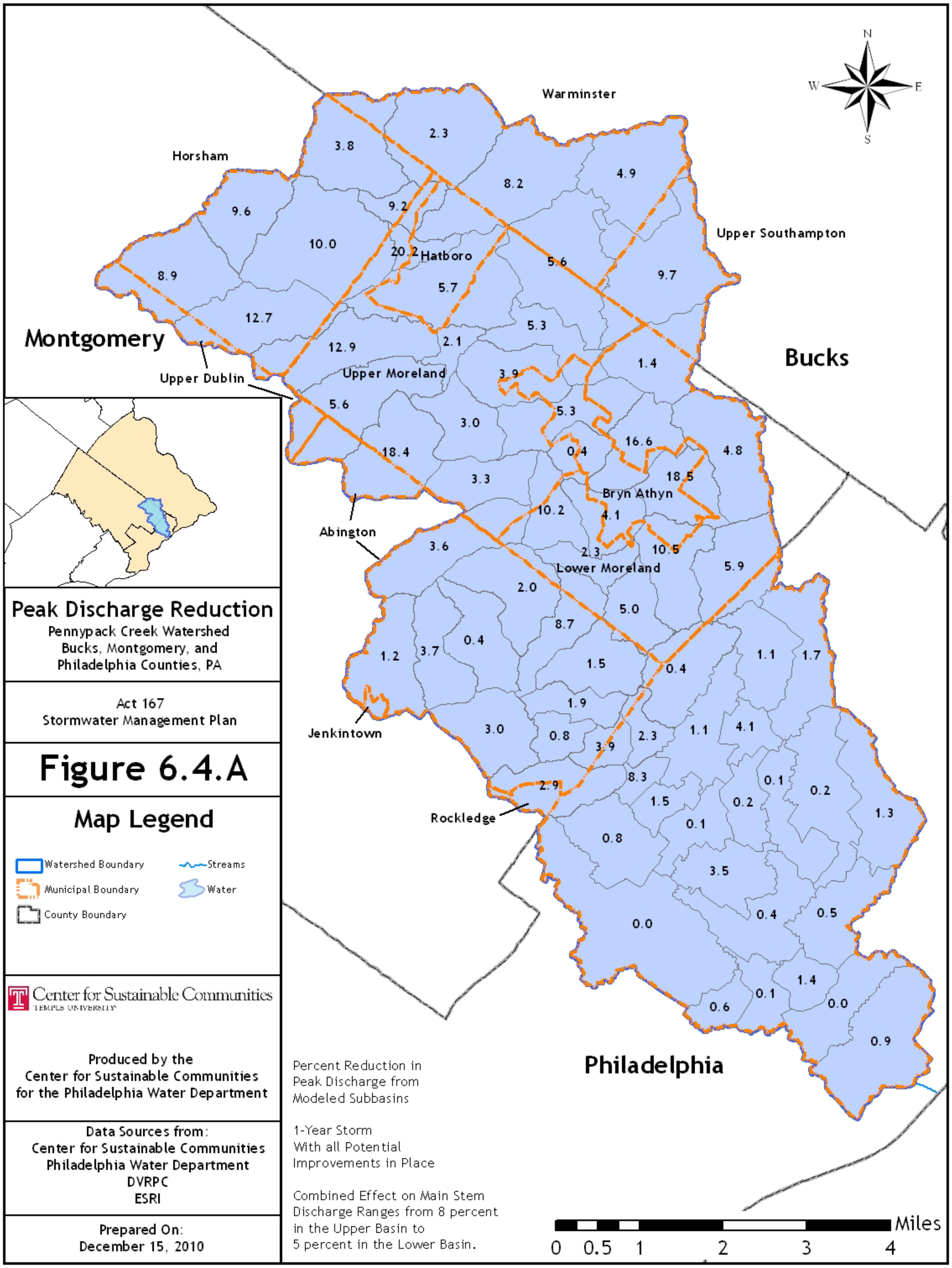
Restoration for one side of stream. Width = 75 ft.

6.4 Hydrologic and Water Quality Impact of the Proposed Improvements

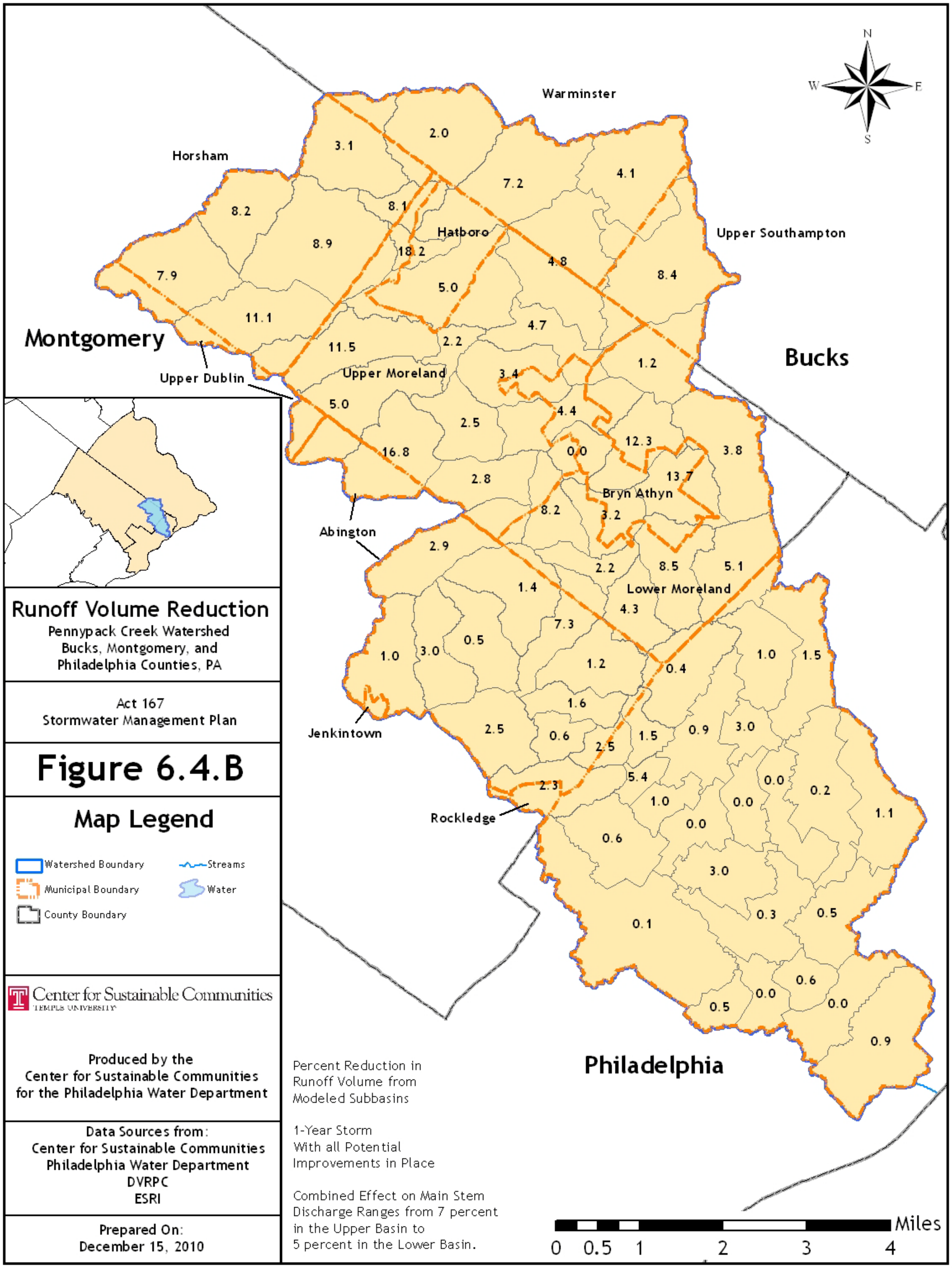
The modeling to evaluate the effect of the proposed improvements is summarized in Section 4.5 of this report. The combined potential additional storage provided by the three categories of improvements is estimated at 383 acre-feet, or 128 million gallons. This volume of storage is equivalent to 0.13 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
Abington
Bryn Athyn
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



Runoff Volume Reduction

Pennypack Creek Watershed
Bucks, Montgomery, and
Philadelphia Counties, PA

Act 167
Stormwater Management Plan

Figure 6.4.B

Map Legend

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

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

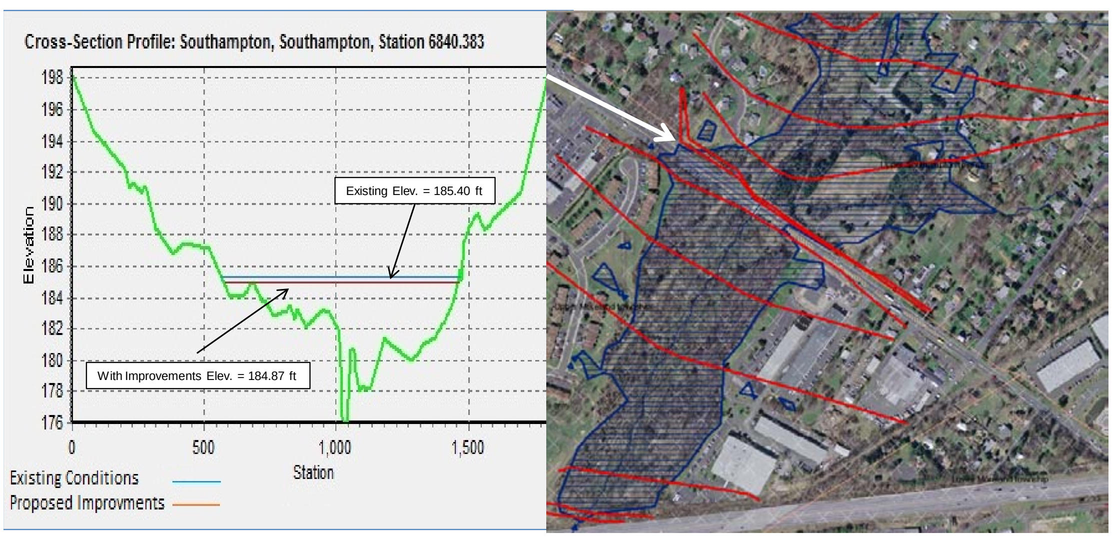
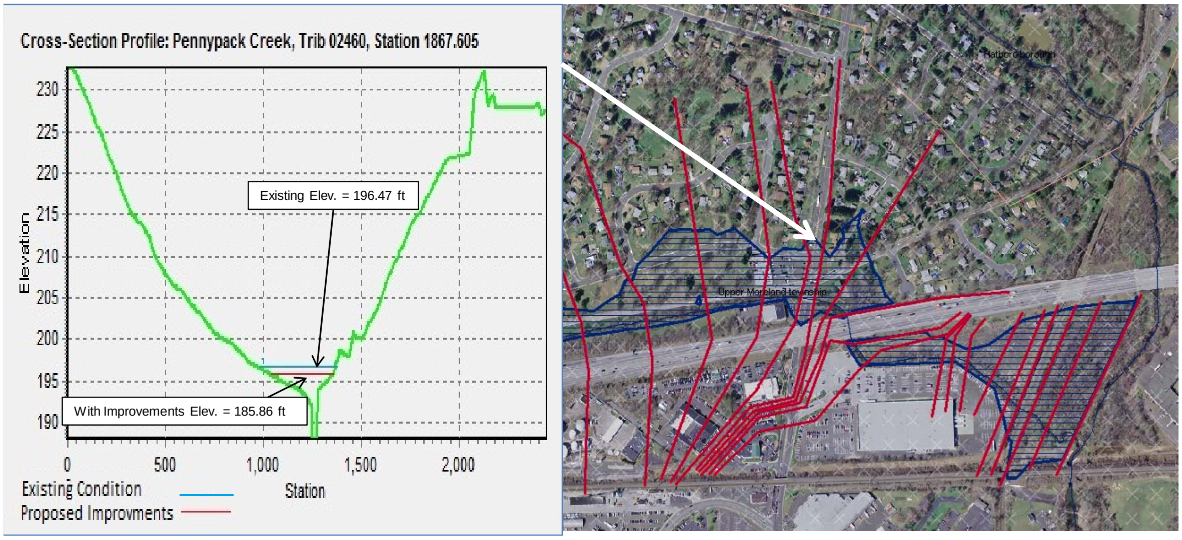


Figure 6.4.E
Tributary to Pennypack Creek at York &Mill Roads, Upper Moreland Twp, Montgomery Co.
Modeled Elevation Change with All Improvements in Place = 0.6 ft for 2-Yr Storm Event

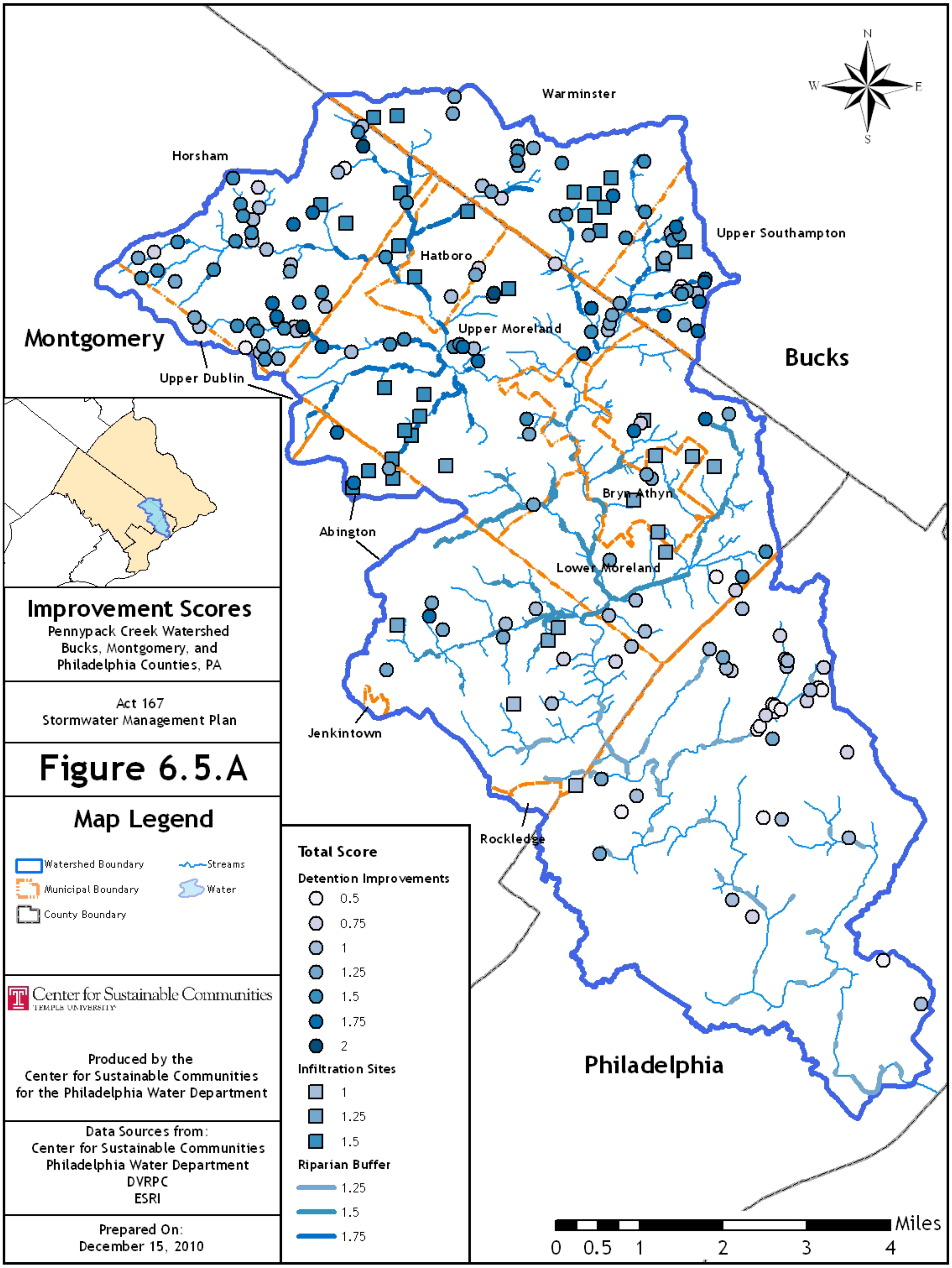


6.5 Improvement Site Ranking

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
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
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
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
0 0.5 1 2 3 4
Miles

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	Spring 2012	Counties, DEP
Adopt and Enforce Ordinances	Six Months after DEP Adoption	Municipalities
Construct Improvements	2012-2017	Municipalities
Monitor Plan and Ordinances	Annual	Counties
Update Plan	2017	Counties