Stormwater Management Guidance Manual

Version 2.1

Revised: February 10, 2014

City of Philadelphia

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Planning & Research
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Philadelphia Stormwater Management Guidance Manual Version 2.1

The Stormwater Management Guidance Manual has been revised to appropriately represent current plan review policies, procedures, and regulations, and to reflect changes to Earth Disturbance, Project Expiration, Flood Management Districts, Operation & Maintenance Agreement, and Record Drawing policies. Outlined below are some of the critical revisions, as well as a complete list of chapters where revisions were incorporated.

Chapter 1: Section 1.1.1 Stormwater Ordinance and Regulations has been updated to reflect existing plan review policies as they relate to the Water Quality Requirement.

Chapter 2: Section 2.1 Earth Disturbance includes a revised definition of earth disturbance. **Section 2.2.4 Stormwater Management Requirements** has been revised to provide clarity regarding exemptions to the requirements and the appropriate method for calculating DCIA.

Chapter 4: Within **Section 4.2**, **Disconnect Impervious Cover** has been updated to clarify the requirements for pavement disconnections, and **Maximize Tree Canopy Over Impervious Cover** has been updated to clarify the requirements for reductions in DCIA as they relate to street trees and existing tree canopies. Within **Section 4.3**, **Estimate Level of Control Needed** has been revised to include updated Flood Management District rates and provide additional clarity for Channel Protection and Flood Control exemptions.

Chapter 5: Within **Section 5.3**, **Runoff Estimation** expands on factors that must be considered in runoff calculations and **Storm Sewer Design** includes revisions to the storm sewer design requirements. **Section 5.4 Operation and Maintenance Agreement** incorporates a new Manual section and includes revisions to the submittal requirements and compilation process, and **Record Drawings**, also a new Manual section, includes revisions to the Record Drawing requirements, and the submittal and review process.

Chapter 7: Section 7.1 Green Roofs has been revised to clarify requirements and recommended design procedures. **Section 7.2 Rain Barrels and Cisterns** has been revised to prohibit irrigation as an acceptable strategy for meeting the Regulations through the use of cisterns. **Section 7.5 Bio-infiltration/Bio-retention** has been revised to clarify recommended design procedures including the static storage requirement, infiltration testing, stone type, and soil depth and mulch specifications. **Section 7.12 Subsurface Infiltration** incorporates additional design procedures and expanded Construction Guidelines, as well as clarifies requirements for clean washed stone. **Section 7.13 Porous Pavement** has been revised to include updated design recommendations. **Section 7.15 Inlet and Outlet Controls** includes revised design requirements and maintenance recommendations for inlet and outlet structures.

Chapter 8: Section 8.1 Planting Recommendations/Guidelines has been revised to identify prohibited noxious weeds. Bioretention planting soil recommendations in **Section 8.2 Facility Specific Landscaping Guidance** have been updated. Vinca minor has been removed from the table of common invasive species within **Section 8.4 Prohibited Non-native and Invasive Plants**.

Appendices: Appendix A: Hotspot Investigation Procedures Section A.2 has revised required steps. **Appendix B: Infiltration Testing Procedures** includes procedural revisions and a discussion of when soil amendments are acceptable. **Appendix D Maps: Zones for Acceptable Practices** includes updated watershed boundaries, collection system locations and flood management district information.

Worksheets 2, 3A, 3B, and **4** and **Checklist B** have also been revised, and the **Infiltration Waiver Request Form** has been updated, as well.

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1 Introduction

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1.1 Background

1.1.1 Stormwater Ordinance and Regulations

Existing Policy

Chapter 14-704(3) of Philadelphia's Code houses the stormwater legislation for the City. See the following Code sections:

§14-704(3).	Stormwater Management
§14-510.	WWO, Wissahickon Watershed Overlay District
§14-704(4).	Flood Protection

The Philadelphia Water Department (PWD) Stormwater Management Regulations (Stormwater Regulations) have been developed as per the Philadelphia Code, Chapter 14-704(3).

Overview of the Stormwater Regulations

There are three major elements to the Stormwater Regulations: Water Quality, Channel Protection, and Flood Control requirements.

<u>Water Quality Requirement</u>

The Water Quality requirement stipulates management of the first one inch of runoff from all Directly Connected Impervious Areas (DCIA) within the limits of earth disturbance. The Water Quality requirement is established to: (1) recharge the groundwater table and increase stream base flows; (2) restore more natural site hydrology; (3) reduce pollution in runoff; and (4) reduce combined sewer overflows (CSO) from the City's combined sewer systems. The requirement is similar to water quality requirements in surrounding states and in other major cities.

1) The requirement must be met by infiltrating the water quality volume unless infiltration is determined to be infeasible (due to contamination, high groundwater table, shallow bed rock, poor infiltration rates, etc.) or where it can be demonstrated that infiltration would cause property or environmental damage.

2) A waiver from the infiltration requirement must be submitted and approved if infiltration is not feasible. Waivers are available in **Appendix F.4**: Special Circumstances and Waiver Requests. For projects in which greater than one (1) acre of earth is disturbed and infiltration is requested to be waived due to soil or groundwater contamination, PADEP must evaluate the waiver request concurrently with PWD.

When infiltration is not feasible for all or a portion of the water quality volume, the remaining portion must be treated by a PWD-approved stormwater management practice (SMP). Treatment and release requirements differ for separate and combined sewer areas, but all areas must route a minimum of 20% of the water quality volume through a PWD-approved SMP that provides volume reduction.

- **Separate sewer areas:** 100% of the water quality volume must be routed through an SMP that provides volume reduction, flow attenuation, and water quality treatment.

Combined sewer areas: Runoff from a minimum of 20% of the DCIA must be routed through a PWD-approved volume reducing SMP. The remaining water quality volume must be detained and slow released on-site. The release rate for the water quality volume must not exceed 0.24 cfs per acre of DCIA, and the volume must be detained in each SMP for no less than 24 hours and no more than 72 hours.

Channel Protection Requirement

The Channel Protection requirement is a slow release of the 1-year, 24-hour storm event detained from DCIA. The Channel Protection requirement is established to: (1) protect quality of stream channels and banks, fish habitat, and man-made infrastructure from the influences of high stream velocity erosive forces and (2) reduce the quantity, frequency and duration of CSOs.

The requirement applies equally to rivers and streams, and also to sites discharging to drainage ditches, natural or man-made ponds, and sewers if those systems ultimately discharge to receiving waters. However, the Channel Protection requirement does not apply to redevelopment which is under one acre or discharges to the Delaware River and the Schuylkill River main channels.

Philadelphia's Channel Protection requirement is modeled after those adopted in many other cities and states, including Atlanta, Baltimore, Boston, Detroit, Minneapolis, Portland, Seattle, Washington D.C., Maryland, New Jersey, and New York.

Channel Protection requirement: Detain and release DCIA runoff at a maximum rate of 0.24 cfs per acre in no less than 24 hours and no more than 72 hours.

Reducing DCIA within the linmits of earth disturbance by 20% between the predevelopment and post-development condition EXEMPTS redevelopment projects from the Channel Protection requirement.

The Water Quality and Channel Protection requirements are not additive. Management of the Water Quality requirement may reduce the storage volume required to meet the Channel Protection requirement. It might also be possible to meet both requirements in the same SMP or in a train of linked SMPs.

Flood Control Requirement

The Flood Control requirement is established to: (1) reduce or prevent the occurrence of flooding in areas downstream of the development site, as may be caused by inadequate sewer capacity or stream bank overflow and (2) to reduce the frequency, duration and quantity of overflows in combined sewer sheds.

The Flood Control requirement is based upon ongoing watershed wide Pennsylvania Stormwater Management Act (Act 167) planning studies determining flood management districts for controlling peak rates of runoff. In general, a development project is required to meet peak rates of runoff post-development equal to pre-development conditions. As Act 167 planning programs are completed for Philadelphia's watersheds, new Flood Control Districts will be listed in the Manual which will more accurately reflect the level of flood protection needed in localized settings.

In Flood Management District C, development sites which can discharge directly to the Delaware River or Schuylkill River main channels without the use of City infrastructure may do so without control of proposed conditions peak rate of runoff. When adequate capacity in

the downstream system does not exist and will not be provided through improvements, the proposed conditions peak rate of runoff must be controlled to the pre-development conditions peak rate as required in District A provisions for the specified design storm.

Reducing DCIA within the limits of earth disturbance by 20% between the predevelopment and post-development condition EXEMPTS redevelopment projects from the Flood Control requirement.

1.1.2 The Changing Regulatory Environment

Stormwater runoff from almost all the developed areas of the City, whether served by separate stormwater sewers or combined sewers, is causing impairment to the aquatic and riparian habitats of streams and rivers in Philadelphia. These water bodies are suffering from streambank and channel erosion resulting in the exposure of sewer infrastructure and decreased stream baseflow due to reduced groundwater recharge. The streams do not support healthy aquatic communities, do not meet uses designated by the State, do not serve as amenities to the community, and occasionally causes property damage due to flooding. In addition, stormwater is an important source of pollution to the drinking water intakes on the Schuylkill and Delaware Rivers.

These problems are not unique to Philadelphia. Stormwater Regulations are changing around the country to address these and similar problems. In general, these newer approaches to stormwater management require controls to improve the quality of stormwater prior to discharge, to reduce the effects of stormwater caused erosion and siltation, and measures to increase groundwater recharge. The Stormwater Regulations in Philadelphia ensures that Philadelphia has an up-to-date and effective stormwater program that meets the state and federal requirements and can be coordinated with the changing Regulations occurring in upstream municipalities.

The Stormwater Regulations were developed to meet a number of environmental, economic, social and regulatory goals for the City:

<u>Quality of Life – Along the Riverfront and in the Neighborhoods</u>

The quality of life for people living and working in Philadelphia depends on both a healthy economy and a healthy environment. Philadelphia sits at the confluence of the Schuylkill and Delaware Rivers and has an extensive park system that conserves most land along its smaller creeks in a natural condition. This creates an opportunity for improved recreational and economic activities along the waterfronts and stream corridors. Philadelphia is making a substantial public investment in parks, greenways (links between neighborhoods and water corridors), and access to water-based activities over the coming decades to identify itself as a New River City. Effective stormwater management is necessary to make these riverfront and stream corridor areas safe and inviting.

<u>Flooding</u>

Historically, Philadelphia's stormwater management requirements have focused on avoidance of flooding caused by increases in impervious coverage. These measures have been generally effective and will be continued. However, some problem areas have been identified in existing developed areas through the Act 167 program. As Act 167 planning studies continue for Philadelphia's watersheds new Flood Control Districts will be determined that more accurately reflect the level of flood protection needed in localized settings. The Stormwater Regulations will ensure that, over time, flooding frequency and severity will decrease as areas are redeveloped according to the stormwater requirements.

<u>Impaired Water Bodies and TMDLs</u>

The Commonwealth of Pennsylvania designates uses that streams and rivers are required to support. These uses generally include water supply, recreation and fish consumption, and support of healthy aquatic communities. Currently, every river and stream in the City is listed as impaired,

or not attaining its designated uses. Urban runoff, storm sewers, and CSOs are listed as sources of impairment for most Philadelphia streams. Some water bodies are listed as impaired by specific pollutants. For these, the State ultimately requires TMDL (Total Maximum Daily Load) to be set and attained. A TMDL is the maximum load of a specific pollutant that can be discharged by all sources and still allow the stream to meet water quality standards. The Stormwater Regulations are designed to significantly reduce the pollution associated with stormwater and CSOs, and will be a significant part of the measures used to attain TMDLs.

NPDES Stormwater Permits and Regulations

Storm sewers discharging to surface waters in Philadelphia are regulated under NPDES (National Pollution Discharge Elimination System). Measures required under NPDES stormwater permits include stormwater management during construction and stormwater management on the developed site after construction. The Stormwater Regulations keep Philadelphia in compliance with requirements in its stormwater permit.

Pennsylvania Stormwater Management Act

The Pennsylvania Stormwater Management Act (Act 167) is administered by Pennsylvania Department of Environmental Protection (PADEP) and is designed to address the management of stormwater runoff resulting from development. Act 167 addresses both water quantity and quality, but it is most focused on quantity and flooding issues. Philadelphia collaborated with Delaware, Montgomery, and Chester Counties to produce an Act 167 Plan for the Darby-Cobbs Creek in 2004. Ultimately, plans will be produced for Tookany/Tacony-Frankford Creek, Pennypack Creek, Poquessing Creek, and Wissahickon Creek. Due to overlapping requirements of the NPDES and Act 167 programs, PADEP encourages municipalities to develop stormwater management programs that meet the requirements of both concurrently. The Stormwater Regulations bring Philadelphia into compliance and ensure that the entire region has similar stormwater management controls in place.

NPDES Combined Sewer Permits and Regulations

Approximately 47% of Philadelphia's land area is served by sewers that carry sanitary sewage and stormwater in a single pipe. During dry weather, all this flow is treated at water pollution control plants before discharge to receiving waters. During wet weather, total flow exceeds the capacity of the sewer system and a portion of the flow is discharged untreated to receiving waters (combined sewer overflow).

Stormwater management is an integral part of Philadelphia's approach to CSO management. United States Environmental Protection Agency's (USEPA) CSO Control Policy, published in 1994, promotes effective stormwater management on a watershed basis. The most effective SMPs increase infiltration and evaporation at the site level and reduce the amount of wet weather flow in the sewer system. Other SMPs detain stormwater and release it to the sewer system at a slower rate, taking advantage of sewer system capacity over a longer period of time. These techniques are most effective during small storms. Techniques designed to limit streambank erosion and flood damage during large storms work equally well in areas of combined sewers and separate storm sewers. The Stormwater Regulations will, over time, significantly decrease the number of CSOs and are necessary if Philadelphia is to comply with federal and state CSO policy.

Drinking Water Source Protection

The Delaware River and Schuylkill River are sources of drinking water for Philadelphia residents. The intakes on these rivers are also influenced by the water quality found in the Wissahickon, Pennypack, and Poquessing Creeks. Protection of source water is critical to citizen health and future economic development in Philadelphia. One of the many critical links between the Stormwater Regulations and the protection of Philadelphia's drinking water sources is USEPA's Surface Water Treatment Rule (SWTR) to address microbial and virus contamination. The SWTR requires that a surface water system have sufficient treatment to reduce source water

concentrations of *Giardia lamblia* cysts and viruses by at least 99.9% (3 log) and 99.99% (4 log), respectively. A watershed control program that includes reduction in stormwater related pollutant loads will be an important aspect of meeting these microbial and virus reduction requirements.

Improving the Development Process in Philadelphia

Clarification of stormwater management requirements and simplification of the development process can benefit both the environment and the economy. Efforts to redevelop vacant and abandoned lands provide opportunities to integrate better stormwater management with economic development. The Stormwater Regulations are designed to create standards consistent with industry practice, to provide checklists and manuals so that developers know exactly what is required, and to apply known, objective standards to all new development or redevelopment applications.

1.2 Organization

This Manual is intended to guide the developer in meeting the requirements of the Stormwater Regulations. Currently some practices and design methods in this manual are considered standards while others are simply recommendations. It is likely that with future revisions some elements will become more prescriptive while others become less prescriptive. Please be aware that these changes might occur and that the most up-to-date version can always be found at the Philadelphia Stormwater website http://www.pwdplanreview.org/.

The Manual is laid out to guide the developer through the entire site design process, beginning with initial site design considerations, through the Post-Construction Stormwater Management Plan (PCSMP) submittal elements, and ultimately PWD prerequisite approval on Building Permit approval. Tools are provided to assist in completion and submittal of a PCSMP consistent with the intent of PWD. They include flowcharts to guide the developer through each section, worksheets to assist with calculations, and checklists to ensure the PCSMP is complete. These tools work together to address stormwater management on the development site from concept to completion.

Each section of the Manual has been arranged with a specific purpose in mind:

- **Section 1** provides an overview of how and why stormwater management is a critical part of holistic site planning in Philadelphia.
- **Section 2** discusses the applicability of the Stormwater Regulations.
- **Section 3** covers preliminary site planning considerations and conceptual review.
- **Section 4** steps through an integrated site design process once the initial site layout is determined. This section describes approaches for using Nonstructural and Structural Controls to manage stormwater.
- **Section 5** explains all of the elements necessary for completing and submitting the PCSMP for the development project.
- **Section 6** presents methods for integrating stormwater management into site design for both non-structural and structural SMPs applicable to urban development in Philadelphia.
- **Section 7** presents technical design guidance for managing stormwater and specifications for structural SMPs.
- **Section 8** provides landscape guidance for non-structural and structural SMPs and lists recommended native plant species as well as prohibited invasive species.

1.3 How to Use this Manual

The following flow chart depicts how the manual can be used to work through the development review process.

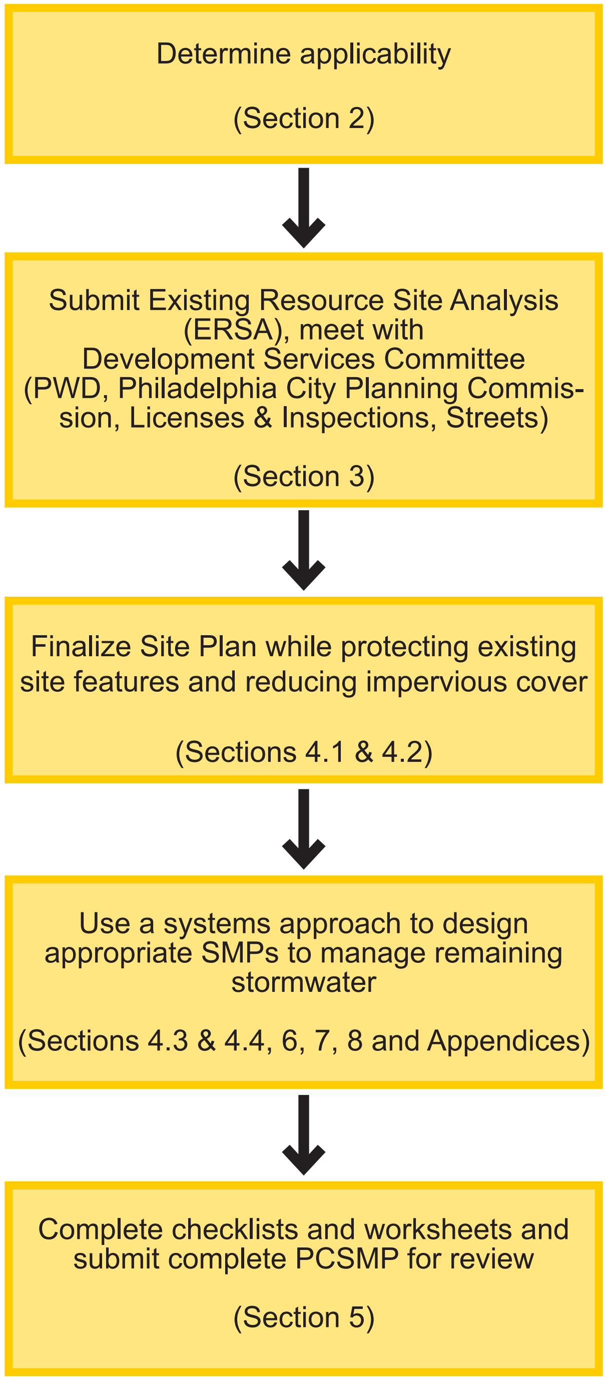

Figure 1.1: Using the Manual

Checklists and Worksheets are provided electronically on http://www.pwdplanreview.org/ in the Technical Libary under the Stormwater Management tab to assist the developer in meeting the requirements of the Stormwater Regulations.

2 Applicability and Approval

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2.0 Introduction

All projects that generate earth disturbance of 5,000 square feet or more must be reviewed by the Philadelphia Water Department (PWD) and must obtain PWD signature on a building or demolition permit application before said permit will be issued by the Department of Licenses and Inspections (L&I). The requirements that must be met to obtain PWD's approval for commencement of earth disturbance activity depend on the project size and location. The requirements include six main components. In general terms these are the Water Quality, Channel Protection, Flood Control, Non-structural Project Control, Erosion and Sediment Pollution Control, and the Post-Construction Stormwater Management Plan requirements.

<table>
<tr><th colspan="2">Table 2.1: Primary Components of Requirements</th></tr>
<tr><th>Stormwater Requirements</th><th>Technical Details</th></tr>
<tr><td>Non-structural Project Control: Use of practical alternatives to surface discharges of stormwater, creation of impervious surfaces, and protection of Waters of the Commonwealth.</td><td>Section 4.1: Protect and Utilize Existing Site Features

Section 4.2: Reduce Impervious Cover to be Managed</td></tr>
<tr><td>Water Quality: Management of the first one inch of runoff from Directly Connected Impervious Areas (DCIA) within the limits of earth disturbance.</td><td rowspan="3">Section 4.3.1: Estimate Level of Control Needed</td></tr>
<tr><td>Channel Protection: Management of the 1-year, 24-hour, NRCS Type II storm event such that the peak rate of discharge does not exceed 0.24 cfs per acre of DCIA.</td></tr>
<tr><td>Flood Control: Attenuation of runoff from larger storm events required depending upon project location within the City.</td></tr>
<tr><td>Erosion and Sediment Pollution Control (E & S): Plan must be prepared in accordance with Pennsylvania Department of Environmental Protection (PADEP) guidelines.</td><td>Section 5.1: Erosion and Sediment Pollution Control Plan</td></tr>
<tr><td>Post-Construction Stormwater Management Plan (PCSMP): Submittal to PWD demonstrating compliance with the PWD Stormwater Management Regulations (Stormwater Regulations).</td><td>Section 5.2: Components of the Post-Construction Stormwater Management Plan</td></tr>
<tr><td colspan="2">Note: Some redevelopment projects may be exempt from the Channel Protection and Flood Control requirements.</td></tr>
</table>

2.1 Earth Disturbance

It is important for the applicant to properly assess the limits of earth disturbance associated with the construction project in order to determine applicable requirements and the level of review and approval required. A project may have multiple boundaries, each of which has significance when determining applicability during the development process. For example, the parcel boundary, earth disturbance, and area that must be managed for stormwater may all be different. The trigger for determining the Stormwater Regulations apply to a project is the area of earth that is disturbed as part of the project. However, some areas within the limits of earth disturbance do not require stormwater management. In the discussion that follows descriptions of earth disturbance boundaries provide guidance on determining the area that is subject to the Stormwater Regulations.

What is earth disturbance:

Earth disturbance is defined as any human activity which moves or changes the surface of land. All earth disturbance activities must be included on all E & S Plans. Examples of earth disturbance include, but are not limited to, the following activities:

- Land Development
- Utility Connections (Including work in public rights-of-way: sidewalks and roads)
- Private Roads
- Rock Construction Entrances
- Stockpiles
- Temporary Stockpiles
- Construction Vehicle Paths
- Grading
- Excavation
- Clearing and Grubbing
- Embankments

What is not earth disturbance:

- Interior renovations
- Temporary stockpiles on existing impervious surfaces
- Restriping of paved areas
- Milling and repaving of paved areas, as long as the subbase is not exposed during the milling process

Stormwater runoff from the following earth disturbance areas within the public ROW does not need to be managed as part of the PCSMP:

- Replacement of existing public roads when stormwater runoff characteristics are not significantly altered as part of development
- Replacement of existing public sidewalks as part of the development project. When calculating the total limit of disturbance for the development project, the earth disturbance area associated with public sidewalk replacement should not be counted toward the total disturbance value triggering the Regulatory threshold.

Stormwater runoff from the following earth disturbance areas within the public ROW must be managed as part of the PCSMP:

- New public streets, as determined by Philadelphia Department of Streets, Philadelphia City Planning Commission (PCPC), and PWD
- New private streets and private sidewalks

When in doubt be conservative:

- Projects that are close to 15,000 square feet of earth disturbance are required to provide an E&S Plan, signed and sealed by a Pennsylvania Licensed Professional, clearly delineating the limits of disturbance before PWD will confirm that Stormwater Management requirements are not applicable to the project. Should a site inspection reveal that more than 15,000 square feet have been disturbed, the site will be required to comply with the Stormwater Regulations and will be subject to the enforcement actions outlined in the Stormwater Regulations.
- Should a site inspection reveal that more than 1 acre of earth disturbance, the site will be required to apply for a PADEP NPDES (National Pollutant Discharge Elimination System) Permit. The site will be subject to the enforcement actions outlined in the Stormwater Regulations until the applicant receives an approved NPDES Permit.
- Please contact PWD Stormwater Plan Review should you need additional clarification regarding what is and is not an earth disturbance activity.

2.2 Determining Applicability

The review components for both Stormwater Management and Erosion and Sediment Control depend on the limits of earth disturbance associated with the project as well as the watershed in which the project is located. Table 2.1 summarizes the requirements that each site must meet. Additional information on each the requirements is provided below.

2.2.1 Conceptual Review

All projects with that generate an earth disturbance of 5,000 square feet or more must submit an Existing Resources and Site Analysis (ERSA) worksheet to PWD for conceptual review. See **Table 2.2**: Applicability of Requirements and **Section 3**: Site Planning for more information.

2.2.2 Erosion and Sediment Control

The Owner is responsible for ensuring that their active construction site is not creating violations of 25 Pa. Code Chapters 92 and/or 102 and the Clean Streams Law, the act of June 22, 1937, P.L. 1987, 35 P.S. §691.1 et seq. Depending on the limit of earth disturbance associated with a project there are specific preparation, review, and approval requirements. All E & S Plans must be prepared in accordance with PADEP guidelines as laid out in the following Manual:

PADEP, Bureau of Waterways Engineering and Wetlands. March 2012. *Erosion and Sediment Pollution Control Program Manual.* Document 363-2134-008.

Table 2.2: Applicability of Requirements

Site Information		Project Requirements					
Earth Disturbance Area (square feet)	Project Location	Submit an ERSA	Comply with Stormwater Management Regulations	Implement E & S BMPs as needed	Submit an E & S Plan to PWD	Have an E & S Plan Approved by PWD	Obtain a NPDES Permit
Less than 5,000 square feet	Project is not located in the Wissahickon Watershed			X			
	Project is located in the Wissahickon Watershed	Contact PWD and PCPC for instructions.	Contact PWD and PCPC for instructions.	X	Contact PWD and PCPC for instructions.	Contact PWD and PCPC for instructions.	
More than 5,000 square feet and less than 15,000 square feet	Project is not located in the Darby-Cobbs or Wissahickon Watershed	X		X	X		
	Project is located in the Wissahickon Watershed	X	Contact PWD and PCPC for instructions.	X	Contact PWD and PCPC for instructions.	Contact PWD and PCPC for instructions.	
	Project is located in the Darby-Cobbs Watershed	X	X	X	X	X	
More than 15,000 square feet and less than 1 acre (43,560 square feet)	All project locations	X	X	X	X	X	
More than 1 acre (43,560 square feet)	All project locations	X	X	X	X	X	X

Note: Some projects can physically be located in one watershed while connecting project infrastructure to another watershed. Projects that are in close proximity to watershed and sewershed boundaries will have the receiving watershed reviewed as part of the conceptual plan review process.

It is important for the applicant to properly assess the limits of earth disturbance associated with the construction project in order to determine the level of review and approval required. Once the limits of earth disturbance have been accurately determined the applicant will follow one of the four E & S review paths listed below:

A. Less than 5,000 square feet (not located in the Wissahickon Watershed*)

- E & S Plan is not mandatory.
- Owner **must** implement E & S Best Management Practices in accordance with the PADEP *Erosion and Sediment Pollutant Control Program Manual* (2000).

B. More than 5,000 square feet, less than 15,000 square feet**

- E & S Plan must be **prepared**, implemented, and kept on site at all times during construction.
- The E & S Plan, which complies with the PADEP *Erosion and Sediment Pollutant Control Program Manual* (2000), must be maintained and submitted to PWD, but does not need to be approved.
- If the site is not subject to the Stormwater Regulations, then submit E & S Plans as an attachment to the ERSA online application at http://www.pwdplanreview.org/.

C. More than 15,000 square feet, less than 1 acre (43,560 square feet)**

- E & S Plan must be prepared, **approved**, implemented and kept on site at all times during construction.
- The E & S Plan **must** be reviewed and approved by PWD before earth disturbance can begin.
- Project is subject to Stormwater Regulations and requires a full PCSMP submittal.
- Notify the PWD Inspections Coordinator at least three (3) days prior to commencement of construction activities and SMP installation.

D. More than 1 acre (43,560 square feet)

- E & S Plan must be prepared, **approved**, implemented and kept on site at all times during construction.
- A **NPDES permit application** must be submitted to PADEP. Proof of issuance of the NPDES permit must be provided to PWD before PWD will sign the applicant's Building Permit application. A Building Permit must be issued prior to commencement of any earth disturbance.
- Project is subject to Stormwater Regulations and requires a full PCSMP submittal.
- Notify the PWD Inspections Coordinator at least three (3) days prior to commencement of construction activities and SMP installation.

*Projects located in the Wissahickon Watershed may be subject to additional requirements which will be assessed as part of the project review performed by PCPC staff.

**Projects located within the Darby-Cobbs Creek Watershed with earth disturbance between 5,000 square feet and 1 acre will follow E & S review path C.

2.2.3 Watershed Specific Requirements

The Stormwater Regulations apply to all projects that generate an earth disturbance of 15,000 square feet or more. However, watershed based Regulations can supersede the Stormwater Regulations. Projects will be required to meet the more stringent of the two requirements. There are currently two watersheds in Philadelphia that have specific Regulations which affect the earth disturbance applicability of the Stormwater Regulations. Additional watershed Regulations may be created. For updated information on watershed-specific Regulations, visit the following website: http://www.pwdplanreview.org/.

Darby-Cobbs Creek Watershed

Projects located in the Darby-Cobbs Creek Watershed are subject to the *Darby and Cobbs Creeks Watershed Act 167 Stormwater Management Plan*. Because of this, all projects of over 5,000 square feet of earth disturbance located in the Darby-Cobbs Creek Watershed are subject to the Stormwater Regulations as described below in **Section 2.2.4**: Stormwater Management Requirements.

Wissahickon Watershed

Projects located in Wissahickon Watershed are subject to §14-510 */WWO, Wissahickon Watershed Overlay District* of the Philadelphia Code. The requirements that must be met depend on the location of the project within the watershed, the impervious cover proposed by the project, and the amount of earth disturbance associated with the project. Contact PCPC for more information on the requirements of a specific site.

2.2.4 Stormwater Management Requirements

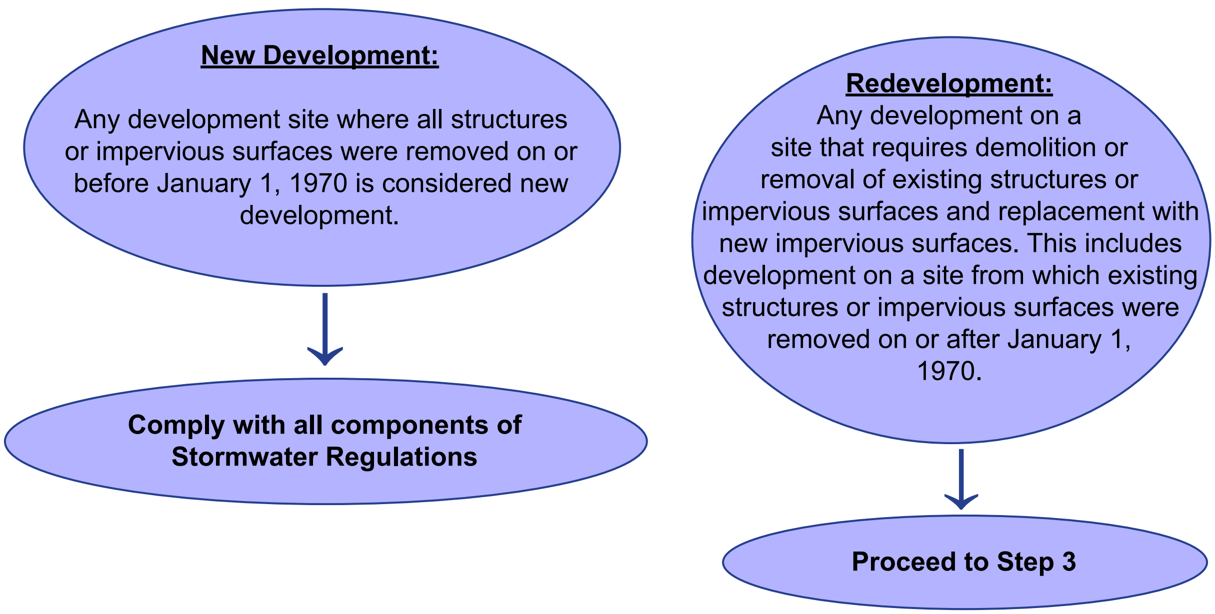
The following steps and flow charts assist in determining applicability and exemption possibilities for a development project.

Step 1: Does my proposed project result in earth disturbance of 15,000 sq ft or more (5,000 sq ft or more in the Darby-Cobbs Creek Watershed)?

> **Yes.** Continue to Step 2 and comply with PADEP (E & S) Controls.
>
> **No.** Is my proposed project located in the Wissahickon Watershed?
>
> > **Yes.** Contact PCPC for instructions.
> >
> > **No.** Comply with PADEP E & S Controls for earth disturbances.

Step 2: Is my development project new development or redevelopment?

Development encompasses both new development and redevelopment and includes the entire development, even when the development is performed in stages. The project will fit into one of the following two categories:



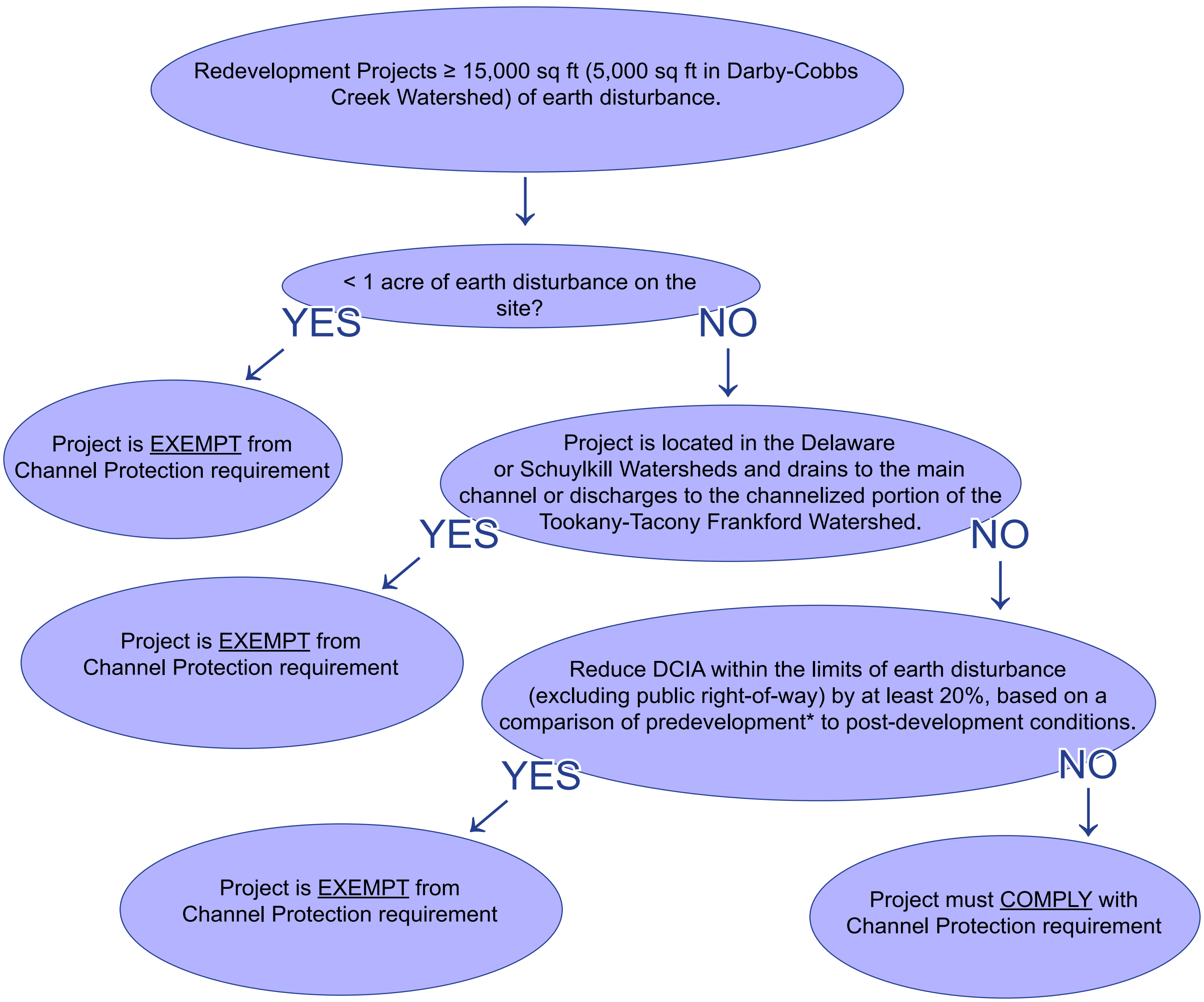
Step 3: Which components of the Stormwater Regulations are required for my development project?

Table 2.3: Required Components of the Stormwater Regulations		
Requirement	**New Development**	**Redevelopment**
Water Quality	Comply	Comply
Channel Protection	Comply	May be Exempt (see step 4)
Flood Control	Comply	May be Exempt (see step 5)
Nonstructural Site Design	Comply	Comply

New Development projects must comply with all components of the Stormwater Regulations.

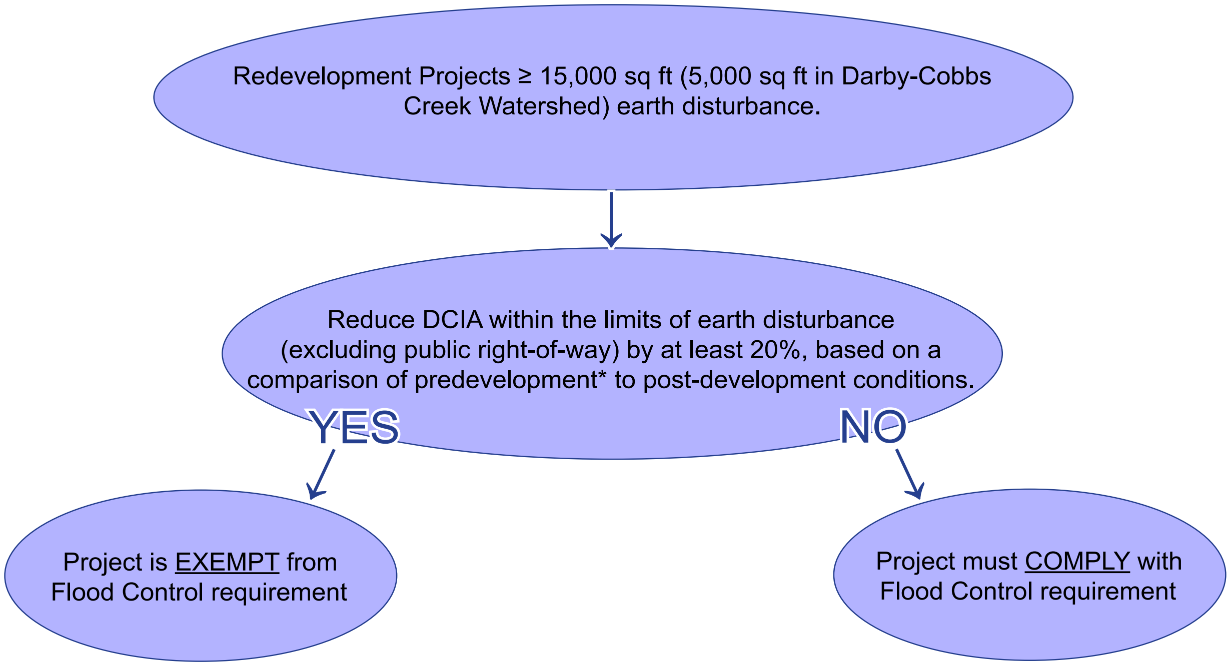
Redevelopment projects must comply with Nonstructural Project Design, and Water Quality requirements. Exemptions and alternative criteria for Channel Protection and Flood Control requirements may be applicable to your project as detailed in the following flow chart.

Step 4: Do I have to comply with the Channel Protection requirement?



* For the purposes of calculating reduction in DCIA from the predevelopment to post-development condition, the predevelopment condition DCIA is determined by the dominant land use for the ten (10) years preceding the project's ERSA submittal.

Step 5: Do I have to comply with the Flood Control requirement?



*For the purposes of calculating reduction in DCIA from the predevelopment to post-development condition, the predevelopment condition DCIA is determined by the dominant land use for the ten (10) years preceding the planned project.

Step 6: What happens next?

After determining which Stormwater Regulations apply to your project site, refer to **Section 3**: Site Planning, **Section 4**: Integrated Site Design, and **Section 5**: Post Construction Stormwater Management Plans for guidance, directions, and requirements before submitting a PCSMP to PWD for approval.

2.2.5 Public Health and Safety Rates

Sites located in areas where known flooding has occurred are required to comply with a maximum release rate (cfs/acre) for the 1 through 10-year storms. This rate is determined by PWD based on analysis of available capacity for the project within the sewershed. If a public health and safety (PHS) release rate is required for your site, it will be noted during the Conceptual Review process. Note, this PHS release rate applies to all area within the project's limit of earth disturbance, not just DCIA.

2.3 The Development Review Process

Stormwater management is one part of the PWD approval process and is only one step in the overall development review process. When a developer has a conceptual idea for a project in Philadelphia, the first step is to conduct an Initial Plan Review with the PCPC. After guidance from PCPC, the developer prepares the ERSA Worksheet, ERSA Map, site photographs, and a Conceptual Site Plan and submit to PWD (See **Section 3**: Site Planning). These must be submitted prior to scheduling a PWD Development Review Meeting. Staff from PWD will provide a Conceptual Review of these materials and, if needed, meet with the developer and their engineers to discuss the Conceptual Site Plan in terms of water and sewer connections, and stormwater management. This meeting is designed to give PWD and developers an opportunity early in the design process to address any potential problem areas and maximize the site's potential.

Upon completion of the PWD Conceptual Review, PWD Staff will send an electronic version followed by a paper copy of the signed and stamped Checklist A: PWD Conceptual Review to the developer. The developer will then complete their Site Plan based on comments received during the Development Review Meeting. A signed and stamped copy of Checklist A: PWD Conceptual Review is one of the required components of a complete Zoning Application.

PWD approval is a required prerequisite on the City's Building Permit application. **Before a Building Permit can be issued by the City of Philadelphia, full PWD approval for Water, Sewer, Erosion and Sediment Control, and Stormwater Management must be obtained.** In order to obtain Stormwater Management approval, the developer must submit a complete PCSMP as described in this Manual (See **Section 5**: Post Construction Stormwater Management Plans). In addition, if more than one (1) acre of earth disturbance will take place on the site, a PADEP issued NPDES Permit must also be obtained before PWD will sign a Building Permit Application.

2.4 Project Expiration Policy

PWD receives and reviews hundreds of projects a year for compliance with the Stormwater Regulations. To maintain appropriate records representing current and ongoing projects related to stormwater management, PWD utilizes a project expiration policy for stormwater management reviews. If a project expires, a new Tracking Number will be required and the project will be subject to the most current Stormwater Regulations and the most current version of the Philadelphia Stormwater Management Guidance Manual along with any Federal, State, and City laws and regulations in effect at the time of submittal. A project is considered Active when a revised plan is submitted for review or, when applicable, the owner/owner representative submits a Project Extension Request for PWD review.

Conceptual Plan Review Phase

A Conceptual Plan Approval will expire after one (1) year of no activity.

Extension: One (1) six-month extension permitted for a total time of eighteen (18) months of no activity.

A Conceptual Plan Rejection will expire after one (1) year of no activity.

Extension: One (1) six-month extension permitted for a total time of eighteen (18) months of no activity.

Post Construction Stormwater Management Plan Review Phase

A Post Construction Stormwater Management Plan Rejection will expire after one (1) year of no activity.

Extension: One (1) six-month extension permitted for a total time of eighteen (18) months of no activity.

A Post Construction Stormwater Management Plan Approval will expire after two (2) years from the date of issuance unless a valid Building Permit is in place.

Extension: None to be granted.

A Post Construction Stormwater Management Exemption will expire after two (2) years from the date of issuance unless a valid Building Permit is in place.

Extension: None to be granted.

A Project Extension Request form can be found under the General Information tab in the Technical Library located at http://www.pwdplanreview.org/.

3 Site Planning

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3.0 Introduction

Philadelphia Water Department (PWD) requires a conceptual review for all projects which are subject to the PWD Stormwater Management Regulations, the *Darby and Cobbs Creek Watershed Act 167 Stormwater Management Plan*, or Philadelphia Code §14.1603.2 *Environmental Controls for the Wissahickon Watershed*. In addition, projects which involve a site larger than 5,000 sq ft may be required by Licenses and Inspections (L & I) to obtain PWD approval for zoning purposes. The Conceptual Site Plan review is designed to assist developers and their engineers in developing a Site Plan that minimizes impacts and stormwater management costs and identifies water and sewer infrastructure constraints and opportunities. This is done early in the development process before significant resources have been spent on final design of the project. This section describes the required submittal items and the review process that must take place during the initial phase of development.

3.1 Site Inventory - Existing Resources and Site Analysis

The developer's first task is to assess features and conditions at the site before design begins. It is during this initial step that the developer is required to complete the **Existing Resources and Site Analysis (ERSA) Worksheet.** Not only does the worksheet assist in site planning, but it is a required submittal for PWD Development Review and included as part of the Post-Construction Stormwater Management Plan (PCSMP) submittal.

The ERSA map or Existing Conditions Plan is intended to help the developer to identify existing features, soil, vegetation, structures (if any), and existing drainage pathways. PWD will discuss opportunities to protect these features and their potential use for more effective post-construction stormwater management. Opportunities identified during the site analysis may help to minimize impacts and stormwater management costs.

For the most recent checklists and worksheets as well as an example Conceptual Site Plan, please refer to the Stormwater Management tab in the Technical Library at http://www.pwdplanreview.org/. Once the existing conditions are analyzed, a Conceptual Site Plan is prepared and the applicant should submit an ERSA submittal. The ERSA Submittal must include the following:

√ ERSA Worksheet (Worksheet 1),

√ ERSA Map,

√ Conceptual Site Plan showing proposed conditions, and

√ Site Photographs (one from each face of the parcel).

All of the above items should be submitted online at http://www.pwdplanreview.org/. PWD will review the ERSA submittal for content and format requirements (see ERSA checklist).

3.2 Philadelphia Water Department Conceptual Review

Upon receipt of the ERSA Submittal (described above), PWD representatives review the submittal and if needed, schedule a meeting with the developer and their engineers to discuss the Conceptual Site Plan in terms of water and sewer connections and availability and stormwater management. Sometimes a meeting with PWD Staff is the most efficient manner in which to address complex site constraints. PWD will schedule a meeting if requested by the applicant or deemed necessary by PWD Staff. The following may take place at the meeting:

- Based on the ERSA, the developer will discuss existing features, soil, vegetation, structures (if any), and existing drainage pathways. PWD will discuss opportunities to protect these features and their potential use for more effective post-construction stormwater management.

- PWD and the applicant will discuss potential issues related to water, sewer, and stormwater design as well as any other PWD concerns associated with the project.

- The developer along with PWD will review the Conceptual Site Plan and discuss ways to minimize impacts and stormwater management cost.

- PWD will provide guidance to developers and assist them with questions regarding the PCSMP Process. This early consultation will contribute to a more effective and economic PCSMP for both the developer and PWD.

Upon completion of the PWD review of the ERSA submittal, PWD Staff will send an electronic copy and hard copy of the following to the applicant:

- Completed Checklist A: PWD Conceptual Review with detailed recommendations for the Site Plan and

- Stamped and signed copy of the Conceptual Site Plan approved for Zoning purposes.

PWD routinely copies the Philadelphia City Planning Commission (PCPC) Staff on the electronic copy of Checklist A and the Conceptual Site Plan to help better coordinate plan reviews. A copy of this checklist is provided in the Technical Library at http://www.pwdplanreview.org/ for reference.

3.3 Site Plan Preparation

Based on the recommendations from PWD, PCPC, and Streets Department, the developer will prepare and submit their complete Zoning Permit Application. As the developer moves forward with Site Plans and Building Plans, they should refer to **Section 4.1**: Protect and Utilize Existing Site Features and **Section 4.2**: Reduce Impervious Cover to be Managed to maximize the efficiency of their Site Plan.

4 Integrated Site Design

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4.0 Introduction

A recommended site design procedure for comprehensive stormwater management is set forth in this section. The site design procedure is based on the Pennsylvania Department of Environmental Protection (PADEP) recommendations, with minor modifications adapted to conditions in Philadelphia. This procedure includes nonstructural controls that reduce the quantity of stormwater to be managed and structural controls that meet the Water Quality, Channel Protection, and Flood Control requirements of the Philadelphia Water Department (PWD) Stormwater Management Regulations (Stormwater Regulations). The integrated site design procedure can be summarized in three steps:

Nonstructural Project Design

1. Protect and Utilize Existing Site Features
2. Reduce Impervious Cover to be Managed

Structural Project Design

3. Manage Remaining Stormwater using a Systems Approach to Stormwater Management Practice (SMP) Design

These steps are implemented initially in sequence and then in an iterative approach leading to formulation of a comprehensive Post Construction Stormwater Management Plan (PCSMP). The intent of the planning process is to promote development of stormwater management solutions that protect receiving waters in a cost effective manner. By introducing stormwater management in the initial stages of site planning, it can be integrated effectively into the site design process.

4.1 Protect and Utilize Existing Site Features

4.1.1 Protect Sensitive/Special Value Features

In order to minimize stormwater impacts, land development should avoid encroachment on areas with important natural stormwater functional values (such as floodplains, wetlands, and riparian areas) and on areas that are especially sensitive to stormwater impacts (such as steep slopes). These features may not be widespread in the urban environment, but where they do exist they should be identified and steps should be taken to minimize impacts. On larger sites, existing drainage pathways should be identified and utilized whenever possible in the post-development condition.

The Existing Resources and Site Analysis (ERSA) worksheet guides the designer through this stage of the design process. Detailed design guidance is available in the following sections, taken directly from the Pennsylvania Stormwater Best Management Practices (BMP) Manual (PA SBMPM):

- PA SBMPM BMP 5.4.1: Protect Sensitive and Special Value Features
- PA SBMPM BMP 5.4.2: Protect/Conserve/Enhance Riparian Areas
- PA SBMPM BMP 5.4.3: Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design

4.1.2 Cluster and Concentrate

Clustering development in a smaller area can reduce disturbance, reduce maintenance, increase open space, and retain the urban character of the City. These principles apply on urban sites where large areas are being redeveloped. Detailed design guidance is available in the following section, taken directly from the PA SBMPM:

- PA SBMPM BMP 5.5.1: Cluster Uses at Each Site; Build on the Smallest Area Possible

4.1.3 Minimize Impacts of Disturbance

Site design can minimize re-grading, vegetation removal, and soil compaction. Areas left as open space following disturbance can be re-vegetated with native species where practical. Detailed design guidance is available in the following sections, taken directly from the Pennsylvania Stormwater Management Manual:

- PA SBMPM BMP 5.6.1: Minimize Total Disturbed Area – Grading
- PA SBMPM BMP 5.6.2: Minimize Soil Compaction in Disturbed Areas
- PA SBMPM BMP 5.6.3: Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species

4.2 Reduce Impervious Cover to be Managed

Reduction of impervious cover will reduce runoff from the site and will thereby reduce the structural stormwater management requirements for the development project. Impervious cover can be effectively removed by limiting the amount of actual impervious surfaces or by reducing the impervious area that is directly connected to the stormwater conveyance system. The directly connected impervious area (DCIA) Worksheet (Worksheet 2), guides the designer through this stage of the design process.

4.2.1 Green Project Review

PWD offers a Green Project Review for redevelopment projects that are able to disconnect 95% or more of the impervious area in the post construction condition. When performing a Green Project Review, PWD is committed to providing review of the stormwater management component within five (5) business days of receipt of a complete project submittal. A Green Project Review is exempt from Channel Protection and Flood Control stormwater requirements. To be eligible for a Green Project Review a project must meet the following criteria:

- Project is redevelopment;
- 95% or more of the post construction impervious area is disconnected;
- Project may not adversely impact or further exacerbate rates and quality of runoff contributing to public infrastructure; and
- Public Health and Safety issues may preclude a project from a Green Project Review.

The submittee **MUST** identify their project as eligible for a Green Project Review in the letter of transmittal sent with the technical submittal. PWD may not be able to provide review comments within five (5) business days without this notification. For more information or to determine if a project is eligible for a Green Project Review, please contact PWD.

4.2.2 Minimize Area of Impervious Cover

In many cases, alternative configurations for streets and parking lots can provide the same function as traditional designs with reduced impervious area. Minimizing the area of pavement and rooftops will reduce the size and cost of SMPs that must be constructed. Detailed guidelines, examples, and additional references are discussed in **Section 6**: Integrated Site Design.

- **Section 6.1**: Street Design
- **Section 6.2**: Parking Lot Design

4.2.3 Disconnect Impervious Cover

Impervious area is considered either connected or disconnected depending on where stormwater runoff is discharged. When stormwater runoff from an impervious area flows directly to a stormwater management facility it is considered DCIA. However, some impervious cover can be disconnected by directing the flow over a pervious area which allows for infiltration, filtration, and increased time of concentration. When this is done correctly, the area may be considered Disconnected Impervious Cover (DIC). Depending on the configuration, all or a portion of the DIC may be deducted from total impervious cover. Minimizing DCIA will reduce the size and cost of SMPs that must be constructed. When performing calculations for applicability and runoff estimation, DIC should be considered as follows:

- DIC may be treated as pervious when determining stormwater control requirements and whether a redevelopment site has met the 20% reduction in impervious surface.
- DIC need not be managed for Water Quality or Channel Protection.
- If the site is required to provide flood control appropriate Curve Number (CN) values must be utilized.

The following sections describe situations in which impervious area can be considered partially or fully disconnected.

Rooftop Disconnection

An adjustment to DCIA is permitted when the downspout is disconnected and then directed to a vegetated area which allows for infiltration, filtration, and increased time of concentration. PWD will support the applicant in their request to obtain relevant necessary plumbing Code variances for approved rooftop disconnections DIC may be treated as pervious when determining whether a redevelopment site has met the 20% reduction in impervious surface. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

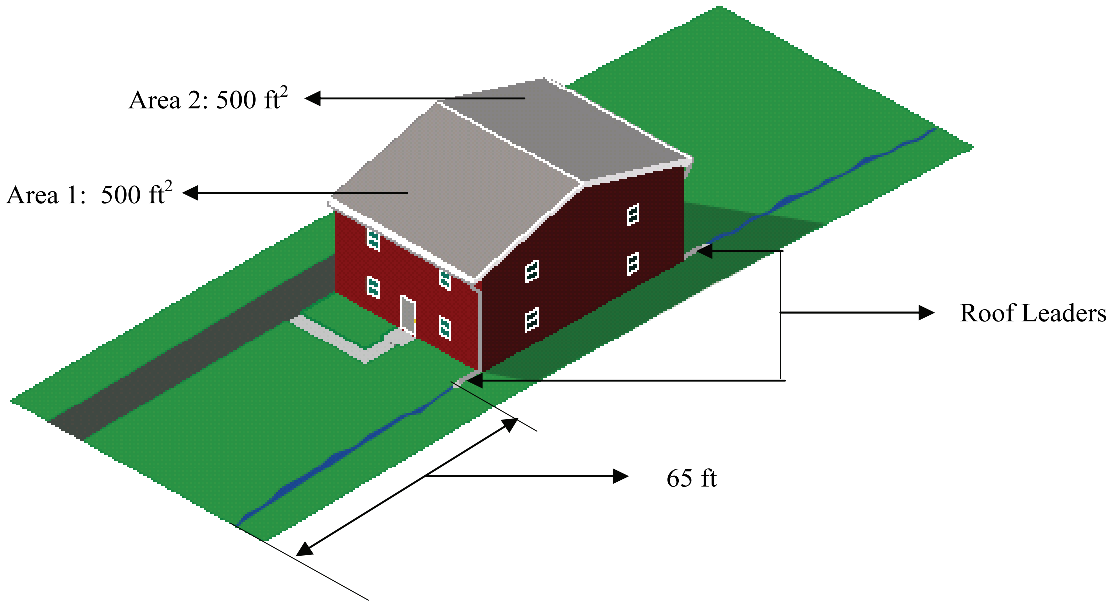
■ A rooftop is considered to be completely or partially disconnected if it meets the requirements below:

- The contributing area of rooftop to each disconnected discharge is 500 square feet or less, and
- The soil is not designated as a hydrologic soil group “D” or equivalent, and
- The overland flow path has a positive slope of 5% or less.

For designs that meet these requirements, the portion of the roof that may be considered disconnected depends on the length of the overland path as designated in Table 4.1.

Table 4.1: Partial Rooftop Disconnection	
Length of Pervious Flow Path*	Roof Area Treated as Disconnected
(ft)	(% of contributing roof area)
0 - 14	0
15 - 29	20
30 - 44	40
45 - 59	60
60 - 74	80
75 or more	100
* Flow path cannot include impervious surfaces and must be at least 15 feet from any ground level impervious surfaces.	

For example, consider a 1,000 square foot roof with two roof leaders each draining an area of 500 square feet. Both roof leaders discharge to a lawn. The lawn has type B soils and a slope of 3%. The distance from the downspout discharge point to the street is 65 feet. Therefore, based on Table 4.1, 80% of the roof area may be considered disconnected and treated as pervious cover when calculating stormwater management requirements. Disconnecting the roof leaders will significantly reduce the size and cost of stormwater management facilities at this site.



Total Roof Area: (Area 1 + Area 2): 1000 ft²
Disconnected Roof Area: (0.8) x (Total Roof Area): 800 ft²
Remaining DCIA: (Total Roof Area - Disconnected Roof Area): 200 ft²

Figure 4.1: Rooftop disconnection

Pavement Disconnection

An adjustment to DCIA is permitted when pavement runoff is directed to a vegetated area which allows for infiltration, filtration, and increases the time of concentration. This method is generally applicable to small or narrow pavement structures such as driveways and narrow pathways through otherwise pervious areas (e.g., a bike path through a park). For structures that meet the requirements, all of the DIC may be deducted from the total impervious cover. DIC may be treated as pervious when determining whether a redevelopment site has met the 20% reduction in impervious surface. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations. The following sections describe situations in which impervious area can be considered partially or fully disconnected.

■ Pavement is disconnected if it meets the requirements below:

- The contributing flow path over impervious cover is no more than 75 feet, and
- The length of overland flow over pervious areas is greater than or equal to the contributing length, and
- The overland flow must be non-concentrated sheet flow over a vegetated area (flow through a swale is not eligible for pavement disconnection credit), and
- The soil is not designated as a hydrologic soil group “D” or equivalent, and
- The slope of the contributing impervious area is 5% or less, and
- The slope of the overland flow path is 5% or less.
- If discharge is concentrated at one or more discrete points, no more than 1,000 square feet may discharge to any one point. In addition, a gravel strip or other spreading device is required for concentrated discharges. For non-concentrated discharges along the entire edge of pavement, this requirement is waived; however, there must be provisions for the establishment of vegetation along the pavement edge and temporary stabilization of the area until vegetation becomes established.

4.2.4 Maximize Tree Canopy Over Impervious Cover

A reduction in DCIA is permitted when new or existing tree canopy from approved species list extends over or is in close proximity to the impervious cover. Under these circumstances, a portion of impervious cover may be treated as disconnected. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations. Trees planted in vegetated practices, such as bioretention areas, that meet the requirements set forth in this Section can be used toward tree disconnection credit. Street trees required by Philadelphia Parks & Recreation (PPR) cannot be counted toward disconnection credit.

■ The DCIA reduction calculated for **new trees** is as follows:

- The tree species must be chosen from the approved list (see **Section 8**: Landscape Guidance).
- New trees planted must be planted within 10 feet of ground level DCIA within the limits of earth disturbance.

• New deciduous trees must be at least 2-inch caliper and new evergreen trees must be at least 6 feet tall to be eligible for the reduction.

• A 100 square foot DCIA reduction is permitted for each new tree. This credit may only be applied to the impervious area adjacent to the tree.

• The maximum reduction permitted, for both new and existing trees is 25% of ground level impervious area within the limits of earth disturbance, unless the width of the impervious area is less than 10 feet. Up to 100% of narrow impervious areas (i.e. sidewalks and paths) may be disconnected through the application of tree credits.

■ The DCIA reduction calculated for **existing trees** is as follows:

• The existing tree species must be on the approved list (see **Section 8**: Landscape Guidance) and at least 4-inch caliper to be eligible for disconnection credit.

• Existing tree canopies must be field measured, and tree location, size, and species must be indicated on submitted plans. Alternatively, an annotated aerial photo clearly showing the existing tree canopy limits must be submitted.

• Only DCIA located directly under the tree canopy area can be considered disconnected.

• Existing tree canopy area overlapping or overhanging that of another, separate existing tree canopy area cannot be counted toward disconnection credit.

• The maximum reduction permitted, for both new and existing trees is 25% of ground level impervious area within the limits of earth disturbance, unless the width of the impervious area is less than 10 feet. Up to 100% of narrow impervious areas (i.e. sidewalks and paths) may be disconnected through the application of tree credits.

Refer to the Technical Library at http://www.pwdplanreview.org/ for the most recent checklists and worksheets, specifically Worksheet 2: Directly Connected Impervious Area for guidance on using the tree adjustment calculations.

4.2.5 Install Green Roofs to Reduce Directly Connected Impervious Area

A reduction in DCIA is permitted when a green roof is installed on a proposed building. The design, construction, and maintenance Plan must meet the minimum requirements specified in **Section 7**: SMP Design Guidelines. To encourage this emerging technology, the entire area of the green roof area may be considered DIC. However, since a green roof is not a zero discharge system, the remaining site design must safely convey roof runoff to the approved point of discharge. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

4.2.6 Install Porous Pavement to Reduce Directly Connected Impervious Area

A reduction in DCIA is permitted when a porous pavement system is installed on the site such that it does not create any areas of concentrated infiltration. Porous pavement systems, including porous asphalt; porous concrete; porous/permeable pavers; and other PWD-approved porous structural

surfaces, can be considered to be DIC if they receive direct rainfall only and if they are underlain by a crushed stone infiltration bed that is at least 8 inches deep. In addition, the travel surface slope in any direction across porous pavement cannot exceed 5% to be eligible for disconnection credit. Porous/permeable pavers must also meet minimum standards for flow-through rate or void percentage. If an underdrain is proposed, the porous pavement will only be considered DIC if the first inch of runoff can be stored below the lowest overflow from the underdrain system. Porous asphalt systems must meet the minimum requirements detailed in **Section 7.13**: Porous Pavement. Infiltration testing is not required for disconnected porous pavement areas; however, it is recommended to ensure timely drainage of the stone base. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

In most cases, if the porous surface receives runoff (overland or piped directly into the subsurface storage bed) from adjacent conventional pavement surfaces, roof, or other impervious surfaces, the porous pavement/infiltration bed system will be considered a structural SMP and the porous surface will be considered DCIA. Those areas considered structural SMPs will require infiltration testing. In some cases, where a small amount of run-on cannot be avoided, it may still be possible to consider the porous pavement disconnected. Such allowances will be considered on a case-by-case basis by PWD.

4.3 Manage Remaining Stormwater

Worksheets 3A and 3B: Stormwater Control Sizing guide the designer through the stage of the design process that manages remaining stormwater after utilizing existing site features and reducing impervious cover. Refer to the Technical Library at http://www.pwdplanreview.org/ for the most recent checklists and worksheets.

4.3.1 Estimate Level of Control Needed

After determining which stormwater management requirements are applicable to the site, the Design Professional then determines the magnitude of those requirements. All requirements must be met concurrently. The Design Professional may choose to meet multiple requirements using a single facility or multiple facilities.

Water Quality Requirement

The required water quality volume is calculated from the following formula:

$$WQ_v = \left(\frac{P}{12}\right) * \left(I\right) \qquad \text{Eqn: 405.1}$$

Where: WQ_v = Water Quality Volume (cubic feet)
P = 1.0 inch
I = DCIA within the limits of earth disturbance (square feet)

To meet the Water Quality requirement, SMPs must be designed to collect and treat the first inch of runoff from all DCIA. It is not acceptable to treat an equivalent volume collected from only a portion of the DCIA.

The water quality volume must be infiltrated except in cases where the Design Professional determines that infiltration is infeasible on the site. Infiltration systems must provide adequate static storage for the entire water quality volume; see design guidelines in **Section 7:** SMP Design Guidelines for information on calculation of static storage. Please note, all infiltration practices must be located a minimum of 10 feet from all building foundations. Infiltration systems must also be a minimum of 10 feet from property lines not adjacent to open public streets unless a deed restriction is put in place extending at least 10 feet from the perimeter of the infiltrating system.

To determine whether or not infiltration is feasible, the Design Professional must perform the following three procedures:

Appendix A: Hotspot Investigation Procedure

Appendix B: Soil Infiltration Testing Procedure

Appendix C: Geotechnical Investigation (Subsurface Stability) Procedure

The intent of the Water Quality requirement is to protect Philadelphia's rivers and streams from polluted runoff associated with rain events. Runoff from the first inch of rainfall accounts for the majority of the annual rainfall volume, and typically carries the majority of the pollutants. Runoff from impervious surfaces is generally more polluted than runoff from pervious surfaces because of the associated uses. Because the Water Quality requirement is designed to make sure that this first inch of water is infiltrated or treated before it leaves the site, the water quality volume must be collected as the first inch of runoff from all DCIA.

Infiltration provides groundwater recharge needed to restore more natural (historical) dry weather flows in creeks while reducing high stream flows and velocities during small storms. However, some sites may not be able to infiltrate all of the water quality volume safely and may request a waiver from infiltration. Waivers are available in **Appendix F.4**: Special Circumstances and Waiver Requests and in the online Technical Library at http://www.pwdplanreview.org/. In cases where a waiver is requested for all or a portion of the infiltration component of the Water Quality requirement, the Design Professional is required to supply the following documentation:

- summary of testing as outlined in **Appendices A**, **B**, and **C,**
- a complete infiltration waiver request cover letter and worksheet detailing the reasons that infiltration is not feasible, and
- supporting evidence why a site should be released from the infiltration requirement.

If it is determined that infiltration of all or part of the water quality volume is not feasible, the remaining water quality volume must be treated and released by a PWD-approved SMP. Treatment and release requirements differ for separate and combined sewer areas, but all areas must route a minimum of 20% of the water quality volume through a PWD-approved SMP that provides volume reduction (See Table 4.3).

Separate Sewer Areas: 100% of the water quality volume the water quality volume must be routed through a SMP that provides volume reduction, flow attenuation, and water quality treatment. PWD-approved practices include: underdrained filters, underdrained bioretention, swales with check dams, ponds and wet basins, and constructed wetlands (see Table 4.3 for a complete list).

Combined Sewer Areas: Runoff from a minimum of 20% of the DCIA must be routed through a PWD-approved volume reducing SMP (see Table 4.3 for a complete list).

The remaining water quality volume must be detained and slow released on-site. The release rate for the water quality volume must not exceed 0.24 cfs per acre DCIA*, and the volume must be detained in the SMP for no less than 24 hours and no more than 72 hours.

*If a SMP will be emptied by a pumping system the average rate must not exceed 0.12 cfs per acre DCIA.

Channel Protection Requirement

SMPs must be designed to detain the runoff from all DCIA within the limits of earth disturbance from a one-year, 24-hour NRCS (Natural Resources Conservation Service) Type II design storm in the proposed site condition such that the runoff takes a minimum of 24 hours and a maximum of 72 hours to drain from the facility. Discharge of water may begin at the beginning of the storm.

Channel Protection requirement: Detain and release runoff from DCIA at a maximum rate of 0.24 cfs per acre of DCIA in no less than 24 hours and no more than 72 hours.

However, the Channel Protection requirement does not apply to redevelopment which is under one acre, discharging to the Delaware or Schuylkill Watersheds' main channels, or discharging to the channelized portion of the Tookany-Tacony Frankford Watershed.

Reducing DCIA within the limits of earth disturbance by 20% between the predevelopment and post-development condition EXEMPTS redevelopment projects from the Channel Protection requirement.

The effects of infiltration may be accounted for when performing Channel Protection calculations. Infiltrating more than the water quality volume is allowed; the Design Professional must determine the best management option based on site-specific conditions.

Flood Control Requirement and Management Districts

Table 4.2 lists the required level of flood control based on location (Management District) within the City. Refer to **Appendix D.2**: Management Districts to determine which Management District requirements apply to a given site. Peak runoff in the proposed condition (left column) must be no greater than peak runoff in the pre-development condition (right column) using the stated design storms. For a given district, the five criteria must be met concurrently. Peak rate reduction provided by facilities that meet the Water Quality and Channel Protection requirements may be considered in sizing calculations for peak rate controls.

If a project is located near or across a Management District border it is strongly recommended that the Developer contact PWD to confirm the Management District requirements that apply to the project. In most cases, a project that is located in multiple management districts will be required to meet the requirements of the management district that covers the majority of the disturbed area.

In Flood Management District C, development sites which can discharge directly to the Delaware River main channel or Schuylkill River major tributary without the use of City infrastructure may do so without control of proposed conditions peak rate of runoff. When

adequate capacity in the downstream system does not exist and will not be provided through improvements, the proposed conditions peak rate of runoff must be controlled to the pre-development conditions peak rate as required in District A provisions for the specified design storm. Refer to **Appendix F.5**: PWD Review Policies.

Table 4.2: Peak Runoff Rates for Management Districts

District	NRCS Type II 24-hour Design Storm applied to Proposed Condition	NRCS Type II 24 –hour Design Storm applied to Pre-Development Condition
A	2 - year	1 - year
A	5 - year	5 - year
A	10 - year	10 - year
A	25 - year	25 - year
A	50 - year	50 - year
A	100 - year	100 - year
B	2 - year	1 - year
B	5 - year	2 - year
B	10 - year	5 - year
B	25 - year	10 - year
B	50 - year	25 - year
B	100 - year	50 - year
B-1	2 - year	1 - year
B-1	5- year	2 - year
B-1	10 - year	5 - year
B-1	25 - year	10 - year
B-1	50 - year	25 - year
B-1	100 - year	100 - year
B-2	2 - year	1 - year
B-2	5 - year	2 - year
B-2	25 - year	5 - year
B-2	50 - year	10 - year
B-2	100 - year	100 - year
C*	Conditional Direct Discharge District	
C-1**	Conditional Direct Discharge District	

*In District C, a Development Site that can discharge directly without use of City infrastructure may do so without control of proposed conditions peak rate of runoff.

**In District C-1, a Development Site which can discharge directly to the Tookany/Tacony-Frankford main channel or major tributaries without the use of City infrastructure may do so without the control of proposed conditions peak rate of runoff greater than the 5-year storm.

For Conditional Direct Discharge Districts, the proposed conditions peak rate of runoff for a Development Site that discharges to City infrastructure must be controlled to the Predevelopment Conditions peak rate as required in District A provisions for the specified Design Storms.

The Predevelopment Condition shall be defined according to the procedures found within this Manual.

■ *Reducing DCIA within the limits of earth disturbance by 20% between the predevelopment and post-development condition EXEMPTS redevelopment projects from the Flood Control requirement.*

4.3.2 Design Stormwater Management Practices Using a Systems Approach

The intent of this section is to propose a systems approach as an organizing principle in SMP design. The designer first defines the level of control needed and then designs a system to provide that level of control.

SMP Selection and Design Process

The following is a general procedure for choosing and designing SMPs on a site.

- Determine whether infiltration is feasible according to **Appendix B:** Soil Infiltration Testing Procedures.
- Identify space constraints, and adjust site design as much as possible to provide open space for stormwater management.
- Where infiltration is feasible, vegetated techniques are preferred. When infiltration is not feasible other volume reducing techniques should be used (see Table 4.3).
- Determine pretreatment requirements for the selected SMP.
- Determine release rate requirements. Design of orifices and underdrains to meet the release rate requirements for small structures on small sites will be the most challenging.

Table 4.3: Acceptable Volume Reducing Stormwater Management Practices

		Infiltration and Groundwater Recharge	Volume Reduction without Infiltration
Landscaped-Intermittently Wet			
Section 6.3	Planter Boxes	Yes	Yes
Section 7.4	Filters	Yes	No
Section 7.5	Bioinfiltration/Bioretention	Yes	Yes (U)
Section 7.7	Berms and Retentive Grading	Yes	No
Section 7.8	Swales	Yes	No
Landscaped-Usually Wet			
Section 7.9	Constructed Wetlands	No	Yes
Section 7.10	Ponds & Wet Basins	No	Yes
Subsurface			
Section 7.12	Subsurface Infiltration	Yes	No
Section 7.13	Porous Pavement	Yes	No
Rooftops			
Section 7.1	Green Roofs	No	Yes
Capture & Reuse			
Section 7.2	Rain Barrels and Cisterns	No	Yes
U =	Underdrained Systems		

On sites where infiltration is not feasible some or all (20% in combined sewer areas, 100% in separate sewer areas) of the DCIA must be routed to an approved volume reducing stormwater management practice. Table 4.3 below presents the SMPs that PWD currently accepts as reducing stormwater volume. Each SMP has design guidelines detailed in **Section 7**. Alternate volume reducing practices may be proposed and will be reviewed on a case-by-case basis. A waiver from the accepted volume reducing practices must be submitted and approved. See **Section F.4**: Special Circumstances and Waiver Requests or the online Technical Library at http://www.pwdplanreview.org/

SMP Functions and Configurations

SMPs are systems that use physical, chemical, and biological processes to provide the level of stormwater control required. This level of control typically includes a required storage volume, a volume to be infiltrated, and an acceptable release rate. These requirements are met through the five principle hydraulic functions of SMPs: storage, infiltration, evapotranspiration, controlled release, and overflow or bypass flow. Figure 4.2 illustrates a variety of design elements available to provide these functions. Depending on the configuration, physical, chemical, and biological processes lead to removal of pollutants during these processes.

By combining design components in a variety of ways, the designer can identify alternative systems that achieve a given function. Figure 4.3 illustrates several different designs that are capable of meeting the Water Quality and Channel Protection requirements.

Figure 4.2: Systems approach to SMP design

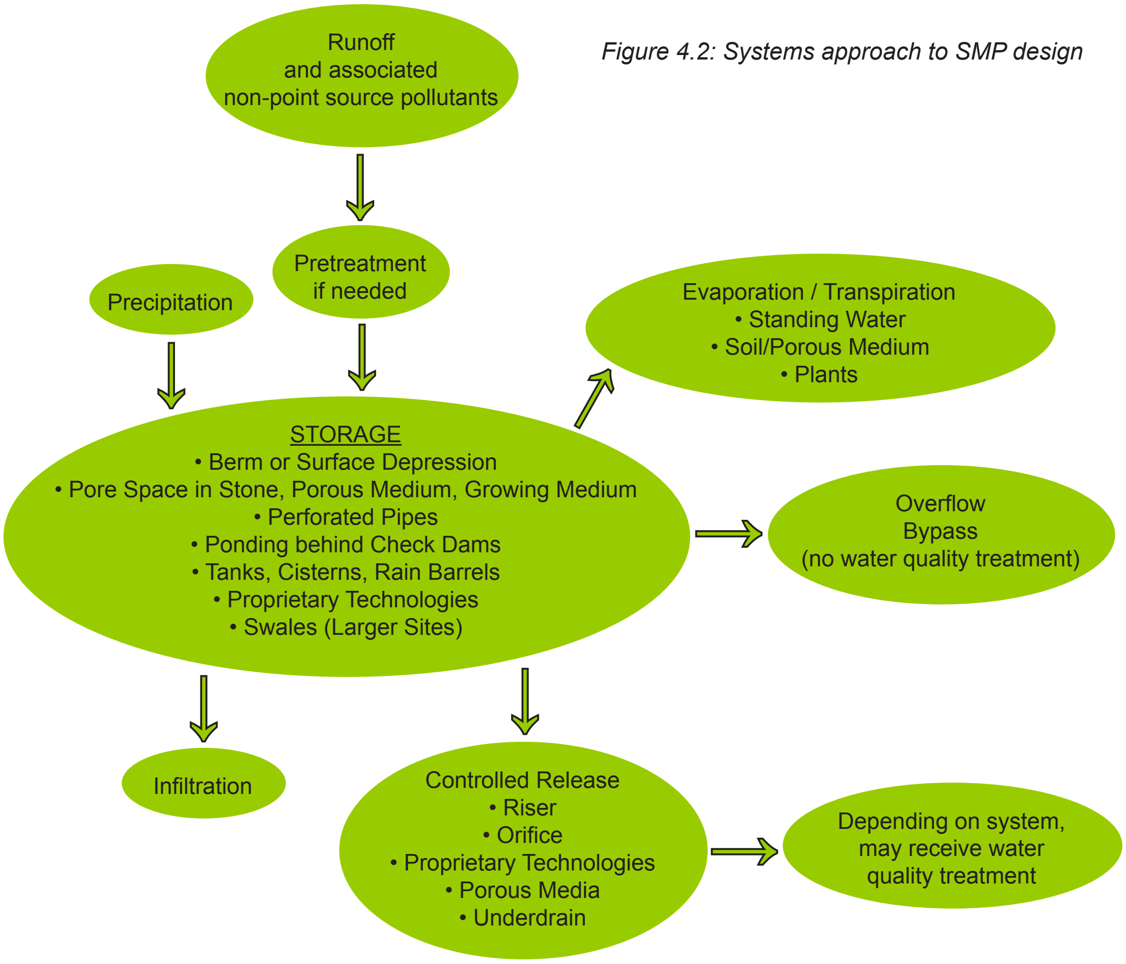
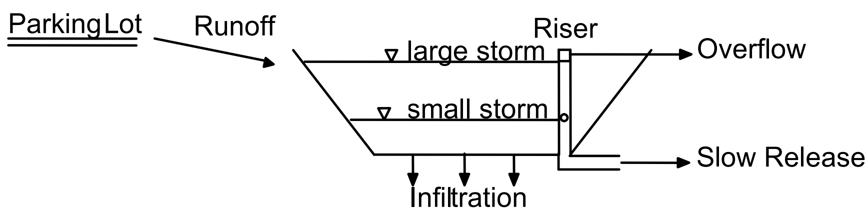


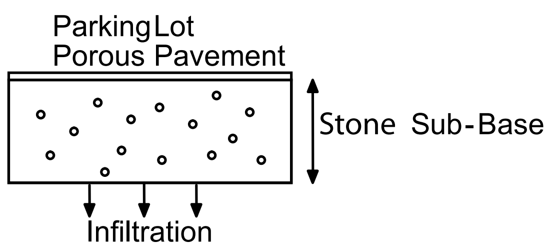
Figure 4.3: Alternative designs for storing runoff

Site: 1 acre parking lot
Objective: Meet Water Quality and Channel Protection requirements
Note: These diagrams are intended to depict general design concepts. Please refer to **Section 7** for detailed design requirements.

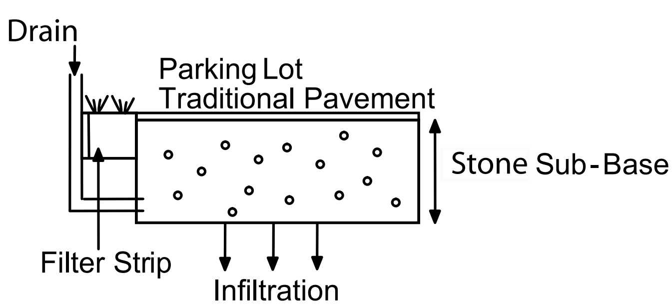
Alternative 1: Traditional detention / infiltration basin



Alternative 2: Porous pavement with deep sub-base



Alternative 3: Traditional pavement with perimeter drains and subsurface infiltration



Alternative 4: Bioretention only

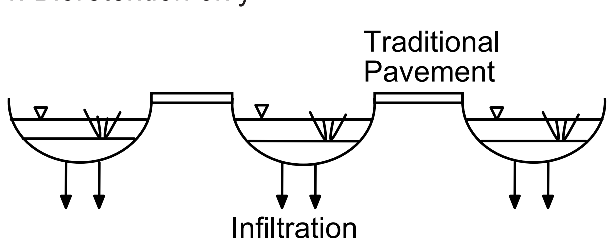
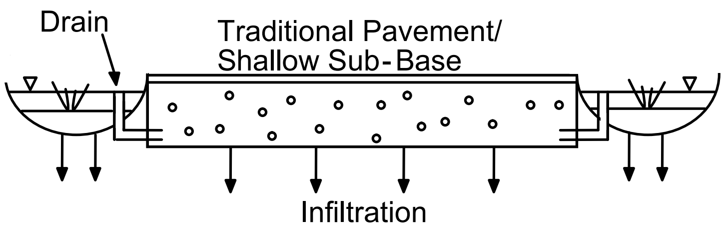
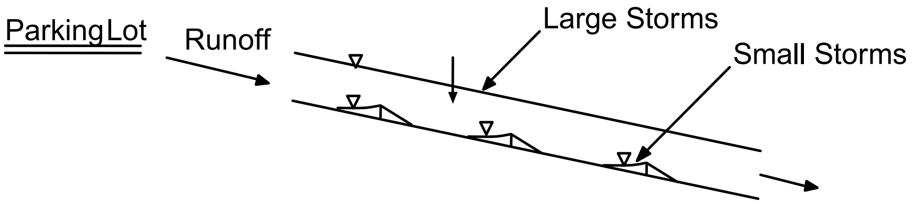


Figure 4.3: Alternative designs for storing runoff (continued)

Alternative 5: Bioretention and subsurface storage



Alternative 6: Swale (large site option)



Storage A traditional detention/infiltration basin (alternative 1, Figure 4.3) provides storage entirely through surface ponding. Subsurface stone storage beds (alternatives 2 and 3) provide storage in stone pore spaces. A bioretention system (alternative 4) provides a combination of surface ponding and storage in soil pores. Bioretention combined with a subsurface stone bed (alternative 5) provides storage in a combination of surface ponding, storage in soil pores, and storage in stone pores. A swale (alternative 6) can provide storage through surface ponding behind check dams, while also functioning as a conveyance system during larger events. Check dams that provide ponding in swales that are designed for volume reduction (infiltration) must not be porous, i.e. comprised of stone gabions., as water should be ponded behind each check dam and forced to infiltrate. If the swales are only being used for conveyance or to increase time of concentration, etc., check dams may be porous.

Infiltration All six alternatives allow stored water to infiltrate into the underlying soil. Surface vegetation (alternatives 1, 4, 5, and 6) helps prolong design life because growth of plant roots helps to keep the soil pore structure open over time. This effect is greatest with vegetation that has a deeper root structure (e.g., trees, shrubs, and native herbaceous species rather than turf grass). Traditional structures such as detention basins and swales can be designed with either type of vegetation. Using such attractive landscaping practices improves quality of life in the urban landscape.

Slow Release Stored water is either infiltrated or released at a slow rate to a sewer or receiving stream. The subsurface storage and bioretention designs (alternatives 2-5) are designed to infiltrate the entire design storm. These designs have a relatively large ratio of infiltration area to drainage area; they provide diffuse infiltration and do not require design or maintenance of a slow release structure. The traditional infiltration basin (alternative 1) provides more concentrated infiltration; depending on site conditions, the designer may choose to infiltrate a portion of runoff and release the remainder slowly through a riser structure. This structure may require design and maintenance measures to avoid clogging. Finally, the swale (alternative 6) infiltrates the portion of runoff that pools behind check dams.

The designer in this case ensures that detention behind check dams and peak attenuation in the flowing swale combine to meet any release rate requirement by the time flow reaches the end of the swale. The swale does not store the entire design storm through ponding at any one time, but it is functionally equivalent to the other designs when resulting flows leave the property. Check dams that provide ponding in swales that are designed for volume reduction (infiltration) must not be porous, i.e. comprised of stone gabions., as water should be ponded behind each check dam and forced to infiltrate. If the swales are only being used for conveyance or to increase time of concentration, etc., check dams may be porous

Evaporation and Transpiration Evaporation and transpiration are minor SMP functions when measured over the course of one storm, but they are significant when measured over time. Surface systems will provide the greatest evaporation and transpiration benefit, particularly if they are vegetated. Some water that infiltrates the surface will evaporate. For this reason, vegetated systems provide both water quality and volume reduction.

Controlled Overflow or Bypass Flow Although not shown for all the examples, all designs must have a mechanism for water to overflow or bypass the system unimpeded during events larger than the design event. For alternatives 1 through 5, a riser or other overflow structure can be incorporated in the design. For alternative 6, the flow capacity of the swale itself acts as a bypass mechanism.

Water Quality Treatment All six design alternatives provide some water quality benefit by slowing water down and allowing settling of suspended solids. A portion of pollutants in stormwater (e.g., nutrients, metals, and/or organics) is associated with this solid fraction. Systems combining soil, water, and plants (alternatives 4 and 5) provide the most treatment. The level of treatment provided by the traditional detention basin (alternative 1) and swale (alternative 6) depends on configuration and vegetation type.

Infiltration reduces the pollutant load reaching surface water and should not endanger groundwater if the soil layer is sufficiently thick. Vegetated filter strips in alternative 3 remove solids through settling and filtration. In alternative 5, a small bioretention basin provides pretreatment for a subsurface stone system. Both pretreatment methods will prolong the life of the subsurface stone bed. The choice between alternatives 3 and 5 is one of designer preference and cost, not one of function.

In areas with combined sewers, two factors contribute to receiving water quality. First, any water that is infiltrated does not reach a combined sewer, does not contribute to combined sewer overflows (CSO), and will not contribute to receiving water pollution. Second, detention and slow release reduces peak flow in the combined sewer during wet weather events, reducing the frequency and magnitude of overflows. Water quality improvement in combined sewered areas is more a matter of managing the quantity and timing of runoff, rather than reducing pollutant concentrations in that runoff.

Space Constraints Traditional basins (alternative 1) and swales (alternative 6) can be implemented on larger sites. On smaller sites, bioretention is an attractive solution due to the benefits of vegetation, including appearance, design life, and water quality. However, surface vegetation does require space to install. A designer might choose to combine bioretention with a subsurface stone bed (alternative 5) to save space, or to use a subsurface stone bed (alternative 2 or 3) alone if all available space is needed for parking.

4.4 Consider Operations and Maintenance in Design

An Operations and Maintenance (O & M) Agreement, discussed in detail in **Section 5.4.4**, is a required component of the PWD Stormwater Regulations. Decisions made in the design phase can affect operations and maintenance and can extend the design life of stormwater facilities. Key factors to consider are ownership, access, maintenance tasks, and frequency.

4.4.1 Designing to Minimize Maintenance

Consider the following design features to minimize maintenance and maximize design life:

- Maximize use of pretreatment systems, particularly for infiltration systems. Reducing velocities and pollutant loads entering SMPs will extend their design lives. (See **Section 7** for appropriate pretreatment design.)

- For infiltration, choose surface vegetated SMPs with deeper-rooted vegetation (trees, shrubs, and native herbaceous species) whenever possible. Root growth helps to keep the soil's pore structure open and maximizes the life of infiltration SMPs. Routine landscaping tasks are the primary maintenance required.

- On smaller sites, choose SMPs that do not require slow-release control structures. These structures can clog and require periodic inspection and maintenance.

4.4.2 Provide Access

Vehicle access from a public right-of-way can help to minimize the difficulty of maintenance. A 15-foot wide vehicle access path leading from a public right-of-way to all stormwater controls is strongly recommended.

4.4.3 Post-Construction Ownership

The owner of the land where the SMP is located is responsible for performing long term maintenance. In the case of a single property owner, that owner is responsible for maintenance. In cases of common ownership, a homeowners' or condominium association may assume responsibility for maintenance. Considering the type of ownership and owner preference can help the designer choose between smaller, distributed SMPs and a single centralized SMP.

5 Post Construction Stormwater Management Plans

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5.0 Introduction

This section is provided to guide developers through the necessary submittals required for stormwater management in Philadelphia. **Section 5.1** describes requirements for the Erosion and Sediment Pollution Control (E & S) Plan. **Section 5.2** describes the required components of the Post Construction Stormwater Management Plan (PCSMP). Acceptable calculation methods for determining sizing and appropriate stormwater management practices (SMPs) are contained in **Section 5.3**. **Section 5.4** describes the PCSMP submittal process.

5.1 Erosion and Sediment Pollution Control Plan

The Owner is responsible for ensuring that their active construction site is not creating violations of 25 Pa. Code Chapters 92 and/or 102 and the Clean Streams Law, the act of June 22, 1937, P.L. 1987, 35 P.S. §691.1 et seq. Depending on the limit of earth disturbance associated with a project there are specific preparation, review, and approval requirements. All E & S Plans must be prepared in accordance with Pennsylvania Department of Environmental Protection (PADEP) guidelines as laid out in the following Manual:

> PADEP, Bureau of Watershed Management, April 15 2000. *Erosion and Sediment Pollutant Control Program Manual*. Document 363-2134-008.

It is important for the applicant to properly assess the limits of earth disturbance associated with the construction project in order to determine the level of review and approval required. Submittal requirements for E & S Plans are located in **Section 2.2**: Determining Applicability. Once the limits of earth disturbance have been accurately determined the applicant will follow one of the four E & S review paths listed below:

Earth Disturbance Categories:

A. Less than 5,000 square feet (not located in the Wissahickon Watershed*)
- E & S Plan is not mandatory.
- Owner must implement E & S best management practices (BMPs) in accordance with the most recent version of PADEP *Erosion and Sediment Pollutant Control Program Manual* (2000).

B. More than 5,000 square feet, less than 15,000 square feet**
- E & S Plan must be prepared, implemented, and kept on site available for inspection at all times.
- The E & S Plan which complies with the PADEP *Erosion and Sediment Pollutant Control Program Manual* (2000) must be maintained and submitted to the Philadelphia Water Department (PWD), but does not need to be approved.
- If the site is not subject to the PWD Stormwater Management Regulations (Stormwater Regulations), then submit E & S Plans as an attachment to the Existing Resources and Site Analysis (ERSA) online application at http://www.pwdplanreview.org/.

C. More than 15,000 square feet, less than 1 acre (43,560 square feet)**
- E & S Plan must be prepared, approved, implemented and kept on site available for inspection at all times.
- The E & S Plan must be reviewed and approved by PWD before PWD will sign the applicant's Building Permit Application. A Building Permit must be issued prior to commencement of any earth disturbance.
- Project is subject to the Stormwater Regulations and requires a full PCSMP submittal. E & S Plans are a component of the full PCSMP. These must be submitted together to:

    Projects Control
    Philadelphia Water Department
    1101 Market St, 2nd Floor
    Philadelphia, PA 19107

The submittal must include a transmittal letter indicating necessary project information and the level of review required as well as all information to be reviewed.

- Notify the PWD Inspections Coordinator at least three (3) days prior to commencement of construction activities and SMP installation.

D. More than 1 acre (43,560 square feet)

- E & S Plan must be prepared, approved, implemented and kept on site at all times.
- A NPDES Permit application must be submitted to PADEP. Proof of issuance of the NPDES Permit must be provided to PWD before PWD will sign the applicant's Building Permit Application. A Building Permit must be issued prior to commencement of any earth disturbance.
- Project is subject to Stormwater Regulations and requires a full PCSMP submittal. E & S Plans are a component of the full PCSMP. These must be submitted together to:

  Projects Control
  Philadelphia Water Department
  1101 Market St, 2nd Floor
  Philadelphia, PA 19107

  The submittal must include a transmittal letter indicating necessary project information and the level of review required as well as all information to be reviewed.
- Notify the PWD Inspections Coordinator at least three (3) days prior to commencement of construction activities and SMP installation.

*Projects located in the Wissahickon Watershed may be subject to additional requirements which will be assessed as part of the project review performed by Philadelphia City Planning staff.

**If during the course of construction additional area is disturbed which changes the applicable requirements, construction will have to cease until new plans are prepared and approved by all relevant regulatory agencies.

Inspections

E & S inspections occur on both a scheduled and complaint driven basis. The E & S inspectors expect that the E & S controls contained within the prepared or approved E & S Plan (depending on the limits of disturbance) are implemented and maintained on site at all times. The E & S Inspectors are authorized to access a site and inspect the effectiveness of E & S BMPs. E & S Inspectors will advise the Owner or responsible party(s) of E & S control problems found during the inspection and what must be done to correct the violations. This may include implementing additional E & S BMPs not shown on the approved plans. Should a project site be disturbing earth without the appropriate approvals or ineffective E & S control BMPs, the site will be subject to the enforcement actions outlined in the Stormwater Regulations.

5.2 Components of the Post Construction Stormwater Management Plan

The PCSMP must contain the elements found in the Checklist B: The Standard Submittal Format. If any of these are missing from a submitted plans, the plan will be returned to the developer for completion prior to review. All items should be submitted together to:

Projects Control
Philadelphia Water Department
1101 Market St, 2nd Floor
Philadelphia, PA 19107

5.2.1 The Standard Submittal Format

Checklist B: The Standard Submittal Format contains an easy to use checklist to determine completion of the PCSMP. It is provided to assist the developer in ensuring that all necessary elements of the PCSMP are complete. Refer to the Technical Library under the Stormwater Management tab at http://www.pwdplanreview.org/ for the most recent checklists and worksheets. This process has been designed to make submittal of the PCSMP easier for both developers and reviewers.

5.2.2 Proof of Application for Applicable Permits

Other state and federal permits may be required for development on a given site. PWD approval of a PCSMP is contingent upon approval by other regulatory agencies. Other permits that may be required include but are not limited to:

- NPDES (National Pollutant Discharge Elimination System) Phase II Permit for Construction Activities
- Pennsylvania Code and Charter Chapter 105: Water Obstruction and Encroachment General and Joint Permits

This list is not exhaustive nor does it imply that all of these permits are required. It is the **responsibility of the developer** to determine which permits are required by other regulatory agencies. **Appendix F.3**: Local Permitting requirements and **Appendix F.4**: Federal and State Permitting requirements provide resources to assist in determining which permits may apply.

Proof of the issuance of all applicable permits **MUST** be provided to obtain PWD sign off on any Building Permit. However, at the time of submittal of a PCSMP, the applicant must demonstrate that they have applied for all relevant permits. A photocopy of permit applications will serve as proof of application. If for some reason approval is denied or revoked by another regulatory agency, it is the developer's responsibility to notify PWD and other City agencies and rectify the situation before the project can proceed any further.

5.2.3 Documentation of Special Circumstances

The City recognizes that on-site stormwater management may not be feasible in part or in full for some development projects. Under these circumstances PWD requires that technical documentation demonstrating the site constraints be submitted to and reviewed by PWD. Alternatives to on-site stormwater management are accepted at the sole discretion of PWD.

Complete details of documentation, stormwater management alternatives and contact information are provided in **Appendix F.4**: Special Circumstances and Waiver Requests.

5.3 Acceptable Methods for Calculations

The worksheets are intended to standardize and summarize the results of design calculations. The designer must also attach relevant data, field testing results, assumptions, hand calculations, and computer program results. This section summarizes calculation methods that are considered acceptable by PWD. Other methods will be considered on a case-by-case basis.

5.3.1 Design Storms

Sizing requirements for the Stormwater Regulations have been developed using long-term computer simulations. These requirements have been translated to single event design conditions that yield roughly equivalent results.

Design Rainfall Totals

The rainfall depths of design storms shown in Table 5.1 are taken from the Pennsylvania Department of Transportation Field Manual (1986). These totals indicate the largest depth one can expect over the specified interval in the specified return period. These design precipitation depths are similar to those found in other standard references such as National Oceanic and Atmospheric Administration (NOAA) Technical Publication 40 or the NOAA Atlas 14; however, Design Professionals must use the values provided in Table 5.1 for their design calculations.

Table 5.1: Design Precipitation Depths (in)

	Return Period						
Duration	1 yr	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
5 min	0.33	0.38	0.45	0.50	0.56	0.63	0.68
15 min	0.64	0.75	0.90	1.00	1.15	1.35	1.50
1 hr	1.10	1.35	1.61	1.85	2.15	2.60	2.98
2 hrs	1.34	1.66	2.00	2.34	2.70	3.26	3.76
3 hrs	1.50	1.86	2.28	2.67	3.09	3.69	4.29
6 hrs	1.86	2.28	2.82	3.36	3.90	4.62	5.40
12 hrs	2.28	2.76	3.48	4.20	4.92	5.76	6.72
24 hrs	2.64	3.36	4.32	5.28	6.24	7.20	8.40

Design Rainfall Distribution

For the Channel Protection and Flood Control calculations, the design rainfall depth must be distributed in a NRCS (National Resources Conservation Service) Type II dimensionless rainfall distribution. The Type II distribution was selected not because it represents a typical event but because it includes periods of low-intensity and high-intensity rainfall; design using this distribution results in a facility that can manage a variety of event types, particularly high

intensity storms.

Table 5.2: Tabulated NRCS 24-Hour Type II Distribution		
Time	Dimensionless Rainfall	
(hr)	Cumulative	Incremental
0.00	0.000	0.000
2.00	0.022	0.022
4.00	0.048	0.026
6.00	0.080	0.032
7.00	0.098	0.018
8.00	0.120	0.022
8.50	0.133	0.013
9.00	0.147	0.014
9.50	0.163	0.016
9.75	0.172	0.009
10.00	0.181	0.009
10.50	0.204	0.023
11.00	0.235	0.031
11.50	0.283	0.048
11.75	0.357	0.074
12.00	0.663	0.306
12.50	0.735	0.072
13.00	0.772	0.037
13.50	0.799	0.027
14.00	0.820	0.021
16.00	0.880	0.060
20.00	0.952	0.072
24.00	1.000	0.048

Storm Return Periods for Large Events and Flow Bypass

At a minimum, safe conveyance of the 10-year, 24-hour design storm must be provided to and from SMPs to comply with the requirements of §14.1603.1.6.C.4. Additionally, the flow that is leaving the system must meet the requirements of the Stormwater Regulations. Many SMPs will be designed to manage smaller storms. A designer might choose to allow runoff from larger storms to bypass or quickly pass through a storage element.

5.3.2 Runoff Estimation

A number of mathematical models are available to estimate stormwater runoff from a given storm. For sites that are dominated by impervious cover, most methods will yield similar results. For sites with significant pervious cover contributing flows to SMPs, infiltration loss models provide more realistic results than the empirical, statistically based methods. However, a thorough understanding of soil behavior is necessary to generate realistic runoff estimates.

The empirical methods can be implemented by computer programs. Examples of computer programs available in the public domain are listed in Table 5.3. In addition, a wide range of proprietary programs are available. Designers are strongly urged to consider the assumptions and mathematical models underlying these programs when choosing an appropriate tool to aid in design. The stormwater model must use the minimum time step allowable by the hydrologic

software. Also, a curve number of 98 must be used with a precipitation depth of 1.2 inches when performing water quality calculations for combined sewer areas where infiltration is not feasible, and a curve number of 100 must be used for the area below the water surface elevation in an above-ground wet pond (retention basin).

Table 5.3: Acceptable Calculation Methods for Runoff Estimation

Type	Mathematical Model	Impervious Cover	Experience Modeling Soil Properties	Hand/Spreadsheet Calculations	Example Computer Programs
Empirical Methods	NRCS Curve Number method	Any	Moderate-High	Yes (smaller sites)	NRCS, TR-55, TR-20, HEC-HMS
Infiltration Loss Models	Constant Loss	Any	Moderate-High	Yes (smaller sites)	HEC-HMS
	Green-Ampt	Any	High	No	EPA SWMM, HEC-HMS
	Horton	Any	High	No	EPA SWMM

Rational Method

The rational method may **not** be used for SMP design, outlet control design, or detention routing. It may be used for storm sewer capacity design as described in **Section 5.3.5**: Storm Sewer Design.

NRCS Curve Number (Soil Complex) Method

The NRCS Curve Number Method is widely used to produce estimates of runoff for both pervious and impervious cover. It empirically accounts for the fact that soils become saturated and gradually yield more runoff during the course of a storm. For a detailed description of the Curve Number Method, see Urban Hydrology for Small Watersheds (NRCS Technical Release 55).

Care should be taken to select appropriate curve number (CN) values since this calculation method is very sensitive to changes in these values. In order to obtain conservative results, separate calculations for pervious and impervious area runoff must be used (weighted curve numbers between pervious and impervious areas are not acceptable). The resulting flows can be routed if necessary and then added. See Table 5.4 for PWD approved CN values for each Hydrologic Soil Group.

Infiltration Loss Models

Infiltration loss models estimate runoff quantity by subtracting depression storage and infiltration losses from rainfall. These models are based on the physics of soil behavior and provide more precise results than empirical models. Used by an experienced modeler with ample soil data, these models produce more realistic estimates than empirical models on sites where a significant portion of runoff is generated by pervious cover. Results depend most strongly on soil properties.

Table 5.4: PWD Accepted Curve Number Values						
Cover Description		Curve Number for Hydrologic Soil Group				
Cover Type	Hydrologic Condition	A	B	C	D	Ub *
Lawns, parks, golf courses, etc...						
	Poor (grass cover < 50%)	68	79	86	89	79
	Fair (grass cover 50% to 75%)	49	69	79	84	69
	Good (grass cover > 75%)	39	61	74	80	61
Meadow		30	58	71	78	58
Athletic Fields		68	79	86	89	79
Porous Turf		70	70	79	84	69
Brush (brush-weed-grass mixture with brush the major element)						
	Poor	57	73	82	86	73
	Fair	43	65	76	82	65
	Good	32	58	72	79	58
Woods-grass combination (orchard or tree farm)						
	Poor	57	73	82	86	73
	Fair	43	65	76	82	65
	Good	32	58	72	79	58
Woods						
	Poor	45	66	77	83	66
	Fair	36	60	73	79	60
	Good	30	55	70	77	55
Paved parking lots, roofs, driveways. streets, etc.		98	98	98	98	98
Gravel/Crushed Stone		76	85	89	91	89
Dirt		72	82	87	89	87
Porous Pavement		70	70	74	80	70
Permeable Pavers		70	70	79	84	70
Pour-in-Place Rubber		70	70	74	80	70
Green Roof **		86	86	86	86	86

* Ub refers to “Urban Land” and generally conforms to a hydrologic soil group classification of B. A Ub CN should be used on redevelopment projects unless the engineer provides soil mapping indicative of another, more approriate, soil classification.

**Existing rainfall runoff models are limited in their ability to predict runoff from green roofs since this process is dominated by percolations through a thin veneer of soil and is not surface runoff. Green roof research studies have back-calculated a range of CN values for various storms and roof media types/ thicknesses. CN values different from that listed in the table may be permitted if appropriate citations are provided with the stormwater report.

Determining the Predevelopment Conditions for Runoff Calculations

The predevelopment condition for any project is determined by the dominant land use for the previous ten (10) years preceding the planned project. If a redevelopment project is able to reduce the DCIA within the limits of earth disturbance by 20% between the predevelopment and post-development conditions, it is exempt from the Channel Protection and Flood Control requirements.

When performing Flood Control calculations, PWD requires the following land use designations for all development and redevelopment in City of Philadelphia:

1) Redevelopment sites in the predevelopment condition:

- All non-forested pervious areas **must** be considered meadow (good condition) for the predevelopment runoff calculations. Pervious area is considered to be area covered by a pervious surface that allows water to drain through it rather than running off of the site. Non-forested pervious area includes the following cover types: meadow, grass/ lawn, brush, gravel, dirt, pervious pavements, and any combination of these cover types. Compacted dirt or gravel is generally considered to be pervious cover.
- In addition to any other pervious area, twenty percent (20%) of the existing impervious cover on site, when present, **must** be considered meadow (good condition) for the predevelopment runoff calculations. Only areas covered by an impervious surface or structure should be considered impervious cover in the predevelopment condition.

2) New Development sites in the predevelopment condition:

- All non-forested, pervious areas **must** be considered meadow (good condition) for the predevelopment runoff calculations.

5.3.3 Storage Volume Estimation

Surface storage: A rough estimate of surface storage can be obtained by averaging the surface area and bottom area of a basin and multiplying by the average depth. For irregular shapes, volume can be estimated by finding the area inside each contour, multiplying each area by the contour interval, and adding the results.

Stone Storage: Storage in stone pores is equal to the volume of the crushed stone bed times the porosity. A design porosity of 40% can be assumed for the stone if specifications for the crushed stone meet those provided in **Section 7**: SMP Design Guidelines.

Porous Media Storage: Storage available in porous media is equal to the initial moisture deficit, the portion of total porosity that is not already occupied by moisture. This portion varies at the beginning of every storm; acceptable design values are 30% for sand and 20% for growing soil.

Active Storage: Not all physical space in a given SMP is active. The maximum elevation that should be considered as active storage is the overflow elevation. In tanks draining by gravity whose bottoms do not infiltrate, any volume below the invert of the orifice or control structure is not considered active storage.

5.3.4 Flow Routing

Sheet Flow and Shallow Concentrated Flow

Sheet flow consists of shallow flow spread out over a plane. Eventually, this flow will generally concentrate into a deeper, narrower stream. There is debate over how prevalent sheet flow is in the natural environment. However, it provides a reasonable mathematical basis for predicting travel time and infiltration losses over short distances. *Urban Hydrology for Small Watersheds* (TR-55) provides a sheet flow equation based on Manning's kinematic solution. Tables of roughness values for sheet flow are available in *Urban Hydrology for*

Small Watersheds and in Table 5.5 shown below. There is debate over the appropriate length of sheet flow; however, PWD will only accept sheet flow for the first 100 feet. After sheet flow, overland flow is considered shallow concentrated flow. Shallow concentrated flow will be considered as flowing over paved or unpaved surface for the purpose of estimating velocity. Another method for routing overland flow is the kinematic wave solution, which can be obtained by coupling the momentum and continuity equations with simplifying assumptions, and it may be solved in a computer program using numerical methods. A computer program also allows practical calculations at a much smaller time step than hand or spreadsheet calculations.

Channel Flow

Channel flow equations may be used to estimate flows in free-flowing gutters and swales. Manning's equation is sufficient for these estimates on many sites. Tables of roughness values are available in *Civil Engineering Reference Manual* (CERM*)* Appendix 19.A. For channels with significant backwater, culverts which may flow under pressure, or other complex features, the St. Venant equations may be needed. These equations represent the complete solution of the momentum and continuity equations in one dimension. They require a computer program to solve.

For reference, the post development time of concentration will be less than or equal to the predevelopment time of concentration values unless the site is specifically altered to increase this path.

Table 5.5: Roughness Coefficients (Manning's n) for sheet flow

Surface Description	n [1]
Roof tops	0.011
Concrete	0.013
Asphalt	0.015
Bare soil	0.018
Sparse vegetation [2]	0.1
Grass:	
Short grass prairie, Lawn	0.15
Dense grasses [3], Meadow (good condition)	0.24
Range (natural)	0.13
Woods: [4]	
Light underbrush	0.40
Dense underbrush	0.80

[1] The n values are a composite of information compiled by Engman (1986) and Akan (1985).

[2] Areas where vegetation is spotty and consists of less than 50% vegetative cover.

[3] Species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.

[4] Consider cover to a height of 0.1 ft. This is the part of the plant cover that will obstruct sheet flow.

Storage Routing

For small storage elements where travel time within the element is insignificant, simple mass balance routing may be performed in a spreadsheet. At each time step, the change in storage volume is the difference between inflows and outflows. Inflows and outflows are a function of design and soil properties.

For larger or more complex structures, where the shape and size of the element have a significant effect on outflows, the Modified Puls (also called storage-indication) method provides more accurate routing.

Table 5.6: Summary of Recommended Methods for Flow Routing				
Type	Mathematical Model	Appropriate For…	Hand/ Spreadsheet Calculations	Example Computer Programs
Overland Flow	simplified Manning kinematic solution	sheet flow path up to 150 feet	Yes	TR-55, TR-20
	shallow concentrated / NRCS empirical curve	overland flow longer than 150 feet	Yes	TR-55, TR-20
	kinematic wave	larger or more complex sites	No	EPA SWMM, HEC-HMS
Channel Flow	Manning equation	uniform flow without backwater	Yes	TR-55, TR-20, EPA SWMM, HEC-HMS
	St. Venant equations	channels with storage, backwater	No	EPA SWMM, HEC-RAS
Storage Routing	simple mass balance	small storage elements	Yes	USACE STORM
	Modified Puls / storage-indication	large or irregularly-shaped elements	Yes	TR-55, TR-20, HEC-HMS

5.3.5 Storm Sewer Design

All storm sewer pipes must be designed to have adequate capacity to safely convey the 10-year storm without surcharging the crown of the pipe. Pipe capacity calculations are required for all stormwater conveyance that is not connected to the roof drainage system. Refer to the Philadelphia Plumbing Code for guidance on sizing roof drainage systems.

If Flood Control is required, runoff from larger storms must be safely conveyed off the site, either through overland flow or a storm sewer. Please note, runoff may not be conveyed to a neighboring property.

Rational method may be utilized when designing storm sewers. Recommended assumptions to obtain conservative results using the rational method include:

- Choose appropriate runoff coefficients based on the Engineer's best judgment of land use type (e.g., see CERM Appendix 20.A).

- For pervious areas with rational coefficients less than 0.2, use a coefficient of 0.2.

- Use a runoff coefficient value of 0.35 for pervious areas and a value of 0.95 for impervious areas.

- Use the precipitation intensity for a 5-minute inlet concentration time in the 10-year storm event, which is 6.95 inches per hour. Refer to the 2010 Edition of the "Field Manual for Pennsylvania Design Rainfall Intensity Charts" PADOT Storm-Intensity-Duration-Frequency Charts (PDT-IDF) for Region 5 for more information.

For a table of rational method coefficients, see CERM Appendix 20.A.

For use with Manning's Equation for calculating full channel flow, a Manning's n value of 0.013 should be used for RCP, VCP, and CIP, and a value of 0.011 should be used for PVC and HDPE.

When designing a site's storm sewer system, be mindful of the following requirements:

- Inlets may not be connected in series. Similarly, roof drainage systems may not tie directly into an inlet. Wye connections, or similar, may be used to ensure that inlets are offline.

- A minimum of 12 inches of vertical clearance is required when a sanitary sewer line crosses above a storm sewer line. The sanitary sewer must be encased in concrete if the clearance is less than 12 inches.

- Any manholes between outlet structures and sewer connections in combined sewer areas must have sanitary (non-vented) covers.

- A cleanout must be provided for all 90-degree bends.

- If curb cuts or non-standard inlets are used to capture runoff, especially from driveways or roadways where the inlets are not in a sump condition, verification that the 1-year storm will be captured by the inlet must be provided.

- All proposed connections to the City sewer must be reviewed and approved by the PWD Water Transport Records Unit. Instructions for obtaining a sewer connection permit can be found in the Technical Library under the Construction Information tab at http://www.pwdplanreview.org/.

5.4 Post Construction Stormwater Management Plan Submittal Process

Because the **PWD Approval Signature and Stamp on Building Permits will only be issued upon approval of Water, Sewer and Stormwater, it is strongly recommended that developers submit Water, Sewer and PCSMP materials at the same time.** All items should be submitted together to:

Projects Control
Philadelphia Water Department
1101 Market St, 2nd Floor
Philadelphia, PA 19107

The PCSMP submittal must include a transmittal letter indicating necessary project information and the level of review required as well as all information to be reviewed.

5.4.1 Project Screening

Only a complete PCSMP will be accepted for review. When a new project is received it undergoes a screening process to make sure it includes all the components necessary to complete a review. If any portion is found to be missing or incomplete the developer will be notified by email. Any additional information that is required should be mailed to PWD Projects Control. If necessary, incomplete PCSMP submittals will be returned to the developer for completion. When a project is screened incomplete no additional review of the project will be done until the required materials have been received. Once a project submittal is found to be complete the developer will be notified and the project will be moved into technical review.

Refer to the Technical Library at http://www.pwdplanreview.org/ for the most recent checklists and worksheets. Checklist B: The Standard Submittal Format is provided to guide the developer and help them ensure that their application is complete prior to submittal.

5.4.2 Technical Review Process

Once a project submittal has been screened and determined to be complete, it will be put in line for technical review. Projects are generally reviewed in the order in which they were received. Because of this, review times depend heavily on the number of projects under review at the time of the submittal.

During the technical review, PWD will examine the submittal to determine if all applicable requirements are being met. Should any deficiencies be identified, PWD will email a letter of review comments to the developer. Additional information or revised materials required based on the comments should be submitted to:

Projects Control
Philadelphia Water Department
1101 Market St, 2nd Floor
Philadelphia, PA 19107

Technical review of the submittal will not continue until a new submittal addressing the comments is received. This submittal should include all required revisions and new material as well as an explanation of how each review comment was addressed. PWD will review the comment responses and new and revised material for compliance with all applicable requirements. Should any deficiencies are identified PWD will update the review letter and email the developer. Please note that additional comments may be added to the review comments based on changes to the plans and calculations. This process continues until all review comments are addressed.

The developer can influence the amount of time their review will take in several ways. If the developer chooses to use development practices that allow disconnection of 95% or more of the post construction directly connected impervious area (DCIA) most projects will be eligible for a Green Project Review. PWD is committed to performing Green Project Reviews within 5 business days. For more information see **Section 4.2**: Reduce Impervious Cover to be Managed. The developer may also influence the length of the review time by being responsive when review comments are issued. Reviews often take less time when a project is resubmitted in a short amount of time because reviewer is less likely to be involved in other projects and will be more familiar with the original comments.

Once all of the review comments have been addressed PWD will email the developer an approval letter. The developer **must** bring this approval letter and proof of issuance of any additional required permits to PWD when acquiring signature on Building Permit applications.

5.4.3 Inspections

PWD or its designee shall inspect the project site during the construction phase. A pre-construction meeting must be held prior to the start of construction activity. Additionally, PWD's Inspections Staff must be contacted to schedule an inspection prior to installation of any SMP. PWD or its designee may inspect any phase of the installation of the permanent SMPs as deemed appropriate by PWD. During any stage of work, if PWD or its designee determines that the permanent SMPs are not being installed in accordance with the PCSMP most recently approved by PWD (Approved PCSMP), or that adequate erosion and sedimentation pollution control practices are not being implemented on-site, the site will be subject to the enforcement actions outlined in the PWD Stormwater Regulations.

A final inspection shall be conducted by PWD or its designee to confirm the constructed conditions of the site and its general accordance with the Approved PCSMP prior to the issuance of the Certificate of Occupancy or other equivalent issuance. Prior to the final inspection, the project's Record Drawing Submission, which documents the as-built conditions of all SMPs, must be submitted to PWD for review.

5.4.4 Operations and Maintenance Agreement

Regular inspections and maintenance, or the lack thereof, can result in significant changes to the performance of a SMP. Routine maintenance is important to ensure the functionality and aesthetic qualities of a SMP, and can also reduce the need for larger, more expensive repairs.

An Operations and Maintenance (O&M) Agreement is a required component of the PWD Stormwater Management Regulations. The owner of any land upon which SMPs will be placed, constructed, or implemented shall have an O&M Agreement. The O&M Agreement is a legally binding agreement between the property owner and the City that must be executed and filed with the Department of Records. This agreement requires the property owner to construct the on-site SMPs in strict accordance with the Approved PCSMP and to maintain these SMPs such that they will adequately perform their design functions.

The maintenance guidelines included in **Sections 7.1 through 7.15** represent typical basic maintenance tasks and frequencies for the SMPs in each of these sections; however, the process of choosing appropriate maintenance tasks and frequencies is both SMP-specific and site-specific. A SMP-specific and site-specific O&M Schedule is required to be prepared by the design engineer and submitted to PWD as part of the PCSMP submittal. The O&M Schedule should be provided to and implemented by the property owner as a guide for long-term operations and maintenance of the SMPs on-site.

The standard O&M Agreement consists of the terms of the agreement followed by a signatory section, signatory acknowledgement sections, an Exhibit A, and an Exhibit B. Should amendments to the O&M Agreement become necessary, the amendments shall be sequentially numbered, and the Exhibits for these amendments shall continue alphabetically. Within the signatory section, each signatory will execute the agreement, including a representative of PWD as well as for the property. The signatories for the property must be authorized to bind the property owner(s) and the property lessee(s), if applicable, in legal agreements with PWD. The signatory acknowledgement sections must be notarized and serve to verify the identities of all parties executing the signatory section of the agreement. Exhibit A contains a legal property description for each parcel on which SMPs are to be constructed.

PWD compiles the signatory section, the signatory acknowledgement sections, and Exhibit A based on the information provided by the applicant within Worksheet 4. Worksheet 4 can be found in the Stormwater Management section of the Technical Library on http://www.pwdplanreview.org/ and must be completed and submitted as part of the initial PCSMP technical submittal. The submitted Worksheet 4 will be reviewed as part of the PCSMP screening process. Incomplete and/or incorrect information within Worksheet 4 will prevent the PCSMP review from proceeding until all omissions and/or discrepancies are addressed.

The O&M Agreement is prepared by PWD as part of the PCSMP technical review process, including the completion of an Exhibit B which lists all SMPs to be constructed on-site. Prior to PCSMP Approval, PWD will issue an electronic copy of the O&M Agreement to the applicant to be signed and notarized by the signatories for the property as specified in the signatory section of Worksheet 4. The applicant must return two (2) executed copies of the O&M Agreement along with the recording fee payment to PWD before a PCSMP Approval will be issued for the project. Upon PWD's receipt of the signed agreement and the recording fee payment, a representative of PWD will sign the agreement, and PWD will then record the agreement with the Department of Records on behalf of the property owner. A copy of the signed, fully-executed agreement will be mailed to the signatory at the conclusion of the recording process.

5.4.5 Record Drawings

It is important, both for the property owner and for PWD, to ensure that all SMPs are constructed in strict accordance with the Approved PCSMP. Even small variations in the characteristics of an SMP (i.e. footprint area, elevations, layer thicknesses, pipe sizing, etc.) can have large effects on the SMP's ability to perform its designed stormwater function. With this in mind, the PWD Stormwater Regulations stipulate that Record Drawings for all PCSMP components must be submitted to the Department.

Record Drawing Overview

- Record Drawing plans are construction drawings revised to represent the as-built conditions, including, at a minimum, all locations, dimensions, elevations, and materials as constructed and installed. PWD uses the project's Record Drawing(s) to verify compliance with the PWD Stormwater Regulations and to document and verify the quantity of stormwater managed on a site. It is critical that the Record Drawing(s) reflect any changes from the approved design that may affect the performance of the SMP(s).
- It is important that the Owner/Developer be aware of the Record Drawing requirements within this Manual and within the PWD Stormwater Regulations, budget accordingly, and consider these requirements when issuing the project for construction bid.
- The design engineer must customize an SMP Construction Certification Form for each SMP proposed on-site. These forms, which are described in further detail in the Record Drawing Submission and Review Process section below, must be provided to PWD for review as part of the PCSMP technical review process. It is recommended that the SMP Construction Certification Form(s) be included in the construction bid documents for the project to ensure that the selected contractor is aware of the requirement to complete the forms during construction. The project's sequence of construction must identify all stages of SMP construction for which the contractor must document the specific elevations and measurements found on the SMP Construction Certification Form(s).
- The contractor must install all on-site SMPs, conveyance piping, structures, and any other features associated with the stormwater management design in strict accordance with the Approved PCSMP. In order to help demonstrate that all SMPs are properly installed during construction, the contractor must complete all SMP Construction Certification Forms, which are described in further detail in the Record Drawing Submission and Review Process section below. All elevations identified on the forms must be documented as they are measured. These forms must be on-site and available for PWD inspection at all times. Upon completion of the construction, all SMP Construction Certification Forms must be submitted to PWD as part of the Construction Certification Package, described below, and the measurements documented on these forms must be reflected on the Record Drawing(s).

PWD Record Drawing Requirements

- The contractor must keep the Approved PCSMP on-site at all times throughout the construction process and document all changes from the Approved PSCMP as they occur. PWD recommends marking up and tracking changes on an actual copy of the Approved PCSMP to simplify preparation of the Record Drawing(s). Using the Approved PCSMP as a base, the Record Drawing(s) should highlight information confirmed to be in accordance with the Approved PCSMP in yellow and identify any deviations in red ink. The Record Drawing(s) must be clear and legible.
- The Record Drawing(s) should include, at a minimum, the following information:
    - Horizontal variations greater than 1.0 foot should be shown dimensionally or

through stations.
- Vertical elevation variations greater than 0.1 feet should be provided for all shown design elevations.
- Measurable plan scale (not to exceed 1” = 50’)
- North arrow
- Locations of all proposed stormwater management facilities in plan view
- Distance from lot lines to the constructed SMPs
- Benchmark elevation, description, and location on each plan sheet
- Locations of all utilities
- Spot grades and grade lines
- Stormwater flow direction arrows
- Elevations at the following locations (minimum): across dam embankment, top of riser, at the invert and rim of all orifice openings in the riser, across the emergency spillway, across the bottom of the pond (dry ponds only), at the outlet of the structure, and the outlet of the pipe
- Measurements for all openings, weirs, or other flow control devices
- Pipe and culvert information (material, length, size, slope, inlet and outlet locations, and rim and invert elevations) and information for any energy dissipation measures
- Drainage areas for each stormwater management facility if they differ from the Approved PCSMP
- Detail or cross-section of each stormwater management practice

- Record Drawings may be prepared by Professional Engineers, Registered Architects, Landscape Architects, Professional Land Surveyors, Professional Geologists, and Licensed Contractors. The preparer of the plan must prominently display their signature and professional seal, or, in the case of Licensed Contractors, their signature and City of Philadelphia Department of Licenses and Inspections Contractor License Number, on each Record Drawing plan sheet.

Record Drawing Submission and Review Process

Record Drawing Submission

The Record Drawing Submission must consist of the following items, which must be submitted to PWD for review after construction has been completed but prior to the post-construction inspection:

- One (1) hard copy and one (1) electronic copy of the Record Drawing(s)
- One (1) electronic copy of the Construction Certification Package
- All materials must be submitted to:

  PWD Projects Control
  1101 Market Street, 2nd Floor
  Philadelphia, PA 19107

The Construction Certification Package must consist of the following items:

- An SMP Construction Certification Form must be prepared by the design engineer for each SMP on-site and provided to PWD for review as part of the PCSMP technical review process. Each form must indicate the measurements which are most critical to the listed SMP’s ability to perform its design function (i.e. elevations, surface areas, layer depths, etc.). All SMP Construction Certification Forms, as prepared by the engineer and found acceptable by PWD during the PCSMP technical review process, must be completed by the contractor during construction. Each measurement documented on the forms must include a measurement date and be initialed by the contractor, or the contractor’s designee, who took, or

witnessed the taking of, the measurement. Once all of the required measurements have been appropriately documented, the contractor must execute and date the form.

- Receipts for materials which pertain to the stormwater management system must be provided to PWD. The material receipts must clearly specify the types, qualities, and quantities of the materials purchased. The materials for which receipts are required may include, but are not limited to, stone, geotextile fabric, perforated pipes, subsurface storage units, soil, porous pavement or pavers, impermeable liner, concrete structures, hoods or traps, and vegetation or plantings.
- Photographs documenting all SMP installations must be provided. The photographs should clearly depict the installation of all components of the SMP. These photographs may include, but are not limited to, photographs of the basin excavation, fabric or liner placement, stone placement, pipe placement, and weir installation.

For more information, please refer to the Construction Certification Package document, which can be found in the Technical Library at http://www.pwdplanreview.org/.

Record Drawing Review Process

PWD will review the submitted Record Drawing(s) and Construction Certification Package to determine if the project has been constructed in strict accordance with the Approved PCSMP. When constructed conditions differ from the Approved PCSMP, calculations performed by a qualified design professional must be provided to demonstrate compliance with PWD's Stormwater Regulations. Specifically, PWD may review and analyze the SMP storage volume, release rate, drainage areas, and any other items that affect the Development Site's compliance with the PWD Stormwater Regulations and other requirements.

Response from PWD

- PWD will issue a letter either confirming the acceptance of the Record Drawing(s) or detailing the deficiencies with the constructed SMPs or submitted materials. Based on PWD's evaluation of these deficiencies, revised plans, details, and/or other documentation, as needed, may be required to demonstrate that the project complies with PWD's Stormwater Regulations. If compliance with PWD's Stormwater Regulations cannot be demonstrated, corrective actions to bring the project into compliance must be proposed by the property owner.
- Projects confirmed to be in compliance with PWD's Stormwater Regulations through a Record Drawing review and post construction inspection may be eligible for Stormwater Billing credits. A Stormwater Credits Application (Form B) may be submitted to PWD for review once the aforementioned steps are completed. This form, and more information on PWD's Stormwater Billing program, can be found at http://www.phila.gov/water/stormwater_billing.html .

6 Utilizing Existing Site Features

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6.0 Introduction

This manual emphasizes an integrated site design approach to stormwater management. By considering stormwater management in conjunction with site uses and functions from the assessment phase through final design, it is possible to develop a site plan that meets the Philadelphia Water Department (PWD) Stormwater Management Regulations (Stormwater Regulations) and other site objectives concurrently.

The following sections present examples from Pennsylvania and across the nation that integrate stormwater management approaches into both original and retrofit site designs. In this way, comprehensive stormwater management can be integrated effectively and economically into the site design process.

The following set of sections illustrates concepts and benefits provided through the application of holistic stormwater management approaches.

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6.1 Street design

Sidewalk planter managing street runoff

provides an opportunity to distribute stormwater management practices (SMPs) and integrate them with neighborhood aesthetics. Street location, width, and design can reduce the volume of stormwater runoff leaving the streets. Utilizing vegetated areas along a street for water quality treatment and detention can also reduce the costs of development by creating less need for underground stormwater infrastructure. Other benefits of low-impact street design include slowed traffic in residential areas, enhanced visual appearance, and improved water quality.

Low-impact street design can be difficult to accomplish within the City of Philadelphia. Design of public streets is highly regulated and structural SMPs are typically not permitted within the public right-of-way. The current residential street width requirements from the Philadelphia City Code are shown below. However, the City is working to develop a green street design that can be implemented throughout Philadelphia. There are also opportunities for low-impact design elements to be applied on private streets and drives such as those within a condominium. This section includes several examples of street design that can serve as a model for development in Philadelphia.

Note:
SMP Design and combinations are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

Table 6.1: Philadelphia's City Codes for Street Widths	
(§14-2104.) - **Minimum street right-of-way and cartway widths shall conform to the Physical Development Plan of the City and where not shown thereon shall conform to the following:**	
primary residential street	64 feet in width, right-of-way 88 feet in width
secondary residential street	34 feet in width, right-of-way 54 feet in width
tertiary residential street	26 feet in width, right-of-way 50 feet in width
marginal access street	26 feet in width, right-of-way might vary with conditions but in no case shall be less than 36 feet
(§11-407.) **- Minimum street width shall conform to the provisions of** *(§ 14-2104.)* **A street which does not conform to** *(§ 14-2104(5))* **may be accepted and placed upon the City Plan if it was physically or legally opened or built upon:** Civil Engineering Reference Manual	
prior to April 2, 1906	must be at least 40 feet in width;
prior to April 8, 1890	must be at least 30 feet in width;

example:

The City of Portland “Green Streets Project” on NE Siskiyou Street incorporates landscaped curb extensions or bumpouts designed to capture stormwater.

Green Streets Project: Portland, Oregon

NE Siskiyou before

NE Siskiyou during construction

NE Siskiyou after

City of Portland, Bureau of Environmental Services

Diverse plants make the curb extension pleasing while absorbing runoff.

project overview

The neighborhood is served by combined sewers that carry both sewage from homes and stormwater runoff from streets. When it rains, combined sewer pipes fill to capacity and overflow to the Willamette River.

Portland’s Bureau of Environmental Services built two landscaped curb extensions in the parking zone on each side of Siskiyou Street just above the storm drain inlets. Stormwater slows when it enters the landscaped areas, water infiltrates into the ground, and vegetation help filter pollutants. The Northeast Siskiyou Green Street Project is Portland’s first residential, on-street stormwater management project. It is a sustainable approach that mimics natural conditions while improving water quality and neighborhood aesthetics.

Private developments within the City of Philadelphia may not currently use area within the public right-of-way to meet their stormwater management requirements. However, this design may be modified for on-site treatment or applied to private roads such as those within a condominium.

design elements

- Dense, low growing plant material in a bioinfiltration bed for stormwater capture, filtration, and recharge to local soils.
- Curb openings to allow stormwater runoff into the planted area.
- Check dams to increase retention times to promote infiltration and uptake by native plantings.

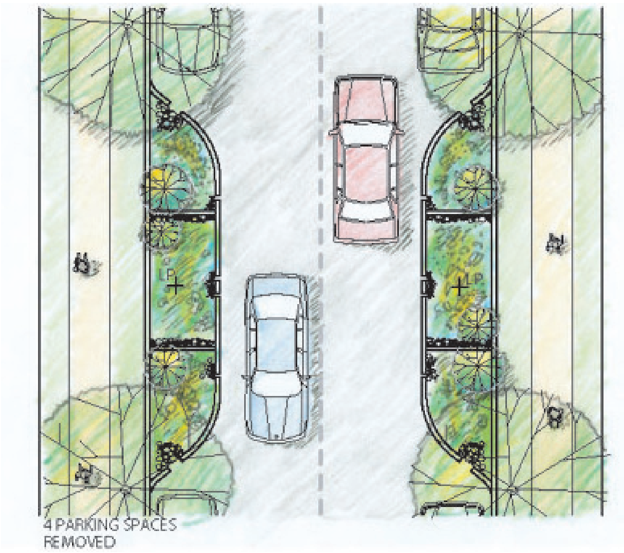

Figure 6.1: Traffic calming device on secondary street that also provides stormwater management

example:

The City of Seattle's Pilot Street Edge Alternative Project (SEA Streets) provides drainage that mimics the natural landscape prior to development more closely than traditional systems.

Street Edge Alternatives (SEA) Seattle, Washington


Seattle Public Utilities


Seattle Public Utilities


Seattle Public Utilities

Curbless roads allows stormwater to runoff to the streets


Seattle Public Utilities

Bioretention swale between sidewalk and paved road

project overview

As the Street Edge Alternatives Project gathered more data and information concerning the damage runoff causes, they began exploring new approaches to manage stormwater. These natural drainage systems meet multiple goals and help manage flooding in neighborhoods. At the same time, they improve the appearance and function of the street right-of-way. Two years of monitoring shows that SEA Streets reduce the volume of stormwater runoff by 99% for a two-year storm event, and help the city meet Local, State, and Federal Environmental Regulations.

design elements

- Curbless roads provide traffic calming and soft-edged, aesthetic environments.
- Bioretention swales mimic the natural landscape and provide drainage and absorption of pollutants.
- Infiltration in bioretention swales can be used to meet Water Quality requirements for contributing Directly Connected Impervious Area (DCIA).

Figure 6.2: Secondary street with bioretention basins

cul-de-sac design

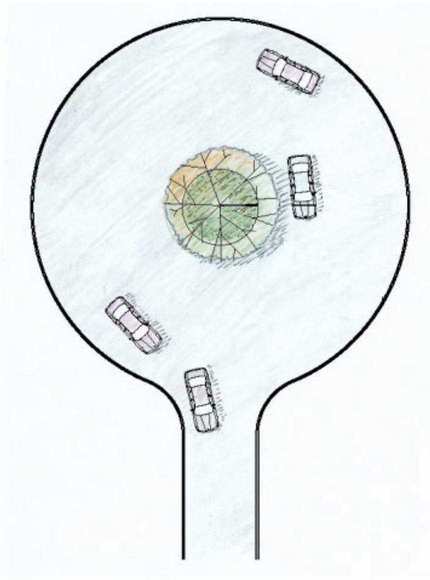

Figure 6.3: Cul-de-sac with bioretention

Though cul-de-sacs and 'dead ends' are not encouraged in urban street design, they do exist within urban areas. In Philadelphia, dead end streets are prohibited, except as short stubs to permit future street extension into adjoining tracts, or when designed as a cul-de-sac. (§14-2104. Subdivision Design Standards.) Where cul-de-sacs are unavoidable, they can be designed with central islands that reduce impervious area and to allow for infiltration of stormwater runoff.

design overview

Careful cul-de-sac design can greatly reduce total impervious area and can create a stormwater management facility. Philadelphia Code stipulates, "Cul-de-sacs, permanently designed as such shall have at the closed end a turn-around containing a right-of-way having an outside radius of not less than 50 feet, which shall be paved to a radius of 40 feet." (§14-2104)

A cul-de-sac can be designed to meet these standards and still provide stormwater management. An island can be designed in the center of a cul-de-sac that provides a sufficient travel lane, but reduces impervious area and manages stormwater from the street and adjacent properties. The entire street should be graded to the central island to the extent that surrounding topography allows. The island would be designed like a bioretention facility and runoff can enter the island through curb openings or a curbless design.

design elements

- Bioretention islands capture stormwater runoff.
- Flow controls direct stormwater from street and adjacent properties into the island.

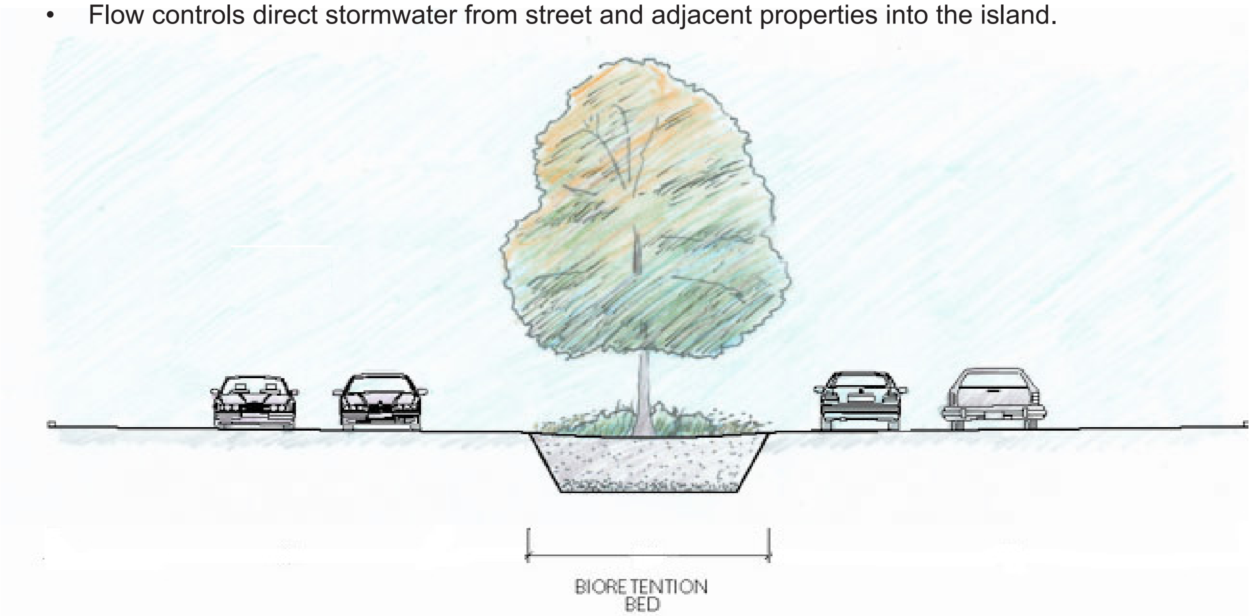

Figure 6.4: Cross-section view of a bioretention cul-de-sac. The island of the cul-de-sacs accepts stormwater from surrounding pavement

vegetated medians

Bioretention incorporated in highway median

Vegetated swale in street median

Medians that are retrofitted to provide stormwater control are effective elements of traffic calming and stormwater management while enhancing the visual quality of the streetscape. There are different ways to help prevent stormwater runoff pollution from reaching Philadelphia's rivers. Bioinfiltration swales and concave designs are just a few examples of effective stormwater control. These provide for an attractive and healthier appearance of the city, but still deliver the necessary benefits to our natural resources.

design overview

Median strips can be graded concave and incorporate vegetated SMPs (see **Section 7.5:** Bioretention and **Section 7.8:** Swales). Water draining into these SMPs can be treated for water quality through infiltration or an underdrained system may be installed to allow water to be treated and slowly released depending on soil conditions.

design elements

- Bioinfiltration swales for runoff control on both sides of traffic.
- Planted native vegetation to enhance appearance and provide capture and filtration
- Curb openings or curbless design to allow controlled stormwater inflow

Note:
Designs and combinations are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

Figure 6.5: Cross-section view of secondary street with bioretention basins

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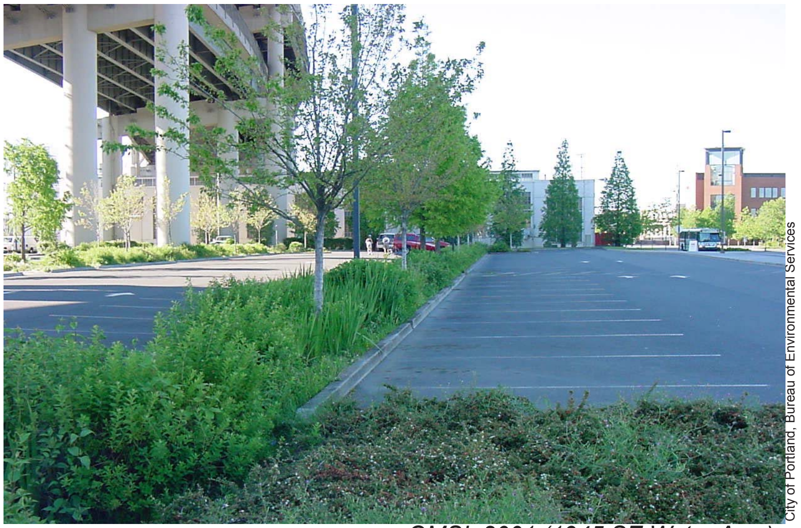
6.2 Parking lot design

The requirements of the Stormwater Regulations, including non-structural project design, can be met in many cases by rethinking parking lot design. Effective use of the minimum parking space and aisle dimensions as permitted in the City's Zoning Code allows the number of parking spaces to remain the same, while reducing impervious surface, providing stormwater management, and adding valuable green space to a parking lot.



City of Portland, Bureau of Environmental Services

OMSI, 2001 (1945 SE Water Ave.)

City of Portland, Bureau of Environmental Services

Glencoe Elementary School Parking Lot (825 SE 51st)

bioretention garden

design overview

Sheet flow from the parking lot is directed toward shallow bioretention gardens. The runoff is then temporarily detained and infiltrated into the subsurface. Bioretention gardens can replace the need for other conventional stormwater management techniques. Distributed bioretention gardens offer the greatest benefit. Sites can benefit from bioretention gardens placed along the edges of the site as well as in islands and medians.

Traditional stormwater infrastructure can be reduced, and parking lot aesthetics are also greatly improved. The use of large trees help improve the air quality and provide shading for the cars in the parking lot.

design elements

- Bioretention garden with acceptable vegetation (refer to **Section 7.5:** Bioinfiltration/Bioretention and **Section 8:** Landscape Guidance)
- Curb openings with flow controls, such as flow spreaders and energy dissipaters (refer to **Section 7.15**: Inlet and Outlet Controls).

porous/permeable pavement

design overview

The use of porous or permeable pavement creates a parking lot that distributes stormwater evenly into a subsurface infiltration bed. These systems can be designed to infiltrate even the large storms. Seasonal maintenance is required for most porous pavement systems to ensure continued function.

Multnomah Arts Center Eco-Stone parking lot

design elements

- Porous pavement combined with subsurface infiltration (refer to **Section 7.13**: Porous Pavement).
- Documentation of flow through rate or void percentage must be provided when using permeable pavers


Onion Flats grass paving parking lot

grass paving

design overview

Void spaces found in grass paving techniques offer area infiltration while maintaining parking support. Replacement of conventional pavement with grass paving systems can reduce urban heat effects.

design elements

- Reinforced grid system (refer to **Section 7.13**: Porous Pavement)

6.3 Planter boxes

Planter boxes reduce impervious cover by retaining stormwater runoff rather than allowing it to directly drain into nearby sewers. There are two main types of planter boxes: Flow-through and Contained. Planter boxes can play an important role in the city by minimizing stormwater runoff, reducing water pollution, and creating a greener and healthier look. Planter boxes can be used on sidewalks, plazas, rooftops and other otherwise impervious areas. They can also be constructed alongside buildings, provided proper waterproofing measures are used to protect foundations.

Broad Street planter box

flow-through

The flow-through planter box is designed with an impervious bottom or is placed on an impervious surface. Water quality treatment, attenuation of flow, and some volume reduction is achieved as the water filters through the soil. Flow control is obtained by storing the water in a reservoir above the soil. This type of planter can be used adjacent to a building if lined properly.

City of Portland, Bureau of Environmental Services

Flow-through planter box

The planters should be designed to retain and slowly release water. Vegetation includes rushes, reeds, sedges, irises, dogwoods, and other acceptable shrubs, trees, and forbs/grasses. Planters should be designed to receive less than 15,000 square-feet of impervious area runoff.

Suggested structural elements of planters include stone, concrete, brick, or pressure-treated wood. Certain treated wood should be avoided if it leaches toxic chemicals that can contaminate any filtered stormwater. The flow-through planter is completely contained and is not designed to drain directly into the ground. Irrigation is optional and used to maintain plant viability and reservoir height. Pipes can also be designed to transport water to an approved disposal point.

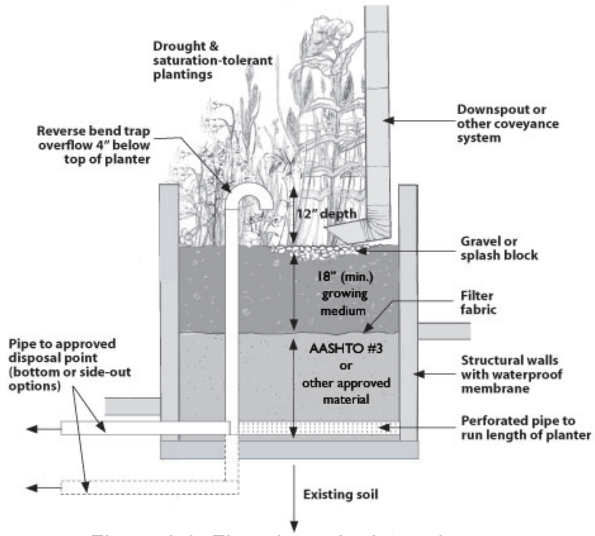


Figure 6.6: Flow-through planter box

City of Portland, Bureau of Environmental Services

contained

Contained planter boxes reduce impervious area by retaining rainwater which slows stormwater runoff from draining into sewers. Contained planters are used for planting trees, shrubs, and ground cover. The planter is either prefabricated or permanently constructed and has a variety of shapes and sizes. Planters are placed on impervious surfaces like sidewalks, plazas, and rooftops. Contained planters may drain onto impervious surfaces through their base or by an overflow structure.

Plants should be hardy and self-sustaining with little need for fertilizers or pesticides. Irrigation is optional though plant viability should be maintained. Trees are highly encouraged because of the natural canopy they will provide and the reduction of urban heat. The structural elements of the planters should be stone, concrete, brick, wood, or any other suitable material. Treated wood should be avoided if it leaches any toxic chemicals.

Broad Street planter box

Information on Special Detention Areas
can be found in the
Pennsylvania Stormwater BMP Manual

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6.5 Disconnecting impervious cover

will reduce runoff from the site and therefore can reduce the structural stormwater management requirements for the development project. Impervious cover can be disconnected by directing the flow over a pervious area which allows for infiltration, filtration, and increased time of concentration. When this is done correctly, the area may be considered Disconnected Impervious Cover (DIC). Depending on the site configuration, all or a portion of impervious cover can be effectively removed by limiting the amount of actual impervious surfaces or by reducing the impervious area that is directly connected to the stormwater conveyance system. The DCIA Worksheet guides the designer through this stage of the design process.

minimize area of impervious cover

In many cases, alternative configurations for streets and parking lots can provide the same function as traditional designs with reduced area. Minimizing the area of pavement and rooftops will reduce the size and cost of SMPs that must be constructed. See the Parking Lot Design, **Section 6.2** for more information and ideas on how to minimize the impervious area.

disconnect impervious cover

Rooftop Disconnection

An adjustment to DCIA is permitted when the downspout is disconnected and then directed to a pervious area which allow for infiltration, filtration, and increased time of concentration. PWD will support the applicant in their request to obtain relevant necessary Plumbing Code variances for approved rooftop disconnections.

- DIC may be treated as pervious when determining whether a redevelopment site has met the 20% reduction in impervious surface.

- DIC need not be managed for Water Quality. However, for Flood Control and Channel Protection, appropriate Curve Number (CN) values must be utilized when calculating management for these requirements.

A rooftop is considered to be completely or partially disconnected if it meets the requirements below:

- The contributing area of rooftop to each disconnected discharge is 500 square feet or less,
- The soil is not designated as a hydrologic soil group “D” or equivalent, and
- The overland flow path has a positive slope of 5% or less.

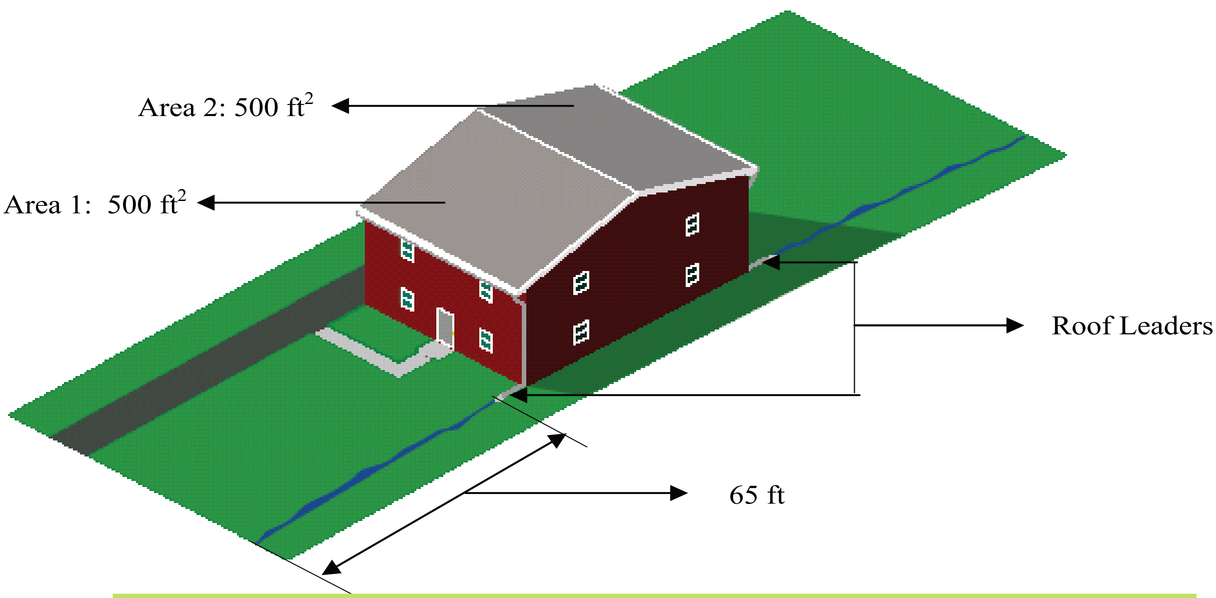
For designs that meet these requirements, the portion of the roof that may be considered DIC depends on the length of the overland path as designated in the following table.

Table 6.2: Partial Rooftop Disconnection

Length of Pervious Flow Path*	Roof Area Treated as Disconnected
(ft)	(% of contributing roof area)
0 - 14	0
15 - 29	20
30 - 44	40
45 - 59	60
60 - 74	80
75 or more	100

* Flow path cannot include impervious surfaces and must be at least 15 feet from any impervious surfaces.

For example, consider a 1,000 square foot roof with two roof leaders each draining an area of 500 square feet. Both roof leaders discharge to a lawn. The lawn has type B soils and a slope of 3%. The distance from the downspout discharge point to the street is 65 feet. Therefore, based on Table 4.1, 80% of the roof area may be considered DIC and treated as pervious cover when calculating stormwater management requirements. Disconnecting the roof leaders will significantly reduce the size and cost of stormwater management facilities at this site.



Total Roof Area: (Area 1 + Area 2): 1000 ft²
Disconnected Roof Area: (0.8) x (Total Roof Area): 800 ft²
Remaining DCIA: (Total Roof Area - Disconnected Roof Area): 200 ft²

Figure 6.7: Rooftop disconnection

Pavement Disconnection

An adjustment to DCIA is permitted when pavement runoff is directed to a pervious area which allows for infiltration, filtration, and increase the time of concentration. This method is generally applicable to small or narrow pavement structures such as driveways and narrow pathways through otherwise pervious areas (e.g., a bike path through a park). For structures that meet the requirements, all of the DIC may be deducted from the total impervious cover. DIC may be treated as pervious when determining whether a redevelopment site has met the 20% reduction in impervious surface. DIC need not be managed for Water Quality. If the site does not successfully reduce impervious cover by 20%, then appropriate CN values must be utilized when calculating Flood Control and Channel Protection. Pavement is disconnected if it meets the requirements below:

- The contributing flow path over impervious cover is no more than 75 feet,
- The length of overland flow is greater than or equal to the contributing length,
- The soil is not designated as a hydrologic soil group “D” or equivalent,
- The slope of the contributing impervious area is 5% or less, and
- The slope of the overland flow path is 5% or less.

If discharge is concentrated at one or more discrete points, no more than 1,000 square feet may discharge to any one point. In addition, a gravel strip or other spreading device is required for concentrated discharges. For non-concentrated discharges along the entire edge of pavement, this requirement is waived; however, there must be provisions for the establishment of vegetation along the pavement edge and temporary stabilization of the area until vegetation becomes established.

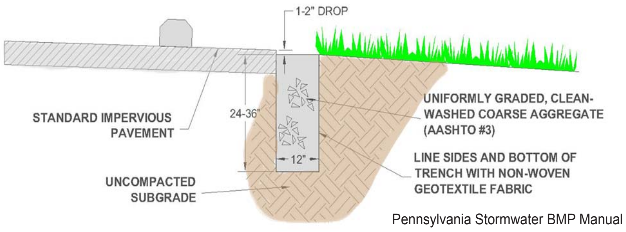


Figure 6.8: Gravel filter strip

Note:
Filter strips are recommended only as a viable stormwater management pretreatment option. Filter strips are recommend for use as pretreatment for many intensive structural SMPs.

maximize tree canopy over impervious cover

A reduction in DCIA is permitted when new or existing tree canopy from the approved species list extends over or is in close proximity to the impervious cover. Under these circumstances, a portion of impervious cover under tree canopy may be treated as DIC and deducted from total impervious cover. DIC is considered pervious when calculating stormwater control requirements.

For a new tree to be eligible for the reduction:

- The tree species must be chosen from the approved list provided by the PWD Office of Watersheds.
- Trees must be planted within 10 feet of ground level DCIA within the limits of earth disturbance.
- New deciduous trees must be at least 2-inch caliper and new evergreen trees must be at least 6 feet tall to be eligible for the reduction.
- A 100 sq. ft DCIA reduction is permitted for each new tree. This credit may only be applied to the impervious area directly adjacent to the tree.
- The maximum reduction permitted, including existing trees is 25% of ground level impervious area within the limits of earth disturbance.

Install Green Roofs to Minimize DCIA

A reduction in DCIA is permitted when a green roof is installed on a proposed building. The design, construction, and maintenance Plan must meet the minimum requirements specified in **Section 7**: SMP Design Guidelines. To encourage this emerging technology, the entire area of the green roof area may be considered DIC. However, since a green roof is not a zero discharge system, the remaining site design must safely convey roof runoff to the approved point of discharge. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

Install Porous Pavement to Reduce DCIA

A reduction in DCIA is permitted when a porous pavement system is installed on the site such that it does not create any areas of concentrated infiltration. Porous pavement systems, including porous asphalt; porous concrete; porous/permeable pavers; and other PWD-approved porous structural surfaces can be considered to be DIC if they receive direct rainfall only and are underlain by a crushed stone infiltration bed that is at least 8 inches deep. Porous/permeable pavers must also meet minimum standards for flow-through rate or void percentage. If an underdrain is proposed, the porous pavement will only be considered DIC if the first inch of runoff can be stored below the lowest overflow from the underdrain system. Porous asphalt systems must meet the minimum requirements detailed in **Section 7.13**: Porous Pavement. Infiltration testing is not required for disconnected porous pavement areas; however, it is recommended to ensure timely drainage of the stone base. DIC need not be managed for Water Quality or Channel Protection. Appropriate CN values must be utilized when performing Flood Control calculations.

In most cases, if the porous surface receives runoff (overland or piped directly into the subsurface storage bed) from adjacent conventional pavement surfaces, roof, or other impervious surfaces, the porous pavement/infiltration bed system will be considered a structural SMP and the porous surface will be considered DCIA. Those areas considered structural SMPs will require infiltration testing. In some cases, where a small amount of run-on cannot be avoided, it may still be possible to consider the porous pavement disconnected. Such allowances will be considered on a case-by-case basis by PWD.

7 Stormwater Management Practice Design Guidelines

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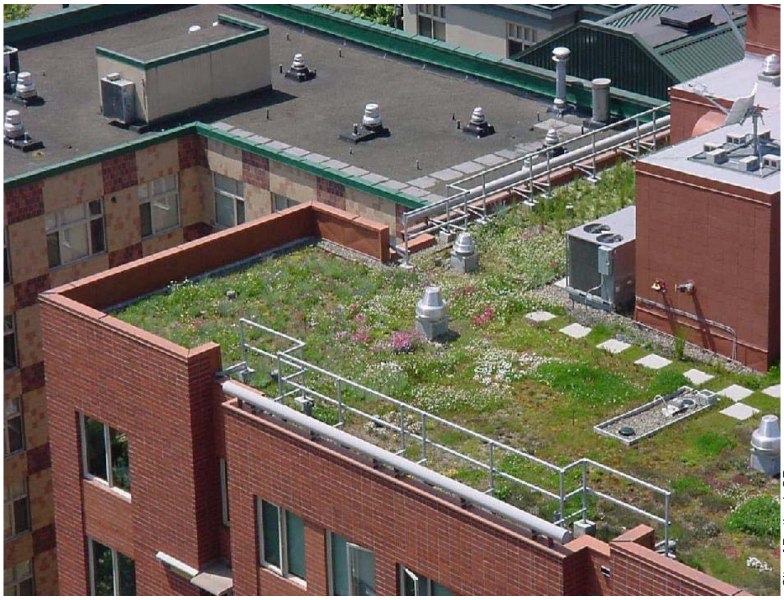
7.1 Green roofs



City of Portland, OR

(vegetated roof/eco roof/roof garden) consist of a layer of vegetation that completely covers an otherwise conventional flat or pitched roof. The hydrologic response of a green roof bears closer resemblance to a lawn or meadow than impervious surface. The green roof system is composed of multiple layers including waterproofing, a drainage layer, engineered planting media, and specially selected plants. Vegetated roof covers can be optimized to achieve water quantity and quality benefits. Through the appropriate selection of materials, vegetated covers can provide rainfall retention and detention functions.

key elements :

- Extensive green roofs with engineered media at least 3 inches in depth can be considered pervious in stormwater design calculations.
- Vegetated roof covers intended to achieve water quality benefits should maintain a soluble nitrogen level of 4ppm.
- Internal drainage, including provisions to cover and protect deck drains or scuppers, must anticipate the need to manage large rainfall events without inundating the cover.
- Provide urban green space and aesthetically pleasing views.
- Act as heat sink to reduce heating and cooling costs.
- Can extend roof life by two to three times.
- Improve air quality by filtering dust particles.

potential applications

Residential Subdivision:	Case by case
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	No

acceptable forms of pre-treatment

N/A

stormwater regulations

Water Quality:	
Infiltration:	No
Volume Reduction: (no infiltration)	Yes
Channel Protection:	Not included in DCIA
Flood Control:	Low

Green Roofs in the Urban Landscape

Unlike conventional roofing, green roofs promote retention, slow release, and evapotranspiration of precipitation. This stormwater management technique is very effective in reducing the volume and velocity of stormwater runoff from roofs.

Green roofs can be installed on many types of roofs, from small slanting roofs to large commercial flat roofs. Green roofs are an ideal option for new buildings that are taking long term cost savings and energy conservation into consideration. Many existing buildings can also be retrofitted with green roofs.

Example of a green roof at the Heinz 57 Center Pittsburgh, PA

Although green roofs are more expensive than conventional roofs up front, they provide long term benefits and cost savings. The vegetated cover assembly should be compatible with and designed to protect the underlying waterproofing materials. By protecting the waterproofing from mechanical damage, shielding it from UV radiation, and buffering temperature extremes, the service life of the roof can be extended by two to three times. Green roofs also may reduce energy costs by acting as a heat sink. The roof slowly absorbs energy from the sun during the day and releases it as the air cools, thereby reducing heating and cooling costs. The benefits will be greatest during the summer months, especially for low buildings. Green roofs also reduce the urban heat island effect by providing evaporative cooling and can improve air quality by filtering dust particles.

Components of a Green Roof

There are two basic types of green roofs. An extensive green roof system is a thin (usually less than 6 inches), lighter weight system planted predominantly with drought-tolerant succulent plants and grasses. An intensive green roof is a deeper, heavier system designed to sustain more complex landscapes. A green roof system, extensive or intensive, is often comprised of the same components:

- Plant material
- Growing medium
- Filter fabric
- Drainage layer
- Waterproof membrane/root barrier
- Roof structure

Plant Material

The plant material chosen for green roofs is designed to take up much of the water that falls on the roof during a storm event. Plant selection is very important to the sustainability of the roof. About 50% of the vegetation on an extensive green roof should be Sedums. Plant material also collects dust, creates oxygen, releases moisture, and provides evaporative cooling.

Growing Medium
The growing medium is a critical element of stormwater storage and detention on a green roof, and provides a buffer between the roof structure and vegetation for root development. Storage is provided by a green roof primarily through water held in tension in the growing medium pores. The growing medium in an extensive green roof should be a lightweight mineral material with a minimum of organic material and should stand up to freeze/thaw cycles.

Filter Fabric
An engineered filter fabric prevents fine soil particles from passing into the drainage layer of the green roof system.

Drainage Layer
The drainage layer may be either a lightweight granular medium or a synthetic layer that underlays and promotes free drainage of the planting medium. In some assemblages, synthetic drainage layers may also incorporate depressions that can intercept and retain small quantities of runoff.

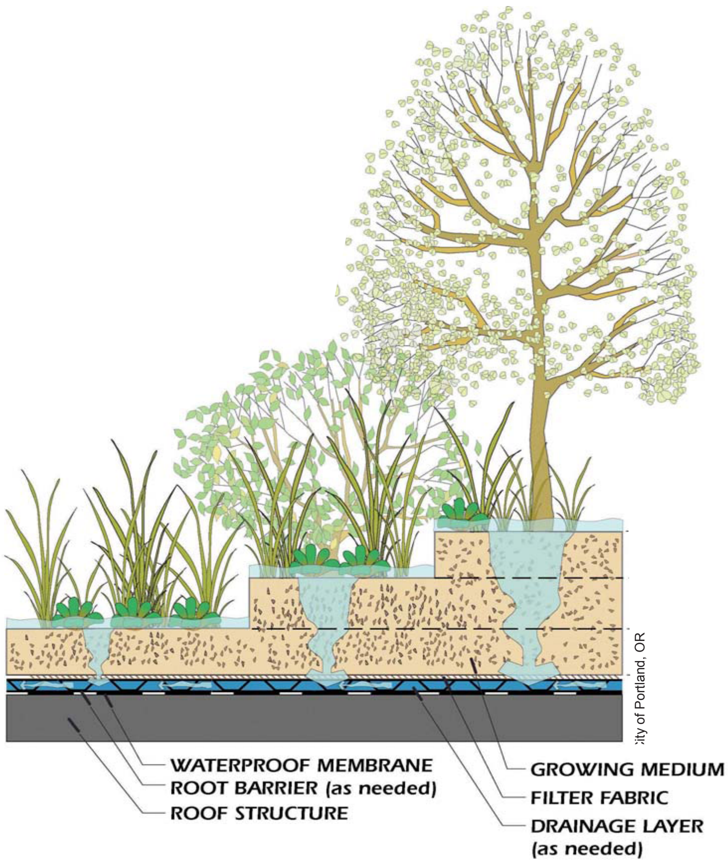


Figure 7.1: Cross-section view of roof garden

Waterproof Membrane/Root Barrier
To maintain structural integrity of the roof, a waterproof material is laid above the roof structure. Some waterproofing materials are inherently root resistant, whereas others require an additional root barrier.

Roof Structure
The load capacity of a roof structure must be taken into account when considering the installation of a green roof. Extensive green roofs typically weigh between 15 and 30 lbs per square foot and are compatible with wood or steel decks. Intensive green roofs weigh more than 36 lbs per square foot and typically require concrete supporting decks.

Ponding of water on standard rooftop

Rooftop after greenroof installation

Recommended Design Procedure

- Investigate the feasibility of the installation of a green roof. A Structural Engineer should verify that the roof will support the weight of the green roof system. It is important to consider the wet weight of the roof in the design calculations.

- Determine the portion of roof that will have a green roof.

- Extensive green roofs that have an engineered media at least 3 inches thick are permitted a DCIA reduction equal to the entire area of the green roof.

- Impervious roof area directing runoff onto the green roof cannot exceed 50% of the green roof area.

- The minimum thickness of the green roof growing medium is 3 inches. When only a portion of a roof is a green roof, it is acceptable to drain runoff from the impervious portion of the roof to the green roof. The minimum thickness of the green roof qualifying as pervious area is determined using the following formula, where impervious roof area/green roof area ≤ 0.50 :

  Minimum thickness (in inches) of green roof growing medium = 3" + [3 * (Impervious roof area/ Green roof area)]

- The contributing area of rooftop to each disconnected discharge point must be equal to or less than 500 square feet.

- Runoff from impervious roof area onto green roof must be dispersed evenly across it and pass through the growing medium. Drainage piping may be necessary to ensure distribution.

- The green roof is considered pervious area when determining whether a redevelopment project has reduced DCIA by 20%.

- The area of the green roof is not included in the calculation of the Water Quality Volume, because it is not considered DCIA.

- The area of the green roof is not included in the calculation of the Channel Protection Volume, because it is not considered DCIA.

- The green roof area can be considered pervious open space in good condition with moderate soils when determining post-development flow rates for the Flood Control requirement.

- Although green roofs are not considered as impervious surfaces when determining applicability of stormwater management requirements, they are not zero discharge systems. The roof drainage system and the remainder of the site drainage system must safely convey roof runoff to the storm sewer, combined sewer, or receiving water.

- Green roofs with a media thickness less than 3 inches can only be considered pervious if the designer can demonstrate that the initial abstraction of the green roof will be 0.5 inches or greater.

- Develop Planting Plan based on the thickness of the planting media.

- Complete construction plans and specifications.

Materials

Presently, the most complete established standards for green roof construction are those developed in Germany by the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL). The FLL standards and guidelines include industry standard tests for the weight, moisture, nutrient content, and grain-size distribution of growing media. These guidelines are available in English translation directly from FLL. Laboratories in the United States are now offering a full range of FLL tests for green roof materials. Among them is the Agricultural Analytical Services Laboratory (AASL) at Pennsylvania State University. AASL can also conduct tests of waterproofing membranes for root penetration resistance using FLL protocol. Currently there is an American Standard Testing Methods (ASTM) task group that is developing comprehensive American standards for green roof installation. As of June 2007, the following

ASTM standards have been developed;

- E2396 Standard Testing Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Green Roof Systems
- E2397 Standard Practice for Determination of Dead Loads and Live Loads Associated with Green Roof Systems
- E2398 Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Green Roof Systems
- E2399 Standard Test Method for Maximum Media Density for Dead Load Analysis*
- E2400 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems

*Method E2399 includes tests to measure moisture retention potential and saturated water permeability of media, total porosity, and air content of media.

Materials for green roofs will vary somewhat depending on the media thickness, intended uses, and desired appearance. The specifications provided below focus on those for a 3 inch extensive green roof system;

Plant Material

- Green roof plantings should be able to withstand heat, cold, and high winds. After establishment, the plants should be self-sustaining and tolerant of drought conditions.

- For extensive green roofs, about half of the plants should be varieties of Sedums. To ensure diversity and viability, at least four different species of sedum should be used. For an extensive green roof, the remainder of the plants should be herbs, meadow grasses, or meadow flowers, depending on the desired appearance.

- The only Sedum known to be invasive and which should be avoided is Sedum sarmentosum, also known as star sedum, gold moss, stringy stonecrop, or graveyard moss.

- Green roofs should include a significant percentage of evergreen plants to minimize erosion in winter months.

- When fully established, the selected plantings should thoroughly cover the growing medium.

Growing Medium

- Green roof growing medium should be a lightweight mineral material with a minimum of organic material and should meet the following standards:

  - Moisture content at maximum water holding capacity (ASTM E2399 or FLL): ≥ 35%
  - porosity at maximum water holding capacity (ASTM E2399 or FLL): ≥ 6%
  - Total organic matter (MSA) 3-8%
  - pH (MSA) 6.5-8.0
  - Soluble salts (DPTA saturated media extraction) ≤ 6 mmhos/cm
  - Water permeability (ASTM E2399 or FLL) ≥ 0.5 in/min
  - Grain-size distribution, as recommended by FLL

- The nutrients shall be initially incorporated in the formulation of a suitable mix for the support of the specified plant materials.

Filter Fabric

- Filter or separation fabric shall allow root penetration, but prevent the growth medium from passing through into the drainage layer. The fabric should be a non-woven polypropylene geotextile.

Drainage Layer

- A drainage layer is required to promote aerated conditions in the planting medium and to convey excess runoff during large rainfall events. The drainage layer must prevent ponding of runoff


Northwest Ecobuilding Guild, © 2001

Membrane installation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Chicago City Hall

into the planting medium during the 10-minute maximum rainfall rate associated with the one-year storm.

- For vegetated roof cover assemblies with thicknesses of less than 5 inches synthetic drainage layers may be used in lieu of granular drainage layers.

- For vegetated cover assemblies with an overall thickness of 5 inches, or greater, the drainage layer shall meet the following specifications:

  - Abrasion resistance (ASTM-C131-96): ≤ 25% loss
  - Soundness (ASTM-C88): ≤ 5% loss
  - Porosity (ASTM-C29): ≥ 25%
  - Percent of particles passing 1/2-inch sieve (ASTM-C136) ≥ 75%
  - The minimum thickness of the granular layer shall be 2 inches. The granular layer may be installed in conjunction with a synthetic reservoir sheet.

Waterproof Membrane/Root Barrier

- PVC, EPDM, and thermal polyolefin (TPO) are inherently root resistant; other common waterproofing materials might require a root barrier between waterproofing and vegetative cover.

- Avoid using herbicides to prevent root penetration of waterproofing.

Irrigation System

- Extensive systems can be designed so that they do not require irrigation.

- When using an irrigation system for an intensive system, opt for a subsurface drip irrigation system rather than a surface drip or spray irrigation system.

Roof Structure

- Both new and retrofit roof systems should have structural stability inspected by Structural Engineer.

Construction Guidelines

- Apply waterproof membrane and inspect for any irregularities that would interfere with its elemental function within the green roof system. Testing of the layer can display product flaws.

- Install irrigation system, if included in design.

- Install drainage layer, taking care to protect the waterproof membrane from damage.

- Test the drainage and irrigation systems (if used).

- Install the filter fabric or separation layer over entire drainage layer.

- Install growing medium component as specified.

- Establish vegetation
  - Green roofs can be effectively established by broadcasting fresh Sedum cuttings during April-May and September-October. Depending on seasonal conditions, temporary irrigation may be required in the first couple of months after planting.
  - Plugs of Sedum and many perennial plants can be installed anytime between April and November. Depending on the time of installation, temporary irrigation may be required.
  - Perennials can be seeded, except during summer months.
  - A biodegradable or photodegradable wind barrier or hydromulch is required to prevent erosion during the establishment period. It generally takes about two growing seasons for full establishment.
- All drains and scupper should be covered and protected by an enclosure, typically a square or round chamber with a locking lid. These chambers are designed to prevent clogging of the drains by debris.

Note:
Design of Green roofing is not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.


Pennsylvania Stormwater Management Manual

Fencing academy roof in Philadelphia, PA

Maintenance Guidelines

All facility components, including plant material, growing medium, filter fabric, drainage layer, waterproof membranes, and roof structure should be inspected for proper operations, integrity of the waterproofing, and structural stability throughout the life of the green roof.

Table 7.1: Green Roof Maintenance Guidelines	
Activity	**Schedule**
• Roof drains should be cleared when soil substrate, vegetation, debris or other materials clog the drain inlet. Sources of sediment and debris may be identified and corrected. • Plant material should be maintained to provide 90% plant cover. Weeding should be manual with no herbicides or pesticides used. Weeds should be removed regularly. • Irrigation can be accomplished either through hand watering or automatic sprinkler systems if necessary during the establishment period.	As needed
• Growing medium should be inspected for evidence of erosion from wind or water. If erosion channels are evident, they can be stabilized with additional growth medium similar to the original material.	Quarterly
• Inspect drain inlet pipe and containment system. • Test growing medium for soluble nitrogen content. Fertilize as needed.	Annually
• Maintain a record of all inspections and maintenance activity.	Ongoing

- Fertilization should be minimized. Fertilization should be applied according to soil test in order to maintain soluble nitrogen (nitrate and ammonium ion) levels between 1 and 4 ppm. The best source of nutrients for fertilization is mature compost.

- During the plant establishment period, maintenance staff should conduct 3-4 visits per year to conduct basic weeding, fertilization, and in-fill planting. Thereafter, only two annual visits for inspection and light weeding should be required (irrigated assemblies will require more intensive maintenance).

- Spill prevention measures from mechanical systems located on roofs should be exercised when handling substances that can contaminate stormwater.

7.2 Rain barrels

, cisterns, and tanks are structures designed to intercept and store runoff from rooftops. Rain barrels are used on a small scale, while cisterns and tanks may be larger. These systems may be above or below ground, and they may drain by gravity or be pumped. Stored water may be slowly released to a pervious area. This technique only serves an effective stormwater control function if the stored water is emptied between most storms, freeing up storage volume for the next storm. Irrigation as a use for runoff stored in a cistern is not an acceptable strategy for meeting the Regulations.

The design recommendations within this Section serve as guidance only. Site-specific parameters, such as anticipated water demand, may dictate alternative designs and calculations which will be reviewed accordingly.

key elements :

- Storage devices designed to capture a portion of small, frequent storm events.
- Storage techniques may include rain barrels, underground concrete or prefabricated tanks, above ground vertical storage tanks, or other systems.
- Systems must provide for overflow or bypass of large storm events.
- Placement of storage elements higher than areas where water will be reused may reduce or eliminate pumping needs.
- For effective stormwater control, water must be used or discharged before the next storm event.
- Most effective when designed to meet a specific water need for reuse.

potential applications

Residential Subdivision:	Yes
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	No

stormwater regulations

Water Quality:	
Infiltration:	No
Volume Reduction: (no infiltration)	Yes
Channel Protection:	Low
Flood Control:	Low

acceptable forms of pre-treatment

- Screens

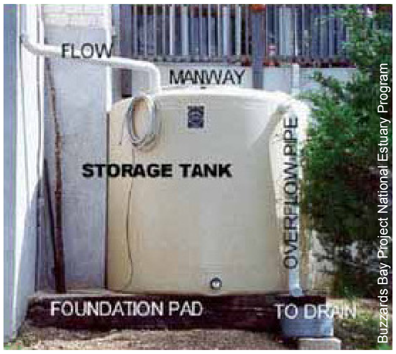
Rain Barrels, Cisterns, and Tanks in the Urban Landscape

Rain barrels, cisterns, and other tanks are storage devices meant to promote detention of small volumes of stormwater runoff. Collectively, these systems can be effective at preventing large volumes of stormwater from entering the sewer system. Rain barrels, cisterns, and vertical storage are suitable where there is a use and need for the stored water or where there is a pervious area to which water can be slowly released between storms. Single-family residences and high-density commercial areas can incorporate these systems into the stormwater management plan. The design of these systems is flexible, because there are many ways to capture and reuse stormwater. The application and use of rain barrels, cisterns, or other tank storage systems are not limited to the examples provided below.

Residential cistern

Rain Barrels on Individual Homes

The most common use of rain barrels is connection of one roof leader (downspout) to a single barrel on a residential property. Stored water can be released slowly to a lawn. Barrels can either be purchased or can be built by the homeowner. They are ideal for gardeners and concerned citizens who want to manage stormwater without a large initial investment. They are also an easy retrofit.



An example of a large surface tank

Large Surface Tanks

Surface tanks may be larger than rain barrels but serve the same function. They can be integrated into commercial sites or homes where a significant water need exists. They may drain by gravity or be pumped.

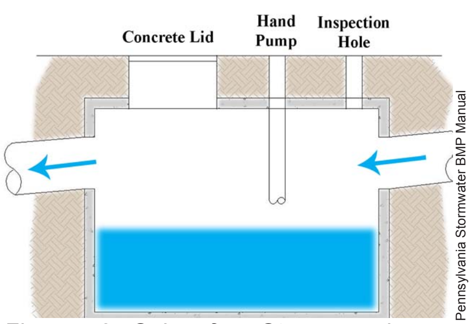
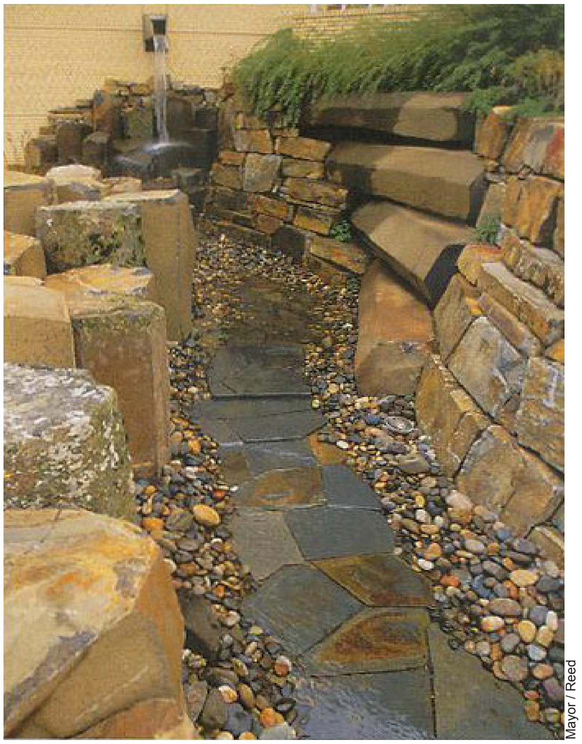


Figure 7.2: Subsurface Storage and reuse is possible using a cistern

Subsurface Storage and Water Reuse

Subsurface systems can be larger and more elaborate than rain barrels. These systems are typically pumped and may be used to supply water to sprinkler systems. Because the cisterns are below the surface, they do not interfere with the landscape. These systems have higher initial costs than rain barrels and are appropriate for commercial and



Oregon Convention Center rainfall water features

Water Features in Public and Institutional Landscapes

Architectural designs have incorporated water storage into site design. Features such as water fountains and ponds capture stormwater from design storms to provide water sources for these landscape features. The photographs below show the water features created at the Oregon Convention Center, which capture roof runoff and integrate it into the landscape design.

Oregon Convention Center rainfall water features

Reusing Stormwater for Indoor Use

Roof runoff can be captured and stored for reuse in washing machines and for showering purposes if properly filtered, treated, and tested. Roof runoff used in toilets does not need to meet potable water standards. A rain barrel or cistern can be directly connected to the plumbing of a residential or commercial site; however, plumbing for non-potable rainwater reuse should be separate from potable plumbing. With more extensive treatment, rainwater may be used for drinking purposes. For more information on reusing rainwater for potable purposes refer to the *Texas Guide to Rainwater Harvesting.*

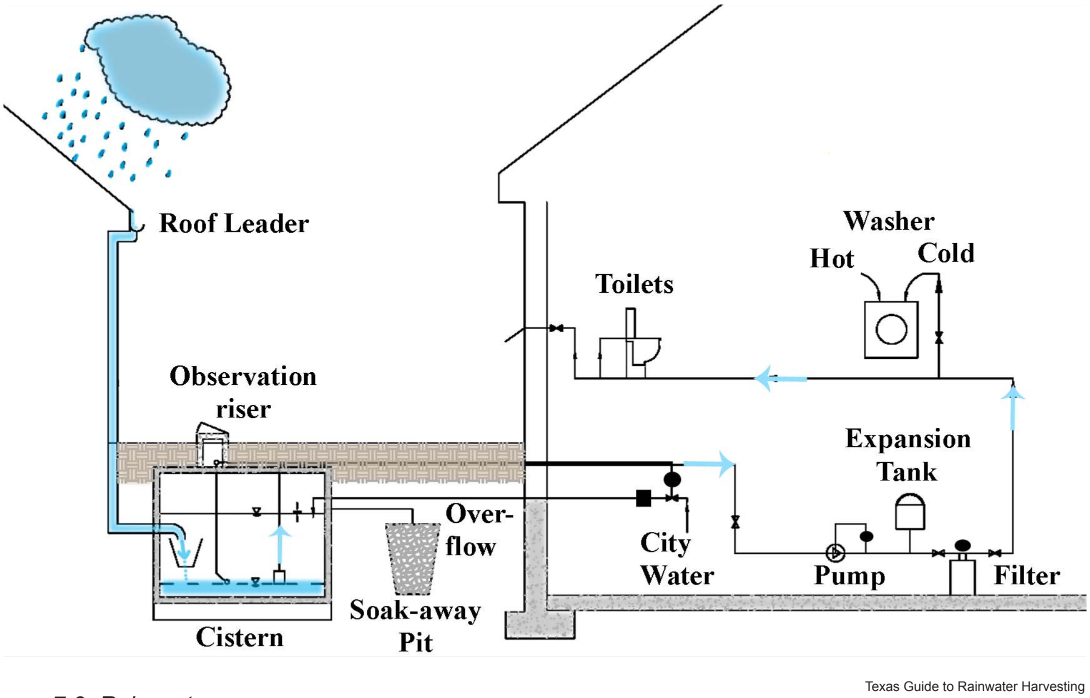


Figure 7.3: Rain water reuse

Components of Rain Barrels, Cisterns, and Tanks

Rain barrels, cisterns, and tanks all require the following basic components:

- a roof leader or other means of conveying roof runoff to the storage element,
- a screen to prevent debris and mosquitoes from entering,
- a storage element,
- a slow release mechanism or pump, a reuse opportunity, or infiltration area, and
- an overflow mechanism to bypass larger storms.

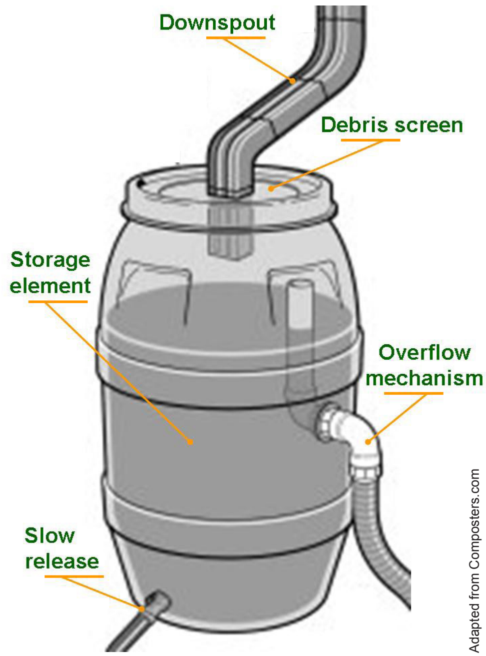


Figure 7.4: Components of a rain barrel

Roof Leader

The gutter and roof leader system collects rooftop runoff and conveys it to the rain barrel, cistern, or other storage element. In most cases conventional roof leaders and downspouts can be used for this purpose.

Screen

A screen keeps leaves and other debris from entering and clogging the storage element. A screen also prevents mosquitoes from breeding in the rain barrel. A screen is typically placed at the end of the roof leader, before flow enters the rain barrel. A leaf strainer may also be placed where the gutter connects to the roof leader.

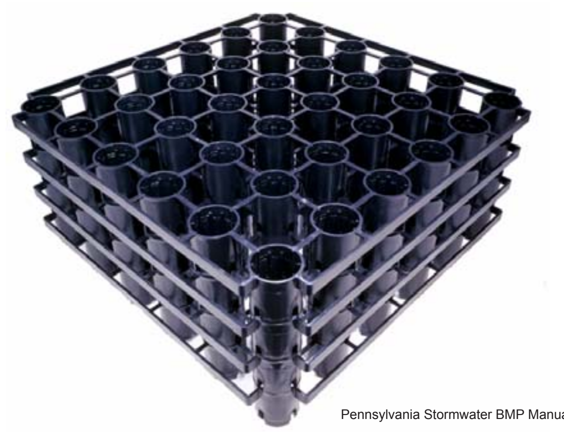
Storage Element

The storage element is the barrel, cistern, or tank itself. Rain barrels are typically made of plastic. Underground cisterns may be poured concrete or prefabricated plastic tanks similar to septic tanks. Proprietary products that store water in a variety of structures are also available. Some of these are designed to bear the weight of vehicles. With the addition of an impervious liner, many of the designs discussed in the section Subsurface Infiltration (such as gravel beds) can be modified to serve as subsurface storage elements. Tanks larger than rain barrels may be used above or below ground.

Slow Release Mechanism or Pump

For the storage element to serve its stormwater control function, it must be completely drained between most wet weather events. Rain barrels are typically drained in one of two ways. A gardener may use the barrel to fill a can; however, this must be done on a regular basis and completely drain the storage element to provide effective stormwater management. Another solution is to use a soaker hose to slowly release stored water to an infiltration area. Larger surface tanks may drain by gravity or may be pumped.

Subsurface systems and systems where stormwater is reused are typically pumped. To perform effective stormwater control, the rate of use must be sufficient to empty the storage between most storms.



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Reuse Opportunity or Infiltration Area

For rain barrels, cisterns, and other tanks to provide effective stormwater management, an opportunity for reuse or infiltration of the stormwater must exist. This opportunity might be provided by a garden or landscaped area that needs to be watered, or an opportunity to reuse stormwater for non-potable uses. Water stored for emergency purposes, such as fire protection is not a suitable reuse opportunity, because the storage volume will not be emptied between each storm.

Overflow Mechanism

The storage capacity of rain barrels, cisterns, and other tanks will be exceeded in large storms. In rain barrels, a flexible hose is provided at an elevation near the top of the barrel. The diameter of the hose is at least equal in size to the roof leader to allow runoff to flow unimpeded during large events. The overflow from cisterns and larger tanks can occur through a hose, weir, pipe, or other mechanism.

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The discharge from the overflow is directed to the same place flow from the roof leader would be directed if there were no rain barrel, cistern, or storage tank.

Recommended Design Procedure

- Determine the Water Quality, Channel Protection, and Flood Control requirements on the site. See **Section 4.3**: Manage Remaining Stormwater. Small sites that are installing rain barrels voluntarily may skip this step.
- Identify opportunities and areas where water can be released to an infiltration area, or meet indoor use needs. Estimate the rate at which water can be reused. If the process of reuse is proposed to meet the Water Quality requirement, the water quality volume must be used in the first 72 hours after the storm event. Identify potential infiltration areas where water may be discharged to at a slow rate. For toilet use, calculate volume based on number of flushes per day times 1.6 gallons per flush (new toilet). If a small rain barrel is discharging to a lawn through a soaker hose, detailed calculations are not necessary.
- Create a Conceptual Site Plan for the entire site, and determine what portion of the sizing requirements will be met by rain barrels, cisterns, or storage tanks (see **Section 4.0**: Site Design). Consider more than one tank if additional storage is required, making sure that there is sufficient demand for the water. For small sites installing rain barrels voluntarily, skip this step.

Table 7.2: Suggested Storage Design Values for Rain Barrels	
Rain Barrel	50 – 135 gallons
Cistern	500 – 7,000 gallons
Larger Above Ground Tank	3,000 – 12,000 gallons

Rain Barrels

- Identify roof leaders where rain barrels can be installed.
- Decide whether to purchase commercial rain barrels or construct rain barrels.
- Choose between a faucet and a soaker hose. Position the outlet as low on the barrel as the design will allow to maximize storage volume. It is recommended that the design allow retention of 1 to 2 inches at the bottom of the barrel to help trap sediment and provide stability.
- Consider placing the barrel on cinder blocks to increase head at ground level.
- It is easiest to install soaker hoses on the ground surface. The hoses can then be easily reconfigured and moved whenever necessary. If buried, soaker hoses should be placed 2-4 inches under soil or 1-2 inches under mulch. Soaker hoses that are buried too deep can be difficult to monitor and are more prone to damage from root growth.
- If emptying the barrel manually, develop a plan so that it is completely emptied on average every 72 hours or less. This is necessary so that the entire storage capacity is available at the beginning of most storms.
- Position the overflow hose to discharge larger storms. The overflow should be discharged to a pervious area if possible. However, roof leaders might need to be connected to a storm sewer or gutter to prevent flooding or property damage in some cases.

Cisterns (Subsurface or Surface)

- Identify which roof leaders can drain to the cistern, and the area of roof draining to each leader.
- Estimate the storage needed. A rough estimate may be obtained by performing a weekly water balance of rainfall and water reuse. The table below lists average monthly rainfall amounts at the Philadelphia International Airport. Estimate the difference on a weekly basis between rainfall depth and water depth needed. Multiply this deficit by the roof drainage area to obtain an estimate of the cistern volume needed. The Design Professional may choose to do a more rigorous analysis using a long-term daily or hourly rainfall record, or using a dryer than average year.

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Table 7.3: Average Monthly Rainfall at the Philadelphia International Airport				
	Average Precipitation	Average Temperature		Potential Evaporation
		High	Low	
Month	(in)	(°F)	(°F)	(in/month)
January	3.3	39.2	24.4	2.1
February	2.9	42.1	26.1	2.1
March	3.6	50.9	33.1	2.1
April	3.4	63	42.6	4.5
May	3.5	73.2	52.9	5.4
June	3.6	81.9	61.7	6.3
July	4.1	86.4	67.5	6.6
August	4.3	84.6	66.2	5.7
September	3.4	77.4	58.6	4.2
October	2.8	66.6	46.9	2.7
November	3.0	55	37.6	2.1
December	3.3	43.5	28.6	2.1

- Determine the pumping requirements or design a gravity system to meet water reuse requirements. The cistern must drain within 72 hours to maximize available storage at the beginning of each storm. A detailed discussion of pumping and outlet hydraulics is beyond the scope of this manual.

- Complete construction plans and specifications.

Materials and Construction Guidelines

Rain Barrels

- Rain barrels are commonly pre-fabricated structures constructed with plastic, wood or steel.

- The container should be made of an opaque material to prevent algae growth in the stored water.

- Debris screen to keep leaves and other debris from entering and clogging the storage element.

- For a detailed list of materials and methods used to construct a rain barrel at home, see the references at the end of this section.

Cisterns

- Cisterns may be constructed of fiberglass, concrete, plastic, brick, or other materials.

Maintenance Guidelines

As with other stormwater management practices (SMPs), these stormwater storage systems require regular maintenance to ensure a prolonged life. The following table suggests maintenance activities to perform on rain barrels, cisterns, or vertical storage.

Table 7.4: Rain Barrels & Cisterns Maintenance Guidelines	
Activity	***Schedule***
• Occasional cleaning may be necessary to remove debris, such as leaves, coming off the drainage area.	As needed
• Flush cisterns to remove sediment. • Brush the inside surfaces and thoroughly disinfect. • To avoid structural damage, the rain barrel should be drained prior to freezing weather.	Annually
• Maintain records of all inspections and maintenance activity.	Ongoing

Note:
Design of rain barrels and cisterns is not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

7.3 Filter strips

are densely vegetated lands that treat sheet flow stormwater from adjacent pervious and impervious areas. They function by slowing runoff, trapping sediment and pollutants, and in some cases infiltrating a portion of the runoff into the ground. Filter strips are a sensible and cost-effective stormwater management pretreatment option applicable to a variety of development sites including roads and highways.

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key elements :

- Filters strips are only considered a viable pretreatment option for other SMPs.
- Sheet flow across the vegetated filter strip is mandatory for proper filter strip function.
- Filter strip length is a function of slope, vegetation type, soil type, drainage area, and desired amount of pretreatment.
- Level spreading devices are recommended to provide uniform sheet flow conditions at the interface of the filter strip and the adjacent land cover.
- The longest flow path to a filter strip, without the installation of energy dissipaters and/or flow spreaders, is 75 feet for impervious ground covers and 150 feet for pervious ground covers.
- Filter strip slope should never exceed 8%. Slopes less than 5% are generally preferred.
- Maximum contributing drainage area is less than 5 acres, and should also never exceed a drainage area to filter strip area ratio of 6:1.
- Maximum contributing drainage area slope is generally less than 5%, unless energy dissipation and/or flow spreaders are provided.
- Construction of filter strips shall entail as little disturbance to existing vegetation at the site as possible.

potential applications

Residential Subdivision:	Yes
Commercial:	Yes*
Ultra Urban:	Limited*
Industrial:	Limited*
Retrofit:	Yes
Highway Road:	Yes

*if designed without an underdrain

stormwater regulations

Water Quality:	
Infiltration:	No
Volume Reduction: (no infiltration)	No
Channel Protection:	N/A
Flood Control:	N/A

acceptable forms of pre-treatment

N/A

Filter Strips in the Urban Landscape

Filter strips are effective at slowing runoff velocities, removing pollutant loads, and promoting infiltration of runoff produced by both impervious and pervious areas.

Filter strips are suitable for many types of development projects. Filter strips can be used as pretreatment facilities for other SMPs in residential, commercial, and light industrial development; roads and highways; and parking lots.

Filter strips are recommended for use as a pretreatment component of other SMPs including but not limited to: bioretention, constructed wetlands, detention, filters, ponds/wet basins, porous pavement, and vegetated swales. The use of a properly maintained filter strip extends the life of the associated SMPs and decreases its hydraulic residence time. It also increases the amount of time before these structures need maintenance.

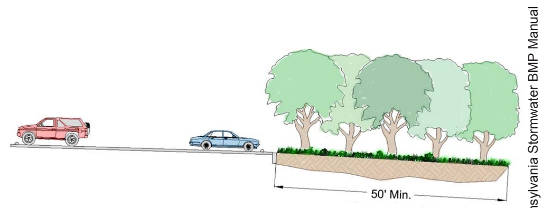

Figure 7.8: Filter strip in forested area

Components of a Filter Strip System

Inlet Control
Filter strips are typically combined with a level spreader or flow control device. A flow control device functions to lessen the flow energy of stormwater prior to entering the filter strip area. Concentrated flow rates can have an erosive effect that can damage the filter strip, rendering the strip ineffective. Curb openings combined with a gravel level spreader are a common type of flow control. See **Section 7.15**: Inlet and Outlet Controls for more information. Slotted or depressed curbs installed at the edge of the impervious area should ensure a well-distributed flow to the filter strip. These slotted openings should be spaced along the length of the curb.

Filter strip providing pretreatment from a parking lot to a bioretention system at Villanova University

Vegetation
The vegetation for filter strips may be comprised of turf grasses, meadow grasses, shrubs, and native vegetation. It can include trees or indigenous areas of woods and vegetation. Vegetation adds aesthetic value as well as water quality benefits. The use of indigenous vegetated areas that have surface features that disperse runoff is encouraged, as the use of these areas will also reduce overall site disturbance and soil compaction. The use of turf grasses will increase the required length of the filter strip compared to other vegetation options.

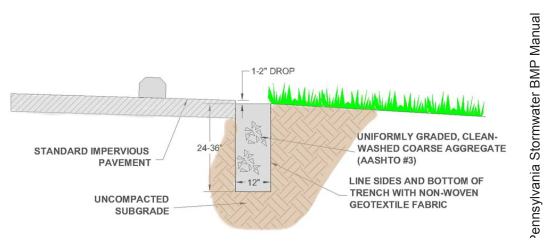

Figure 7.9: Filter strip with gravel trench level spreader

Retentive Grading
Filter strip effectiveness may be enhanced by installing retentive grading perpendicular to the flow path. A pervious berm allows for a greater reduction in both runoff velocity and volume, thus improving pollutant removal capabilities by providing a temporary (very shallow) ponded area. The berm should be constructed according to the design provided in **Section 7.7**: Berms and Retentive Grading.

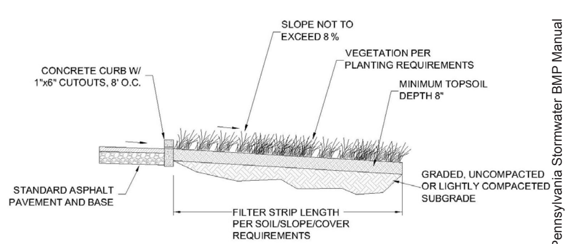

Figure 7.10: Filter strip with curb opening

Check Dams
Filter strips with slopes that exceed 6% should implement check dams to encourage ponding and prevent scour and erosion of the filter strip area. More information on check dams is available in **Section 7.15**: Inlet and Outlet Controls.

Check dams
**Note channel storage capacity created by check dams. Notched center allows safe overflow without scour around sides.*

Recommended Design Procedure

- Determine the Water Quality, Channel Protection, and Flood Control requirements for the site. See **Section 4.3**: Manage Remaining.

- Create a Conceptual Site Plan for the entire site and determine what portion of the sizing requirements filter strips will accommodate (for pretreatment purposes). See **Section 4.0**: Integrated Site Design.

- Investigate the feasibility of infiltration according to soil and vegetative conditions in the area proposed for the filter strip. If infiltration is feasible, determine the of saturated vertical infiltration rate. See **Appendices A, B, and C** for more guidance on requirements.

- Examine size and slope of the drainage area. The maximum contributing drainage area to a filter strip area shall never exceed 5 acres, and should also never exceed a drainage area to filter strip area ratio of 6:1.

    - If the slope of the filter strip parallel to the proposed flow path is ≥ 5%, energy dissipater and/or flow spreaders must be installed.

- Design an inlet control to meet energy dissipation requirements. See **Section 7.15**: Inlet and Outlet Controls.

    - A flow spreader which stretches the entire length (perpendicular to flow path) of the contributing drainage area should be designed to limit flow velocity to prevent erosion and to spread the flow equally across the filter strip. If necessary, a bypass should be installed to prevent excessive, damaging flows.

- Create a conceptual design for the pretreatment filter strip.

Table 7.5: Suggested Starting Design Values for Filter Strip Length

Strip Length Perpendicular to Flow Path	Largest feasible on site
Strip Length Parallel to Flow Path	4* - 150 feet

* The minimum pretreatment filter strip value is based on the length of the receiving flow path. The graph below shows how the minimum length requirement changes as both flow path and filter strip slope change.

- Determine the longest flow path length for the contributing drainage area.

- For contributing drainage areas with flow paths < 30 feet use the following graph to help determine the filter strip length parallel to the flow path.

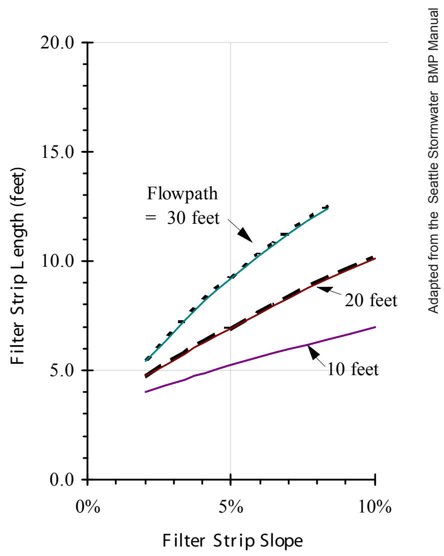

Figure 7.11: Suggested Design Specifications for Narrow Pretreatment Filter Strips with Flow Paths < 30 feet
Note: The filter strip length requirements reflected in the above graph are scaled from dimensions of a grassy vegetative swale for the same slope and flow conditions mention in the table above.

- For filter strips with contributing flow paths > 30 feet, use the suggested flow characteristics for maximum velocity and depth as design restrictions. When choosing an initial filter strip length, the suggested minimum starting design value is 10 feet.

Table 7.6: Suggested Maximum Velocities and Water Depths for Filter Strip Area	
Maximum Velocity (ft/s)	1.0, Less than 0.5 preferred
Maximum Water Depth (in.)	1.0, Less than 0.5 preferred
The values for both maximum Velocity and Water depth were taken from the US DOT Stormwater Best Management Practices (BMPs)in an Ultra-Urban Setting: Selection and Monitoring and the Seattle BMP Manual.	

- Adjust filter strip design characteristics to provide desired amount of pretreatment.

- When considering retentive grading, use the infiltration area and the saturated vertical infiltration rate of the native soil to estimate how long the surface ponding will take to drain. The maximum drain down time for the ponded volume is 72 hours, but a drain down time of 24 – 48 hours is recommended. If ponded water does not drain in the time allowed, adjust water surface depth, soil depth, and/or surface area. Adjust the design until the volume and drainage time constraints are met.
- All retentive grading techniques should encourage soil stabilization and erosion control with vegetative growth. See **Section 7.7**: Berms and Retentive Grading.

- Choose plants and trees appropriate and compatible with the site conditions. See **Section 8**: Landscape Guidance.

- Filter strips may not be used in high use areas unless precautions are taken to minimize disturbance (i.e. signage, placement of sidewalks or paths to minimize disturbance of the filter strip).

- Determine final contours of the filter strip.

- Complete construction plans and specifications.

Materials

• Recommendations for plant materials and soils can be found in **Section 8**: Landscape Guidance.

Construction Guidelines

• Areas for filter strips shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

  • In areas where soil is compacted, tilling to depths of 12-18 inches is necessary. A minimum of 6 inches of top soil must be added into the tilled soil column, and small trees and shrubs with capabilities for deep root penetrations should be introduced to maximize the soil infiltrative capacity. See **Section 8**: Landscape Guidance, for more specification on soil types and preferred plantings.

• Provide erosion and sedimentation control protection on the site such that construction runoff is directed away from the proposed filter strip location.

• Complete site elevation and retentive grading, if proposed. Stabilize the soil disturbed within the limit of earth disturbance.

• Install energy dissipaters and flow spreaders. Refer to **Section 7.15**: Inlet and Outlet Controls for more detailed construction information.

  • The slope (parallel to the flow path) of the top of the filter strip, after the flow spreading device, should be very small (less than 1 %) and gradually increase to designed value to protect from erosion and undermining of the control devise.

• Construct inlet protection as specified in the design.

• Seed and plant vegetation (plants, shrubs, and trees) as indicated on the plans and specifications listed in **Section 8**: Landscape Guidance.

• Once site vegetation is stabilized, remove erosion and sediment control protection.

Maintenance Guidelines

All areas of the filter strip should be inspected after significant storm events for ponding that exceeds maximum depth and duration guidelines. Corrective measures should be taken when excessive ponding occurs.

Table 7.7: Filter Strips Maintenance Guidelines	
Activity	***Schedule***
• Mowing and/or trimming of vegetation (not applicable to all filter strips). Filter strips that need mowing are to be cut to a height no less than 4 inches. Greater than 5 inches is preferred.	As needed
• Inspect all vegetated strip components expected to receive and/or trap debris and sediment for clogging and excessive debris and sediment accumulation; remove sediment during dry periods.	Quarterly
• Vegetated areas should be inspected for erosion, scour, and unwanted growth. This should be removed with minimum disruption to the planting soil bed and remaining vegetation. • Inspect all level spreading devices for trapped sediment and flow spreading abilities. Remove sediment and correct grading and flow channels during dry periods.	Biannually
• Maintain records of all inspections and maintenance activity.	Ongoing

- When correcting grading of a flow spreading device, use proper erosion and sediment control precautions in the concentrated area of disturbance to ensure protection of the remaining portion of the filter.

- Disturbance to filter strips should be minimal during maintenance. At no time should any vehicle be driven on the filter strip. In addition, foot traffic should be kept to a minimum.

- If the filter strip is of the type that needs mowing (i.e., turf grass and possibly other native grasses), the lightest possible mowing equipment (i.e., push mowers, not riding mowers) should be used. The filter strip should be mowed perpendicular to the flow path (however not exactly the same path every mowing) to prevent any erosion and scour due to channeling of flow in the maintenance depressions.

- When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. For more information on vegetative maintenance, refer to **Section 8**: Landscape Guidance.

- Bi-weekly inspections of erosion control and flow spreading devices should be performed until soil settlement and vegetative establishment has occurred.

Note:
Design of filter strips are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

7.4 Filters

are structures or excavated areas containing a layer of sand, compost, organic material, peat, or other filter media. They reduce pollutant levels in stormwater runoff by filtering sediments, metals, hydrocarbons, and other pollutants. Filtered stormwater may be infiltrated or released to a sewer or receiving water. Depending on design, the filter media may provide significant detention time or may be combined with an outlet control.

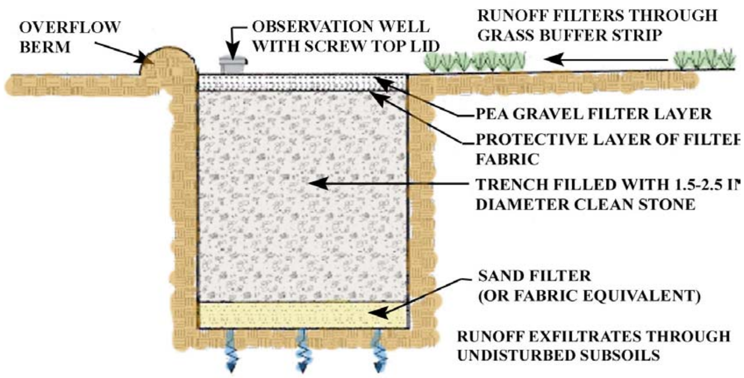

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Figure 7.12: Filter with infiltration

key elements:

- Acceptable technique on sites where vegetated systems are impractical.
- Surface ponding that drains down in no more than 72 hours.
- Filter medium (typically sand, peat, or a mixture) removes pollutants and provides some travel time.
- Underdrain allowed on sites where infiltration is infeasible, or where a filter is used in combination with other practices.
- Flow splitter or positive overflow bypasses large storms.
- Maintenance required to maintain capacity of system.

potential applications

Residential Subdivision:	Limited
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Yes

stormwater regulations

Water Quality:	
Infiltration:	Yes
Volume Reduction: (no infiltration)	No
Channel Protection:	Low/Medium
Flood Control:	Low/Medium

acceptable forms of pre-treatment

- Filter strips
- Appropriate prefabricated and proprietary designs
- Swales
- Sediment forebays
- Bioretention
- Planter boxes

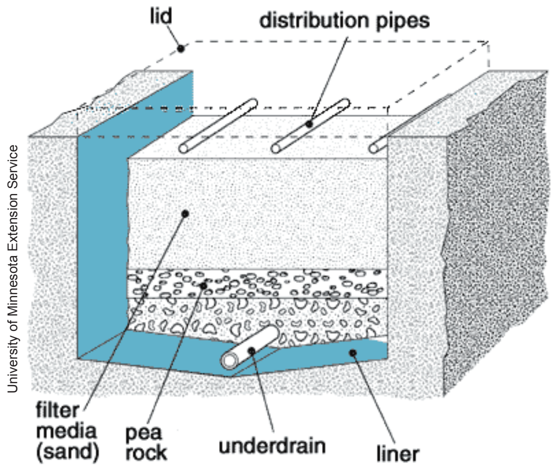


Figure 7.13: Sand filter with underdrain. Underdrains and liners should only be used when infiltration is not possible or prohibited.

Stormwater Filters in the Urban Landscape

Stormwater filters are suitable for sites without sufficient surface area available for vegetated bioretention basins. Filters are designed to either infiltrate or to treat and convey runoff to a disposal point. The only difference between a filter and a bioretention basin, as defined in this manual, is surface vegetation. Vegetated basins often include a filtering layer that may be designed according to the guidelines in this section. Filters are recommended as a viable SMP for use in:

- Parking lots
- Roadways and Highways
- Light Industrial sites
- Marina areas
- Transportation facilities
- Fast food and shopping areas
- Waste Transfer Stations
- Urban Streetscapes

Filters may be visible from the surface, as shown in the photograph below, or completely subsurface as shown in Figure 7.16. They may be designed as a single large chamber (often with a smaller chamber for pretreatment) or as a long, narrow trench at the perimeter of a parking lot (Figure 7.15).

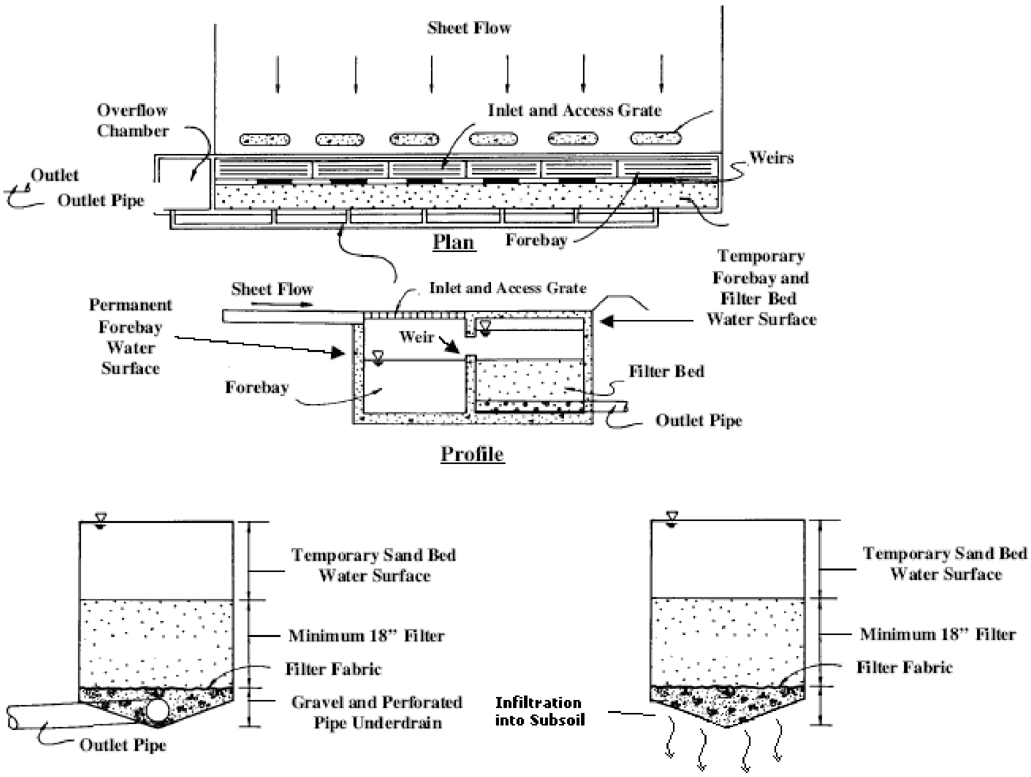
Components of a Stormwater Filter System

Stormwater filters can be designed to infiltrate all or some of the flow. Components of stormwater filter system include:

- Excavation or container
- Pretreatment
- Flow entrance/inlet
- Surface storage (ponding area)
- Filter media
- Underdrain, if required
- Positive overflow

Excavation or Container
The filter media may be contained in a simple trench lined with a geotextile, or it may be contained in a more structural facility such as concrete. In either case, the container may be designed either to allow infiltration or to collect flow in an underdrain system.

Flow Entrance/Inlet
Flow may be introduced to a filter through any of the controls discussed in **Section 7.15**: Inlet and Outlet Controls. If stormwater does not enter as sheet flow, a flow spreader is required.



Adapted from City of Boise

Figure 7.14: Surface sand filter

Stormwater Management, Inc.

Left to right: Granular leaf compost, perlite and granular activated carbon (GAC)

Vegetated peat filter in Carlisle, PA

Surface Storage (ponding area)
The filter allows water to pond during intense storms as water flows slowly through the filter media.

Filter Media
Stormwater flows onto filter media where sediments and other pollutants are separated from the stormwater. Filter materials such as sand, peat, granular activated carbon (GAC), leaf compost, pea gravel and others are used for water quality treatment. Coarser materials allow faster transmission, but finer media filters particles of a smaller size. Sand has been found to be a good balance between these two criteria (Urbonas, 1999), but different types of media remove different pollutants. While sand is a reliable material to remove TSS, (Debusk and Langston, 1997) peat removes slightly more TP, Cu, Cd, and Ni than sand. Depending on the characteristics of the stormwater runoff, a combination of these filter materials will provide the best quality results. In addition to determining the degree of filtration, media particle size determines travel time in the filter and plays a role in meeting release rate requirements.

Underdrain (if required)
Infiltration is required where feasible unless the filter is combined with another facility that provides infiltration. Filters that do not infiltrate collect water through an underdrain system.

Georgia Stormwater Management Manual

Perimeter filter inspection

Positive Overflow

Filters must be designed to allow overflow or bypass of larger storm volumes. Flow splitters, diversion chambers, or proprietary devices can be used to divert a portion of flow to a filter in an off-line design. A design that is considered on-line allows water to flow across the surface of the filter before being discharged over a weir or other control.

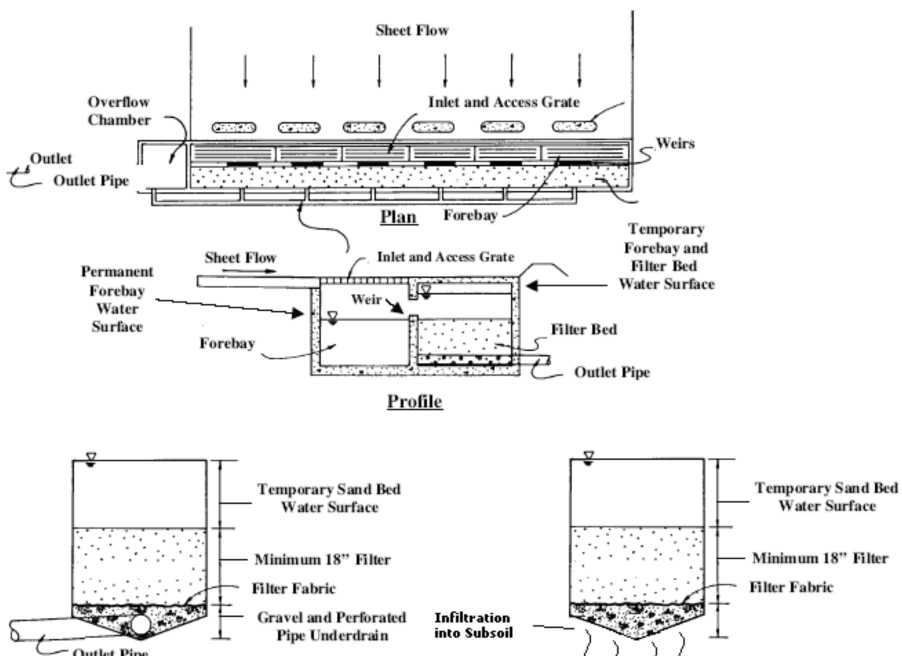
Recommended Design Procedures

- Determine the Water Quality, Channel Protection, and Flood Control requirements for the site. See **Section 4.3**: Manage Remaining Stormwater.

- Create a Conceptual Site Plan for the entire site and determine what portion of the stormwater control requirements the filters will meet. See **Section 4.0**: Integrated Site Design.

- Investigate the feasibility of infiltration in the area proposed for the stormwater filter. If infiltration is feasible, determine the saturated vertical infiltrate rate. See **Appendices A, B, and C** for more guidance on requirements. Design proceeds differently depending on the feasibility of infiltration.

- Create a conceptual design for the stormwater filter.



Adapted from New Jersey Stormwater Best Management Practices Manual

Figure 7.15: Typical schematic of perimeter filter design. Note filters can be designed to infiltrate or to treat and convey via an outlet pipe.

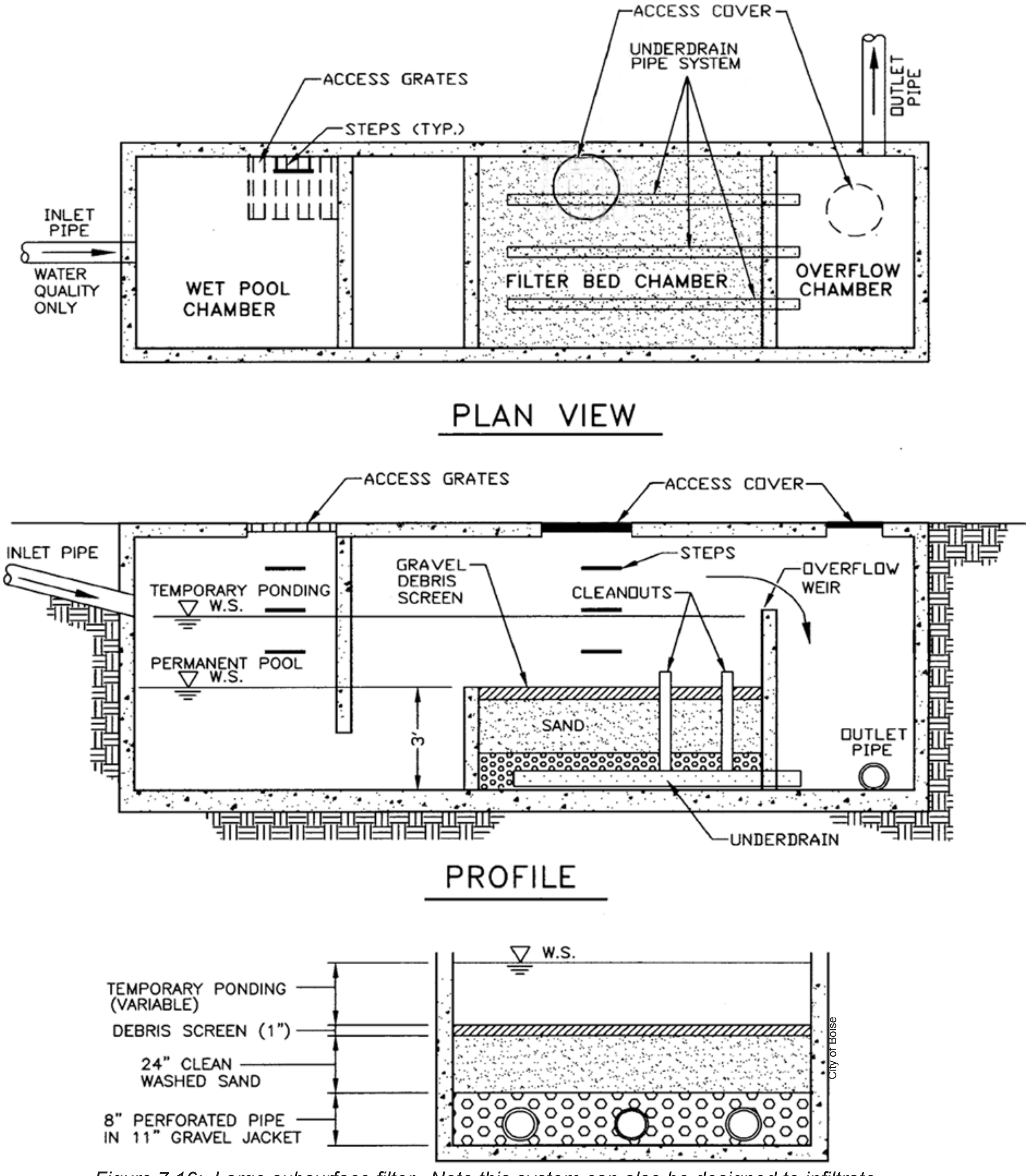


Figure 7.16: Large subsurface filter. Note this system can also be designed to infiltrate directly into the soil or to connect to another infiltration BMP.

- The filter area may be estimated initially using Darcy's Law, assuming the soil media is saturated.

  $A_f = (V \times d) / [k \times t\ (h + d)]$
  Af = Surface area of filter (square feet)
  V = Volume to be managed (cubic feet)
  d = Depth of filter media (feet)
  t = Drawdown time (days)
  h = Head (average in feet)
  k = Saturated hydraulic conductivity (feet/day)
  k Design values: sand = 3.5 feet/day; peat = 2.5 feet/day; leaf compost = 8.7 feet/day

- For filters designed for infiltration, estimate the total storage volume and adjust area and/or depths as needed to provide required storage.

Table 7.8: Suggested Starting Design Values for Ponding and Media Depths	
Average Ponding Depth	3 – 6 inches
Filter Media Depth	18 – 30 inches

- Using stormwater filter area and the saturated vertical infiltration rate of the filter media, estimate the drainage time for ponded surface water. The saturated vertical infiltration rate may be based on the estimated saturated hydraulic conductivity of the proposed filter materials. The maximum drain down time for the entire storage volume is 72 hours, but a surface drain down time of 24-48 hours is recommended. If storage does not drain in the time allowed, adjust pretreatment depth, filter media depth, and surface area. Adjust the design until the volume and drainage time constraints are met.

- Consider an underdrain only under one of the following conditions:

  - in areas with separate storm sewers or direct discharge to receiving waters where infiltration is infeasible (See **Appendices A, B, and C** for more guidance on requirements) and the filter system is needed only to provide water quality treatment;
  - in areas with combined sewers where sufficient detention or travel time can be designed into the system to meet release rate requirements; or
  - in combination with other SMPs where the system as a whole meets storage and release criteria.

- Design underdrains to minimize the chances of clogging. Pea gravel filters can be used for this purpose. Pea gravel filters should include at least 3 inches of gravel under the pipe and 6 inches above the pipe.

- In areas where infiltration is infeasible due to a hotspot or unstable fill that threatens an existing structure, specify an impervious liner (compacted till liner, clay liner, geomembrane liner, or concrete liner with a permeability less than or equal to 10-7 cm/sec).

  - Check that any release rate requirements (including release through any underdrain) are met by the system as designed. For filters with underdrains, release rate is a function of travel time. See **Section 5.3**: Acceptable Calculation Methods, for a discussion of travel time calculations in porous media.

- Design a pretreatment facility.

- Design an inlet control for the filter media chamber to meet energy dissipation requirements. See **Section 7.15**: Inlet and Outlet Controls.

- Design a bypass or overflow control for larger storms.

- Design any structural components required.

- Complete construction plans and specifications.

Materials

Stone Storage (if used)

- Stone used to provide additional storage shall be uniformly-graded, crushed, washed stone meeting the specifications of AASHTO No. 3 or AASHTO No. 5.

- Stone shall be separated from filter medium by a non-woven filter fabric or a pea gravel filter.

Filter Media

- Peat shall have ash content <15%, pH range 3.3-5.2, loose bulk density range 0.12-0.14 g/cc.

- Sand shall be clean, medium to fine sand, and have organic material meeting specifications of AASHTO M-6 (0.02" – 0.04") or ASTM-C-33.

- Prefabricated filter media shall meet filter design and water quality specifications.

Piping

- Pipe shall have continuous perforations, smooth interior, and minimum diameter of 6 inches. High-density polyethylene (HDPE) pipe shall meet specifications of AASHTO M252, Type S or AASHTO M294, Type S.

Construction Guidelines

- Areas for stormwater filters shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

- Permanent filters should not be installed until site is stabilized. Excessive sediment generated during construction can clog filter and prevent its function prior to post-construction benefits.

- Structures such as inlet boxes, reinforced concrete boxes, inlet controls, and outlet structures should be constructed in accordance with manufacturer's guidelines or Engineer's guidance.

- Excavated filters or structural filters that infiltrate should be excavated in such a manner as to avoid compaction of the sub-base. Structures should be set on a layer of clean, lightly compacted gravel specified as AASHTO No. 57.

- A layer of permeable non-woven geotextile should underlie infiltration filters.

- Place underlying gravel/stone in minimum 6 inch lifts and lightly compact. Place underdrain pipes in gravel during placement (if applicable).

- Wrap and secure non-woven geotextile to prevent gravel/stone from clogging with sediments.

Maintenance Guidelines

For filters located entirely underground, unobstructed access must be provided over the entire sand filter, including inlet and outlet pipe structures, by either doors or removable panels. Ladder access is required for vault heights greater than 4 feet.

Table 7.9: Filter Maintenance Guidelines

Activity	Schedule
• Rake filter media surface for the removal of trash and debris from control openings. • Repair of leaks from the sedimentation chamber or deterioration of structural components.	As needed
• Inspect filter for standing water (filter drainage is not optimal) and discoloration (organics or debris have clogged filter surface).	Quarterly
• Removal of the top few inches of filter media and cultivation of the surface when filter bed is clogged. • Clean out accumulated sediment from filter bed chamber. • Clean out accumulated sediment from sedimentation chamber.	Annually
• Maintain records of all inspections and maintenance activity.	Ongoing

In areas where the potential exists for the discharge and accumulation of toxic pollutants (such as metals), filter media removed from filters must be handled and disposed of in accordance with all State and Federal Regulations.

Winter concerns

Pennsylvania's low temperature dips below freezing for about four months out of every year, and surface filtration may not take place as well in the winter. Peat and compost may hold water, freeze, and become impervious on the surface. Design options that allow direct sub-surface discharge into the filter media during cold weather may help overcome this condition.

Note:

Design of stormwater filters are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

7.5 Bioinfiltration / Bioretention

systems use surface storage, vegetation, a select growing medium, flow controls, and other components to meet stormwater management goals. These systems may be referred to by a variety of names such as bioinfiltration areas, biofilters, rain gardens, or recharge gardens. On a small scale, these systems may be contained inside planter boxes. This section will refer to all these systems as bioretention.


R. Traver

key elements:

- Preferred stormwater management design that replicates natural hydrologic processes.
- Flexible in size and configuration; can be used for a wide variety of applications.
- Water Quality volume that drains down in no more than 72 hours.
- Modified soil that provides temporary stormwater storage and enhances plant growth.
- Native plantings that provide evapotranspiration of stormwater, remove pollutants, and enhance the landscape.
- Positive overflow limits inundation depth.
- Maintenance of vegetation is required.

potential applications

Residential Subdivision:	Yes
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Yes

stormwater regulations

Water Quality:	
Infiltration:	Yes
Volume Reduction: (no infiltration)	Yes
Channel Protection:	Medium
Flood Control:	Low/Medium

*if designed without an underdrain

acceptable forms of pre-treatment

- Energy dissipation to prevent erosion and scour of SMP

Bioretention in the Urban Landscape

Bioretention systems are shallow, vegetated depressions used to promote absorption and infiltration of stormwater runoff. This management practice is very effective at removing pollutants and reducing runoff volume. Stormwater flows into the bioretention area, ponds on the surface, infiltrates into the soil bed, and is used by plants and trees in the system.

Bioretention areas are suitable for many types and sizes of development, from single-family residential to high-density commercial projects. Bioretention areas are generally capable of managing stormwater from areas of up to about 1 acre, but they can also be integrated throughout a site to manage larger areas. Flexible and easy to incorporate in landscaped areas, bioretention facilities are ideal for placement in roadway median strips and parking lot islands. They can also provide water quality treatment from pervious areas, such as golf courses.

In highly urbanized watersheds, bioretention is often one of the few retrofit options that can be cost-effectively employed by modifying existing landscaped areas, converting islands or under-used parking areas, or integrating into the resurfacing of a parking lot. Applications of bioretention systems in urban environments include planter boxes, residential on-lot landscaping, parking lots, roadways, and industrial and commercial applications, which can capture both site and roof runoff. The application of bioretention systems is not limited to this list; however, examples for each of these alternatives are provided below.

Planter Boxes
A flow-through planter box is designed with an impervious bottom or is placed on an impervious surface. Pollutant reduction is achieved as the water filters through the soil. Flow control is obtained by storing the water in a reservoir above the soil and detaining it as it flows through the soil. This planter can be used adjacent to a building if the box is properly lined.

Residential On-lot
Landscaped garden areas can be designed with bioretention systems to create decorative features, habitat, and stormwater treatment at a residential site. The design can be as simple as incorporating a planting bed into the lowest point on a site. It is recommended that downspouts be directed into these systems after appropriate pre-treatment.

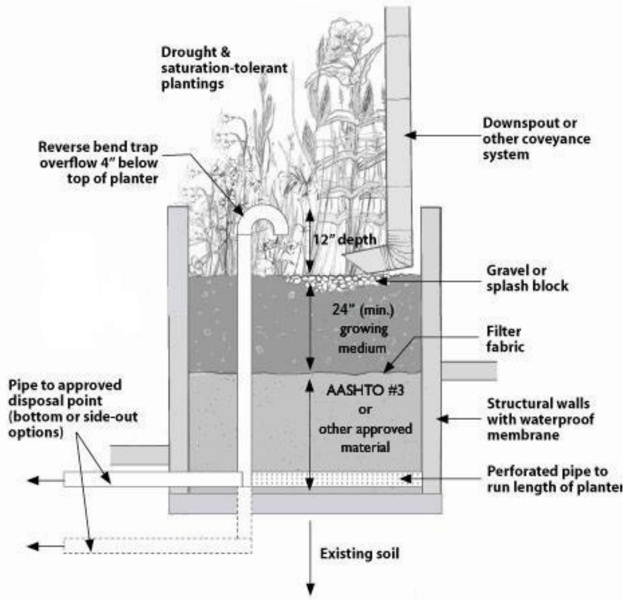


Figure 7.17: Profile of flow-through planter box

highlights:

- Can store and treat runoff.
- Can be used for infiltration or to meet the Water Quality requirements where infiltration is not feasible.
- Use vegetation to filter and transpire.
- Contribute to better air quality, water quality and help reduce urban heat island impacts.
- Can improve property value through attractive landscaping.

City of Portland, OR

Parking lot recharge garden

Tree Wells

Bioretention principles can be incorporated into a tree well design to create mini-treatment areas throughout a site. Care should be taken to ensure that the ponding area depth is appropriate to the tree size and species.

Parking Lots

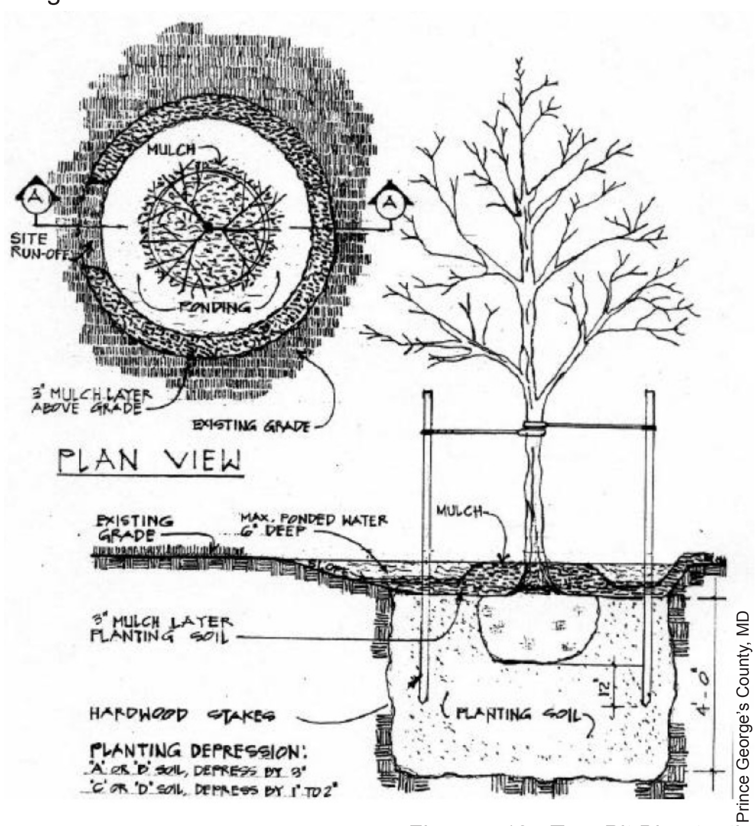
Parking lots are an ideal location for bioretention systems. Bioretention can be incorporated as an island, median, or along the perimeter of the parking area. Bioretention areas can enhance the aesthetics of a parking lot while managing stormwater from the site. Site grading must not result in erosive velocities.

Roads and Highways

Linear bioretention basins can be constructed alongside roads or highways, in roadway medians, or in bump-outs that double as traffic calming devices. The system will manage runoff from the street and help to control automotive pollutants. The systems can also help to control roadway flooding.

Commercial/Industrial/Institutional

At commercial, industrial, and institutional sites, areas for stormwater management and green space are often limited. At these sites, bioretention systems serve the multiple purposes of stormwater management and landscaping. Bioretention areas can be used to manage runoff from impervious site areas such as parking lots, sidewalks, and rooftops.



Prince George's County, MD

Figure 7.18: Tree Pit Bioretention

Components of a Bioretention System

Bioretention systems can be designed to infiltrate all or some of the flow that they treat. The primary components of a bioretention system are:

- Pretreatment if the site will generate high sediment loads
- Flow entrance/inlet
- Surface storage (ponding area)
- Organic layer or mulch
- Planting soil and filter media
- Native plantings
- Sand bed or stone filter and underdrain, if required
- Stone storage for additional storage, if needed
- Positive overflow

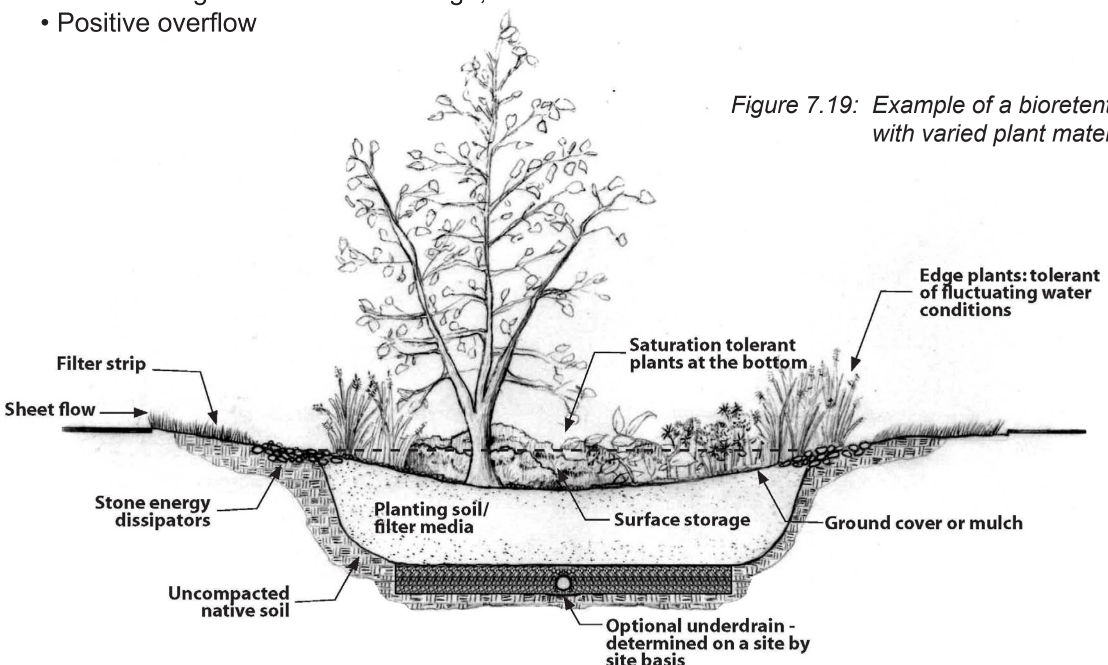


Figure 7.19: Example of a bioretention system with varied plant materials

Pretreatment

Pretreatment is not required for all bioretention systems because the soil-plant system provides treatment. However, pretreatment is recommended for bioretention systems on sites that generate high sediment loads. Additional pretreatment may prolong the life of the system by reducing sediment and other pollutant loads.

Flow Entrance / Inlet

It is recommended that runoff is conveyed to a curbless bioretention area via sheet flow over a grass or gravel filter strip. This is not always possible due to site constraints or space limitations. On sites where curb removal is not an option or where flow is concentrated by the time it reaches the bioretention area, curb openings coupled with energy dissipaters provide an alternative runoff inlet.

Roof leaders that flow into bioretention areas also require energy dissipaters to prevent erosion in the bed. Refer to **Section 7.15**: Inlet and Outlet Controls for details about energy dissipaters.


Prince George's County, MD

Flow enters the bioretention system via a curb opening inlet that is protected with an energy dissipater (stones).

Surface Storage (Ponding Area)
Surface storage provides temporary storage of stormwater runoff before infiltration, evaporation, and uptake can occur within the bioretention system. Ponding time provides water quality benefits by allowing larger debris and sediment to settle out of the water. Recommended ponding design depths are provided in order to reduce hydraulic loading of underlying soils, minimize facility drainage time, and prevent standing water.

Planting Soil and Filter Media
The planting soil acts as a filter between the surface storage and the native soil. The prepared planting soil provides additional storage while the water infiltrates into the native soil. Storage area is a function of both soil depth and bioretention surface area. The planting soil also provides a medium suitable for plant growth. (see **Section 8:** Landscape Guidance for planting soil specifications.)

Native Plantings
The plant material in a bioretention system removes nutrients and stormwater pollutants through vegetative uptake, removes water through evapotranspiration, and creates pathways for infiltration through root development and plant growth. A varied plant community is recommended to avoid susceptibility to insect and disease infestation and to ensure viability. A mixture of groundcover, grasses, shrubs, and trees is recommended to create a microclimate that can ameliorate urban stresses as well as discourage weed growth and reduce maintenance. **Section 8**: Landscape Guidance contains information on native plant and tree selection and landscape design. Do not use invasive species listed in **Section 8**.

Organic layer or mulch
The organic layer or mulch provides a medium for biological growth, decomposition of organic material, adsorption, and binding of heavy metals. The mulch layer can also serve as a sponge that absorbs water during storms and retains water for plant growth during dry periods.

Sand bed or stone filter and Underdrain (if necessary)
An underdrain is a perforated pipe that collects water at the bottom of the system and conveys it quickly to the system outlet. Underdrains eliminate most infiltration because they provide a preferential pathway for flow. A sand layer or gravel filter should surround the underdrain to filter sediment and facilitate flow to the underdrain. If a sand layer is used, the underdrain should be surrounded by a non-woven filter fabric to prevent clogging.

Stone Storage (if necessary)
A stone storage layer can be included to provide higher void space storage if needed in addition to the surface and soil storage.

Positive Overflows
A positive overflow must be provided at the maximum ponding depth. When runoff exceeds system storage capacity, the excess flow leaves the system through the positive overflow. If additional stormwater controls are required on the site, the overflow can connect to a system that will provide channel protection or peak rate control. If no additional stormwater controls are required, the overflow can be connected to storm sewer, combined sewer, or receiving water, as appropriate for the site. Types of overflow structures are discussed in **Section 7.15**: Inlet and Outlet Controls.

Surface inlet

Recommended Design Procedures

Design of bioretention systems is somewhat flexible. The area, depth, and shape of the system can be varied to accommodate site conditions and constraints. The following design procedures are general guidelines that designers can follow.

- Determine the Water Quality, Channel Protection, and Flood Control requirements for the site. See **Section 4.3**: Manage Remaining Stormwater.
- Create a Conceptual Site Plan for the entire site and determine what portion of the stormwater management requirements bioretention will meet and what the drainage area will be. See **Section 4.0**: Integrated Site Design.
- Investigate the feasibility of infiltration in the area proposed for bioretention. If infiltration is not feasible, consider an underdrained bioretention system or an alternate location for the bioretention area. If infiltration is feasible, determine the saturated vertical infiltration rate. See **Appendices A, B, and C** for more guidance on requirements.
- Create a conceptual design for the bioretention basin.

Table 7.10: Suggested Starting Design Values for Areas and Depths

Area (surface area and infiltration area) and Loading Ratio	Largest feasible area on site, with a required minimum of 1 square foot of infiltration area for every 10 square feet of contributing DCIA (10:1 Loading Ratio)
Typical ponding depth*	6-12 inches
Soil depth	2 – 3 feet

* Note pond depth may not exceed 2 feet

- Estimate the total storage volume, and adjust area and/or depths as needed to provide required storage.
- If infiltration is not feasible, static storage of the entire water quality volume must be provided above the bioretention basin surface, between the top of soil elevation and the lowest outlet in the bioretention area. Void space in the soil and/or stone layers beneath the bioretention area surface may not be considered part of the available volume of the SMP.
- If infiltration is feasible, static storage of the entire water quality volume must be provided below the outlet in the bioretention area, and the voids in the soil and/or stone layers beneath the bioretention area surface may be included as storage for the water quality volume. If the soil layer is counted toward storage volume, it must be demonstrated that the runoff will infiltrate into the bioretention soil before reaching the bioretention area's outlet control device.
- Estimate how long the surface ponding and soil storage will take to drain based on the infiltration area and the saturated vertical infiltration rate of the native soil. The maximum drain down time for the entire storage volume (surface, planting soil, and gravel if used) is 72 hours, but a surface drain down time of 24 – 48 hours is recommended. If storage does not drain in the time allowed, adjust surface depth, soil depth, and/or surface area. Adjust the design until the volume, drainage time, and site constraints are met.
- Design underdrains to minimize clogging. Pea gravel filters can be used for this purpose. Pea gravel filters should include at least 3 inches of gravel under the pipe and 6 inches above the pipe.
- Determine and specify the infiltration rate of the bioretention soils.

• In areas where infiltration is infeasible due to a hotspot or unstable fill that threatens an existing structure, specify an impervious liner (compacted till liner, clay liner, geomembrane liner, or concrete liner with a permeability less than or equal to 10-7 cm/sec).

Table 7.11: Suggested Minimum Soil Depths for Plant Growth	
Soil Depth for Herbaceous Species	24 inches
Soil Depth for Woody Species	4 inches deeper than largest root ball or 24 inches, whichever is greater

• Design an inlet control to meet energy dissipation requirements and provide pretreatment if required. See **Section 7.15**: Inlet and Outlet Controls.

• Pretreatment of runoff from all inlets and roof drainage systems is required for infiltrating SMPs. At a minimum, this can be achieved through the use of sumps and traps for inlets, sump boxes with traps downstream of roof drainage systems and trench drains, and filter strips for overland flow. See **Section 7.15**: Inlet and Outlet Controls.

• Design a positive overflow for large storms.

• Given the design area and average depths, determine the final contours of the basin.

*Table 7.12: Suggested Maximum Ponding Depths and Side Slopes**	
Maximum Ponding Depth	2 feet
Side Slopes	3 horizontal to 1 vertical recommended; 2:1 maximum
*These decisions affect safety and appearance rather than stormwater function; acceptable dimensions are ultimately a decision to be made jointly by the Engineer and Owner.	

• Complete construction plans and specifications.

• Soils underlying infiltration practices must have a tested infiltration rate between 0.5 and 10 inches per hour. Soils with rates in excess of 10 inches per hour will require soil amendments. During construction, upon achieving final subgrade elevations, a 2-foot thick layer of amended soil must be placed across the entire cross-section of the infiltrating SMP, below the bottom elevation of the SMP, and a minimum of two (2) infiltration tests must be performed within the amended soil layer. The procedure utilized must be the double-ring infiltrometer test, and it must be in compliance with the current Philadelphia Stormwater Management Guidance Manual. The engineer must provide a signed and sealed infiltration testing report with a testing location plan and summary of results. All information must be submitted to PWD for review and approval before proceeding with construction. If soil amendments are installed and the tested infiltration rate is determined to be outside of the PWD-allowable range of 0.5 to 10 inches per hour or varies significantly from the design infiltration rate, additional soil amendments and/or a system redesign will be required.

• PWD generally does not allow more runoff than that of the 1-year storm to be statically stored for infiltration. Projects may statically store runoff volumes from greater than the 1-year storm up to the runoff volume from the 10-year storm if the applicant provides a letter, signed and sealed by both the geotechnical and design engineer, indicating that the proposed design is recommended, with the following components acknowledged and considered (Contact PWD for further guidance when pursuing this basin design):

- Provide a summary of the long-term impacts to the neighboring properties, including, but not limited to subsidence, change in basement moisture/ water, and structural damage;
- Indicate the location of the groundwater table;
- Provide references to other projects that have successfully infiltrated the 1-year storm event; and
- Provide rigorous pre-treatment to promote longevity of the infiltration system.

• Rock construction entrances must not be located on top of any infiltration practices. It may be necessary to phase the erosion and sediment control plan to avoid compaction of the infiltration area.

• Where bioretention is used for areas that require groundwater protection (as in karst, stormwater hot spots, or source water protection locations) or in close proximity to basements, an appropriate impervious liner should be specified. Clay liners should be of an appropriate design as specified by a geotechnical engineer. Synthetic liners, such as HDPE or PVC, should be of appropriate thickness (at least 30 mil is recommended). Sections of geosynthetic liner must be joined by heat sealing or as required to form an impervious seam by the manufacturer.

Materials

Planting Soil

• See Bioretention Landscaping Recommendations in **Section 8.2** for planting soil specifications.

Mulch

• Organic mulch shall be aged, double-shredded hardwood bark mulch or composted leaf mulch.

• Mulch shall be free of weeds.

• Organic mulch shall be placed on bioretention surface to a depth of 2-3 inches.

Plants

• It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select bioretention plants from the list of native species in **Section 8**: Landscape Guidance. Take ponding depth, drain down time, sunlight, salt tolerance, and other conditions into consideration when selecting plants from this list. Although plants will be subject to ponding, they may also be subject to drought especially in areas that get a lot of sunlight or are in otherwise highly impervious areas.

Storage Stone (if used)

• Stone used to provide additional storage shall be uniformly-graded, crushed, clean-washed stone. PWD defines "clean-washed" as having less than 0.5% wash loss, by mass, when tested per the AASHTO T-11 wash loss test. AASHTO No. 3 and No. 57 stone can meet this specification.

• Stone shall be separated from soil medium by a non-woven filter fabric or a pea gravel filter.

Construction Guidelines

• Areas for bioretention shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

• Provide erosion and sedimentation control protection on the site such that construction runoff is directed away from the proposed bioretention location. Proposed bioretention areas may only be used as sediment traps during construction if at least two feet of soil are removed and replaced.

• Complete site elevation grading and stabilize the soil disturbed within the limits of disturbance. Do not finalize bioretention excavation and construction until the drainage area is fully stabilized.

• Excavate bioretention area to proposed invert depth and manually scarify the existing soil surfaces. Do not compact in-situ soils. Heavy equipment shall not be used within the bioretention basin. All equipment shall be kept out of the excavated area to the maximum extent possible. The use of machinery to load any proposed stone from outside of the basin footprint is recommended.

• All stone, if used, that makes up the infiltration SMP must remain free of sediment. If sediment enters the stone, the contractor may be required to remove the sediment and replace with clean washed stone.

- If using an underdrain and/or a gravel storage bed, place filter fabric or pea gravel filter, then place the rock, and set the underdrain according to the plans.

- If an underdrain and/or gravel storage are not used, rototill 2-3 inches of sand into the base of the facility, then rototill 3-4 inches of planting soil into the sandy subgrade to create a gradation zone.

- Backfill the excavated area as soon as the subgrade preparation is complete to avoid accumulation of debris. Place bioretention soil in 12-18 inches lifts and tamp lightly. Slight overfilling might be necessary to account for settlement. Presoak soil at least one day prior to final grading and landscaping to allow for settlement.

- After allowing for settlement, complete final grading within about 2 inches of the proposed design elevations, leaving space for top dressing of mulch or mulch/compost blend.

- Seed and plant vegetation as indicated on the plans and specifications.

- Place mulch and hand grade to final elevations.

- Install bioretention energy dissipaters as specified on the plans (if applicable).

- Water vegetation at the end of each day for two weeks after planting is completed.

- Water vegetation regularly during first year to ensure successful establishment.

Landscape maintenance of a bioretention basin

City of Portland, OR

Glencoe Elementary's newly planted bioretention garden

Maintenance Guidelines

Properly designed and installed bioretention systems require little maintenance. During periods of extended drought, bioretention systems may require watering approximately every 10 days.

Table 7.13: Bioinfiltration/Bioretention Maintenance Guidelines

Activity	*Schedule*
• Water vegetation at the end of each day for two weeks after planting is completed. • Water vegetation regularly to ensure successful establishment.	First year after installation
• Remulch void areas. • Treat diseased trees and shrubs. • Keep overflow free and clear of leaves.	As needed
• Inspect soil and repair eroded areas. • Remove litter and debris. • Clear leaves and debris from overflow.	Monthly
• Inspect trees and shrubs to evaluate health, replace if necessary. • Inspect underdrain cleanout. • Verify drained out time of system.	Biannually
• Add additional mulch. • Inspect for sediment buildup, erosion, vegetative conditions, etc.	Annually
• Maintain records of all inspections and maintenance activity.	Ongoing

Note: Design of bioretention systems are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

7.6 Detention Basins


Virginia Stormwater Manual

Detention Basins are constructed to provide temporary surface or subsurface storage of runoff and function hydraulically to attenuate stormwater runoff peaks. Traditional detention basins function primarily to provide water quantity control. The designer should note that detention basins can also be configured to provide water quality treatment. These designs are referred to as dry extended detention basins. More information on dry extended detention basins can be found in the Pennsylvania Stormwater BMP Manual.

key elements :

- Detention basins should completely drain in 72 hours.
- Most basins are designed to provide Channel Protection and Flood Control only.
- A sediment forebay helps decrease maintenance and prolong design life of the basin.
- Vegetation stabilizes the soil in the basin.
- Outlet structure design is critical and determines how the basin meets stormwater control requirements.

potential applications

Residential Subdivision:	Limited
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Limited

stormwater regulations

Water Quality:	
Infiltration:	No
Volume Reduction: (no infiltration)	No
Channel Protection:	High
Flood Control:	High

acceptable forms of pre-treatment

- Sediment forebays
- Filter strips
- Vegetated swales

Detention Basins in the Urban Landscape

Detention basins are suitable for large developments and high-density commercial projects. They require substantial open space; however, they can often be designed for use between storm events, creating an open space available for recreational purposes.

Components of a Detention Basin

Detention basins are typically comprised of the following components:

- Sediment forebay
- Vegetation
- Micropool
- Outflow structure

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Sediment forebay

Sediment Forebay
Supplementing a dry pond design with a sediment forebay is required to increase the treatment efficiency. The sediment forebay improves pollutant reduction by trapping larger particles near the inlet of the pond. The forebay should include a permanent pool to minimize the potential for scour and re-suspension. A sediment forebay will enhance the removal rates of particulates, decrease the velocity of incoming runoff, and reduce the potential for control structure failure due to clogging. Sediment forebays should be designed for ease of maintenance. Forebays must be accessible to heavy machinery. Those constructed with a bottom made of concrete or other solid materials make sediment removal easier and more accessible by heavy machinery.

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Athletic field to be used as a detention basin

Vegetation
Surface vegetation in the basin provides erosion control and sediment entrapment. Side slopes, berms, and basin surface should be planted with appropriate native species. Appropriate species can be found in **Section 8**: Landscape Guidance.

Micropool at the Outlet (Optional)
Applying a micropool design to a detention basin can maximize water quality performance. The micropool is typically shallow and permanently inundated. Its function is to concentrate finer sediment and reduce re-suspension. The micropool is normally planted with wetland vegetation species such as cattails.

Outflow Structure
The outlet structure determines the performance of the basin. By installing a multi-stage riser, the basin can be designed to meet both Water Quality and Flood Control requirements.

A gate valve or orifice plate should regulate the drawdown time. In general, the outflow structure should have a trash rack or other acceptable means of preventing clogging at the entrance to the structure. See **Section 7.15**: Inlet and Outlet Controls for more information.

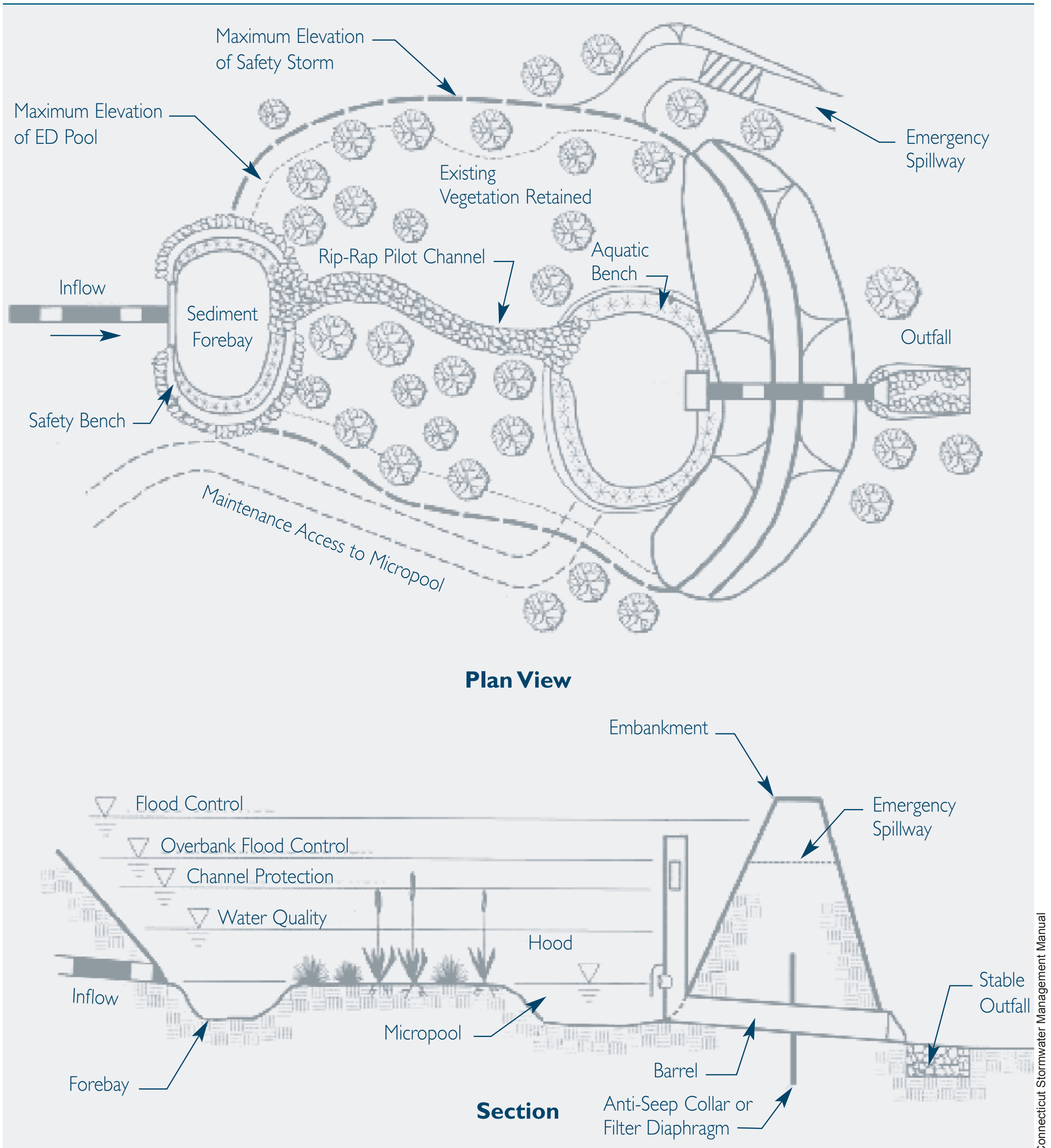

Figure 7.20: Extended detention basin schematic

Recommended Design Procedure

- Determine the stormwater management requirements for the site. See **Section 4.3**: Manage Remaining Stormwater.

- Create a Conceptual Site Plan for the entire site and determine what portion of the control requirements the detention basin will meet.

    - Consider a dry extended detention basin to provide water quality treatment if infiltration is infeasible on the site.

    - Detention basins may not be built on steep slopes. Slopes may not be significantly altered or modified to reduce the steepness of the existing slope. See **Section 4.0**: Integrated Site Design.

    - Extended detention basins shall not be constructed within jurisdictional waters, including wetlands.

- Create a conceptual design for the basin. Estimate required basin size according to an approved calculation method in **Section 5.3**: Acceptable Methods for Calculations.

Table 7.14: Starting Design Parameters for Detention Basins	
Detention time for water quality volume	24-hour minimum
Water depth	10 feet (Maximum)
Width	10 feet (Minimum)
Shape	• To maximize length of stormwater flow pathways. • To minimize short-circuited inlet-outlet systems.
Length to width ratio	2:1 (Minimum - recommended to maximize sedimentation)

- Design an outlet structure (or multiple structures) that provides the level of control required. (A multi-stage outlet structure will be required in most cases.)

    - Energy dissipaters are to be placed at the end of the primary outlet to prevent erosion.

    - If the basin discharges to a channel with dry weather flow care shall be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone between the outlet and natural channel.

    - The hydraulic design of all outlet structures must consider any significant tailwater effects of downstream waterways.

    - The primary and low flow outlet shall be protected from clogging by an external trash rack.

    - On sites that have the potential for accidental spills, the outflow structure should be fitted with a valve so that discharge from the basin can be halted. This same valve also can be used to regulate the rate of discharge from the basin.

- The detention basin must provide an emergency overflow capable of passing the 100-year design storm. This spillway may not direct emergency flows toward neighboring properties.

- Determine the final contours of the basin.

Table 7.15: Contour Design Parameters for Detention Basins	
Lowest basin elevation	2 feet above seasonal high water table (Minimum)
Basin shape	Irregularly shaped to appear more natural
Low flow channels	Only use where there is a concern for severe ponding due to native soils Always vegetate with a maximum slope of 3% to encourage sedimentation Consider other SMPs such as wet ponds, constructed wetlands or bioretention
Vegetated embankments	Less than or equal to 3 feet in height (Recommended) 15 feet in height (Maximum)* Maximum slope 3:1 (Horizontal to vertical)
Basin freeboard	Minimum 1 foot above the 100-yr design storm
*15 feet or higher or that which will impound more that 50 acre-feet of runoff during high-water condition will be regulated as dams by PADEP. Consult chapter 105 on the Pennsylvania State Code.	

- Design an inlet control and a sediment forebay. The sediment forebay volume may be considered to meet a portion of the water quality volume.

Table 7.16: Inlet Control and Sediment Forebay	
Forebay length	10 feet (Minimum)
Storage	Designed to trap sediment over a period of 2 to 10 years

- Verify that the basin meets all control requirements concurrently as designed.

- Choose appropriate vegetation using the guidelines in **Section 8**: Landscape Guidance. Fertilizers and pesticides shall not be used.

- Complete construction plans and specifications.

Materials

Basin Soil

- A minimum of 6 inches of planting soil is recommended. Soil shall be a high-quality topsoil with a loam or sandy loam texture.

- Clay cores may be necessary in basins designed to withstand excessive pressures and seepage forces.

Plants

- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select plants from the list of native species in **Section 8**: Landscape Guidance.

- Trees and shrubs shall be freshly dug and grown in accordance with good nursery practice.

- Perennials, grass-like plants, and groundcover plants shall be healthy, well-rooted specimens.

- Plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

Construction Guidelines

- Install all temporary erosion and sedimentation controls. The area immediately adjacent to the basin must be stabilized in accordance with the Pennsylvania Department of Environmental Protection (PADEP) *Erosion and Sediment Pollution Control Program Manual* (2000 or latest edition) prior to basin construction.

- Prepare site for excavation and/or embankment construction.

- All existing vegetation should remain if feasible and shall only be removed if necessary for construction.

- Care should be taken to prevent compaction of the basin bottom.

- If excavation is required, clear the area to be excavated of all vegetation. Remove all tree roots, rocks, and boulders only in excavation area.

- Excavate bottom of basin to desired elevation (if necessary).

- Install surrounding embankments and inlet and outlet control structures.

- Grade subsoil in bottom of basin, taking care to prevent compaction. Compact surrounding embankment areas and around inlet and outlet structures.

- Apply and grade planting soil.

- Apply geotextile and other erosion-control measures.

- Seed, plant, and mulch according to Planting Plan.

Maintenance Guidelines

- Maintenance is required for the proper operation of detention basins.

Table 7.17: Detention Basin Maintenance Guidelines	
Activity	***Schedule***
• Remove trash and debris. • Remove invasive plants. • Grassed areas require periodic prudent fertilizing, dethatching and soil conditioning. • Trees, shrubs, and other vegetative cover will require periodic maintenance such as fertilizing, pruning, and pest control. • Mow / trim detention basin vegetation.	As needed
• Sediment should be removed from the basin.	As needed (at least once every 5 to 25 years)*
• Inspect outlet control structure for clogging.	Quarterly and after every storm greater than 1 inch
• Inspect detention basin for potential problems including: subsidence, erosion, cracking or tree growth on the embankment; damage to the emergency spillway; sediment accumulation around the outlet; inadequacy of the inlet/outlet channel erosion control measures; changes in the condition of the pilot channel; and erosion within the basin and banks.	Annually
• Maintain records of all inspections and maintenance activity.	Ongoing
* The frequency of sediment removal depends on site conditions such as soil type and maintenance of site stabilization which influence the sediment load on the basin.	

- In most cases, no specific limitations have been placed on disposal of sediments removed from detention basins. Studies to date indicate that pond sediments are likely to meet toxicity limits and can be safely landfilled. On-site sediment disposal is always preferable as long as the sediments are deposited away from the shoreline to prevent their re-entry into the pond and away from recreation areas where people could inhale resulting dust. Information regarding sediment disposal should be provided to the property owner by the design engineer.

- Sediments should be tested for toxicants in compliance with current disposal requirements if land uses in the drainage area include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed.

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7.7 Berms

and retentive grading techniques use a site's topography to manage stormwater and avoid erosion. They may function alone in grassy areas or may be incorporated into the design of other stormwater control facilities such as bioretention and constructed wetlands. They are landscaped features placed parallel to existing contours that direct runoff while promoting retention and infiltration of stormwater.

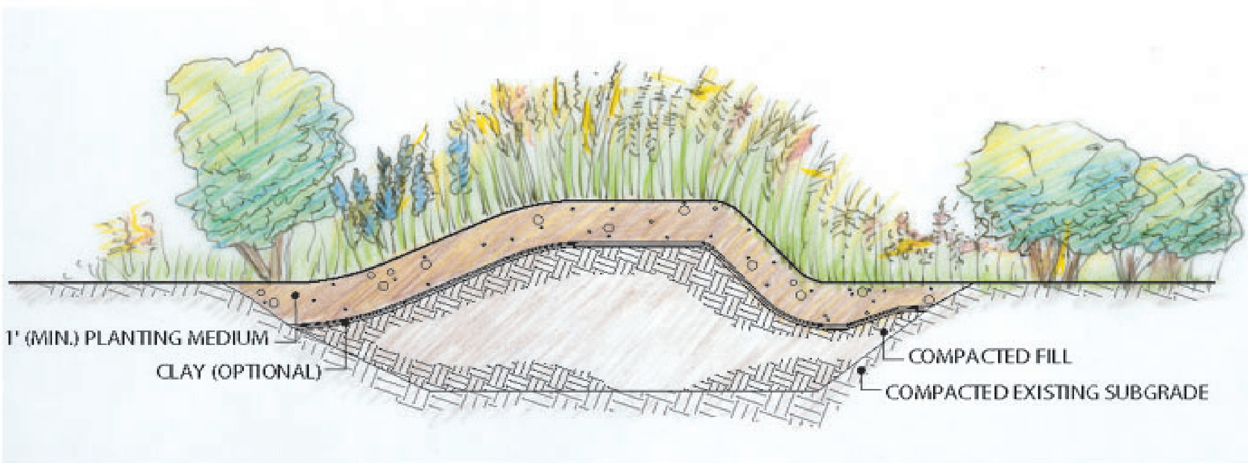


Figure 7.21: Berm cross-section

key elements :

- High quality topsoil in outer layer of berm that provides growing medium for plants (minimum 4 inches).
- Inner layer of berm constructed of a stable fill material.
- Established vegetation to prevent erosion and improve appearance.
- An overflow weir or runoff bypass mechanism.

potential applications

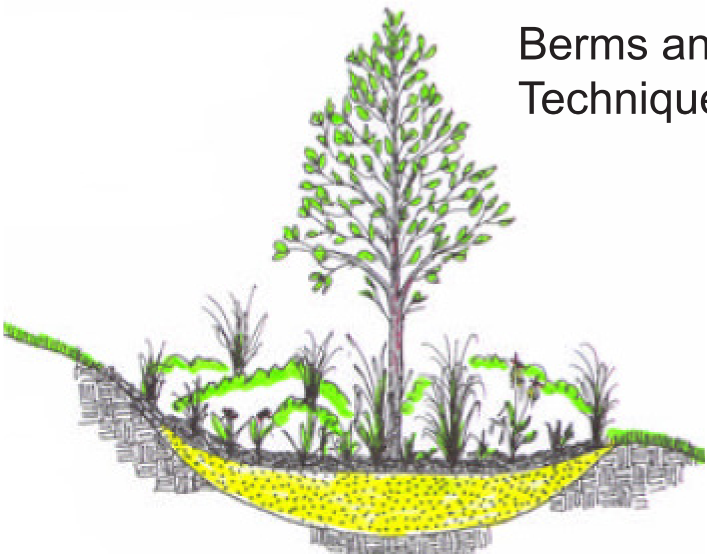
Residential Subdivision:	Yes
Commercial:	Yes
Ultra Urban:	Limited
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Yes

stormwater regulations

Water Quality:	
Infiltration:	Yes
Volume Reduction: (no infiltration)	No
Channel Protection:	N/A
Flood Control:	N/A

acceptable forms of pre-treatment

N/A



Prince George's County, MD

Figure 7.22: Example of retentive grading used to create a small bioretention basin which can be vegetated to various extents

Berms and Retentive Grading Techniques in the Urban Landscape

Berms are applicable in many urban settings such as parking, commercial and light industrial facilities, roads and highways, residential developments, and vacant lots. Berms and shallow depressions are well suited for both small and large projects. It can be an inexpensive method of reusing soil on site to manage stormwater.

Pretreatment for other Facilities
A berm and small depression can act as a sediment forebay before stormwater enters a bioretention basin, subsurface infiltration facility, or other facility.

Retention and Increased Capacity for other Facilities
A berm placed on the downslope side of a bioretention basin or other facility built on a mild slope can help retain stormwater in that facility and increase its capacity without additional excavation.

Retention and Infiltration in a Shallow Depression
A shallow depression can be created behind a berm to provide an infiltration area without the need for a more complex stormwater facility.

Flow Diversion
A berm can be placed across a slope to divert water to a nearby channel or facility.

Berms in Series
A series of small berms and depressions can be placed along a slope to provide infiltration and detention while stabilizing the slope.

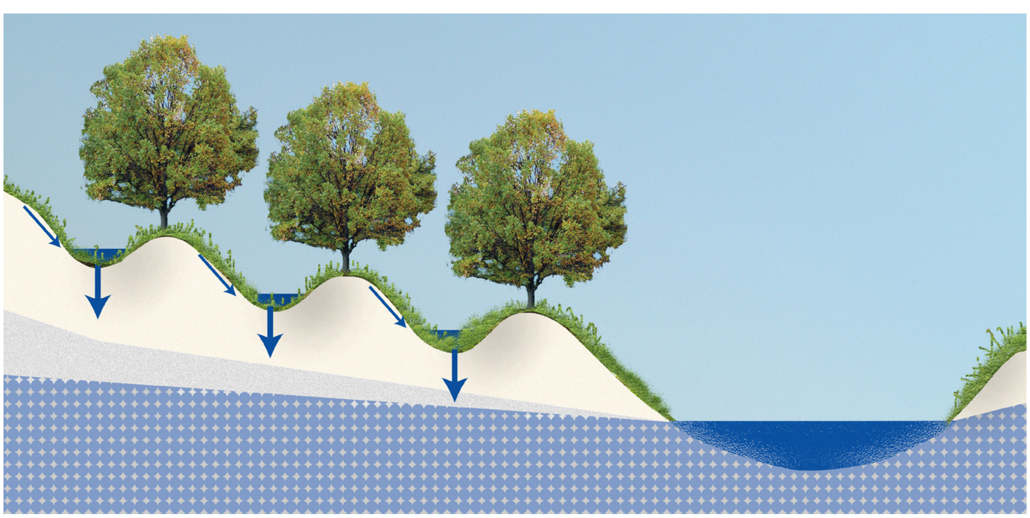


Figure 7.23: Woodland infiltration berms in series

Components of Berms and Retentive Grading Techniques

Berms and retentive grading systems are designed to convey and infiltrate all of the stormwater they receive in small storms. These systems often include the following components:

- Topsoil
- Fill
- Vegetation
- Weir or Bypass Mechanism

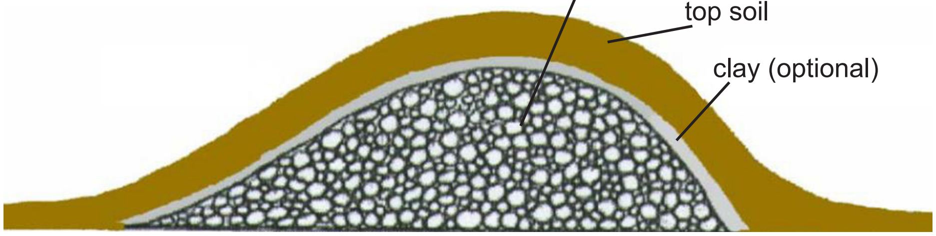


Figure 7.24: Ideal substrate components of a berm

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Topsoil
The outer portion of the berm consists of high quality topsoil to provide a barrier to flow and act as a growing medium for plants. A berm may consist entirely of high quality topsoil. To reduce cost, only the top 4 to 8 inches needs to consist of high quality topsoil, with well-drained soil making up the remainder of the berm.

Fill
A berm may consist entirely of high quality topsoil. However, cost may be reduced by constructing the inner portion of the berm of a stable fill material. In many cases, soil may be reused from elsewhere on the site.

Vegetation
Vegetation stabilizes and prevents erosion of the soil layer. Native trees and grasses are encouraged for aesthetic reasons and because of their deeper root systems, but turf is acceptable.

Weir or Bypass Mechanism
The berm may not be able to retain all flow during large events. An overflow weir may be designed to allow flow to overtop the berm without causing erosion. In other cases, the contours of the site may allow excess flow to bypass around the end of the berm.

Traver

The sediment forebay at Villanova University uses a rock and soil berm as pretreatment for their constructed wetland

Recommended Design Procedure

• Determine the Water Quality, Channel Protection, and Flood Control requirements on the site. See **Section 4.3**: Manage Remaining Stormwater.

• Create a Conceptual Site Plan for the entire site, and determine what portion of the sizing requirements berms and retentive grading will help meet. Determine the general location of these features and the role they will play on the site. See **Section 4.0**: Integrated Site Design.

• Create a conceptual design for the berm (or berms), including height of berm and depth of depression.

Table 7.18: Starting Design Values for Berm Areas and Depths	
Area (surface area and infiltration area)	Largest feasible on site (Minimum of 1 square foot of infiltration area for every 5 square feet of contributing DCIA recommended.)
Average Ponding Depth	6 – 12 inches
Berm Height	6 – 24 inches

• For a berm-depression system intended to promote infiltration, investigate the feasibility of infiltration in the proposed location. See **Appendix A**: Hotspot Investigation Procedures, **Appendix B**: Soil Infiltration Testing Guidelines, and **Appendix C**: Geotechnical Investigation Procedures for more guidance on requirements. Infiltration testing must be within 25 feet of the infiltration footprint.

• Estimate runoff reaching the system during the design storm and the maximum water level reached at the berm.

• Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long the surface ponding will take to drain. The maximum drain down time for the entire storage volume is 72 hours, but the Engineer may choose a shorter time based on site conditions and Owner preference. A surface drain down time of 24 – 48 hours is recommended. If storage does not drain in the time allowed, adjust berm height and depression depth. Adjust the design until the volume and drainage time constraints are met.

• Design an overflow or bypass mechanism for large storms.

• Consider maintenance activities when choosing berm materials and shape. Figure 7.25 illustrates the recommended shape.

• If a berm is to be mowed, the slope should not exceed a 4:1 ratio (horizontal to vertical) in order to avoid “scalping” by mower blades. If trees are to be planted on berms, the slope should not exceed a 5:1 to 7:1 ratio. Other herbaceous plants, which do not require mowing, can tolerate slopes of 3:1, though this may promote increased runoff rate and erosive conditions. Berm side slopes should never exceed a 2:1 ratio.

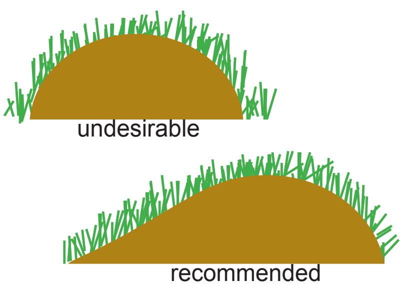

Figure 7.25: Recommended berm shape

• To minimize cost, check the volume of cut and fill material. Berm height and depression depth may be adjusted to more closely balance the two.

• Choose vegetation as recommended in **Section 8**: Landscape Guidance.

Materials

Soil

• Satisfactory soil materials are defined as those complying with ASTM D2487 soil classification groups GW, GP, GM, SM, SW, and SP.

• Unsatisfactory soil materials are defined as those complying with ASTM D2487 soil classification groups GC, SC, ML, MH, CL, CH, OL, OH, and PT.

• Topsoil stripped and stockpiled on the site should be used for fine grading. Topsoil is defined as the top layer of earth on the site, which produces heavy growths of crops, grass or other vegetation.

• Soils excavated from on-site may be used for berm construction provided they are deemed satisfactory as per the above recommendations or by a soil scientist.

Vegetation

• It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Native trees and grasses are strongly recommended but turf grass is acceptable. Select native plants from the list in **Section 8**: Landscape Guidance. Take ponding depth, drain down time, sunlight, and other conditions into consideration when selecting plants from this list. Although plants will be subject to ponding, they may also be subject to drought.

• Trees and shrubs shall be freshly dug and grown in accordance with good nursery practice.

• Perennials, grass-like plants, and groundcover plants shall be healthy, well-rooted specimens.

• Plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

• A native grass/wildflower seed mix can be used as an alternative to groundcover planting. Seed mix shall be free of weed seeds.

Construction Guidelines

• Areas for infiltration berms shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

• Provide erosion and sedimentation control protection on the site such that construction runoff is directly away from the proposed infiltration berm location.

• Complete site elevation grading and stabilize the soil disturbed within the limit of disturbance. Do not finalize berm excavation and construction until the drainage area is fully stabilized.

• Manually scarify the existing soil surfaces of the proposed infiltration berm locations. Do not compact in-situ soils. Heavy equipment shall not be used within the berm area.

• Backfill the excavated area as soon as the subgrade preparation is complete to avoid accumulation of debris. Place berm soil in 8 inch lifts and compact after each lift is added according to design specification. Grade berm area as fill is added.

• Protect the surface ponding area at the base of the berm from compaction. If compaction occurs scarify soil to a depth of at least 8 inches.

• After allowing for settlement, complete final grading within 2 inches of proposed design elevations. The crest and base of the berm should be level along the contour.

• Seed and plant vegetation as indicated on the plans and specifications.

• Place mulch to prevent erosion and protect establishing vegetation and manually grade to final elevations.

• Water vegetation at the end of each day for two weeks after planting is completed.

Maintenance Guidelines

Infiltration berms have low to moderate maintenance requirements, depending on the design.

Table 7.19: Berm & Grading Maintenance Guidelines

Activity	***Schedule***
• Remove trash and debris. • Remove invasive plants. • If desired, mow grass to maintain 2 – 4 inch height.	As needed
• Inspect soil for erosion and repair eroded areas.	Monthly
• Maintain records of all inspections and maintenance activity.	Ongoing

Note:
Design of berms and grading techniques are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site. Berms may be used within larger basins (e.g., wetlands, wet ponds) to lengthen flow paths; these applications are discussed in **Section 7**: SMP Design Guidance for each type of basin.

7.8 Swales

A swale is an open channel vegetated with a combination of grasses and other herbaceous plants, shrubs, and trees. A traditional swale reduces peak flow at the discharge point by increasing travel time and friction along the flow path. A swale provides some infiltration and water quality treatment; these functions can be enhanced by adding check dams periodically along its length. Swales planted with turf grass provide some of these functions but turf grass is not as effective as deeper-rooted vegetation at decreasing peaks, allowing infiltration, and decreasing erosion. A swale can be more aesthetically pleasing than a concrete or rock-lined drainage system and is generally less expensive to construct.

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key elements :

- Open channel design that balances storage, treatment, and infiltration with peak flow conveyance needs
- Check dams often used to increase storage, dissipate energy, and control erosion
- Native vegetation increases friction and stabilizes soil
- Designed to fit into many types of landscapes in an aesthetically pleasing manner

potential applications

Residential Subdivision:	Yes
Commercial:	Yes
Ultra Urban:	No
Industrial:	Limited
Retrofit:	Yes
Highway Road:	Yes

stormwater regulations

Water Quality:	
Infiltration:	Yes
Volume Reduction: (no infiltration)	Yes
Channel Protection:	Medium
Flood Control:	Medium

acceptable forms of pre-treatment

Filter strips (Optional)
Sediment Forebay (Optional)

Swales in the Urban Landscape

Swales are landscaped channels that convey stormwater and reduce peak flows by increasing travel time and friction. Depending on design, they can effectively reduce runoff volume and improve water quality. Check dams increase these functions by providing ponding areas where settling and infiltration can occur. As the number of check dams increases, a swale may resemble a series of bioinfiltration/ bioretention basins while still being designed to convey peak flows. The first ponding area may be designed as a sediment forebay and function as a pretreatment practice for the remainder of the swale or other stormwater management facilities.

Curbless driveway drains to stone and vegetated swales

Curb opening to grass swale in residential development

Swales are applicable in many urban settings such as parking, commercial and light industrial facilities, roads and highways, and residential developments. For instance, a swale is a practical replacement for roadway median strips and parking lot curb and gutter.

Commercial, Light Industrial, and Institutional Sites
These facilities often have landscaped or grassed areas that can also function as drainage pathways and infiltration areas.

Roads and Highways
Swales can be installed in some median strips and shoulders. In some cases, these systems may replace costly curb and gutter systems.

Residential Development
With approved property agreements, swales can be constructed parallel to the sidewalks and streets. Alternatively they can collect stormwater from multiple properties and convey it to a shared facility.

Components of a Swale

Swale systems often include the following components:

- Inlet Control
- Pretreatment (Optional)
- Excavated Channel
- Soil
- Outlet Control
- Check dams
- Stone (Optional)
- Underdrain (Limited Application)
- Vegetation

Inlet Control
Runoff can enter the swale through a curb opening, pipe, weir, or other design. Runoff may flow off a curbless parking lot or road and down a swale slope in a diffuse manner.

Pretreatment (Optional)
Pretreatment is optional but can extend the life of the design. Vegetated or stone filter strips are options for pretreatment. A sediment forebay may be constructed at the swale inlet, or the first swale segment and a check dam may be designed as a sediment forebay.

Excavated Channel
The channel itself provides the storage volume and conveyance capacity of the swale. Swale design balances needs for infiltration and treatment during small storms with needs for conveyance during large storms.

Soil
The soil provides a growing medium for plants and allows for infiltration. Growing medium may consist of amended native soils or imported soil.

Check Dams
It is recommended that swale designs include check dams. Ponding behind check dams provides storage, increases infiltration, increases travel time, reduces peaks, and helps prevent erosion by dissipating energy.

Stone
A crushed stone layer may be added beneath the soil to increase storage and promote infiltration. Stone will perform this function most effectively when placed in ponded areas.

Underdrain
In some cases, an underdrain and piping system may be designed to prevent prolonged ponding of stormwater or to collect and convey water to another facility such as an infiltration trench. Underdrained systems may be appropriate in locations where conditions are not ideal for infiltration.

Outlet Control
A swale may have an outlet control to convey water to a sewer or receiving water.

River rock swale with structural check dams that manages runoff from sloped street

Recommended Design Procedures

- Determine the Water Quality, Channel Protection, and Flood Control requirements on the site. See **Section 4.3**: Manage Remaining Stormwater.

- Create a Conceptual Site Plan for the entire site, and determine what portion of the requirements the vegetated swale will meet. Consider the site's natural topography in siting the swale; if possible, locate the swale along contours and natural drainage pathways with slopes of 2-3%. See **Section 4.0**: Integrated Site Design.

- Investigate the feasibility of infiltration according to conditions in the area proposed for the vegetated swale. If infiltration is feasible, determine the saturated vertical infiltration rate. See **Appendices A, B, and C** for more guidance on requirements.

- Create a conceptual design for the vegetated swale.

Vegetated swales at Swarthmore University

Table 7.20: Suggested Swale Starting Design Values	
Bottom Width	2-8 feet
Side Slopes	3-4 horizontal to one vertical recommended; 2:1 maximum•
Check Dams	Evenly spaced, 6-12 inches high••
•Swales may be trapezoidal or parabolic in shape. Recommended widths and slopes in this table may be used as a general guide for parabolic channels	
••Check dams are recommended for most applications to improve infiltration and water quality. They are strongly recommended for swales in which flow in combination with soil, slope, and vegetation may result in erosive conditions	

- Estimate the portion of Infiltration, Water Quality, Channel Protection, and Flood Control requirements met by the design. See **Section 4.3**: Manage Remaining Stormwater for guidance on these calculations.

- Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long storage behind check dams will take to drain. The maximum drain down time for the entire storage volume is 72 hours, but the Engineer may choose a shorter time based on site conditions and Owner preference. A surface drain down time of 24 – 48 hours is recommended. If storage does not drain in the time allowed, adjust channel shape, number of check dams, or check dam height. Adjust the design so that performance and drainage time constraints are met concurrently.

- Check the peak flow capacity of the swale. It is recommended that the swale convey the 10-year, 24-hour design storm with 6 inches of freeboard, an average ponding depth of 12 inches or less, and a maximum ponding depth of 18 inches or less. Flow over check dams may be estimated using a weir equation. For rock weirs that allow flow through the weir, an equation is suggested in **Section 7.15**: Inlet and Outlet Controls. Ultimately, the level of service provided on the site during large events is a joint decision of the Engineer and Owner based on safety, appearance, and potential property damage.

- Choose soil mix and swale vegetation. A minimum of 6 inches of prepared soil is recommended for the channel bottom and slopes.

- Check resistance of the swale to erosion. It is recommended that the swale convey the 2-year, 24-hour design storm without erosion. The PADEP *Erosion and Sediment Pollution Control Program Manual* (2000 or latest edition) is recommended as a reference for these calculations. Adjust soil mix, vegetation, and temporary or permanent stabilization measures as needed.

- Design inlet controls, outlet controls, and pretreatment if desired.

- Check that the design meets all requirements concurrently, and adjust design as needed.

- Complete construction plans and specifications.

Materials

Soil

- Swale soil shall have a sandy loam, loamy sand, or loam texture per USDA textural triangle.

Vegetation

- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select plants from the list of native species in **Section 8**: Landscape Guidance. Take ponding depth, drain down time, sunlight, salt tolerance, and other conditions into consideration when selecting plants from this list. Turf grass is generally not recommended but may be acceptable provided the designer can show it meets all requirements.

Check Dams

- Check dams can be constructed from natural wood, concrete, stone, boulders, earth, or other materials.

- If a stone check-dam is designed to be overtopped, appropriate selection of aggregate will ensure stability during flooding events. In general, one stone size for a dam is recommended for ease of construction. However, two or more stone sizes may be used, provided a larger stone (e.g. R-4) is placed on the downstream side, since flows are concentrated at the exit channel of the weir. Several feet of smaller stone (e.g. AASHTO #57) can then be placed on the upstream side. Smaller stone may also be more appropriate at the base of the dam for constructability purposes.

- Check dams that provide ponding in swales that are designed for volume reduction (infiltration) must not be porous, i.e. comprised of stone gabions, as water should be ponded behind each check dam and forced to infiltrate. If the swales are only being used for conveyance or to increase time of concentration,

etc., check dams may be porous.

Storage Stone

- Stone used to provide additional storage shall be uniformly-graded, crushed, clean-washed stone. PWD defines "clean-washed" as having less than 0.5% wash loss, by mass, when tested per the AASHTO T-11 wash loss test. AASHTO No. 3 and No. 57 stone can meet this specification.

- Stone shall be separated from soil medium by a non-woven geotextile or a pea gravel filter.

Non-Woven Geotextile

- Geotextile shall consist of needled non-woven polypropylene fibers and meet the following properties:

    - Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
    - Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
    - Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft2
    - UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
    - Heat-set or heat-calendared fabrics are not permitted

Pipe

- Pipe used for an underdrain shall be continuously perforated and have a smooth interior with a minimum inside diameter of 4-inches. High-density polyethylene (HDPE) pipe shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S.

Construction Guidelines

- Begin vegetated swale construction only when the up gradient site has been sufficiently stabilized and temporary erosion and sediment control measures are in place. Vegetated swales should be constructed and stabilized very early in the construction schedule, preferably before mass earthwork and paving increase the rate and volume of runoff. (Erosion and sediment control methods shall adhere to the PADEP *Erosion and Sediment Pollution Control Program Manual*, March 2000 or latest edition).

- Rough grade the vegetated swale. Equipment shall avoid excessive compaction and/or land disturbance. Excavating equipment should operate from the side of the swale and never on the bottom. If excavation leads to substantial compaction of the subgrade (where an infiltration trench is not proposed), 18 inches shall be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. At the very least, topsoil shall be rototilled into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores. Following this, the area should be disked prior to final grading of topsoil.

- Construct check dams, if required.

- Fine grade the vegetated swale. Accurate grading is crucial for swales. Even the smallest non-conformities may compromise flow conditions.

- Seed and vegetate according to final planting list. Seeding with an annual turf grass is recommended to provide temporary stabilization. Plant the swale at a time of the year when successful establishment without irrigation is most likely. However, temporary irrigation may be needed in periods of little rain or drought. Vegetation should be established as soon as possible to prevent erosion and scour.

- Concurrent with the previous step, stabilize freshly seeded swales with appropriate temporary or permanent soil stabilization methods, such as erosion control matting or blankets. If runoff velocities

are high, consider sodding the swale or diverting runoff until vegetation is fully established. Erosion and sediment control methods shall adhere to the PADEP's *Erosion and Sediment Pollution Control Program Manual*, March 2000 or latest edition.

- Once the swale is sufficiently stabilized, remove temporary erosion and sediment controls. It is very important that the swale be stabilized before receiving stormwater flow.

Maintenance Guidelines

The following schedule of inspection and maintenance activities is recommended:

Table 7.21: Swale Maintenance Guidelines

Activity	**Schedule**
• Remulch void areas. • Treat or replace diseased trees and shrubs. • Keep overflow free and clear of leaves.	As needed
• Inspect soil and repair eroded areas. • Remove litter and debris. • Clear leaves and debris from overflow.	Monthly
• Inspect trees and shrubs to evaluate health.	Biannually
• Add additional mulch. • Inspect for sediment buildup, erosion, vegetative conditions, etc.	Annually
• Maintain records of all inspections and maintenance activity.	Ongoing

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7.9 Constructed Wetlands
can be found in the
Pennsylvania Stormwater BMP Manual

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7.10 Ponds and Wet Basins
can be found in the
Pennsylvania Stormwater BMP Manual

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7.11 Subsurface vaults

Subsurface vaults are underground structures designed primarily to reduce peak stormwater flows, although in some cases they may allow infiltration. They are usually constructed of either concrete or corrugated metal pipe (CMP) and must account for the potential loading from vehicles. Pretreatment structures can be used at the inlet to treat stormwater runoff and remove debris. A permanent pool can also be incorporated to dissipate energy and improve the settling of particulate stormwater pollutants. Dry systems are primarily used for volume control or in combination with pretreatment, whereas wet systems include a permanent pool and provide water quality treatment.

key elements :

- Effective for urban areas with limited space for SMPs.
- More effective in areas of combined sewer than in areas of separate sewers.
- Provides peak rate control.
- Pretreatment may be included to remove sediment and pollutants associated with sediment.
- Traffic loading capabilities.
- Maintenance required periodically to remove sediment and debris.

potential applications

Residential Subdivision:	Limited
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Yes

stormwater regulations

Water Quality:	
Infiltration:	No
Volume Reduction: (no infiltration)	No
Channel Protection:	Medium / High
Flood Control:	Medium / High

acceptable forms of pre-treatment

- Sediment chamber
- Sediment forebay
- Appropriate prefabricated and proprietary designs

Subsurface Vaults in the Urban Landscape

Subsurface vault systems are suitable for projects where space is limited and other stormwater management systems are not feasible. Subsurface vaults may be used for commercial, industrial, or roadway projects. The presence of a subsurface vault in most cases does not alter the intended land use at the surface. The subsurface vault must meet structural requirements for overburden support and traffic loading to be applicable in urban settings. Some applications of subsurface vaults are provided; however, examples are not limited to this list.

Components of a Subsurface Vault

Subsurface vault systems contain a combination of the following components:

Inlet Control
The inlet control of a subsurface vault should be connected to the stormwater catchment area. The subsurface vault should be sized according to the area entering into the system. Parking lots, roadways, and large rooftop areas are typically the drainage areas contributing to the subsurface vault system. The inlet control may include a flow splitter to regulate the rate and volume of water entering the vault.

Pretreatment
Pretreatment can include a forebay/grit chamber, sand filter, or water quality inlet. It may also include features to trap floatables and an oil/water separator. A baffle inserted within the subsurface vault separates the entire volume into two chambers. A sedimentation chamber is created using a baffle wall. Storage volume present in a pretreatment structure may be considered part of the total storage volume required.

Storage Structure
Storage often provided by a concrete structure, a large pipe, or a group of pipes.

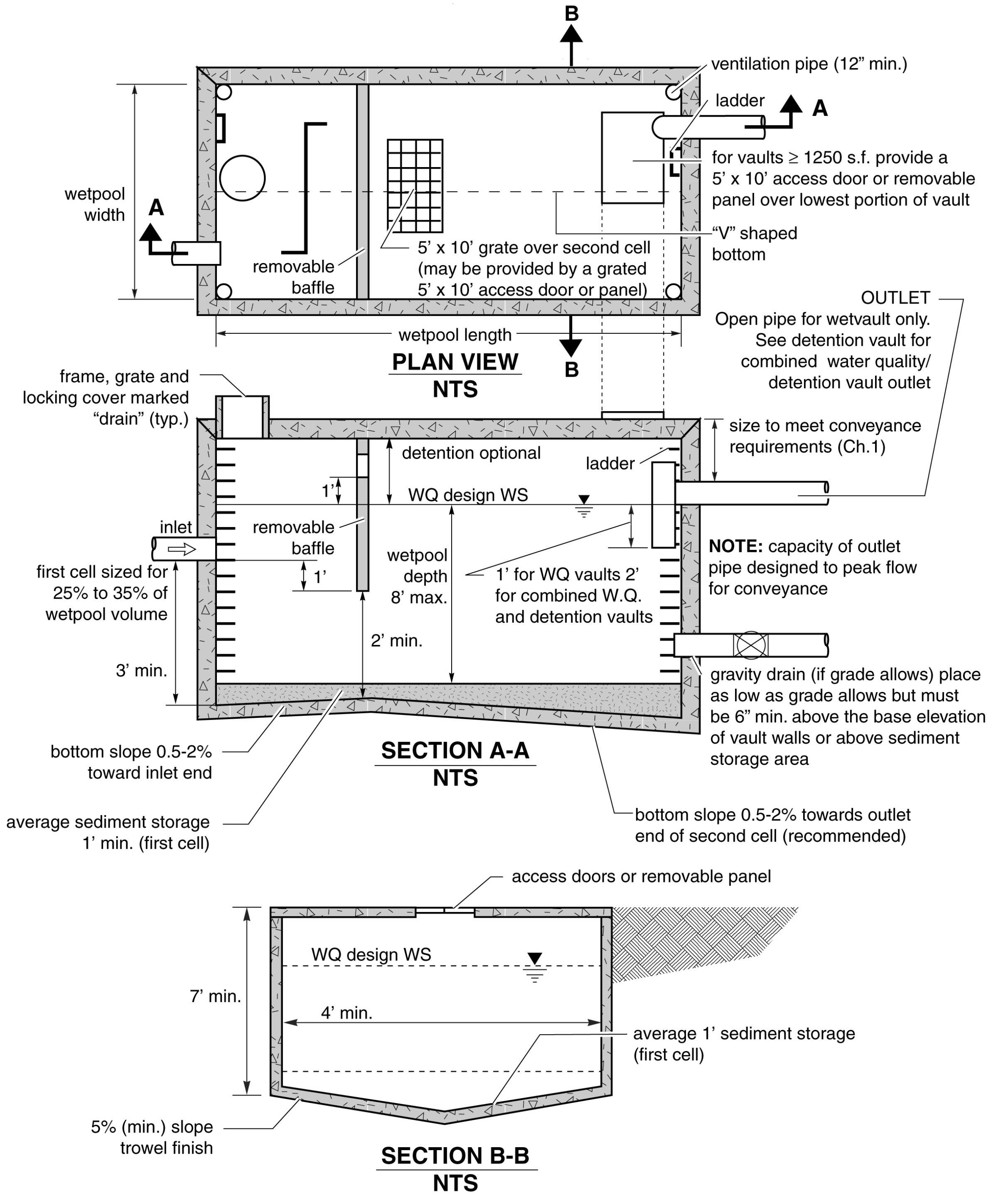
Infiltration Feature
Infiltration is typically not a major function of a subsurface vault; however, some designs may allow it. The designer must consider soil conditions and maximize the ratio of infiltration area to drainage area. For more information on subsurface infiltration design see **Section 7.12**: Subsurface Infiltration.

Permanent Pool
A permanent pool of water may be incorporated to dissipate energy and improve the settling of particulate pollutants. When a permanent pool is incorporated in a design, the design may be referred to as a "wet vault". This design provides a benefit similar to that of a surface wet pond, with the exception of evaporation and functions improved by vegetation.

Slow Release Structure
The slow release structure regulates the rate of outflow for storms up to the design capacity. The storage volume and slow release together allow a subsurface vault to meet channel protection and peak release rate criteria.

Overflow Structure
An overflow structure allows storms in excess of the design storm to pass through the structure without being detained or receiving treatment. An overflow structure at the outlet, a flow splitter at the inlet, or a combination may be used to safely convey large storms.

Access Feature
This feature is used for maintenance and inspection purposes and most commonly consists of a panel leading to the storage area.



Metropolitan Environmental Council

Figure 7.26: Schematic of a subsurface wet vault

Recommended Design Procedure

- Determine the water quality/recharge, stream bank protection, and peak rate control requirements on the site. See **Section 4.3**: Manage Remaining Stormwater.

- Create a Conceptual Site Plan for the entire site, and determine what portion of the sizing requirements the subsurface vault will meet. See **Section 4.0**: Integrated Site Design.

- Create a conceptual design for the subsurface vault, including enough volume to meet storage requirements.

- Estimate the total storage volume and adjust facility sizing as needed to provide required storage. Any permanent pool areas should not be included in the storage volume estimation.

- Decide whether to include pretreatment, a permanent pool, or a combination. This decision may be based on which option is more cost-effective; frequency and ease of maintenance desired by the Owner; land use and expected stormwater constituents.

- Choose and design pretreatment as appropriate. The pretreatment volume is part of the total volume. By maximizing the flowpath and stabilizing the flow rate from inlet to outlet, residence time and treatment effectiveness are increased. A baffle oil/water separator can be used to treat incoming flow from industrial sites or parking lots. In this case, the subsurface vault should include a baffle to create two chambers within structure. If a baffle is used, the following design is recommended:

    - The baffle should extend from a minimum of 1 foot above the design water surface to a minimum of 1 foot below the invert elevation of the inlet pipe.
    - The lowest point of the baffle should be a minimum of 2 feet from the bottom of the vault, and greater if feasible.

- Permanent pool sizing follows the same procedure explained in the BMP 6.14: Wet Ponds / Retention Basin of the Pennsylvania Stormwater BMP Manual (PA SBMPM). A minimum depth of 3 feet is recommended to minimize disturbance of sediment. The shape of the permanent pool should be designed to promote adequate mixing as follows:

    - Maximize the flowpath between inlet and outlet, including the vertical path, to enhance treatment by increasing residence time.
    - The ratio of flowpath length to width from the inlet to the outlet should be at least 3:1.
    - All inlets should enter the first cell. If there are multiple inlets, the length-to-width ratio should be based on the average flowpath length for all inlets.
    - Refer to the references for additional shape recommendations.

- Decide whether to design for infiltration. The procedure followed is similar to that in **Section 7.12**: Subsurface Infiltration.

- Design a slow release structure. If a gate valve is used, it should be close to the bottom of the vault but above the sediment storage level. A check valve or other backflow prevention device is often incorporated. Check that any release rate requirements are met by the system as designed. See **Section 7.15**: Inlet and Outlet Controls.

- Design a positive overflow or bypass system for large storms. The outlet structure and design head should provide adequate flow to avoid overtopping the vault. See **Section 7.15**: Inlet and Outlet Controls.

- Design a maintenance access door or grate to connect to ground level. A grated access panel is ideal for air flow. A minimum of 50 square feet of grate is recommended for permanent pool designs. For vaults in which the surface area is larger than 1250 square feet, 4 percent of the top should be grated.

- Complete construction plans and specifications. At a minimum, plans should include plan view, cross-sections, and inlet and outlet details.

Maintenance Guidelines

The systems must be designed so that the vault can have easy access for inspection and maintenance. Vault maintenance procedures must meet OSHA confined space entry requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

Table 7.22: Subsurface Vaults Maintenance Guidelines	
Activity	***Schedule***
• Removal of sediment and debris from subsurface vault sedimentation chamber when the sediment zone is full. Sediments should be tested for toxicants in compliance with current disposal requirements if land uses in the catchment include commercial or industrial zones, or if indications of pollution are noticed.	As needed
• Inspection of subsurface vault and control structures. • Floating debris and accumulated petroleum products should be removed.	Quarterly
• Maintain records of all inspections and maintenance activity.	Ongoing

Note:
The designs of subsurface vaults are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.


Kitsap

Ejector truck used for maintenance of subsurface vaults

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7.12 Subsurface infiltration

systems are designed to provide temporarily below grade storage infiltration of stormwater as it infiltrates into the ground. Dry wells, infiltration trenches and beds are a few examples of these types of systems.

City of Portland, OR

key elements :

- Infiltration testing is required for this SMP.
- Reduce volume of runoff from a drainage area by promoting infiltration though uncompacted subgrade.
- Flexible design can be sited beneath lawns, parking areas, and recreational areas.
- Maintain minimum distance of 10 feet from building foundations and property lines not abutting Public Right-of-Way.
- Open-graded aggregate or other approved material provides storage.
- System must be designed to drain down in less than 72 hours.
- Greater than 2 feet from any limiting zone such as groundwater or bedrock.
- Pre-treatment is required.
- Positive overflow required for large storms.
- Areas of soil contamination or areas of unstable soils should be avoided.

potential applications

Residential Subdivision:	Yes
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Yes

acceptable forms of pre-treatment

- Filter
- Bioretention
- Filter strips
- Appropriate prefabricated and proprietary design
- Sumped inlets with traps

stormwater regulations

Water Quality:	
Infiltration:	Yes
Volume Reduction: (no infiltration)	No
Channel Protection:	Low/Medium
Flood Control:	Low/Medium

Subsurface Infiltration in the Urban Landscape

Subsurface infiltration systems are typically stone-filled beds or trenches beneath landscaped or paved surfaces. Stormwater flows into the subsurface infiltration system collects within the aggregate void space, and slowly infiltrates into surrounding soils.

Subsurface infiltration is a versatile management practice suitable for many different types of land uses. Both high-density development and individual residences can implement subsurface infiltration systems for stormwater control. Their flexibility also makes them an option for a stormwater retrofit. Several example uses for subsurface infiltration are provided below.

Parking Lots and Roadways
Stormwater inlets in parking lots or streets can be directly connected to subsurface infiltration systems. Sumped or trapped inlets prevent sediment and debris from migrating into the infiltration bed. The inlets can be connected to subsurface infiltration systems located underneath landscaped areas, recreation areas, or under the impervious surfaces themselves.

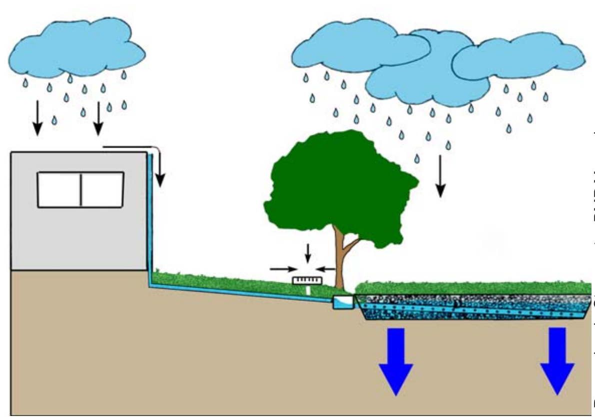
Lawns and Recreational Areas
Open green spaces can collect, store, and infiltrate runoff from impervious surfaces.

Direct Connection of Rooftops
Downspouts can be connected to subsurface infiltration beds at both residential and commercial sites. Small subsurface infiltration areas that manage roof runoff from residential roofs or that are distributed around a larger building to manage runoff from smaller sections of roof are often called dry wells. Although roofs do not often generate high sediment loads, sumped cleanouts should be located between the roof and the infiltration area. The roof leader connects to perforated piping when it reaches the subsurface infiltration area.

Villanova University

Subsurface infiltration occurs beneath this picnic area

Subsurface infiltration beds were installed at the Penn-Alexander School in Philadelphia



Pennsylvania Stormwater BMP Manual

Figure 7.27: Direct connection of a roof into a subsurface infiltration bed

Components of a Subsurface Infiltration System

There are many variations of subsurface infiltration systems, but they are often comprised of these components:

- Inflow/Pretreatment
- Storage
- Observation well
- Infiltration/Outflow

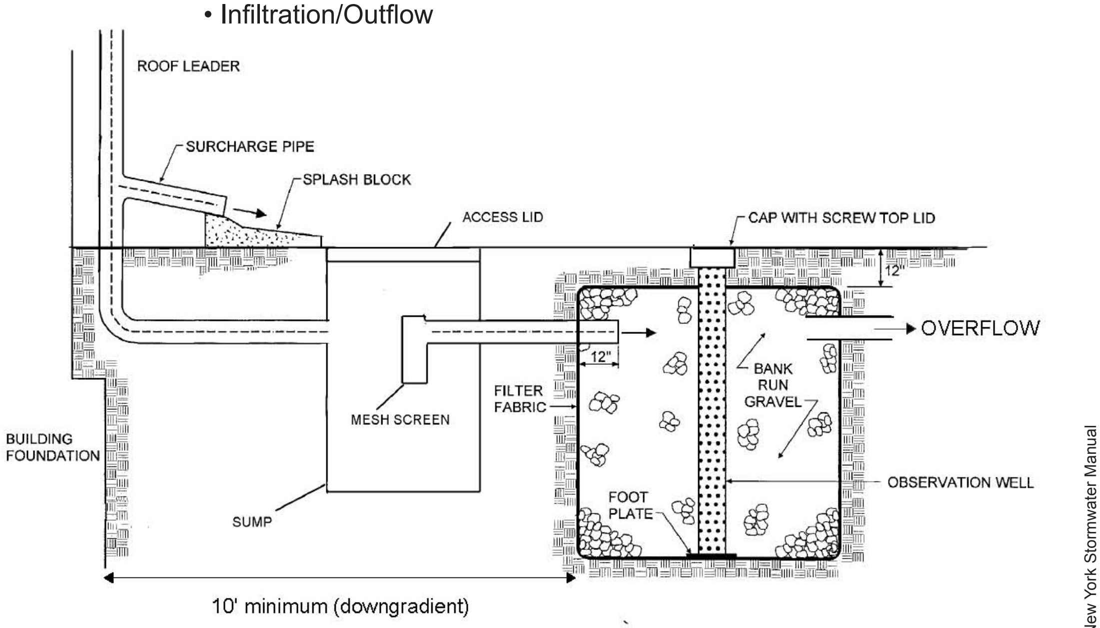


Figure 7.28: Intermediate sump box and dry well

Inflow/Pretreatment

Subsurface infiltration systems are capable of intercepting stormwater inflow from many sources, including rooftops, parking lots, roads, sidewalks, and driveways. It is important to prevent coarse sediments and debris from entering subsurface infiltration systems, because they could contribute to clogging and failure of the system. The following are acceptable forms of pretreatment.

- Roof leader sump, or an intermediate sump box
- Roof gutter guard (may required additional sump unit depending on structure design).
- Filter Strips, see Section 7.3
- Vegetated Swales, See Section 7.8

Storage

The storage component of a subsurface infiltration area is typically provided by a stone filled, level-bottomed bed or trench. The void spaces between the stones stores stormwater until it can percolate into surrounding soils.

Alternative subsurface storage products may also be used to provide temporary storage. These include a variety of proprietary, interlocking plastic units with much greater storage capacity than stone fill (up to 96% void space). Perforated pipe in a stone bed can also increase the effective void space of the system. The higher void ratio requires

Prefabricated storage

a smaller footprint and can allow more flexibility in an urban environment, but proper analysis should be completed to ensure that the in-situ soils will adequately drain with the additional loading and that loading ratio and effective head maximums are not exceeded.

Observation Well

An observation well should be located at the center of the trench to monitor water drainage from the system. In a subsurface infiltration system, the water level is the primary means of measuring infiltration rates and drain-down times. A lockable above ground cap is recommended. Adequate inspection and maintenance access to the observation well should be provided. Observation wells not only provide necessary access to the system, but they also provide a means through which pumping of stored runoff can be accomplished in a failed system. A manhole may be used in lieu of an observation well only if the invert of the manhole is installed at the same invert elevation as the bottom of the basin.

Infiltration/Outflow

Outflow occurs via infiltration through subsurface soil surrounding the infiltration storage area. A bypass system should be implemented for all infiltration systems to convey high flows around the system to downstream drainage systems. Depending on the level of stormwater management required at the site, overflows can connect to an approved discharge point or other SMPs.

Infiltration testing

Recommended Design Procedure

- Determine the Water Quality, Channel Protection, and Flood Control requirements on the site. See **Section 4.3**: Manage Remaining Stormwater.

- Must be greater than 10 feet down-gradient.

- Create a Conceptual Site Plan for the entire site and determine what portion of the sizing requirements subsurface infiltration will meet. See **Section 4**: Integrated Site Design.

- Investigate the feasibility of infiltration in the area proposed for a subsurface infiltration system. See **Appendix A**: Hotspot Investigation Procedures, **Appendix B**: Soil Infiltration Testing Guidelines, and **Appendix C**: Geotechnical Investigation Procedures for more guidance on requirements. Infiltration testing must be within 25 feet of the infiltration footprint.

- Create a conceptual design for the subsurface infiltration system.

Table 7.23: Starting Design Values for Subsurface Infiltration Areas and Depths	
Area (surface area and infiltration area) and Loading Ratio	Largest feasible area in moderately sloped areas of the site, with a required minimum of 1 square foot of infiltration area for every 5 square feet of contributing DCIA (5:1 Loading Ratio)
Minimum distance above limiting zone	2 feet
Maximum drain down time	72 hours

- Estimate the total storage volume and adjust area and/or depths as needed to provide required storage. Open-graded aggregate sub-base may be assumed to have 40% void space for storage.

- Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long the surface ponding and soil storage will take to drain. The maximum drain down time for the entire storage volume is 72 hours, but the Engineer may choose a shorter time based on site conditions and Owner preference. If storage does not drain in the time allowed, adjust the depth and/or surface area. Adjust the design until the volume and drainage time constraints are met.

- Design a positive overflow or bypass system for larger design storms. All systems must design overflow structures and pipes to convey at least the 10-year storm.

- Incorporate acceptable form(s) of pretreatment into design. Pretreatment of runoff from all inlets and roof drainage systems is required for infiltrating SMPs. At a minimum, this can be achieved through the use of sumps and traps, or sumps and hoods, for inlets, sump boxes with traps downstream of roof drainage systems and trench drains, and filter strips for overland flow. See **Section 7.15**: Inlet and Outlet Controls.

- Observation well to be designed with 4 inch diameter perforated plastic pipe, and placed at the invert of infiltration bed with a lockable above-ground cap.

- Use minimum 36-inch diameter header pipes, and provide manholes at each corner of the basin. Alternatively, smaller header pipes may be used if cleanouts are provided on every second manifold pipe/header pipe junctions, on alternating sides of the basin.

- Complete construction plans and specifications.

- Soils underlying infiltration practices must have a tested infiltration rate between 0.5 and 10 inches per hour. Soils with rates in excess of 10 inches per hour will require soil amendments. During construction, upon achieving final subgrade elevations, a 2-foot thick layer of amended soil must be placed across the entire cross-section of the infiltrating SMP, below the bottom elevation of the SMP, and a minimum of two (2) infiltration tests must be performed within the amended soil layer. The procedure utilized must be the double-ring infiltrometer test, and it must be in compliance with the current Philadelphia Stormwater Management Guidance Manual. The engineer must provide a signed and sealed infiltration testing report with a testing location plan and summary of results. All information must be submitted to PWD for review and approval before proceeding with construction. If soil amendments are installed and the tested infiltration rate is determined to be outside of the PWD-allowable range of 0.5 to 10 inches per hour or varies significantly from the design infiltration rate, additional soil amendments and/or a system redesign will be required.

- PWD generally does not allow more runoff than that of the 1-year storm to be statically stored for infiltration. Projects may statically store runoff volumes from greater than the 1-year storm up to the runoff volume from the 10-year storm if the applicant provides a letter, signed and sealed by both the geotechnical and design engineer, indicating that the proposed design is recommended, with the following components acknowledged and considered (Contact PWD for further guidance when pursuing this basin design):
    - Provide a summary of the long-term impacts to the neighboring properties, including, but not limited to subsidence, change in basement moisture/ water, and structural damage;
    - Indicate the location of the groundwater table;
    - Provide references to other projects that have successfully infiltrated the 1-year storm event; and
    - Provide rigorous pre-treatment to promote longevity of the infiltration system.

• Rock construction entrances must not be located on top of any infiltration practices. It may be necessary to phase the erosion and sediment control plan to avoid compaction of the infiltration area.


Pennsylvania Stormwater BMP

Installation of a subsurface infiltration trench

Materials

Storage Stone

- Stone used for subsurface storage shall be uniformly-graded, crushed, clean-washed stone. PWD defines "clean-washed" as having less than 0.5% wash loss, by mass, when tested per the AASHTO T-11 wash loss test. AASHTO No. 3 and No. 57 stone can meet this specification.

- Stone shall be separated from soil by a non-woven geotextile filter fabric or a pea gravel filter.

Non-Woven Geotextile

- Geotextile shall consist of needled non-woven polypropylene fibers and meet the following properties:

    - Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
    - Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
    - Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft2
    - UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
    - Heat-set or heat-calendared fabrics are not permitted

- AASHTO Class 1 or Class 2 geotextile is recommended.

Pipe

- Pipe used within the subsurface system shall be continuously perforated and have a smooth interior with a minimum inside diameter of 4-inches. High-density polyethylene (HDPE) pipe shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S.

- Any pipe materials outside the SMP are to meet City Plumbing Code Standards.

Soil Amendments

- If soil amendments are required, see Bioretention Landscaping Recommendations in **Section 8.2** for amended soil specifications.

Construction Guidelines

- Areas for proposed subsurface infiltration systems shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction. If areas are compacted during construction additional infiltration testing may be required.

- Provide erosion and sedimentation control protection on the site such that construction runoff is directed away from the proposed subsurface infiltration system.

- If the infiltration area is being used as a sediment basin during construction the bottom elevation of the sediment basin must be a minimum of 2 feet above the infiltration bed invert elevation.

- Complete site elevation grading and stabilize the soil disturbed within the limit of disturbance. Do not finalize the subsurface infiltration system's excavation and construction until the drainage area is fully stabilized.

- Excavate subsurface infiltration area to proposed invert depth and manually grade and scarify the existing soil surface. The bottom of the infiltration bed shall be at a level grade.

- Existing subgrade shall NOT be compacted or subject to excessive construction equipment prior to placement of geotextile and stone bed. The use of machinery to load stone from outside of the basin footprint is recommended. If it is essential that equipment be used in the excavated area, all equipment must be approved by the Engineer. Use of equipment with narrow tracks or tires, rubber tires with large lugs, or high pressure tires will cause excessive compaction and shall not be used. Should the subgrade be compacted during construction additional testing of soil infiltration rates and system redesign may be required.

- Place geotextile and recharge bed aggregate immediately after approval of subgrade preparation to prevent accumulation of debris or sediment. Prevent runoff and sediment from entering the storage bed during the placement of the geotextile and aggregate bed.

- All stone that makes up the infiltration SMP must remain free of sediment. If sediment enters the stone, the contractor may be required to remove the sediment and replace with clean washed stone.

- Place geotextile in accordance with manufacturer's standards and recommendations. Adjacent strips of filter fabric shall overlap a minimum of 16 inches. Fabric shall be secured at least 4 feet outside of bed.

- Install aggregate course in lifts of 6-8 inches. Lightly compact each layer with equipment, keeping equipment movement over storage bed subgrades to a minimum. Install aggregate to grades indicated on the drawings.

- Complete surface grading above subsurface infiltration system, using suitable equipment to avoid excess compaction.

Maintenance Guidelines

As with all infiltration practices, subsurface infiltration systems require regular and effective maintenance to ensure prolonged functioning. The following table describes minimum maintenance requirements for subsurface infiltration systems.

Table 7.24: Subsurface Infiltration Maintenance Guidelines	
Activity	**Schedule**
• Regularly clean out gutters and catch basins to reduce sediment load to infiltration system. Clean intermediate sump boxes, replace filters, and otherwise clean pretreatment areas in directly connected systems.	As needed
• Inspect and clean as needed all components of and connections to subsurface infiltration systems. • Evaluate the drain-down time of the subsurface infiltration system to ensure the drain-down time of 24-72 hours.	Biannually
• Maintain records of all inspections and maintenance activity.	Ongoing

Note:
Design of subsurface infiltration systems are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

7.13 Porous pavement

provides the structural support of conventional pavement, but allows stormwater to drain directly through the surface into the underlying base and soils, thereby reducing stormwater runoff. There are porous varieties of asphalt, concrete, and interlocking pavers. Porous pavements are designed with an open graded subbase that allows water to pass through to the native soil and provides temporary storage.

key elements :

- Pervious structural surface with high infiltration rate.
- Porous surface and stone sub-base suitable for design traffic loads. Can be used on most travel surfaces with slopes less than 5%.
- Uncompacted, level sub-grade allows infiltration of stormwater.
- Open-graded aggregate sub-base provides storage.
- Additional storage and control structures can be incorporated to meet channel protection and flood control.
- Positive overflow prevents system flooding.

potential applications

Residential Subdivision:	Yes
Commercial:	Yes
Ultra Urban:	Yes
Industrial:	Yes
Retrofit:	Yes
Highway Road:	Limited

stormwater regulations

Water Quality:	
Infiltration:	Yes
Volume Reduction: (no infiltration)	No
Channel Protection:	Low/Medium
Flood Control:	Low/Medium

acceptable forms of pre-treatment

- Maintenance

Porous Pavement in the Urban Landscape

Porous pavement systems are used to promote infiltration of stormwater runoff. This technique is very effective in removing pollutants and reducing the volume of stormwater entering a sewer system. During a rain event, stormwater flows through the porous surface, drains into the crushed stone subbase beneath the pavement, and remains stored until stormwater can infiltrate into the soil. Porous asphalt and concrete mixes are similar to their impervious counterparts, but do not include the finer grade particles. Interlocking pavers have openings that are filled with stone to create a porous surface.

Porous pavement systems are suitable for any type of development. They are especially well suited for parking lots, walkways, sidewalks, basketball courts, and playgrounds. Proper training of maintenance staff will help to prolong the life of the system.

Alternate for Paved Surfaces

Almost any surface that is traditionally paved with an impervious surface can be converted to a porous pavement system. Porous surfaces are particularly useful in high density areas where there is limited space for other stormwater management systems. Porous pavement can be used for parking lots, basketball courts, playgrounds, and plazas. Interlocking porous pavers can be used to provide an interesting aesthetic alternative to traditional paving. Porous pavement can be designed to meet the loading requirements for most parking lots and travel surfaces. However, for lots or loading areas that receive a high volume of heavy traffic, porous pavement can be used for parking stalls and conventional asphalt for travel lanes if the impervious surfaces are graded toward the porous surfaces.

Direct connection of roof leaders and/or inlets

The subbase storage of porous pavement systems can be designed with extra capacity, and roof leaders and inlets from adjacent impervious areas can be tied into the subbase to capture additional runoff. These beds can be sized to accommodate runoff from rooftops via direct connection or to supplement other SMPs. Pretreatment may be necessary to prevent particulate materials from these surfaces from clogging the subbase of the porous pavement system. If roof leaders or inlets are connected into the bed, the porous asphalt cannot be considered disconnected and a positive overflow must be provided.

Direction of Impervious Runoff to Porous Pavement

Adjacent impervious surfaces can be graded so that the flow from the impervious area flows over the porous pavement and into the subbase storage below if sufficient capacity is created. If impervious runoff is directed onto porous pavement, it cannot be considered disconnected and a positive overflow must be provided.

Pennsylvania Stormwater BMP Manual

Porous pavement parking lot in Radnor Township

Pennsylvania Stormwater BMP Manual

Porous asphalt playground at the Penn-Alexander Partnership

Pennsylvania Stormwater BMP Manual

Porous pavement at Pennsylvania State University, Berks Campus

Components of a Porous Pavement System

Different porous surfaces are used for porous pavement systems, but all rely on the same primary components:

- Inflow/Surfacing
- Storage
- Infiltration/Outflow

Porous Concrete

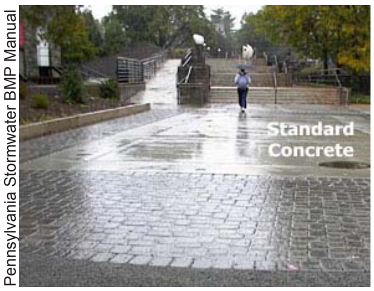
Inflow/Surfacing

There are many different types of structural surfaces that allow water to flow through void spaces in the surface. Any of these alternatives serve as a form of conveyance and filtration for the storage bed below. Several of the most commonly used porous structural surfaces are described below, but this does not represent an exhaustive list of the porous surfaces appropriate for stormwater management applications.

Porous Concrete

Porous concrete was developed by the Florida Concrete Association and has seen the most widespread application in Florida and other southern areas. Like porous asphalt, porous concrete is produced by substantially reducing the number of fines in the mix in order to establish voids for drainage. Porous concrete has a coarser appearance than its conventional counterpart.

Pennsylvania Stormwater BMP Manual



Percolation of water through porous concrete at Villanova University

Porous Asphalt

Porous asphalt pavement was first developed in the 1970s and consists of standard bituminous asphalt in which the fines have been screened and reduced, allowing water to pass through very small voids. Recent research in open-graded mixes for highway application has led to additional improvements in porous asphalt through the use of additives and binders. Porous asphalt is very similar in appearance to conventional, impervious asphalt.

City of Portland, OR

Porous pavers

Permeable Pavers

Permeable pavers are interlocking units (often concrete) with openings that can be filled with a pervious material such as gravel. These units are often very attractive and are especially well suited to plazas, patios, small parking areas, etc. There are also plastic grids that can be filled with gravel to create a fully gravel surface that is not as susceptible to rutting and compaction as traditional gravel lots. Gravel used in interlocking concrete pavers or plastic grid systems must be well-graded to ensure permeability.

Rag Flats in Philadelphia, where grass pavers filter stormwater before it flows into subsurface storage and infiltrates

Reinforced Turf

Reinforced turf consists of interlocking structural units with openings that can be filled with soil for the growth of turf grass and are suitable for traffic loads and parking. They are often used in overflow or event parking. Reinforced turf grids are made of concrete or plastic and are underlain by a stone and/or a sand drainage system for stormwater management. While both plastic and concrete units perform well for stormwater management and traffic needs, plastic units may provide better turf establishment and longevity, largely because the plastic will not absorb water and diminish soil moisture conditions.

Artificial Turf

Artificial, or synthetic, turf is a water permeable surface of synthetic fibers that emulates the aesthetic of natural grass. First gaining popularity in the 1960s, artificial turf has undergone a number of changes to its standard composition, with the most widely-used systems today featuring infills that are mixtures of sand and recycled ("crumb") rubber. Its most common application remains athletic fields, however, significant improvements to the quality of the turf design, an increased variety of available synthetic grasses, reduced costs of maintenance, and the appeal of foregoing irrigation and trimming has led to an increase in residential and commercial usage, as well.

Storage

In addition to distributing mechanical loads, coarse aggregate laid beneath porous surfaces is designed to store stormwater prior to infiltration into soils. The aggregate is wrapped in a non-woven geotextile to prevent migration of soil into the storage bed and resultant clogging. The storage bed also has a choker course of smaller aggregate to separate the storage bed from the surface course. The storage bed can be designed to manage runoff from areas other than the porous surface above it, or can be designed with additional storage and control structures that meet the Channel Protection requirements and/or meet the Flood Control requirements.

Positive Overflow

Positive overflow must be provided for porous pavement systems that manage runoff from additional impervious surfaces. Positive overflow conveys runoff from larger storms out of the system and prevents flooding. A perforated pipe system can convey water from the storage bed to an outflow structure. The storage bed and outflow structure can be designed to control the Channel Protection and/or Flood Control requirement. Inlets can be used to provide positive overflow if additional rate control is not necessary. More information about large underground storage systems can be found in **Section 7.12**: Subsurface Infiltration.

Recommended Design Procedure

Design of porous pavement systems is somewhat flexible. The area and shape are dependent on the site design and selection of the surface material is dependent on intended site uses and desired appearance. The depth of the stone base can be adjusted depending on the management objectives, total drainage area, traffic load, and soil characteristics. The following design procedures are general guidelines that designers can follow.

- Determine the Water Quality, Channel Protection, and Flood Control requirements on the site. See **Section 4.3**: Manage Remaining Stormwater.

- Create a Conceptual Site Plan for the entire site and determine what portion of the sizing requirements porous pavement will meet. See **Section 4.0**: Integrated Site Design.

- Investigate the feasibility of infiltration in the area proposed for a porous pavement. See **Appendix A**: Hotspot Investigation Procedures, **Appendix B**: Soil Infiltration Testing Guidelines, and **Appendix C**: Geotechnical Investigation Procedures for more guidance on requirements. Infiltration testing must be within 25 feet of the infiltration footprint..

- Create a conceptual design for the porous pavement system.

Table 7.25: Suggested Starting Porous Pavement Design Values	
Area (surface area and infiltration area)	Largest feasible on site
Choker course depth	2 inches
Aggregate storage stone bed depth for porous pavement disconnection	8 inches for parking lots, 4 to 6 inches for walkways or play surfaces
Aggregate storage stone bed depth for porous pavement SMP	Minimum dictated by design requirements, and not to exceed static storage of 1-year storm

- Estimate the total storage volume and adjust area and/or depths as needed to provide required storage. Assume a void ratio of approximately 40% for AASHTO No 3 stone.

- Design system with a level bottom. Use a terraced subbase system on slopes.

- Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long the surface ponding and soil storage will take to drain. The maximum drain down time for the entire storage volume is 72 hours, but the Engineer may choose a shorter time based on site conditions and Owner preference. If storage does not drain in the time allowed, adjust aggregate depth and/or surface area. Adjust the design until the volume and drainage time constraints are met.

- Consider an underdrain for systems that manage runoff from surrounding impervious areas.

- Design distribution and overflow piping to minimize chance of clogging.

- Check that any release rate requirements (including release through any underdrain) are met by the system as designed. See **Section 7.15**: Inlet and Outlet Controls.

- Complete construction plans and specifications.

Materials

Subsurface Storage Beds

- All aggregates within infiltration beds shall meet the following:

    1. Maximum wash loss of 0.5%
    2. Minimum Durability Index of 35
    3. Maximum abrasion of 10% for 100 revolutions and maximum of 50% for 500 revolutions.

- Choker course aggregate shall meet the specifications of AASHTO No. 57.

Table 7.26: Required Choker Course Gradation

U.S. Standard Sieve Size	***Percent Passing***
1 ½” (37.5 mm)	100
1” (25 mm)	95 – 100
½” (19 mm)	25 – 60
4 (4.75 mm)	0 – 10
8 (2.36 mm)	0 – 5

- Storage stone should meet the specifications of AASHTO No. 3. Additional storage materials are further discussed in **Section 7.12**: Subsurface Infiltration.

Table 7.27: Required Stone Storage Gradation

U.S. Standard Sieve Size	***Percent Passing***
2 ½ “ (63 mm)	100
2” (50 mm)	90 – 100
1 ½” (37.5 mm)	35 – 70
1” (25 mm)	0 – 15
½” (12.5 mm)	0 – 5

Porous Bituminous Asphalt

- Bituminous surface shall be laid with a bituminous mix of 5.75% to 6% by weight dry aggregate. In accordance with ASTM D6390, drain down of the binder shall be no greater than 0.3%. Aggregate grain in the asphalt shall be a minimum 90% crushed material and have the following gradation.

Table 7.28: Porous Bitumainous Aggregate Gradation

U.S. Standard Sieve Size	Percent Passing
½ (12.5 mm)	100
3/8 (9.5 mm)	92 - 98
4 (4.75 mm)	34 – 40
8 (2.36 mm)	14 – 20
16 (1.18 mm)	7 – 13
30 (0.60 mm)	0 - 4
200 (0.075 mm)	0 - 2

- Neat asphalt binder modified with an elastomeric polymer to produce a binder meeting the requirements of PG 76-22 as specified in AASHTO MP-1. The elastomer polymer shall be styrene-butadiene-styrene (SBS), or approved equal, applied at a rate of 3% by weight of the total binder.

- Hydrated lime should be added at a dosage rate of 1% by weight of the total dry aggregate to mixes containing granite. Hydrated lime shall meet the requirements of ASTM C 977. The additive must be able to prevent the separation of the asphalt binder from the aggregate and achieve a required tensile strength ratio (TSR) of at least 80% on the asphalt mix when tested in accordance with AASHTO T 283. The asphaltic mix shall be tested for its resistance to stripping by water in accordance with ASTM D-1664. If the estimated coating area is not above 95 percent, anti-stripping agents shall be added to the asphalt.

- The asphaltic mix shall be tested for its resistance to stripping by water in accordance with ASTM D-3625. If the estimated coating area is not above 95 percent, anti-stripping agents shall be added to the asphalt.

Porous Concrete

- Portland Cement Type I or II conforming to ASTM C 150 or Portland Cement Type IP or IS conforming to ASTM C 595:

- No. 8 coarse aggregate (3/8 to No. 16) per ASTM C 33 or No. 89 coarse aggregate (3/8 to no. 50) per ASTM D 448.

- An aggregate/cement ratio range of 4:1 to 4.5:1 and a water/cement ratio range of 0.34 to 0.40 should produce pervious pavement of satisfactory properties in regard to permeability, load carrying capacity, and durability characteristics.

Paver and Grid Systems

- Paver and grid systems shall conform to manufacturer specifications.

- A minimum flow through rate of 5 in/hr or a void percentage of no less than 10%.

Non-Woven Geotextile

- Geotextile shall consist of needled non-woven polypropylene fibers and meet the following properties:
  - Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
  - Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
  - Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft2
  - UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
  - Heat-set or heat-calendared fabrics are not permitted
- AASHTO Class 1 or Class 2 geotextile is recommended.

Pipe

- Distribution pipe within bed shall be continuously perforated and have a smooth interior with a minimum inside diameter of 4-inches. High-density polyethylene (HDPE) pipe shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S.

Construction Guidelines

The construction guidelines for the installation of the subsurface infiltration beds are applicable to all porous pavement systems. Guidelines are also provided specifically for porous asphalt.

- Areas for porous pavement systems shall be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

- Excavate porous pavement subsurface area to proposed depth. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material shall be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake or equivalent and light tractor.

- Existing subgrade shall NOT be compacted or subject to excessive construction equipment prior to placement of geotextile and stone bed. The use of machinery to load stone from outside of the basin footprint is recommended. If it is essential that equipment be used in the excavated area, all equipment must be approved by the Engineer. Use of equipment with narrow tracks or tires, rubber tires with large lugs, or high pressure tires will cause excessive compaction and shall not be used. Should the subgrade be compacted during construction additional testing of soil infiltration rates and system redesign may be required.

- Bring subgrade of stone infiltration bed to line, grade, and elevations indicated in the Drawings, while avoiding compaction. The bottom of the infiltration bed shall be at a level grade.

- Place geotextile and recharge bed aggregate immediately after approval of subgrade preparation to prevent accumulation of debris or sediment. Prevent runoff and sediment from entering the storage bed during the placement of the geotextile and aggregate bed.

- Place geotextile in accordance with manufacturer's standards and recommendations. Adjacent strips of filter fabric shall overlap a minimum of 16 inches. Fabric shall be secured at least 4 feet outside of bed. This edge strip should remain in place until all bare soils contiguous to beds are stabilized and vegetated. As the site is fully stabilized, excess geotextile can be cut back to the edge of the bed.

- Install aggregate course in lifts of 6-8 inches. Compact each layer with equipment, keeping equipment movement over storage bed subgrades to a minimum. Install aggregate to grades indicated on the drawings.

Guidelines for Installation of Porous Asphalt

- Install and compact choker course aggregate evenly over surface of stone bed. Choker base course shall be sufficient to allow for even placement of asphalt, but no thicker than 1-inch in depth.

Aggregate is placed in the infiltration bed

Unexcavated earthen berms between terraced bottoms

- Appropriate vehicles with smooth, clean dump beds shall be used to transport the asphalt mix to the site. Control cooling of asphalt by covering mix. Porous asphalt mix shall not be stored for more than 90 minutes before placement.
- The porous bituminous surface course shall be laid in one lift directly over the storage bed and stone base course and compacted to a 2½-inch finished thickness.
- Compaction of the surface course shall take place when the surface is cool enough to resist a 10-ton roller. One or two passes is all that is required for proper compaction. More rolling could cause a reduction in the surface porosity and permeability, which is unacceptable
- After rolling asphalt, no vehicular traffic is permitted on the surface until cooling and hardening has taken place (minimum 48 hours).
- After hardening, test pavement surface by applying clean water at a rate of at least 5 gpm over surface. The water applied to the surface should infiltrate without creating puddles or runoff.
- Do not use the porous pavement area for equipment or materials storage; no soil shall be deposited on porous pavement surfaces.

Maintenance Guidelines

As with most SMPs, porous pavement systems require regular maintenance to extend their life. The following table displays maintenance recommendations for porous pavement systems.

Table 7.29: Porous Pavement Maintenance Guidelines

Activity	Schedule
• Mow grass in paver or grid systems that have been planted with grass.	As needed
• Vacuum porous asphalt or concrete surface with commercial cleaning unit (pavement washing systems and compressed air units are not recommended). • Clean out inlet structures within or draining to the subsurface bedding beneath porous surface	Biannually
• Maintain records of all inspections and maintenance activity.	Ongoing

Sediment Control

Superficial dirt does not necessarily clog the voids in porous surfaces. However, dirt that is ground in repeatedly by tires can lead to clogging. Therefore, trucks or other heavy vehicles should be prevented from tracking or spilling dirt onto the pavement. Furthermore, all construction or hazardous materials carriers should be prohibited from entering a porous pavement lot.

Winter Maintenance

Winter maintenance for a porous parking lot may be necessary, but is usually less intensive than that required for a standard asphalt lot. By its very nature, a porous pavement system with subsurface aggregate bed has better snow and ice melting characteristics than standard pavement. Once snow and ice melt, they flow through the porous pavement rather than refreezing. Therefore, ice and light snow accumulation are generally not as problematic. However, snow will accumulate during heavier storms. Abrasives such as sand or cinders shall not be applied on or adjacent to the porous pavement. Snow plowing is acceptable, provided it is done carefully (i.e. by setting the blade about one inch higher than usual). Salt is acceptable for use as a deicer on the porous pavement, though non-toxic, organic deicers, applied either as blended, magnesium chloride-based liquid products or as pretreated salt, are preferable. Any deicing materials should be used in moderation.

Repairs

Potholes are not common; though settling might occur if a soft spot in the subgrade is not removed during construction. Damaged areas that are smaller than 50 square feet can be patched with a porous or standard asphalt mix, depending on the location within the porous area. In many cases the loss of porous surface will be insignificant. If an area greater than 50 square feet is in need of repair, approval of patch type must be sought from either the engineer or owner. Porous pavement must never be seal coated under any circumstances. Any required repair of drainage structures should be done promptly to ensure continued proper functioning of the system.

Note:

Design of porous pavement systems are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

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7.14 Prefabricated and Proprietary Designs
can be found in the
Pennsylvania Stormwater BMP Manual

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7.15 Inlet &Outlet Controls

are the structures or landscape features that manage the flow into and out of a stormwater management facility. Flow splitters, level spreaders, curb openings, energy dissipaters, traditional inlets, and curbless design are all examples and elements of inlet controls. Outlet controls regulate the release of stormwater from a management facility. Examples of outlet controls include risers and orifices, underdrains, permeable weirs, positive overflows, and impervious liners. Outlet control structures limit flow to meet release rate requirements and bypass larger flows to prevent re-suspension of sediment, hydraulic overload, or erosion of management practices.

key elements :

- Inlet Controls: Flow splitters divert a portion of the storm hydrograph to a management facility, while allowing the remainder of the flow to bypass the facility.
- Inlet Controls: Curbless roads, streets, and parking lots allow stormwater to sheet flow into a SMP.
- Inlet Controls: Curb openings allow water to flow through a curb that would otherwise block the flow.
- Inlet Controls: Level spreaders spread out concentrated flow and release it as low-velocity, non-erosive diffuse flow.
- Inlet Controls: Large-scale energy dissipaters slow down and spread flow from culverts and steeper slopes.
- Outlet Controls: Risers and orifices release ponded water at a reduced rate.
- Outlet Controls: Positive overflows allow stormwater to safely flow out of an SMP.
- Outlet Controls: Underdrains collect water that has filtered through a porous medium and convey it to an outlet.
- Outlet Controls: Impervious liners prevent water from infiltrating the soil where infiltration is not desirable.
- Outlet Controls: Permeable weirs allow water to flow slowly through smaller openings and more quickly over the top of the weir.

Inlet Controls

Flow Splitter

Flow splitting devices are used to direct a fraction of runoff into a stormwater management facility, while bypassing excess flows from larger events around the facility into a bypass pipe or channel. The bypass typically connects to another stormwater management facility or to the receiving drainage system, depending on the design and management requirements. This type of inlet control can also serve as the positive overflow for the SMP.

Flow splitters can be constructed by installing diversion weirs in stormwater control structures such as inlets and manholes. On a larger scale, they can be constructed using concrete baffles in manholes. Example designs for larger-scale flow splitters are shown in Figures 7.30 and 7.31. Smaller-scale designs operate using a similar concept.

Design Criteria

There are two basic components involved in the design of flow splitters: the elevation of the bypass weir, which is based on the maximum ponding elevation in the SMP, and capacity of the pipe to and from the SMP, which controls the maximum flow the SMP can receive and discharge.

Bypass Elevation:

The elevation of the bypass baffle or weir dictates the maximum elevation of the water in the SMP. The bypass elevation can be selected by setting it equal to the design storage elevation in the SMP. Flow will only start to bypass the SMP once it exceeds the design storage level of the SMP. The water level in the SMP may exceed the design level for large infrequent storms that utilize the bypass, so the SMP should provide adequate freeboard to prevent overflow.

Pipe Capacity:

The capacity of the influent and effluent pipes can also limit flow into and out of the SMP. Controlling flows in this fashion can help to minimize erosion and scour in the SMP and at the outlet structure. At a minimum, all pipes must convey the peak runoff from the 10-year, 24-hour rainfall with an NRCS (Natural Resources Conservation Service) Type II distribution without surcharging (as specified within §14.1603.1 Stormwater controls, of the Philadelphia Code). Adequate bypass capacity should be provided for conveyance of larger storms.

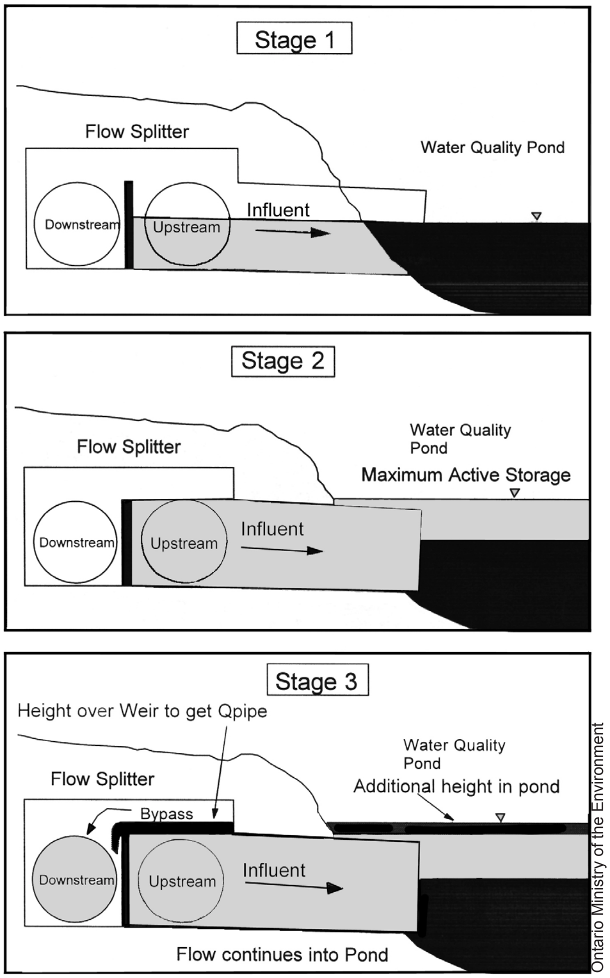
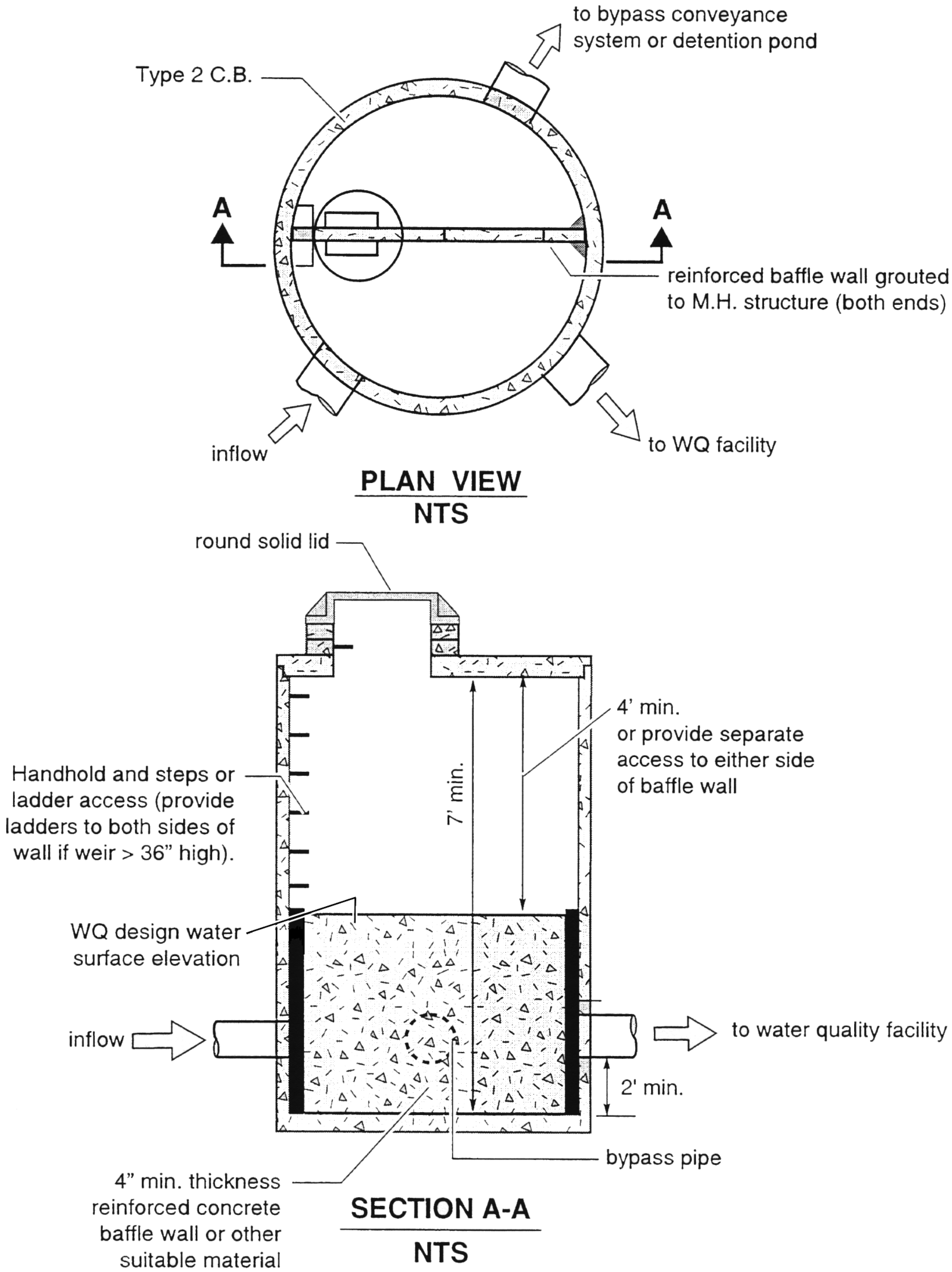


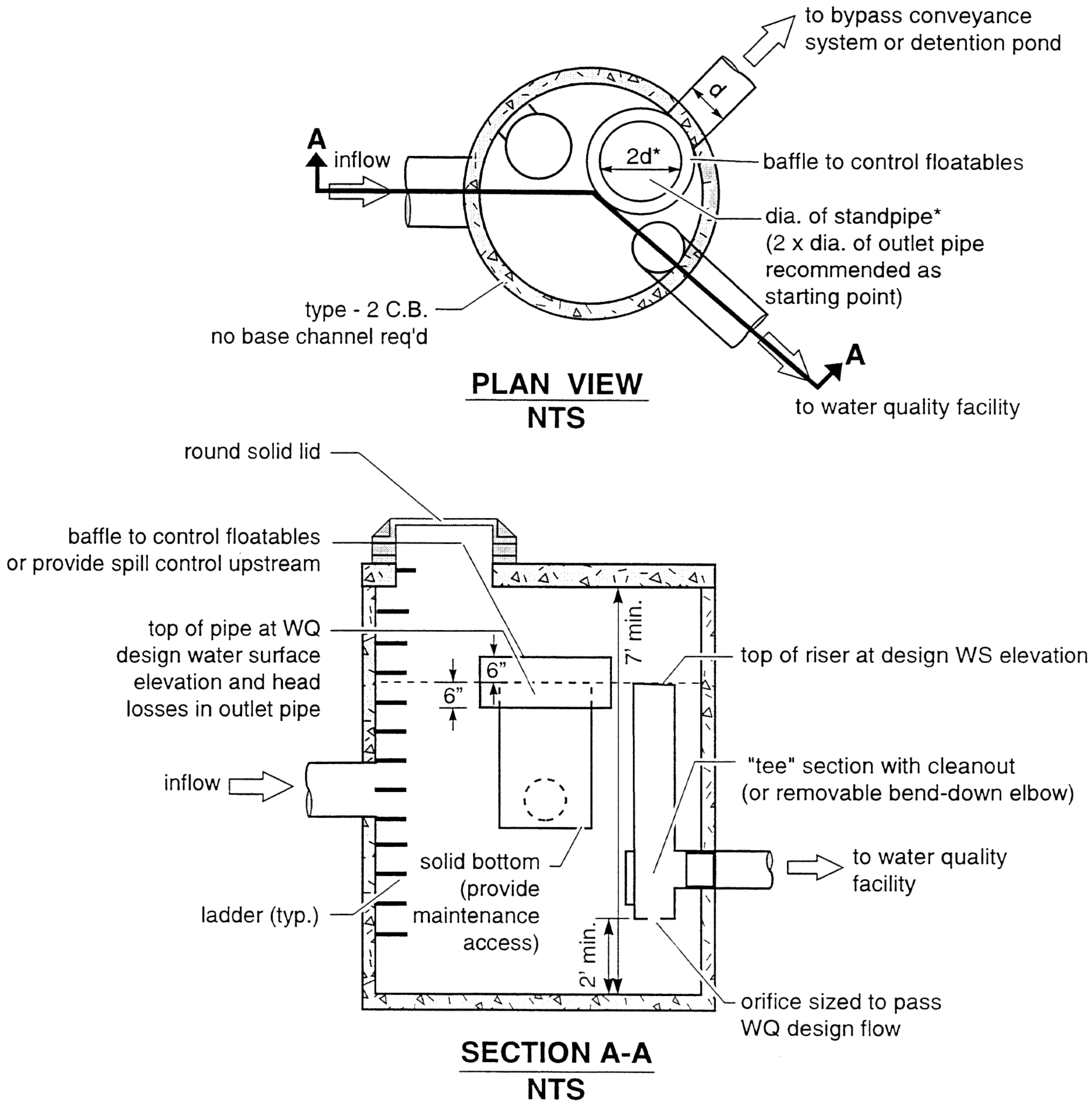
Figure 7.29: Flow splitting device



Note: The water quality discharge pipe may require an orifice plate be installed on the outlet to control the height of the design water surface (weir height). The design water surface should be set to provide a minimun headwater/diameter ratio of 2.0 on the outlet pipe.

King County Department of Natural Resources

Figure 7.30: Schematic of a flow splitter (1 of 2)



* **NOTE:** Diameter (d) of standpipe should be large enough to minimize head above WQ design WS and to keep WQ design flows from increasing more than 10% during 100-year flows.

King County Department of Natural Resources

Figure 7.31: Schematic of a flow splitter (2 of 2)

Curbless Design

Curbless designs allow stormwater to flow directly from the impervious source to the SMP. This type of design discourages concentration of flow and reduces the energy of stormwater entering a management facility. Curbless designs are often used with bioretention islands or roadside swales.


City of Seattle, WA

Curbless street design in Seattle, WA.

Curb Openings
Curb openings provide an alternative inlet control when a curbless design is not possible. Bioretention and landscaped islands in curbed parking lots or roadways often use curb openings as inlet controls.

If flow is to be introduced through curb openings, the pavement edge should be slightly higher than the elevation of the vegetated areas. Curb openings should be at least 12 -18 inches wide to prevent clogging (CA Stormwater Manual). Small rock or stone should be used at the inlet of the curb openings to provide erosion protection.


Prince George's County, MD

Flow enters the bioretention system via a curb opening inlet


City of Portland, OR

Curb openings allow flow to enter the bioretention system in the choker


City of Portland, OR

Curb openings in a parking lot allow flow to enter a bioretention island

Level Spreaders
Level spreaders are inlet controls that are designed to uniformly distribute concentrated flow over a large area. There are many types of level spreaders that can be selected based on the peak rate of inflow, the duration of use, and the site conditions. Level spreaders help reduce concentrated flow, thereby reducing erosion and increasing the design life of many stormwater facilities.

All level spreader designs follow the same principles:

- Concentrated flow enters the spreader at a single point such as a pipe, swale, or curb opening.
- The flow is slowed and energy is dissipated.
- The flow is distributed throughout a long linear shallow trench or behind a low berm.
- Water then flows over the berm or edge of trench uniformly along the entire length.

The following considerations are important when designing and constructing level spreaders:

- It is critical that the edge over which flow is distributed is exactly level. If there are small variations in height on the downstream lip small rivulets will form. Experience suggests that variations of more than 0.25 inches can cause water to re-concentrate and potentially cause erosion downstream of the level spreader. The site selected for the installation of a level spreader must be nearly level before construction. Changes in ground elevation greater than 4 inches across the entire length of the level spreader can begin to make level construction difficult.

• The downslope side of the level spreader should be clear of debris. After construction, debris such as soil, wood, and other organic matter might accumulate immediately downstream of the level spreader. This effectively blocks water as it flows out of the level spreader, forcing it to re-concentrate.

• The downstream side of the level spreader should be fully stabilized before the level spreader is installed. If a level spreader is installed above a disturbed area without sufficient vegetative cover or other ground cover such as mulch or construction matting, erosion rills will quickly form. Even sheet flow can cause significant downstream erosion on disturbed areas.

• Do not construct level spreaders in newly deposited fill. Undisturbed earth is much more resistant to erosion than fill. Erosion is even likely to occur over a well-established young stand of grass planted on fill.

• Level spreaders should not be considered to be sediment removal facilities. Significant sediment deposition in the spreader can render it ineffective.

Types of Level Spreaders

Rock lined Channel

Rock-lined channels function as level spreaders when the lower (downslope) lip of the channel is level. The channel must be dug along an elevation contour, which helps make the downstream lip level. Rock-lined channel depths and widths are typically about 6-12 inches. The depth of the channel depends on the flow. Rock-lined channels do not serve as detention devices.

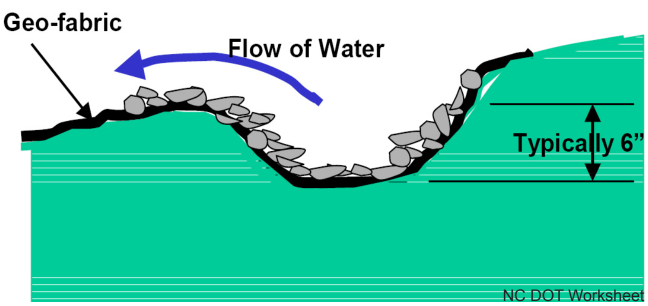


Figure 7.32: Cross-section of rock-lined channel

Concrete Troughs and Half Pipes

Concrete troughs 4-12 inches deep can be used as level spreaders. Half sections of pipe can also be used for the same function. The depths of the trough or pipe will depend on the flow. Concrete troughs are a more expensive level spreader alternative; however, they are easy to maintain and have a longer design life. If sediment or debris accumulates in the trough or pipe, it can be easily removed. Concrete level spreaders have design lives of up to 20 years while other level spreader designs may be able to effectively function for a period of 5-10 years. Accordingly, long term maintenance and replacement costs should be lower if installed properly.

Treated Lumber

Treated lumber is not recommended as a level spreading device due to issues with deformation and decomposition.

Level Spreader System Configuration

A typical level spreader system consists of pre-treatment (e.g., a forebay), principal treatment (e.g., a level spreader with grassed buffer), and emergency treatment (e.g., a reinforced grassy swale downslope of spreader). A stilling area such as a forebay is particularly useful upstream of a level spreader, because flow energy should be dissipated before the flow enters a level spreader. The forebay will periodically fill with sediment, which must be removed.

Energy Dissipaters

Energy dissipaters are large-scale engineered devices such as rip-rap aprons or concrete baffles designed to reduce the velocity, energy, and turbulence of the flow. These structures can be employed when highly erosive velocities are encountered at the end of culverts or at the bottom of steep slopes where aesthetics are not a concern. A standard reference for design of these structures is U.S. Army Corps of Engineers, Hydraulic Engineering Center Circular 14 (HEC-14).

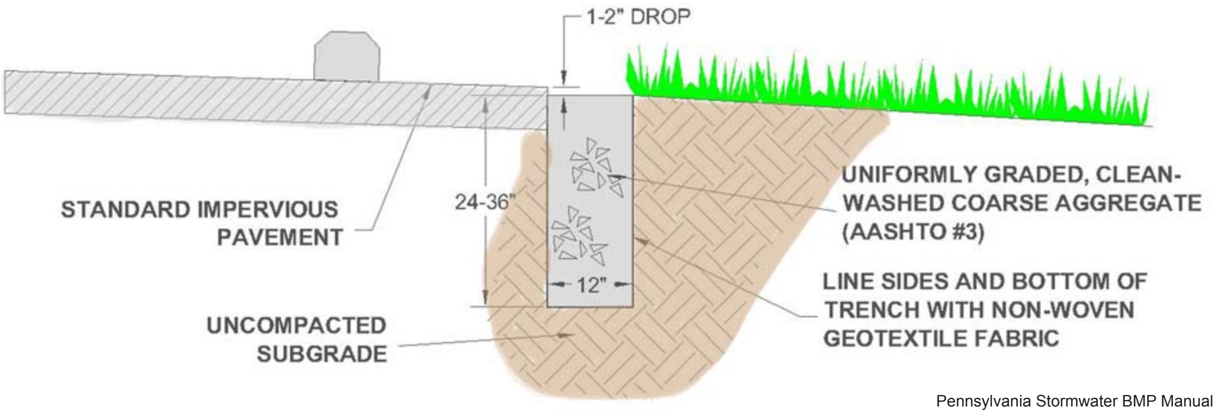


Figure 7.33: Filter strip with gravel trench level spreader.

Riprap Aprons

Riprap aprons are commonly used for energy dissipation, due to their relatively low cost and ease of installation. A flat riprap apron can be used to prevent erosion at the transition from a pipe or box culvert outlet to a natural channel. Riprap aprons will provide adequate protection if there is sufficient length and flare to dissipate energy by expanding the flow. Riprap aprons should be sized for the 10-year storm event. Refer to sizing information in the PADEP *Erosion and Sediment Pollution Control Program Manual*.

Riprap Basins

A riprap outlet basin is a pre-shaped scour hole lined with riprap that functions as an energy dissipater.

Baffled Outlets

A baffled outlet is a boxlike structure with a vertical hanging baffle and an end sill, as shown in Figure 7.36. Energy is dissipated primarily through the impact of the water striking the baffle and through the resulting turbulence.

Inlets and Catch Basins

Traditional inlets and catch basins may be used as an inflow device for stormwater facilities where curb and gutter design is desired or required. The disadvantage of traditional inlets is that the inverts of the outlet pipes are relatively deep, and excavation of stormwater facilities may need to be deeper than with curb openings or a curbless design. A standard reference for designing traditional drainage systems is U.S. Army Corps of Engineers, Hydraulic Engineering Center Circular 22 (HEC-22).

All inlets must include a sump and trap or sump and hood for pretreatment of stormwater runoff. The sump depth must be 15 inches below the bottom of the trap or 12 inches below the bottom of the hood. Traps or hoods in combined sewer areas must be air-tight. Refer to the City of Philadelphia Standards Details and Standard Specifications for Sewers booklet and the Philadelphia Plumbing Code Section P-1001.7 for guidance.

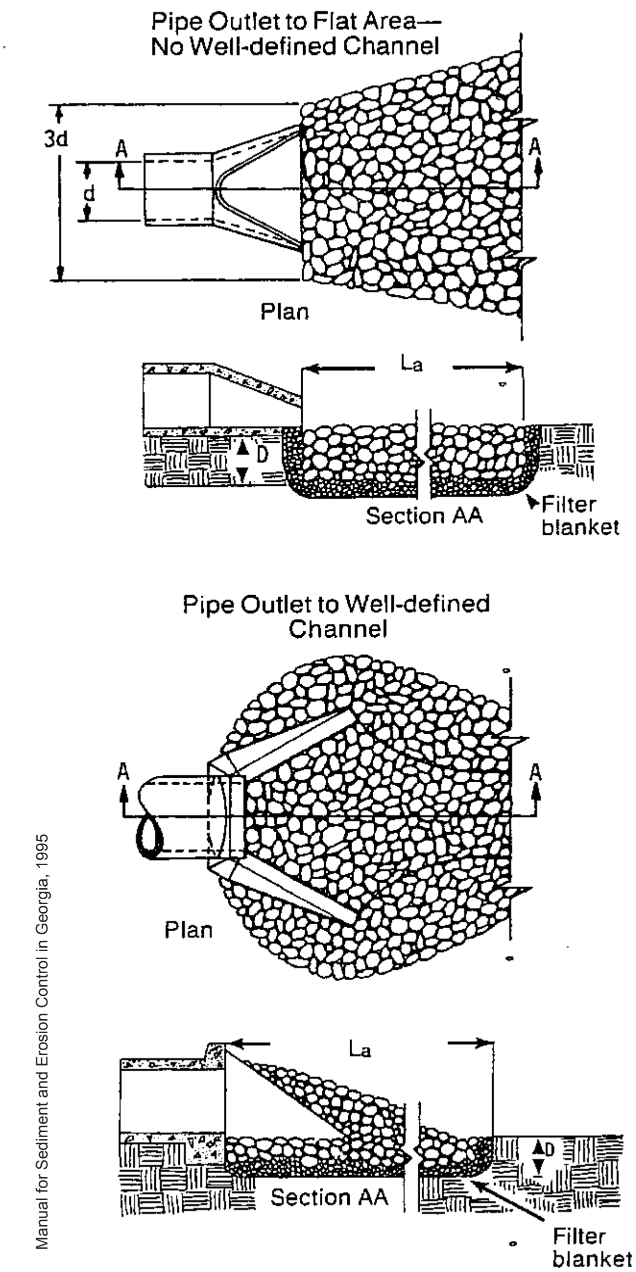
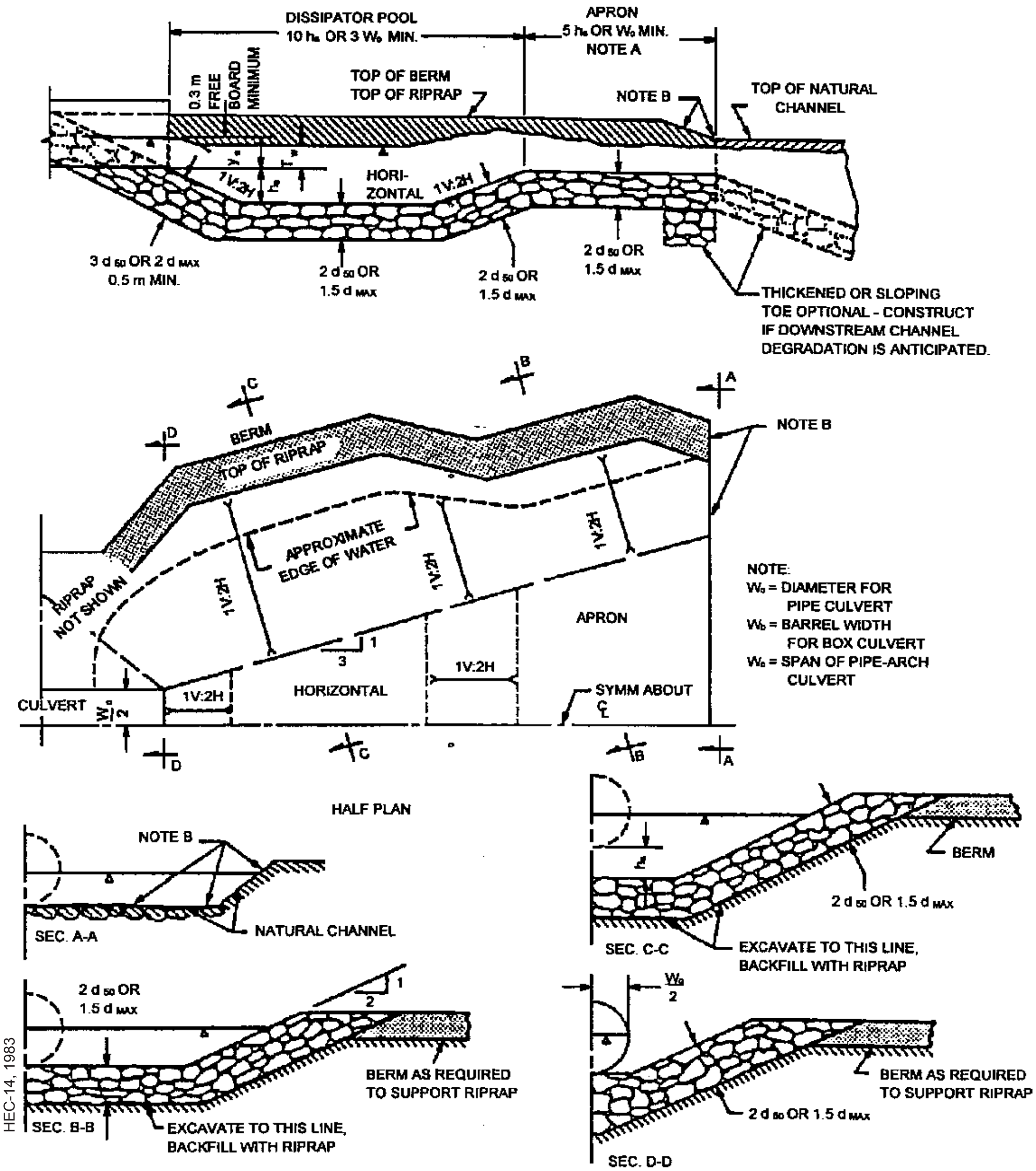


Figure 7.34: Riprap apron

Notes

1. L_a is the length of the riprap apron.
2. D = 1.5 times the maximum stone diameter but not less than 6".
3. In a well-defined channel extend the apron up the channel banks to an elevation of 6" above the maximum tailwater depth or to the top of the bank, whichever is less.
4. A filter blanket or filter fabric should be installed between the riprap and soil foundation.



HEC-14, 1983

NOTE A - IF EXIT VELOCITY OF BASIN IS SPECIFIED, EXTEND BASIN AS REQUIRED TO OBTAIN SUFFICIENT CROSS-SECTIONAL AREA AT SECTION A-A SUCH THAT Q/(CROSS SECTION AREA AT SEC. A-A) = SPECIFIED EXIT VELOCITY.

NOTE B - WARP BASIN TO CONFORM TO NATURAL STREAM CHANNEL. TOP OF RIPRAP IN FLOOR OF BASIN SHOULD BE AT THE SAME ELEVATION OR LOWER THAN NATURAL CHANNEL BOTTOM AT SEC. A-A.

Figure 7.35: Details of riprap outlet basin

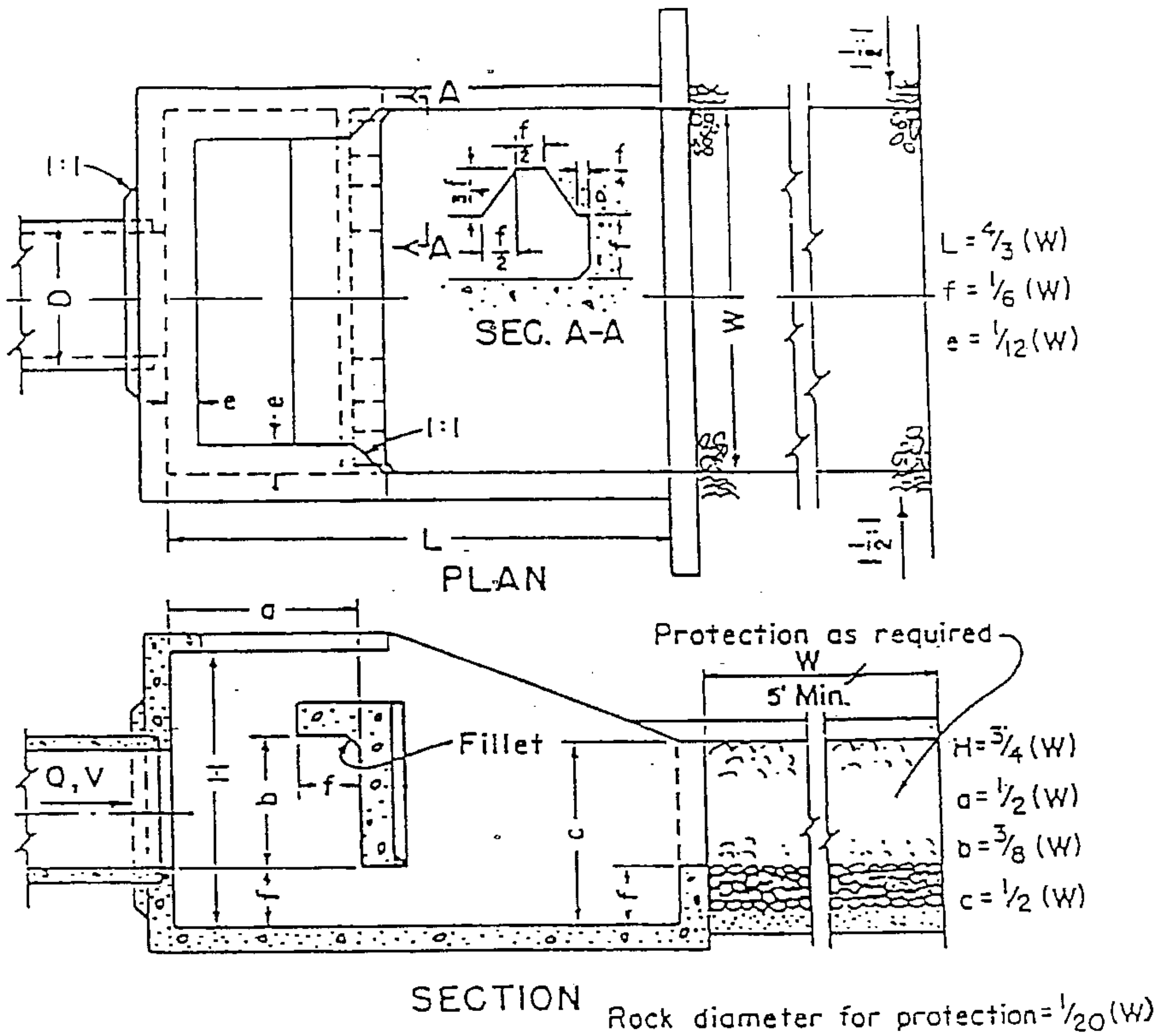


Figure 7.36: Schematic of a baffled outlet

U.S. Dept. of the Interior

Maintenance Concerns for Inlet Controls

Table 7.30: Inlet Maintenance Guidelines	
Activity	***Schedule***
• Inlet control devices should be inspected after several storms to ensure that they are functioning properly and that there are no erosion problems developing. • Source of sediment contamination should be identified and controlled when native soil is exposed or erosion channels are present.	As needed
• Inspected for sediment and debris buildup. Sediment buildup exceeding 2 inches in depth or that begins to constrict the flow path should be removed. • Clean out leaves, trash, debris, etc.	Biannually
• Maintain records of all inspections and maintenance activity.	Ongoing

Outlet Controls

Risers and Orifices
An orifice is a circular or rectangular opening of a prescribed shape and size that allows a controlled rate of outflow when the orifice is submerged. When it is not submerged, the opening acts as a weir. The flow rate depends on the height of the water above the opening and the size and edge treatment of the orifice. A riser is a vertical structure with one or more orifices that provide the controlled release in combination. A standard reference for discharge through a submerged orifice is Brater and King's Handbook of Hydraulics (1996).

Control structures may consist of several orifices and weirs at different elevations to meet stormwater management requirements. Multiple orifices may be necessary to meet the Channel Protection and Flood Control performance requirements for a detention system. Orifices may be located at the same elevation if necessary to meet performance requirements.

Flow through multiple orifices, such as the perforated plate shown in Figure 7.37, can be computed by summing the flow through individual orifices. For multiple orifices of the same size and under the influence of the same effective head, the total flow can be determined by multiplying the discharge for a single orifice by the number of openings.

The site's water quality volume must be statically stored through the use of the outlet control structure. In addition, for Channel Protection and Flood Control, if an SMP's soil layer is counted toward storage volume, it must be demonstrated that the contributing drainage area will sufficiently infiltrate into the soil before reaching the SMP's outlet control device in order to avoid system overflow during larger storm events.

Design of a control structure with multiple orifices is an iterative process. An orifice is designed and positioned to meet each control requirement independently (e.g., Channel Protection and Flood Control). Calculations are then performed on the two orifices together, and the design is adjusted to meet all requirements concurrently without oversizing the basin. The Outlet Structures section of the Georgia Stormwater Management Manual at www.georgiastormwater.com/ (current August 12, 2005) is recommended for detailed instructions on design of multi-stage outlet structures.

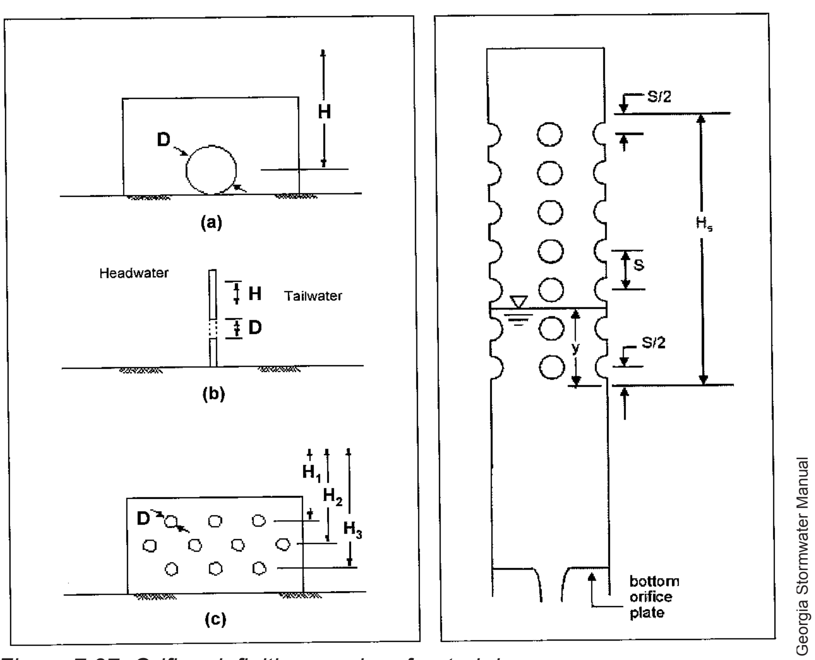


Figure 7.37: Orifice definitions and perforated riser

Small orifices are sometimes needed when a stormwater management systems must meet low flow rate requirements. Control structures with small orifices must meet the following requirements:

- The orifice diameter should always be greater than the thickness of the orifice plate.

- The minimum recommended diameter for an orifice is 3 inches. A waiver must be submitted for use of an orifice smaller than 3 inches in diameter. The required waiver form can be found in **Appendix F.4**: Special Circumstances and Waiver Requests or downloaded from the Technical Library at http://www.pwdplanreview.org/.

- Protection from clogging is required for any orifice smaller than 3 inches in diameter.

- Ladder bars must be included in the outlet structure for maintenance of the small orifice.

- A large enough outlet structure box with two manhole access lids for access to both sides of the weir wall is required for maintence of the small orifice. It is recommended to allow for at least 4 feet by 3 feet of space on each side of the weir wall.

Protection from Clogging

Small orifices used for slow release applications can be susceptible to clogging, which prevents the structural control from performing its function, potentially causing adverse impacts. Design measures can be taken to prevent clogging. These measures are most effective when used in combination with periodic inspection and maintenance. These measures are summarized below; the Design Professional is encouraged to consult the original sources for more information.

Since sediment will tend to accumulate around the lowest stage outlet, the inside of the outlet structure for a dry basin should be depressed below the ground level to minimize clogging due to sedimentation. Depressing the outlet bottom to a depth below the ground surface at least equal to the diameter of the outlet is recommended.

All outlet structures in combined sewer areas must include a sump and trap or sump and hood. The sump depth must be 15 inches below the bottom of the trap or 12 inches below the bottom of the hood, and the traps or hoods must be air-tight. Refer to the City of Philadelphia StandardsDetails and Standard Specifications for Sewers booklet and the Philadelphia Plumbing Code Section P-1001.7 for guidance.

The Georgia Stormwater Management Manual recommends the following measures:

- The use of a reverse slope pipe attached to a riser for a stormwater pond or wetland with a permanent pool. The inlet is submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the pond. See Figure 7.38 for an example.

- The use of a hooded outlet for a stormwater pond or wetland with a permanent pool. See Figure 7.39 for an example.

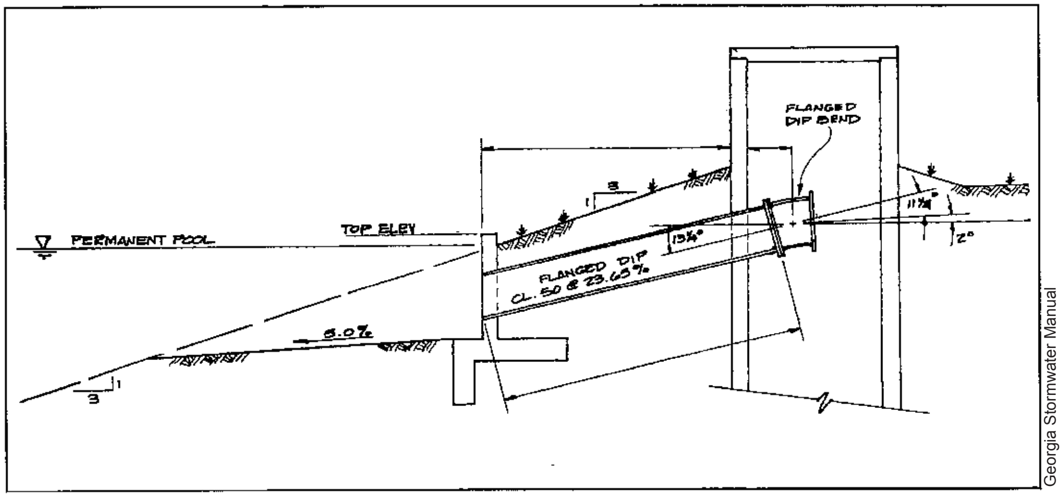


Figure 7.38: Reverse slope pipe outlet

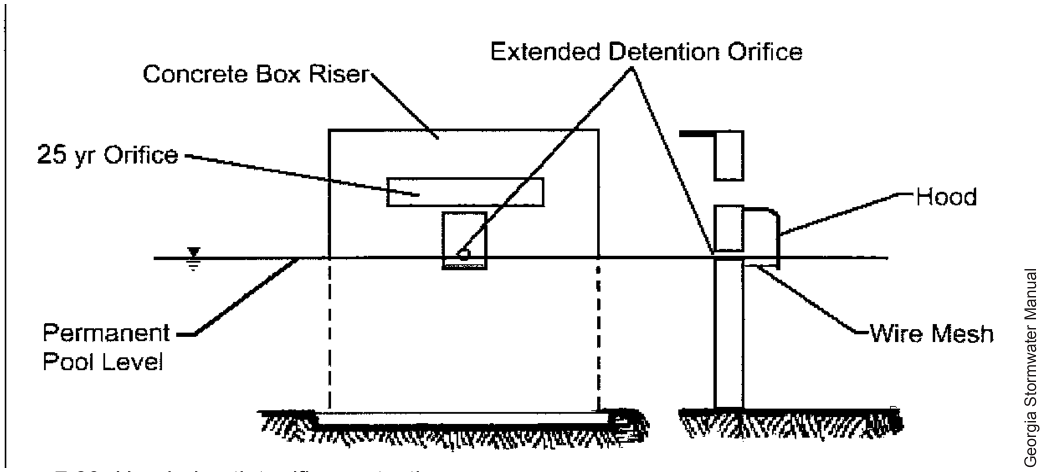


Figure 7.39: Hooded outlet orifice protection

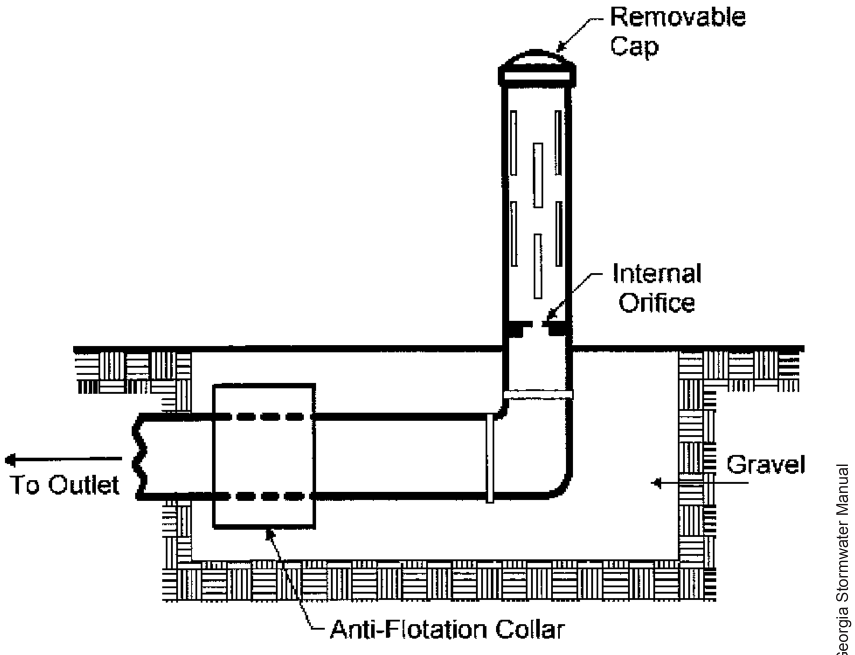


Figure 7.40: Internal control for orifice protection

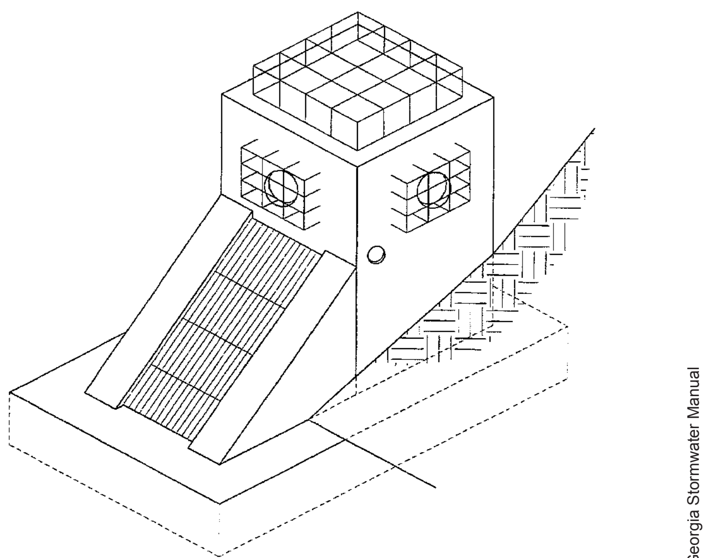


Figure 7.41: Trash racks

City of Portland, OR

Surface inlet for overflows in a bioretention system.

- Internal orifice protection through the use of an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wire cloth and a stone filtering jacket. See Figure 7.40 for an example.

- Use of trash racks on larger outlets. See Figure 7.41 for an example.

Positive Overflows

A positive overflow permits stormwater to flow out of the SMP when the water level reaches a maximum design elevation in a subsurface feature or a maximum ponding depth in a surface feature. Flow through the positive overflow can either connect to another SMP or an approved point of discharge. A multi-stage outlet control may include a number of orifices for controlled flow and a positive overflow to quickly pass flow during extreme events. Overflow structures should be sized to safely convey larger storms from the SMP. If flow reaches the SMP via a flow splitter, this structure can provide the positive overflow.

Underdrains

Underdrains are conduits, such as perforated pipes and/or gravel filled trenches that intercept, collect, and convey stormwater that has percolated through soil, a suitable aggregate, and/or geotextile. Perforated underdrains are an outlet control because they collect water and convey it to a system outlet. Underdrains may be used in combination with other techniques such as layering of porous media to regulate outflow. They can also be connected to an outlet structure that then controls the ponding elevation or release rate through weirs or orifices. Design of underdrains must meet the following criteria:

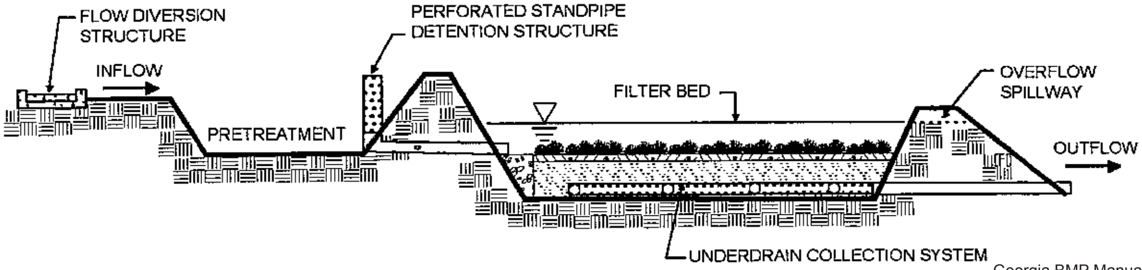


Figure 7.42: Sand filter with underdrain implemented

Georgia BMP Manual

- A permeable filter fabric is placed between the gravel layer and surrounding soil to prevent sediment contamination.

- Clean out access must be provided for all underdrain systems.

- Underdrain pipes are spaced a maximum of 10 feet on center.

Impervious Liners

Impervious liners are considered an outlet control because they prevent water from infiltrating and thus crossing a system boundary. Impervious liners may be selected from the following four types and must exhibit a permeability of less than or equal to 10-7 cm/sec: compacted till liners, clay liners, geomembrane liners, and concrete liners.

The Stormwater Management Manual for Western Washington is recommended for more information on choosing and designing impervious liners.

Permeable Weirs

Permeable weirs are typically constructed from treated lumber stacked with spaces between each timber to provide long, narrow openings that slowly pass stormwater. They have the appearance of a wooden fence. Under low flow conditions, water ponds behind the permeable weir and slowly seeps through the openings between the timbers, functioning like a dry extended storage pond. Under high flow conditions, water flows both over and through the weir.

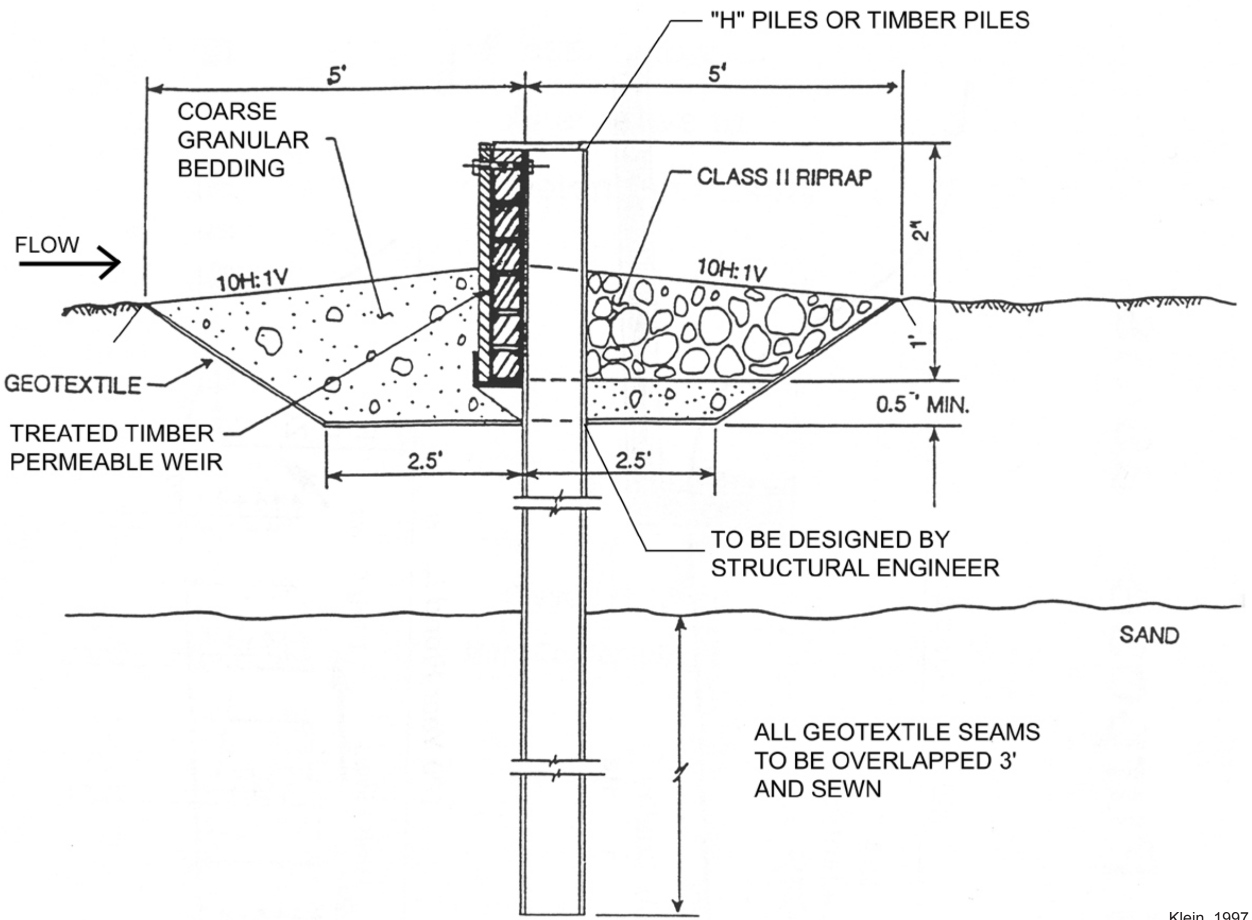


Figure 7.43: Typical permeable weir section

Klein, 1997

Permeable weirs are generally used in wetland areas or constructed water quality treatment ponds. They promote sedimentation by slowing flow velocities as water ponds behind the weir. They also provide a means of spreading runoff as it is discharged, helping to decrease concentrated flow and reduce velocities as the water travels downstream.

Permeable weirs are most often used in large drainage areas as regional SMPs. The permeable weir concept could be applied to smaller sites, where the permeable weir would act as a wooden check dam, placed in a ditch or swale.

Maintenance Concerns for Outlet Controls

Table 7.31: Outlet Maintenance Guidelines

Activity	***Schedule***
• Outlet control devices should be inspected after several storms to ensure that they are functioning properly and that there are no erosion problems developing • Source of sediment contamination should be identified and controlled when native soil is exposed or erosion channels are present.	As needed
• Inspected for sediment and debris buildup. Sediment buildup exceeding 2 inches in depth or that begins to constrict the flow path should be removed. • Clean out leaves, trash, debris, etc.	Biannually (Quarterly for small orifice designs)
• Maintain records of all inspections and maintenance activity.	Ongoing

Note:

Design of inlet and outlet controls are not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

Sediments should be tested for toxicants in compliance with current disposal requirements if land uses in the drainage area include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed.

8 Landscape Guidance

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8.0 Introduction

Landscaping is a critical element to improve both the function and appearance of stormwater management practices (SMPs). Integrated stormwater landscapes can provide many benefits such as construction cost savings, reduced maintenance, aesthetic enhancement, and the improved long-term functionality. A well-designed and established landscape will also prevent post-construction soil erosion. Additionally, these approaches can help mitigate urban heat island effects, improve air quality, and reduce atmospheric carbon levels.

Vegetated stormwater management systems are a preferred practice. SMPs can be integrated within planned landscape areas, with minor modifications to conventional landscape design. It is essential that impervious surfaces be graded toward the vegetated areas that are used as SMPs and that these SMPs are depressed to allow for flow and/or surface ponding. Guidance for the design of inlets to vegetated SMPs can be found in **Section 7.15**: Inlet and Outlet Controls. Since these design approaches are still new to many construction contractors it is advisable to clearly show these details in cross section and plan view drawings. Additional guidance can be found in **Section 4.0**: Integrated Site Design as well as in **Section 7**: SMP Design Guidelines of this Manual.

This section provides landscaping criteria and plant selection guidance for effective SMPs and is organized as follows: **Section 8.1**: Planting Guidance contains general guidance that should be considered when landscaping any SMP. **Section 8.2**: SMP Specific Landscaping Requirements includes specific planting and site preparation information for selected SMPs. **Section 8.3**: Native and Recommended Non-invasive Plants lists appropriate plants for use in SMPs in this region. Key information useful for the selection of plant material for stormwater landscaping is presented, including National Wetland Indicator Status, preferred hydrologic zones, and aesthetic considerations. Finally, **Section 8.4**: Prohibited Non-native Invasive Plants lists prohibited invasive plants.

8.1 Planting Recommendations / Guidelines

General guidance for all SMP plantings:

Plant selection and arrangement

- Existing native and non-invasive vegetation should be preserved where possible.

- Noxious weeds and invasive species shall not be specified or used. Prohibited noxious weeds, as identified in Pennsylvania Code Section 110.1. Noxious Weed Control List, are as follows:

    - Marijuana (Cannabis sativa)
    - Purple Loosestrife (Lythrum salicaria)
    - Canada Thistle (Cirsium arvense)
    - Multiflora Rose (Rosa multiflora)
    - Johnson Grass (Sorghum halepense)
    - Musk Thistle, or Nodding Thistle (Carduus nutans)
    - Bull Thistle, or Spear Thistle (Cirsium vulgare)
    - Jimson Weed (Datura stramonium)
    - Mile-a-minute (Polygonum perfoliatum)
    - Kudzuvine (Puerria lobata)
    - Shattercane (Sorghum bicolor)
    - Giant Hogweed (Heracleum mantegazzianum)
    - Goatsrue (Galega officinalis)

- Plant stream and water buffers with trees, shrubs, ornamental grasses, and herbaceous materials where possible, to stabilize banks and provide shade. This will help to reduce thermal warming, reduce erosion, increase roughness and protect habitat.

- Avoid plantings that will require routine or intensive chemical applications (i.e. turf area). Use low maintenance ground cover as an alternative to turf.

- Stressors (e.g. wind, exposure, exposure to deicing salt, salt tolerance, insects, drought and inundation

tolerance, and disease), micro-climates, and sunlight conditions should also be considered when laying out the planting plan.

- Aesthetics and visual characteristics should be a prime consideration. Plant form, texture, color, bloom time and fragrance are important to the overall feel of the site. Plants can be used to enhance and frame desirable views or screen undesirable views. Care should be taken to not block views at entrances, exits, or along difficult road curves.

- Trees and shrubs should be placed in a manner that restricts pedestrian access to steep pools or slopes without blocking maintenance access.

- Existing and proposed utilities must be identified and considered.

Maintenance considerations

- The designer should carefully consider the long-term vegetation management strategy for the SMP, keeping in mind the maintenance legacy for the future owners. The SMP maintenance agreement must include requirements to ensure vegetation cover in perpetuity.

- Provide signage to help educate the public about SMPs and to designate limits of mowing (wildflower areas, meadows, etc.).

Embankments, spillways, dams, and orifices

- Planting of trees, shrubs, and/or any type of woody vegetation is not allowed on structural embankments.

- All emergency spillways should be stabilized with plant material that can withstand strong flows. Root material should be fibrous and substantial but lack a taproot.

- Trees or shrubs known to have long taproots should not be planted within the vicinity of an earthen dam or subsurface drainage facilities.

- Plant trees and shrubs at least 25 feet away from a principal spillway structures.

- Plant trees and shrubs at least 15 feet away from the toe of slope of a dam.

Soils

SMP soils should provide adequate infiltration rates and be suitable for healthy tree and vegetation growth. Soil analysis shall be conducted within the SMP area to determine appropriate levels and types of soil amendments.

If topsoil exists on site and is stockpiled for re-use, appropriate erosion control measures as required by the Pennsylvania Department of Environmental Protection (PADEP) *Erosion and Sediment Pollution Control Manual*, shall be used. Soil analysis tests shall be performed on stockpiled soil if it will be used within the SMP area. See **Section 7** for SMP specific soil requirements.

Site Selection, Preparation and Grading

When selecting a location for the SMP, take into consideration the physical variables of the site and the effects they will have on the SMP. Some variables to consider include amount of sunlight received and solar orientation, wind speed and direction, temperature gain and surface character. For example: sites facing northeast receive morning sun and tend to be cooler and wetter than those facing southwest; runoff from asphalt will be hotter than that from concrete; etc. Combinations of these variables create different micro-climates and should be taken into account when placing the SMP and selecting plants.

Unwanted vegetation in the SMP area shall be removed during site preparation with equipment appropriate for the type of material encountered and site conditions. It is recommended that the maximum amount of pre-existing native vegetation be retained and protected.

No material storage or heavy equipment is allowed within the SMP area after site clearing and grading has been completed, except to excavate and grade as needed to build the SMP. No compaction of infiltration areas should occur during this excavation.

After the SMP area is cleared and graded, any necessary soil amendments should be added and tilled into the existing soil to the depth specified for each SMP. No tilling shall occur within the drip line of existing trees. After tilling is complete, no other construction traffic shall be allowed in the area, except for planting and related work. Where topsoil is needed, (for example swales and dry detention basins) it should be spread to a depth of 4-8 inches and lightly compacted to minimum thickness of 4 inches. This provides organic matter and important nutrients for the plant material. The use of topsoil allows vegetation to become established faster and roots to penetrate deeper. This ensures quicker and more complete stabilization, making it less likely that the plants will wash out during a heavy storm.

Mulch

The mulch layer helps maintain soil moisture and avoid surface sealing which reduces permeability. Mulch helps prevent erosion, and provides a micro-environment suitable for soil biota at the mulch/soil interface. It also serves as a pretreatment layer, trapping the finer sediments which remain suspended after the primary pretreatment. Approved mulching materials include organic materials such as compost, bark mulch, leaves, as well as small river gravel, pumice, or other inert materials. Grass clippings should not be used as mulch. For ground cover plantings, the mulch shall be applied to cover all soil between plants. Care should be exercised to use the appropriate amount of mulch – any more than 3-4 inches can negatively impact growing conditions and cause excessive nutrients to leach into the SMP. Mulch shall be weed-free. Manure mulching and high-fertilizer hydroseeding are prohibited in a SMP area during and after construction.

Irrigation

Newly installed plant material requires water in order to recover from the shock of being transplanted. Be sure that some source of water is provided during establishment of the SMP, especially during dry periods. This will reduce plant loss and provide the new plant materials with a chance to establish root growth.

Permanent irrigation systems are allowed, but designers are encouraged to minimize the need for permanent irrigation. Innovative methods for watering vegetation are encouraged, such as the use of cisterns and air conditioning condensate.

SMP Screening

SMP elements such as chain link fences, concrete bulkheads, outfalls, rip-rap, gabions, large steel grates, steep side slopes, manhole covers/vault lids, berm embankments planted only with grasses, exposed pipe, banks, retaining walls greater than 2 feet high, and access roads are generally not aesthetically pleasing. When these elements face public right-of-way or other private property, The Philadelphia Water Department (PWD) recommends that they be screened with plant materials. Designers are strongly encouraged to integrate aesthetically pleasing landscape design with SMPs.

Pollution Prevention

Stormwater pollution prevention practices related to landscaping can be categorized into two broad categories: Toxic Substance Use Reduction and Pollutant Source Reduction.

Toxic Substance Use Reduction
Projects shall be designed to minimize the need for toxic or potentially polluting materials such as herbicides, pesticides, fertilizers, or petroleum based fuels within the SMP area before, during, and after construction. Use of these materials creates the risk of spills, misuse, and future draining or leaching of pollutants into facilities or the surrounding area.

Pollutant Source Reduction
Materials that could leach pollutants or pose a hazard to people and wildlife shall not be used as components of a SMP. Some examples of these materials are chemically treated railroad ties and lumber and galvanized metals. Many alternatives to these materials are available.

SMP Establishment and Maintenance

Establishment procedures should include: control of invasive weeds, prevention of damage from animals and vandals, use of erosion control mats and fabrics in channels, temporary diversion of flows from seeded areas until stabilized, mulching, re-staking, watering, and mesh or tube protection replacement, to the extent needed to ensure plant survival. To ensure landscape plant survival and overall stormwater facility functional success, the design and construction documents must include elements that help achieve these results. Construction specifications and details need to include staking, irrigation schedule, soil amendments, plant protection, over planting, and potentially mycorrhizal inoculation.

Table 8.1: Planting Specifications

Specification Element	Elements
Sequence of Construction	Describe site preparation activities, soil amendments, etc.; address erosion and sediment control procedures; specify step-by-step procedure for plant installation through site clean-up.
Contractor's Responsibilities	Specify the contractors responsibilities, such as watering, care of plant material during transport, timeliness of installation, repairs due to vandalism, etc.
Planting Schedule and Specifications	Specify the materials to be installed, the type of materials (e.g., B&B, bare root, containerized); time of year of installations, sequence of installation of types of plants; fertilization, stabilization seeding, if required; watering and general care.
Maintenance	Specify inspection periods; mulching frequency (annual mulching is most common); removal and replacement of dead and diseased vegetation; treatment of diseased trees; watering amount and schedule after initial installation (once per day for 14 days is common); repair and replacement of staking and wires.
Warranty	All systems should contain a 2 year warranty. Specifications should contain the warranty period, the required survival rate, and expected condition of plant species at the end of the warranty period.

8.2 Facility Specific Landscaping Guidance

The planting recommendations shown under this section are based on research, local experience and/or standard landscape industry methods for design and construction. It is critical that selected plant materials are appropriate for soil, hydrologic, and other site conditions. SMPs shall use appropriate native and recommended non-invasive species from the Recommended Plant Lists in Table 8.2. The design for plantings shall minimize the need for herbicides, fertilizers, pesticides, or soil amendments at any time before, during, and after construction and on a long-term basis. Plantings should be designed to minimize the need for mowing, pruning, and irrigation. Grass or wildflower seed shall be applied at the rates specified by the suppliers. If plant establishment cannot be achieved with seeding by the time of substantial completion of the SMP portion of the project, the contractor shall plant the area with wildflower sod, plugs, container plants, or some other means to complete the specified plantings and protect against erosion.

Green Roof Landscaping Requirements

Plantings used on green roofs shall be self-sustaining, with little to no need for fertilizers or pesticides. Shrubs, herbs, succulents, and/or grasses shall be used to cover most of the green roof. See **Section 7.1**: Green Roofs for more specific information on green roof requirements.

Planter Box Landscaping Recommendations

The following quantities per 100 square feet of planter box area are recommended:

- 4 - Large shrubs/small trees 3-gallon containers or equivalent.
- 6 - Shrubs/large grass-like plants 1-gallon containers or equivalent
- Ground cover plants: 1 per 12 inches on center, triangular spacing. Minimum container: 4-inch pot. Spacing may vary according to plant type.

Note: Container planting requires that plants be supplied with nutrients that they would otherwise receive from being part of an ecosystem. Since they are cut off from these processes they must be cared for accordingly.

Note: Tree planting is not required in planters, but is encouraged where practical. Tree planting is also encouraged near planters.

Illustration provided by Heidi Natura of the Conservation Research Institute

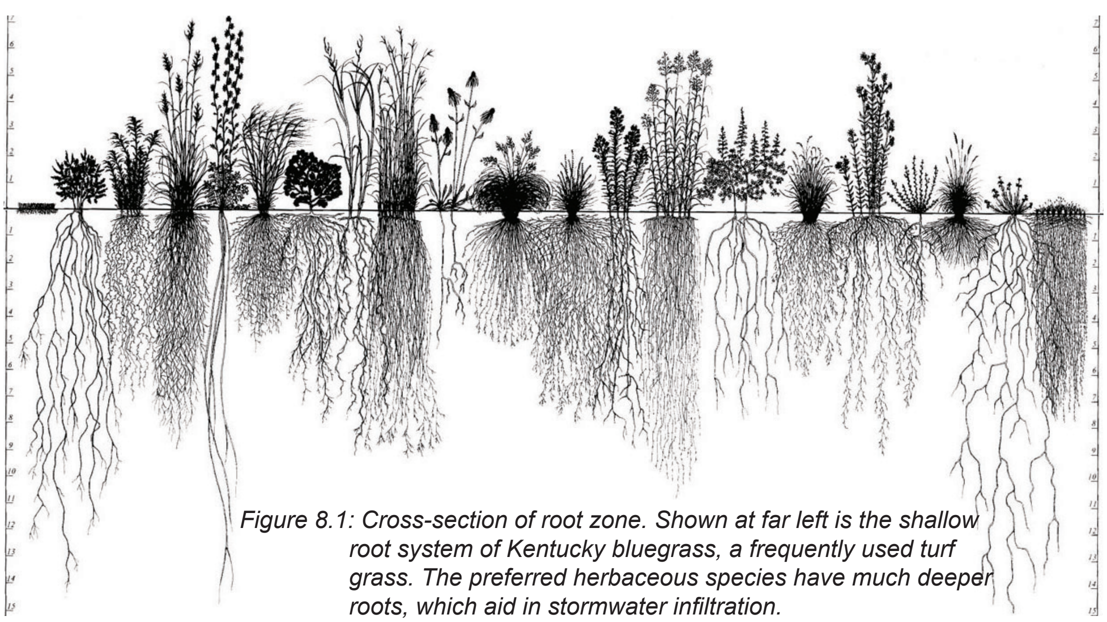

Figure 8.1: Cross-section of root zone. Shown at far left is the shallow root system of Kentucky bluegrass, a frequently used turf grass. The preferred herbaceous species have much deeper roots, which aid in stormwater infiltration.

Infiltration and Filter System Recommendations

Infiltration and filter systems either take advantage of existing permeable soils or create a permeable medium such as sand for water quality and groundwater recharge volume. In some instances where permeability is high, these facilities may be used for the Channel Protection requirement as well. The most common systems include infiltration trenches, infiltration basins, sand filters, and organic filters. When properly planted, vegetation will thrive and enhance the functioning of these systems. For example, pre-treatment buffers will trap sediment that is often bound with phosphorous and metals. Vegetation planted in the SMP will aid in nutrient uptake and water storage. Additionally, plant roots will create macropores for stormwater to permeate soil for groundwater recharge (see Figure 8.1). Finally, successful plantings provide aesthetic value and wildlife habitat, making these facilities more desirable to the public.

Design Constraints:
Along with the guidelines listed at the start of this section, the following should be adhered to:

- Determine areas that will be saturated with water and water table depth so that appropriate plants may be selected (hydrology will be similar to bioretention facilities, see Figure 8.2 and associated tables for planting material guidance).
- Plants shall be located so that access is possible for structure maintenance.

Vegetated Swale Landscaping Recommendations

The following quantities per 200 square feet of swale area are recommended:

- 1 Evergreen or Deciduous tree:
  - Evergreen trees: Minimum height: 6 feet.
  - Deciduous trees: Minimum caliper: 1 ½ inches at 6 inches above base.
  - Multi-stem trees: Minimum root ball diameter: 20 inches
- Grass: Seed or sod is required to completely cover the swale bottom and side slopes.
- (Shrubs are optional)

Vegetation or ground cover within the swale should be suitable for expected velocities. For the swale flow path, approved native grass mixes are preferable. The applicant shall have plants established at the time of SMP completion (at least 3 months after seeding). No runoff should be allowed to flow in the swale until grass is established. Native wildflowers, grasses, and ground covers are preferred to turf and lawn areas. These type of landscape can be designed to require mowing only once or twice annually.

Vegetated Infiltration Basin and Dry Detention Pond Landscaping Recommendations

Vegetation increases evapotranspiration, helps improve infiltration functions, protects from rain and wind erosion and enhances aesthetic conditions. The following quantities per 300 square feet of basin area are recommended:

- 1 Evergreen or Deciduous tree:
  - Evergreen trees: Minimum height: 6 feet.
  - Deciduous trees: Minimum caliper: 1 ½ inches at 6 inches above base.
  - Multi-stem trees: Minimum root ball diameter: 20 inches
- 4 Large shrubs/small trees 3-gallon containers or equivalent.
- 6 Shrubs/large grass-like plants 1-gallon containers or equivalent
- Ground cover plants: 1 per 12 inches on center, triangular spacing, for the ground cover planting area only, unless seed or sod is specified. Minimum container: 4-inch pot. At least 50 percent of the SMP shall be planted with grasses or grass-like plants.

Native wildflowers, grasses, and ground covers are preferred to turf and lawn areas.
These type of landscape can be designed to require mowing only once or twice annually.

Appropriate plants should be selected based on ponding depth and drain-down time in the basin. Infiltration systems will be dry much of the time and should be vegetated with drought tolerant species especially if they will not be irrigated.

Bioretention Landscaping Recommendations

Planting Soil Bed Characteristics

The characteristics of the soil for the bioretention system are perhaps as important as the facility location, size, and treatment volume. The soil must be permeable enough to allow runoff to filter through the media, while having characteristics suitable to promote and sustain a robust vegetative cover crop. In addition, much of the nutrient pollutant uptake (nitrogen and phosphorus) is accomplished through adsorption and microbial activity within the soil profile. Therefore, the soils must balance soil chemistry and physical properties to support biotic communities above and below ground.

Planting soil should meet all the specifications listed below and should be a fertile, natural soil, free from large stones, roots, sticks, clods, plants, peat, sod, pockets of coarse sand, pavement and building debris, glass, noxious weeds including invasive species, infestations of undesirable organisms and disease causing pathogens, and other extraneous materials harmful to plant growth.

1. Texture of planting soil should conform to the classification within the USDA triangle for Sandy Loam or Loamy Sand. Planting soil should be a mixture of sand, silt, and clay particles as required to meet the classification. Ranges of particle size distribution, as determined by pipette method in compliance with ASTM F-1632:
    - Sand (0.05 to 2.0 mm) 50 - 85%
    - Silt (0.002 to 0.05mm) 40% maximum
    - Clay (less than 0.002mm) 10% maximum
    - Gravel (2.0 to 12.7 mm) 15% maximum
2. Planting soil should be screened and free of stones larger than a half-inch (½”; 12.7 mm) in any dimension. No more than ten percent (10%) of the soil volume should be composed of soil peds greater than one inch (1”).
3. Clods, or natural clumps of soils, greater than three inches (3”) in any dimension should be absent from the planting soil. Small clods ranging from one to three inches (1-3”) and peds, natural soil clumps under one inch (1”) in any dimension, may be present but should not make up more than ten percent (10%) of the soil by volume.
4. The pH of the planting soil should have a range of 5.8 to 7.1. Extremes should be avoided.
5. Soluble salts should be less than 2.0 mmhos/cm (dS/m), typically as measured by 1:2 soil-water ratio basic soil salinity testing. Sodic soils (Exchangeable Sodium Percentage (ESP) greater than 15 and/or Sodium Adsorption Ratio (SAR) greater than 13) shall not be acceptable for use regardless of amendment.
6. Organic content of planting soil should have a range of three to fifteen percent (3-15%) by weight as determined by loss on ignition (ASTM D2974). To adjust organic content, planting soil may be amended, prior to placing and final grading, with the addition of organic compost.

Planting Plan Guidance

- Trees and shrubs shall be freshly dug and grown in accordance with good nursery practice.

- Perennials, grass-like plants, and ground-cover plants shall be healthy, well-rooted specimens.

- Plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

The following quantities per 100 square feet of bioretention area are recommended:

- 1 large tree per 100 square feet of bioretention area
- 2-4 small trees or shrubs per 100 square feet of bioretention area
- 6 ferns or grass-like plants per 100 square feet of bioretention area (1-gallon containers)
- Groundcover plantings and wildflower plugs on 12 inch centers with triangular spacing.
- A native grass/wildflower seed mix can be used as an alternative to groundcover planting. Seed mix shall be free of weed seeds.

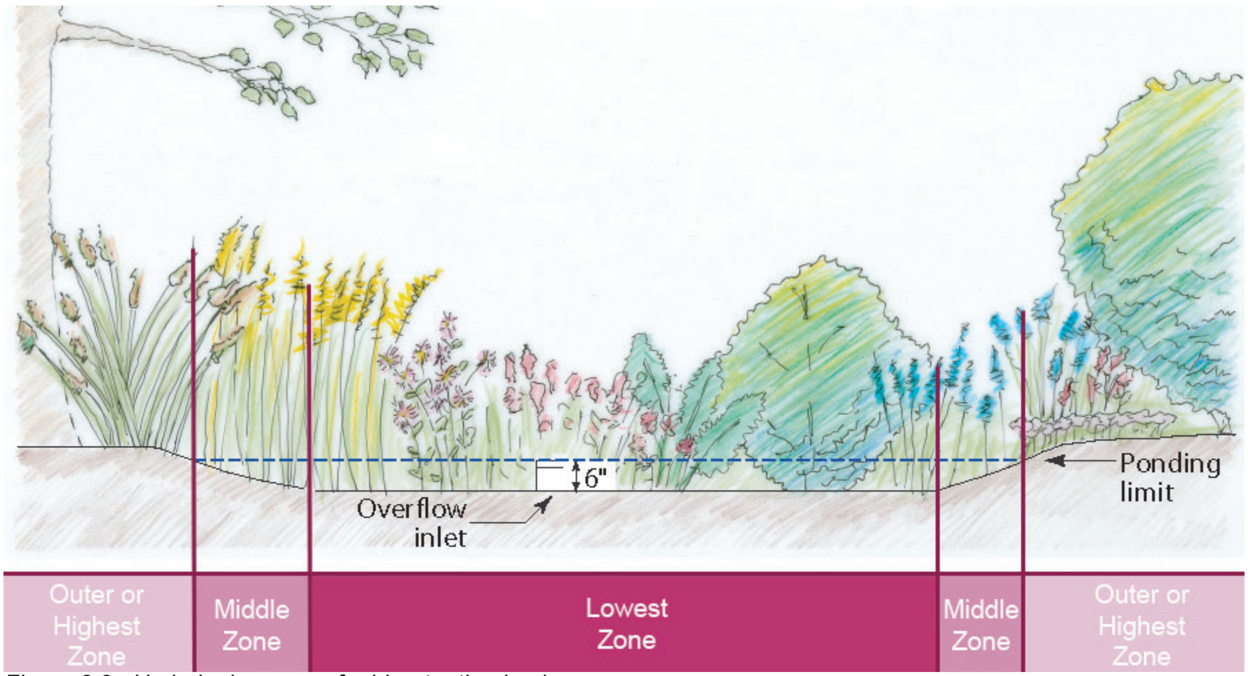

Figure 8.2: Hydrologic zones of a bioretention basin

Plant material selection should be based on the goal of simulating a terrestrial forested community of native species. Bioretention simulates an ecosystem consisting of an upland-oriented community dominated by trees, but having a distinct community, or sub-canopy, of understory trees, shrubs and herbaceous materials. The intent is to establish a diverse, dense plant cover to treat stormwater runoff and withstand urban stresses from insect and disease infestations, drought, temperature, wind, and exposure.

The proper selection and installation of plant materials is key to a successful system. There are essentially three zones within a bioretention system (Figure 8.2). The lowest elevation supports plant species adapted to standing and fluctuating water levels. The middle elevation supports a slightly drier group of plants, but still tolerates fluctuating water levels. The outer edge is the highest elevation and generally supports plants adapted to dryer conditions. However, plants in all the zones should be drought tolerant. Plants should also have high salt tolerance if bioretention area receives runoff from ground level impervious surfaces.

Lowest Zone (Hydrologic zones 2-4):
Plant species adapted to standing and fluctuating water levels. Frequently used native plants include*:

asters (*Aster spp.*)	winterberry (*Ilex verticillata*)
goldenrods (*Solidago spp.*)	arrowwood (*Viburnum dentatum*)
bergamot (*Monarda fistulosa*)	sweet pepperbush (*Clethra alnifolia*)
blue-flag iris (*Iris versicolor*)	bayberry (*Myrica pensylvanica*)
sedges (*Carex spp.*)	buttonbush (*Cephalanthus occidentalis*)
ironweed (*Vernonia noveboracensis*)	swamp azalea (*Rhododendron viscosum*)
blue vervain (*Verbena hastata*)	elderberry (*Sambucus canadensis*)
joe-pye weed (*Eupatorium spp.*)	green ash (*Fraxinus pennsylvanica*)
swamp milkweed (*Asclepias incarnata*)	river birch (*Betula nigra*)
switchgrass (*Panicum virgatum*)	sweetgum (*Liquidambar styraciflua*)
shrub dogwoods (*Cornus spp.*)	northern white cedar (*Juniperus virginiana*)
swamp rose (*Rosa palustris*)	red maple (*Acer rubrum*)

* Refer to the plant list for a complete listing

Middle Zone (Hydrologic zones 4-5):
This zone is slightly drier than the lowest zone, but plants should still tolerate fluctuating water levels. Some commonly planted native species include*:

black snakeroot (*Cimicifuga racemosa*)	spicebush (*Lindera benzoin*)
switchgrass (*Panicum virgatum*)	hackberry (*Celtis occidentalis*)
spotted joe-pye weed (*Eupatorium maculatum*)	willow oak (*Quercus phellos*)
cutleaf coneflower (*Rudabeckia lacinata*)	winterberry (*Ilex verticillata*)
frosted hawthorn (*Crataegus pruinosa*)	slippery elm (*Ulmus rubra*)
marginal wood fern (*Dryopteris marginalis*)	viburnums (*Viburnum spp.*)
ironwood (*Carpinus caroliniana*)	witch-hazel (*Hamamelis virginiana*)
serviceberry (*Amelanchier canadensis*)	steeplebush (*Spiraea tomentosa*)
obedient plant (*Physostegia virginiana*)	blueberry (*Vaccinium spp.*)

* Refer to the plant list for a complete listing

Outer Zone (Hydrologic zones 5-6):
Generally supports plants adapted to drier conditions. Examples of commonly planted native species include*:

many grasses & wildflowers	juniper (*Juniperus communis*)
basswood (*Tilia americana*)	sweet-fern (*Comptonia peregrina*)
white oak (*Quercus alba*)	eastern red cedar (*Juniperus virginiana*)
scarlet oak (*Quercus coccinea*)	smooth serviceberry (*Amelanchier laevis*)
black oak (*Quercus velutina*)	american holly (*Ilex opaca*)
american beech (*Fagus grandifolia*)	sassafras (*Sassafras albidum*)
black chokeberry (*Aronia melanocarpa*)	white pine (*Pinus strobus*)

* Refer to the plant list for a complete listing

Constructed Wetlands and Wet Ponds Landscaping Requirements

Refer to the *Pennsylvania Stormwater Management Best Management Practices Manual* for additional guidance regarding constructed wetlands and wet ponds.

Filter Strip Landscaping Requirements

It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select vegetation from the list of native species found in this section (Table 8.2). Take soil infiltration capacities, sunlight, pollution tolerances, root structure, and other considerations into account when selecting plants from this list.

Filter strips should be planted with meadow grasses, shrubs, and native vegetation (including trees) from the list provided in **Section 8.3**: Native and Recommended Non-invasive Plants.

For the filter strip, approved native grass mixes are preferable. Seed shall be applied at the rates specified by the supplier. The applicant shall have plants established at the time of SMP completion (at least 3 months after seeding). No runoff shall be allowed to flow across the filter strip until the vegetation is established. Trees and shrubs may be allowed in the flow path if the filter strip exceeds the minimum length and widths specified.

Filter strips often make a convenient area for snow storage. Therefore, filter strip vegetation should be salt-tolerant, and the maintenance schedule should involve removal of sand build-up at the toes of the slope. If the filter strip cannot provide pretreatment in the winter due to snow storage or vegetation choice, other pretreatment should be provided.

Vegetation cover should be maintained at 85 percent. If vegetation is damaged, the damaged areas should be reestablished in accordance with the original specifications or according to a new design approved by the Water Department. In all design cases where vegetation is to be established, the planting regime should be as dense as the soil conditions can sustain. This is especially true at the top portions of the filter strip where the highest sheet flow velocities are found. Soils that can sustain higher quantities and qualities of vegetation may need to be added to insure thick vegetative densities needed for sustainable filter strip performance. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides if possible.

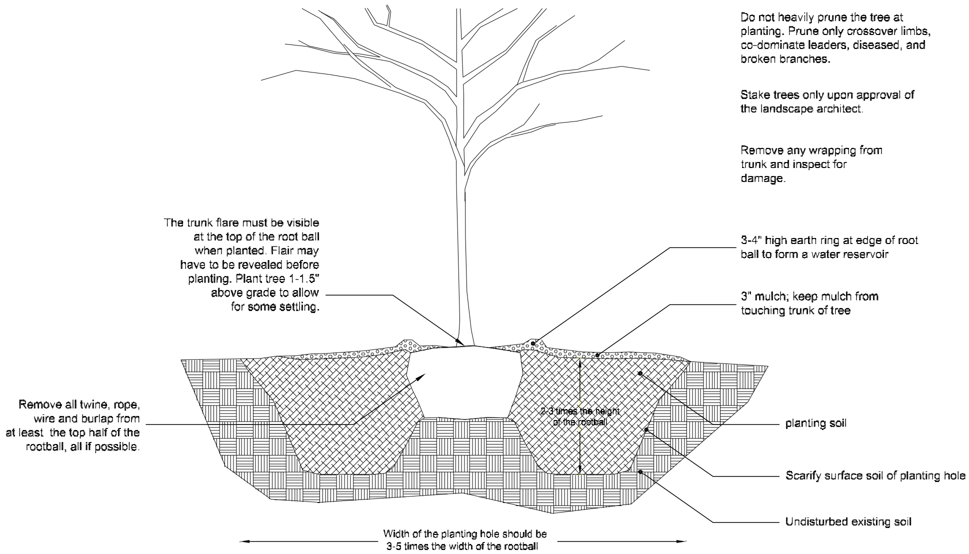

Figure 8.3: Balled & Burlapped (B&B) tree and shrub planting diagram

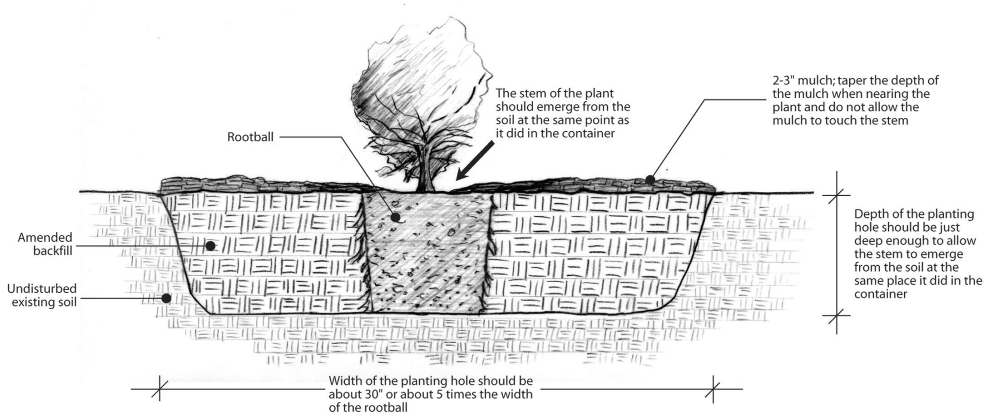

Figure 8.4: Containerized tree and shrub planting diagram

8.3 Native and Recommended Non-invasive Plants

Native plant species are recommended over exotic foreign species because they are well adapted to local climate conditions. This will result in less replacement and maintenance, while supporting the local ecology.

The pages at the end of this section present a list of herbaceous, tree and shrub plants native to Philadelphia and Pennsylvania and suitable for planting in stormwater management facilities (Table 8.2). The list is intended as a guide for general planting purposes and planning considerations. Knowledgeable landscape designers and nursery suppliers may provide additional information for considering specific conditions for successful plant establishment and accounting for the variable nature of stormwater hydrology. Because individual plants often have unique growing requirements difficult to convey in a general listing, it will be necessary to research specific information on the plant species proposed in order to ensure successful plant establishment.

Table 8.2 lists native and recommended plants, trees, shrubs, and grasses and is organized by Type and Latin name. Additional information given for each species includes: Common name, National Wetland Indicator Status, hydrologic zone, inundation tolerance, drought tolerance, salt tolerance, mature canopy spread, mature height, light requirements, nativity, commercial availability, and notes to provide guidance for application and selection. For example, some trees are well suited to landscaped areas that will receive stormwater runoff, while others may not tolerate the additional moisture.

Hydrologic Zones

For planting within a SMP, it is necessary to determine what hydrologic zones will be created. Hydrologic zones describe the degree to which an area is inundated by water (see Figure 8.2 for an example of hydrologic zones in a bioretention basin). Plants have differing tolerances to inundation and as an aid to landscape designers, these tolerance levels have been divided into six zones and corresponding plant species have been identified. In Table 8.2 each plant species has a corresponding hydrologic zone provided to indicate the most suitable planting location for successful establishment. While the most common zones for planting are listed in parenthesis, the listing of additional zones indicates that a plant may survive over a broad range of hydrologic conditions. Just as plants may, on occasion, be found outside of their hardiness zone, they may also be found outside of their hydrologic zone. Additionally, hydrologic conditions in a SMP may fluctuate in unpredictable ways; thus the use of plants capable of tolerating wide varieties of hydrologic conditions greatly increases a successful planting. Conversely, plants suited for specific hydrologic conditions may perish when hydrologic conditions fluctuate, thus exposing the soil and increasing the chance for erosion.

Wetland Indicator Status

The Wetland Indicator Status (from Region 1, Reed, 1988) has been included to show “the estimated probability of a species occurring in wetlands versus non-wetlands” (Reed, 1988). Reed defines the indicator categories as follows:

- Obligate wetland (OBL): Plants, which nearly always (more than 99% of the time) occur in wetlands under natural conditions.
- Facultative Wetland (FACW): Plants, which usually occur in wetlands (from 67 to 99% of the time), but occasionally found in non wetlands.
- Facultative (FAC): Plants, which are equally likely to occur in wetlands and non wetlands and are found in wetlands from 34 to 66% of the time.
- Facultative Upland (FACU): Plants, which usually occur in non wetlands (from 67 to 99% of the time), but occasionally found in wetlands.

- Upland (UPL): Plants, which almost always (more than 99% of the time) under natural conditions occur in non wetlands.
- A given indicator status shown with a “+” or a “-” means that the species is more (+) or less (-) often found in wetlands than other plants with the same indicator status without the “+” or “-” designation.

Inundation Tolerance

Since the Wetland Indicator Status alone does not provide an indication of the depth or duration of flooding that a plant will tolerate, the “Inundation tolerance” column is designed to provide further guidance. If a plant is capable of withstanding permanent saturation, the depth of this saturation is listed (for example, “saturated” indicates the soil can be moist at all times, “sat, 0-6”“ indicates that the species can survive in constantly moist soil conditions with up to 6” of standing water). Conversely, a plant may only tolerate seasonal inundation – such as after a storm event – or may not tolerate inundation at all. This type of plant would be well suited for an SMP that is expected to drain quickly or in the drier zones of the SMP.

Drought Tolerance (N=none; L=low; M=medium; H=high)

The drought tolerance column is meant to provide a way for SMP designers to select appropriate native plants that can survive in hot summer conditions, with a minimum of irrigation. Drought tolerance is defined as the relative tolerance of the plant to drought conditions compared to other plants in the same region (USDA, 2005).

Salt Tolerance (N=none; L=low; M=medium; H=high; U=unknown)

This column ranks the relative tolerance of a species to salt content in the soil. If U (unknown) is displayed, no research was found for that particular species.

Mature Canopy Spread

This column gives the SMP designer a rough estimate of the diameter (or spread) of a tree species’ branching when it has matured. This information indicates what the light conditions will be like beneath the tree for understory plantings; how much space should be left open between the tree planting pit and any vertical structures, such as buildings; how far apart the trees should be planted; and it gives an idea, along with the mature height of the species, of the tree’s growth habit. The mature canopy spread also provides a rough idea for how much leaf surface area will be available to intercept stormwater before it reaches the ground.

Mature Height

This column provides the approximate mature height of plant species in optimal growing conditions. This height may be reduced dramatically in the urban environment where light, space, and other factors may not be as readily available as in a forest or field setting. However, by providing as much space as possible for a plant to grow and by choosing appropriate species for a planting area, improved – if not optimal - growing conditions can be achieved. For example, a tree planted in a sidewalk pit measuring 4 feet x 4 feet may only reach half its mature height, while a tree planted in a 4 foot wide “trough” style planting bed will grow taller and live longer, because it will have greater access to air and water.

Light Requirement

The light requirements for each species are listed as ranges between full shade and full sun. At the bottom of the range – full shade – plants thrive in conditions where they receive filtered, or dappled, light for the entire day (such as under an oak tree). In the middle of the range are

plants that grow best in part shade, where they are in full shade for 2-3 hours during midday. Plants that require full sun should be sited so that they receive 5 or more hours of direct sun during the growing season. Some plants requiring full sun may still do well in a part shade environment, depending on the quality and duration of the light the plants receive when they are not in the shade.

Nativity

A native plant is an indigenous species that occurred in the region prior to settlement by the Europeans. In this column, each species is located within a range of nativity to Philadelphia. Plants known to have existed in Philadelphia County are native to Philadelphia, while a wider geographic range lists plants native to the state, but not necessarily to the county. The widest geographic range lists a few species native to the United States, but not necessarily to Pennsylvania. The plants listed that are not specifically native to Philadelphia are included because of their demonstrated success within SMPs.

Commercial Availability (C=container; P=plug; S=seed)

Wildflower and grass species often come in a form known as a plug. These are often grown and sold in trays of 50 of the same species. They are essentially very small container plants, with a root/soil mass about an inch wide and 2-4 inches long. Most species available in plug form are also sold as seed. Often, a combination of plugs and seed will be used to establish a SMP quickly and provide immediate visual interest and stabilization.

Container-grown plants include trees, shrubs, wildflowers, ferns, grasses, and sedges. This is an excellent alternative to the far more expensive balled-and–burlapped (B&B) form of trees and shrubs, although the size of the tree is almost always smaller. Nurseries often provide a few container sizes for each species.

Notes

PWD has included the recommendations for street trees in the notes section of the native plant list and recommended non-invasive plants, trees, shrubs, and grasses list to assist designers in selection of vegetation most appropriate for the harsh conditions which are often associated in close proximity to streets. It is likely that most these areas will be hot in summer months until the trees become established.

Table 8.2: Native and Recommended Non-invasive Plants

Type	Latin Name	Common Name	National Wetland Indicator *	Hydrologic zone **	Inundation tolerance	Drought tolerance(N=none; L=low; M=medium; H=high)	Salt tolerance (N=none; L=low; M=medium; H=high; U=unknown)	Mature canopy spread	Mature height	Light requirement	Nativity	Commercial availability (C=container; P=plug; S=seed	Notes
fern	Adiantum pedatum	maidenhair fern	FAC-	4, 5, 6	no	L	N		1-3'	part shade-full shade	Philadelphia County	C	slightly acidic soils
fern	Dennstaedtia punctilobula	hayscented fern	UPL	4, 5, 6	no	L	U		1-2'	part sun-shade	Philadelphia County	C	groundcover; grows easily in poor soils
fern	Dryopteris marginalis	marginal wood fern	FAC+	4, 5, 6	no	L	U		1-2'	part sun-shade	Philadelphia County	C	evergreen
fern	Onoclea sensibilis	sensitive fern	FACW	(3, 4) 5	saturated	N	U		1-2'	sun-shade	Philadelphia County	P,S	groundcover; needs consistent moisture
fern	Osmunda cinnamomea	cinnamon fern	FACW	2 (3, 4)	saturated	M	N		2-4'	part-full shade	Philadelphia County	P,S	acidic soils
fern	Osmunda regalis	royal fern	OBL	2 (3, 4)	saturated	L	N		2-4'	part-full shade	Philadelphia County	P,S	groundcover; acidic soils
fern	Polystichum acrostichoides	christmas fern	FACU-	6	no	M	U		1-3'	part shade-full shade	Philadelphia County	C	groundcover; evergreen; silvery fiddleheads
fern	Thelypteris noveboracensis	new york fern	FAC	(3, 4) 5	saturated	M	N		1-2.5'	part shade-shade	Pennsylvania	C	groundcover; delicate fronds spread rapidly in moist areas
forb	Acorus americanus	sweet flag	OBL	3, 4	sat, 0-6"	L	M		4'	full sun	Pennsylvania	P,S	occurs in shallow water of ponds
forb	Anaphalis margaritacea	pearly everlasting		5, 6	no	M	N		1-3'	full sun-part shade	Philadelphia County	S	attractive white, globular flowers
forb	Aquilegia canadensis	columbine	FAC	(4, 5) 6	no	M	N		2'	part sun-shade	Philadelphia County	P,S	flowers with scarlet sepals and yellow petal blades; very adaptable
forb	Asarum canadense	wild ginger	FACU-	4, 5, 6	seasonal	L	N		1'	part-full shade	Philadelphia County	P,S	groundcover; semi-evergreen spreads rapidly; small purple/brown flowers
forb	Asclepias incarnata	swamp milkweed	OBL	2 (3, 4)	sat, 0-6"	N	N		2-6'	full sun-part shade	Philadelphia County	P,S	pink-rose purple flowers in several umbels
forb	Asclepias syriaca	common milkweed	FACU-	5, 6	no	M	N		2-6'	full sun	Philadelphia County	P,S	fragrant brownish-pink flowers in umbels
forb	Asclepias tuberosa	butterfly-weed		5, 6	no	H	N		2-3'	full sun	Philadelphia County	P,S	bright orange flowers in umbels
forb	Aster cordifolius	blue wood aster		5, 6	no	M	L		1.5-4'	part-full shade	Philadelphia County	P,S	blue-violet to rose disk and ray flowers
forb	Aster divaricatus	wood aster		4 (5, 6)	no	M	L		1-3'	part-full shade	Philadelphia County	P,S	white rays, center yellow and reddish-purple
forb	Aster novae-angliae	new england aster	FAC	(3, 4) 5	seasonal	M	L		2-8'	full sun-part shade	Philadelphia County	P,S	rays bright pink or purple
forb	Aster novi-belgii	new york aster	FACW+	(3, 4) 5	seasonal	L	N		1-4'	full sun	Philadelphia County	P,S	violet to blue rays with yellow disks
forb	Baptisia australis	blue false indigo		4, 5, 6	seasonal	H	N		3-6'	full sun	Pennsylvania	P,S	showy blue flowers; shrub-like; nitrogen fixer; adaptable
forb	Baptisia tinctoria	wild indigo		5, 6	no	H	N		2-3'	full sun-part shade	Philadelphia County	P,S	sandy, acidic soils; yellow pea-like flowers; dark blue-green leaves
forb	Bidens aristosa	tickseed sunflower	FACW-	4, 5, 6	seasonal	L	N		1-3'	full sun	US	S	daisy-like yellow flower
forb	Bidens cernua	bur marigold	OBL	3, 4, 5	saturated	L	N		1-3'	full sun	Philadelphia County	S	many flowers crowded together into a head
forb	Bidens frondosa	beggars-ticks	FACW	5, 6	no	L	N		1-4'	full sun	Philadelphia County	S	orange flowers; adaptable
forb	Caltha palustris	marsh marigold	OBL	2, 3, 4	sat, 0-6"	N	N		1-2'	full sun-part shade	Philadelphia County	P,S	ideal for wetland gardens; clump-forming
forb	Chamaecrista fasciculata	partridge-pea	FACU	4, 5, 6	no	M	L		to 3'	full sun	Philadelphia County	S	showy yellow flowers; found on stream banks
forb	Chelone glabra	white turtlehead	OBL	3, 4, 6	seasonal	L	N		2-3'	full sun-part shade	Philadelphia County	P,S	snapdragon-type white flowers
forb	Chrysogonum virginianum	green and gold		6	no	N	N		1'	part shade	Pennsylvania	P,S	groundcover; golden daisy-like flowers continue until frost; spreads easily
forb	Cimicifuga racemosa	black snakeroot		4, 5, 6	seasonal	L	N		3-8'	full sun-part shade	Pennsylvania	C	woodland edge plant; white, wand-like blooms
forb	Dicentra eximia	wild bleeding heart		5, 6	no	L	N		1.5'	part shade-shade	Pennsylvania	C	mound of finely-cut foliage; delicate pink hearts
forb	Dodecatheon media	shooting star	FACU	5, 6	no	L	N		1-2'	part shade	Philadelphia County	C	nodding white, pink, or lilac flowers in a terminal umbel
forb	Eupatorium coelestinum	mist flower	FAC	4, 5, 6	seasonal	M	N		2'	full sun-part shade	Pennsylvania	P,S	groundcover; blue flowers on neat foliage; spreads easily
forb	Eupatorium fistulosum	joe-pye-weed	FACW	(3, 4) 5	seasonal	L	N		to 10'	sun-shade	Philadelphia County	S	many white flowers in large, branching clusters
forb	Eupatorium hyssopifolium	hyssopleaf thoroughwort		5, 6	no	M	M		1-4'	full sun-part shade	Philadelphia County	P,S	white flowers in flat topped terminal clusters
forb	Eupatorium maculatum	spotted joe-pye-weed	FACW	(3, 4) 5	seasonal	L	N		to 5'	full sun-part shade	Pennsylvania	P,S	light purple flowers; attracts butterflies
forb	Eupatorium perfoliatum	boneset	FACW+	(2, 3) 4	seasonal	L	U		2-5'	full sun-part shade	Philadelphia County	P,S	clusters of grayish-white flowers
forb	Eupatorium purpureum	joe-pye-weed	FAC	3 (4, 5)	seasonal	L	U		6-8'	full sun-part shade	Philadelphia County	P,S	vanilla-scented flowers
forb	Eupatorium rugosum	white snakeroot		5, 6	no	M	M		1-5'	sun-shade	Philadelphia County	P,S	white flowers in large clusters
forb	Filipendula rubra	queen of the prairie	FACW	4, 5, 6	seasonal	N	U		4-6'	full sun-part shade	Pennsylvania	S	prefers well-drained moist soils; foamy clusters of blooms
forb	Geranium maculatum	wild geranium	FACU	5, 6	no	M	U		1-2'	full sun-part shade	Philadelphia County	P,S	groundcover; rose-purple flowers in small clusters
forb	Helenium autumnale	sneezeweed	FACW+	3, 4, 5	seasonal	L	N		3-5'	full sun-part shade	Philadelphia County	P,S	showy yellow daisy-like flowers; moist meadows; stream banks
forb	Helianthus angustifolius	swamp sunflower	FACW	3, 4, 5	seasonal	M	N		6-8'	full sun	Pennsylvania	S	yellow flowers with maroon centers
forb	Helianthus giganteus	swamp sunflower	FACW	3, 4, 5	seasonal	L	N		5-10'	full sun-part shade	Philadelphia County	S	yellow flowers on red-purple stems
forb	Heliopsis helianthoides	ox-eye		3, 4, 5, 6	seasonal	M	U		2-5'	full sun-part shade	Philadelphia County	P,S	pale yellow cone-shaped rays with yellow disks
forb	Heuchera americana	alumroot		5, 6	no	M	U		1-1.5'	full sun-part shade	Philadelphia County	P,S	groundcover; white airy flowers
forb	Hibiscus moscheutos	swamp mallow	OBL	2, 3	sat, 0-12"	N	M		3-7'	full sun-part shade	Philadelphia County	P,S	large pink, purplish, or white flowers with a dark center
forb	Houstonia caerulea	bluets	FACU	5, 6	no	M	U		2-8"	full sun-part shade	Philadelphia County	S	delicate pale blue flowers with yellow centers
forb	Iris versicolor	blue-flag iris	OBL	2 (3, 4)	sat, 0-6"	N	L		1-3'	full sun	Philadelphia County	P,S	blue-violet flowers
forb	Liatris spicata	spiked gay-feather	FAC+	4, 5	seasonal	L	L		4-5'	full sun	Philadelphia County	P,S	easy to grow; tall spikes of lavender blooms
forb	Lillium superbum	turk's cap-lily	FACW+	4, 5	seasonal	N	U		3-8'	full sun	Philadelphia County	S	nodding flowers, orange or orange-red with spots
forb	Lobelia cardinalis	cardinal flower	FACW+	3, 4	saturated	M	N		2-5'	part-full shade	Philadelphia County	P,S	brilliant scarlet red flowers

Table 8.2: Native and Recommended Non-invasive Plants (continued)

Type	Latin Name	Common Name	National Wetland Indicator *	Hydrologic zone **	Inundation tolerance	Drought tolerance(N=none; L=low; M=medium; H=high)	Salt tolerance (N=none; L=low; M=medium; H=high; U=unknown)	Mature canopy spread	Mature height	Light requirement	Nativity	Commercial availability (C=container; P=plug; S=seed	Notes
forb	Lobelia siphilitica	great-blue lobelia	FACW+	3, 4	saturated	N	U		1-3'	full sun-part shade	Philadelphia County	P,S	blue-white flowers
forb	Maianthemum racemosum	false-solomon's seal		5, 6	no	L	U		1-3'	shade	Philadelphia County	C	creamy-white flowers in branched, pyramidal clusters
forb	Mertensia virginica	virginia bluebells	FACW	5, 6	no	L	N		1-2'	full-part shade	Philadelphia County	C	woodland flower; entire plant dies back by mid-summer
forb	Mimulus ringens	allegheny monkey-flower	OBL	3, 4	saturated	N	U		1-3'	full sun-part shade	Philadelphia County	P	blue-violet flowers
forb	Monarda didyma	bee-balm	FAC+	(4, 5) 6	no	N	U		2-5'	full sun	Philadelphia County	C	red flowers, scented leaves
forb	Monarda fistulosa	wild bergamot	UPL	5, 6	no	N	L		2-4'	full sun-part shade	Philadelphia County	P,S	pink to lavender flowers, scented leaves
forb	Monarda punctata	horsemint	UPL	6	no	M	U		2-3'	full sun	Pennsylvania	P,C	pink, showy bracts and yellow flowers with purple spots
forb	Oenothera fruticosa	sundrops	FAC	5, 6	no	L	H		1-2'	full sun	Philadelphia County	P,S	bright yellow flowers in spike or racemes
forb	Peltandra virginica	arrow-arum	OBL	(1, 2) 3	sat, 0-1'	N	L		1-2'	full sun	Philadelphia County	P,S	emergent aquatic; resembles an arrowhead
forb	Penstemon digitalis	white beardtongue	FAC	5, 6	no	H	M		2-4'	full sun-part shade	Philadelphia County	P,S	white with purple tinged tubular flowers
forb	Phlox maculata	wild sweet-william	FACW	4, 5	seasonal	M	N		1-3'	full sun	Philadelphia County	P,S	deep pink to rose-purple flower clusters
forb	Phlox paniculata	summer phlox	FACU	4, 5, 6	no	M	U		2-6'	full sun-part shade	Philadelphia County	P	magenta pink flower clusters
forb	Phlox subulata	moss phlox		6	no	M	N		3-5"	full sun-part shade	Pennsylvania	C	groundcover; evergreen; forms mats; good for hillsides and rocky areas
forb	Physostegia virginiana	obedient plant	FAC+	4, 5	seasonal	L	U		1-5'	full sun-part shade	Philadelphia County	P,S	tall graceful plant with pink tubular flowers; very tolerant
forb	Polygonatum biflorum	solomon's seal	FACU	5, 6	no	L	U		1-3'	full-part shade	Philadelphia County	C	greenish bell-shaped flowers hang from leaf axils in pairs
forb	Polygonum pensylvanicum	pennsylvania smartweed	FACW	2 (3, 4)	sat, 0-6"	M	L		to 6'	full sun	Pennsylvania	S	attractive pink flowers; great species for disturbed sites and stream banks
forb	Pontederia cordata	pickerel-weed	OBL	(2, 3) 4	saturated	N	L		1-3'	full sun	Philadelphia County	P, C	heart-shaped leaves with purple flowers in a spike
forb	Rudbeckia fulgida	early coneflower	FAC	5, 6	no	M	U		1.5'	full sun-part shade	Pennsylvania	P,S	yellow flowers with black eyes
forb	Rudbeckia hirta	black-eyed susan	FACU-	4, 5, 6	no	M	U		1-3'	full sun-part shade	Pennsylvania	P,S	flowers from seed in the first year
forb	Rudbeckia laciniata	tall coneflower	FACW	4, 5	seasonal	H	N		5-10'	full sun-part shade	Pennsylvania	P,S	yellow flowers with drooping rays and green eyes; moist thickets; swamps
forb	Rudbeckia triloba	three-lobed coneflower	FACU	5, 6	no	M	U		1-3'	full sun-part shade	Pennsylvania	P,S	yellow flowers with large, black eyes; moist to dry soils
forb	Sagittaria latifolia	arrowhead	OBL	1, 2, 3	sat, 0-2'	N	N		1-4'	full sun	Philadelphia County	P,S	emergent aquatic, tubers are edible
forb	Saururus cernuus	lizard's tail	OBL	2, 3, 4	sat, 0-1'	N	U		2-4'	sun-part shade	Philadelphia County	P,S	emergent aquatic, fragrant white flowers
forb	Sedum ternatum	wild stone crop		6	no	M	U		3-8"	full sun-part shade	Philadelphia County	P,S	groundcover; likes rocky banks
forb	Senecio aureus	golden ragwort	FACW	4, 5	seasonal	L	N		1-3'	sun-shade	Philadelphia County	P,S	groundcover; flowers in terminal clusters with many golden rays
forb	Solidago bicolor	silver-rod		5, 6	no	M	U		1-3'	part sun	Philadelphia County	S	only native white goldenrod
forb	Solidago nemoralis	gray goldenrod		6	no	M	N		1-3'	full sun-part shade	Philadelphia County	S	dry, sterile soils; yellow flower clusters
forb	Solidago odora	sweet goldenrod		6	no	M	U		2-4'	full sun-part shade	Philadelphia County	S	leaves smell and taste like licorice
forb	Solidago rugosa	wrinkle-leaf goldenrod	FAC	3, 4, 5	no	M	N		3-7'	sun-part shade	Philadelphia County	P,S	yellow flowers
forb	Solidago sempervirens	sea-side goldenrod	FACW	3, 4, 5	seasonal	H	M		3-5'	full sun	Philadelphia County	P,S	showy yellow flowers
forb	Tiarella cordifolia	foamflower	FAC-	5, 6	no	L	U		1'	part sun-full shade	Pennsylvania	P,S	groundcover; spreads rapidly; leaves are evergreen; flowers are small and white
forb	Tradescantia virginiana	spiderwort	FACU	5, 6	no	M	N		1-3'	full sun-part shade	Philadelphia County	P,S	long blooming; deep blue-purple or white flower; dry to moist soils
forb	Vallisneria americana	wild celery	OBL	1	sat, 1' min.	N	N		1'	full sun-part shade	Pennsylvania	C	tolerant of murky water and high nutrient loads
forb	Verbena hastata	blue vervain	FACW+	3, 4	saturated	N	U		2-6'	full sun	Philadelphia County	P,S	violet blue flowers in erect spikes
forb	Veronia novaborescensis	new york ironweed	FACW+	3, 4	saturated	M	N		5-6'	full sun	Philadelphia County	P,S	30-50 small rose-purple flowers on a head
forb	Zizia aptera	golden alexander	FAC	5, 6	no	L	U		1-3'	full sun-part shade	Philadelphia County	C	umbels of yellow flowers; all leaves are compound
grass	Andropogon gerardii	big bluestem	FACW+	(4, 5) 6	no	H	M		3-6'	full sun	Philadelphia County	P,S	warm-season grass
grass	Andropogon virginicus	broom sedge	FACU	5, 6	no	H	N		3-8'	full sun-part shade	Philadelphia County	P,S	warm-season grass
grass	Chasmanthium latifolium	river oats	FACU	4, 5	seasonal	M	N		2-3'	full sun-part shade	Pennsylvania	P,S	groundcover; resembles bamboo; dangling "oats"
grass	Danthonia spicata	poverty grass		6	no	L	U		1-3'	full sun	Pennsylvania	P,S	usually found in poor, dry soils; very tolerant; cool-season
grass	Distichlis spicata	seashore saltgrass	FACW+	5, 6	no	M	H		1'	full sun	Philadelphia County	P,S	especially useful in saline wetlands; dense roots act as a pollutant filter
grass	Eleocharis palustris	creeping spike-rush	OBL	2, 3, 4	sat, 0-6"	L	L		1-2'	full sun	Pennsylvania	P,S	forms dense tufts; roots fix nitrogen; important food and cover for waterfowl
grass	Elymus canadensis	Canada rye	FACU+	4, 5, 6	seasonal	M	M		3-6'	full sun-part shade	Philadelphia County	S	cool season, clump-forming grass with wheat-like spikes that remain until winter
grass	Elymus virginicus	virginia wild rye	FACW-	4, 5	seasonal	M	N		2-3'	part shade-shade	Philadelphia County	P,C	spreads easily; good for erosion control; very tolerant
grass	Eragrostis spectabilis	purple lovegrass	UPL	5, 6	no	H	N		1-2.5'	full sun	Philadelphia County	P,S	groundcover; delicate purple flowers seem to float above the plant
grass	Glyceria grandis	american mannagrass	OBL	2, 3, 4	seasonal	N	U		to 5'	full sun	Philadelphia County	S	decorative cool-season bunchgrass; purple seed heads
grass	Glyceria striata	fowl mannagrass	OBL	(2, 3) 4	seasonal	L	N		2-4'	full sun-part shade	Philadelphia County	P,S	clump forming
grass	Hordeum jubatum	foxtail barley	FAC	5, 6	no	M	M		1-3'	full sun	Philadelphia County	S	soft and airy appearance; compaction resistant; often found on roadsides
grass	Leersia oryzoides	rice cutgrass	OBL	(2, 3) 4	sat, 0-6"	L	N		2-5'	full sun	Philadelphia County	P,S	single flower clusters slightly drooping
grass	Panicum dichotomiflorum	smooth panic-grass	FACW-	4, 5, 6	seasonal	N	M		5-7'	full sun-part shade	Philadelphia County	S	green or purple inflorescence
grass	Panicum virgatum	switch-grass	FAC	(4, 5) 6	seasonal	M	M		3-6'	full sun-part shade	Philadelphia County	P,S	groundcover; bluish-green foliage; purple panicle of flowers

Table 8.2: Native and Recommended Non-invasive Plants (continued)

Type	Latin Name	Common Name	National Wetland Indicator *	Hydrologic zone **	Inundation tolerance	Drought tolerance(N=none; L=low; M=medium; H=high)	Salt tolerance (N=none; L=low; M=medium; H=high; U=unknown)	Mature canopy spread	Mature height	Light requirement	Nativity	Commercial availability (C=container; P=plug; S=seed	Notes
grass	Schizachyrium scoparium	little bluestem	FACU	6	no	H	N		2-3'	full sun	Philadelphia County	P,S	warm-season grass, tolerates poor, dry soils
grass	Sorghastrum nutans	indian grass	UPL	5, 6	no	M	M		5-7'	full sun	Philadelphia County	P,S	warm-season grass
grass	Tridens flavus	purpletop	FACU	6	no	H	N		2-5'	full sun	Philadelphia County	P,S	groundcover; purple drooping branches
grass	Typha angustifolia	narrow-leaved cattail	OBL	1 (2, 3)	sat, 0-1'	L	M		to 6'	full sun	Pennsylvania	P,S	provides food and cover for geese, ducks, and spawning fish
grass	Typha latifolia	broad-leaved cattail	OBL	1, 2, 3	sat, 0-1'	N	L		to 10'	full sun-part shade	Pennsylvania	P,S	provides food and cover for geese, ducks, and spawning fish
grass	Zizania aquatica	wild rice	OBL	2, 3, 4	saturated	N	L		to 9'	full sun	Philadelphia County	S	yellow-red edible grains; found in tidal and nontidal marshes; requires still water
grass-like	Alisma subcordatum	southern water-plantain	OBL	2	sat, 0-1'	N	N		to 4'	full sun	Philadelphia County	S	emergent aquatic, slow moving water
grass-like	Carex crinita	finged sedge	OBL	2 (3, 4)	saturated	L	N		to 4'	full sun-part shade	Philadelphia County	P,C	groundcover; emergent aquatic, distinctive sedge
grass-like	Carex lurida	lurid sedge	OBL	2, 3, 4	saturated	L	N		to 3'	full sun-part shade	Philadelphia County	P, C	seed heads resemble small sweetgum fruits; remains attractive in warm temps.
grass-like	Carex pensylvanica	pennsylvania sedge		5, 6	seasonal	M	N		3-15"	part-full shade	Philadelphia County	P,C	slow-spreading
grass-like	Carex scoparia	broom sedge	FACW	3 (4) 5	sat, 0-6"	N	L		1-3'	full sun	Philadelphia County	P,S	green flowers in clusters at the top of the stem
grass-like	Carex stricta	tussock sedge	OBL	1 (2, 3) 4	sat, 0-6"	L	N		to 3'	full sun	Philadelphia County	P,C	emergent aquatic
grass-like	Carex vulpinoidea	fox sedge	OBL	1, 2 (3) 4	sat, 0-6"	L	N		to 3'	full sun-part shade	Philadelphia County	P,C	seed heads resemble a fox's tail
grass-like	Juncus effusus	soft rush	FACW+	(2, 3) 4	sat, 0-1'	M	L		2-3'	full sun	Philadelphia County	P,C	clump forming
grass-like	Juncus gerardii	black-grass	FACW+	3, 4	sat, 0-6"	N	H		1-2'	full sun-part shade	Philadelphia County	P,C	purplish to burgundy flower clusters
grass-like	Pontederia cordata	pickerel-weed	OBL	1, 2, 3	sat, 0-1'	N	L		1-3'	full sun	Philadelphia County	S	emergent aquatic, heart-shaped leaves, purple flowers
grass-like	Schoenoplectus (Scirpus) pungens	three-square	FACW+	2, 3, 4	sat, 0-6"	N	H		1-3'	full sun	Philadelphia County	P,S	good bank stabilizer; erosion control; spreads easily
grass-like	Scirpus cyperinus	wool-grass	FACW+	2 (3, 4)	saturated	L	N		to 6'	full sun	Philadelphia County	P,C	forms dense tussocks; large inflorescence
grass-like	Scirpus polyphyllus	bulrush	OBL	2, 3, 4	saturated	N	U		to 4'	shade	Philadelphia County	S	numerous leaves along stem, flowers at the top of the stem
grass-like	Sparganium americanum	bur-reed	OBL	(2, 3) 4	sat, 0-6"	N	N		1-3'	full sun	Philadelphia County	P,C	emergent aquatic
grass-like	Sparganium eurycarpum	giant bur-reed	OBL	1 (2, 3)	sat, 0-12"	N	N		2-4'	full sun	Philadelphia County	P,C	emergent aquatic
shrub	Alnus serrulata	smooth alder	OBL	(1, 2) 3	sat, 0-3"	L	N	6-10'	6-10'	full sun	Philadelphia County	C	stabilizes stream banks, roots fix nitrogen
shrub	Amelanchier canadensis	serviceberry	FAC	4, 5, 6	seasonal	L	H	15-20'	6-20'	full sun-part shade	Philadelphia County	C	compaction sensitive
shrub	Aronia arbutifolia	red chokeberry	FACW	3 (4, 5)	seasonal	L	M	3-4'	6-10'	full sun-part shade	Philadelphia County	C	compaction resistant, bank stabilizer, white flowers
shrub	Aronia melanocarpa	black chokeberry	FAC	3 (4, 5)	seasonal	M	M	3-6'	5-10'	full sun-part shade	Philadelphia County	C	compaction tolerant, white flowers
shrub	Baccharis halimifolia	groundsel-tree	FACW	4, 5, 6	seasonal	L	M	6-12'	6-12'	full sun	Philadelphia County	C	compaction resistant
shrub	Cephalanthus occidentalis	buttonbush	OBL	1 (2, 3)	sat, 0-3'	M	M	4-8'	3-6'	full sun	Philadelphia County	C	compaction tolerant, interesting flowers
shrub	Chionanthus virginicus	fringetree	FAC+	4, 5	seasonal	M	N	12-20'	12-25'	sun-shade	Philadelphia County	C	white, pendulous, fragrant flowers; gold fall color; very adaptable; acidic soils
shrub	Clethra alnifolia	sweet pepperbush	FAC+	3, 4, 5	seasonal	L	M	4-6'	3-8'	full sun-shade	Philadelphia County	C	compaction tolerant, acidic soils
shrub	Comptonia peregrina	sweet-fern		6	no	H	N	4-8'	2-5'	full sun-part shade	Pennsylvania	C	very adaptable; aromatic leaves; nitrogen fixer
shrub	Cornus amomum	silky dogwood	FACW	(3, 4) 5	seasonal	L	N	8'	6-10'	full sun-part shade	Philadelphia County	C	compaction tolerant, bank stabilizer, white flowers
shrub	Cornus racemosa	gray dogwood	FAC-	3 (4, 5)	seasonal	M	N	10-15'	10-15'	full sun-shade	Philadelphia County	C	compaction tolerant, very adaptable, white flowers
shrub	Cornus sericea	red-osier dogwood	FACW+	(3, 4) 5	seasonal	L	N	8-12'	7-9'	full sun	Philadelphia County	C	compaction tolerant, stream bank stabilizer, red bark
shrub	Corylus americana	hazelnut	FACU-	4 (5, 6)	no	M	N	8-13'	8-10'	full sun-light shade	Philadelphia County	C	compaction tolerant, edible nuts
shrub	Euonymus americanus	hearts-a-burstin'	FAC	4, 5, 6	seasonal	N	N	4-6'	4-6'	full sun-part shade	Philadelphia County	C	small brown flowers; fuchsia hearts; green stems add winter interest
shrub	Hamamelis virginiana	witch-hazel	FAC-	4 (5, 6)	no	L	N	15-20'	20-30'	full sun-shade	Philadelphia County	C	ornamental, unusual yellow flowers
shrub	Hydrangea arborescens	wild hydrangea	FACU	3, 4, 5	no	N	U	3-5'	3-5'	part-full shade	Philadelphia County	P,S	creamy white flowers; dry to moist soil
shrub	Ilex verticillata	winterberry	FACW+	(3, 4) 5	seasonal	L	N	3-12'	6-12'	full sun-part shade	Philadelphia County	C	compaction resistant, red berries persist through winter
shrub	Itea virginica	virginia sweet spire	OBL	3, 4, 5	seasonal	L	N	3-5'	3-9'	sun-shade	Pennsylvania	C	fragrant white tassels; good fall color
shrub	Juniperus communis	juniper		6	no	H	N	7-13'	5-10'	full sun	Philadelphia County	C	mounded shrub; deep taproot; high wildlife value; evergreen
shrub	Leucothoe racemosa	swamp sweetbells	FACW	3, 4, 5	seasonal	L	L	3-8'	3-8'	part-full shade	Pennsylvania	C	white drooping flowers; evergreen leaves; moist soil
shrub	Lindera benzoin	spicebush	FACW-	3, 4, 5	seasonal	L	M	6-12'	6-12'	full sun-shade	Philadelphia County	C	compaction tolerant, drought sensitive
shrub	Lonicera sempervirens	trumpet honeysuckle	FACU	6	no	L	N	3-6'	10-20'	full sun-part shade	Philadelphia County	P,S	vine with bright orange trumpet-shaped flowers; flood intolerant
shrub	Myrica pensylvanica	bayberry	FAC	(3, 4) 5	seasonal	H	M	5-9'	9'	full sun	Philadelphia County	C	compaction resistant, roots fix nitrogen, winter fruits
shrub	Parthenocissus quinquefolia	virginia creeper	FACU	4, 5, 6	seasonal	H	M	5-10'	30-50'	full sun-part shade	Philadelphia County	C	very adaptable vine; compaction resistant; beautiful red fall color
shrub	Physocarpus opulifolius	ninebark	FACW	3, 4, 5	seasonal	H	N	4-6'	5-10'	full sun	Philadelphia County	C	compaction resistant
shrub	Rhododendron maximum	Rosebay	FAC	3, 4, 5	seasonal	H	N	4-25'	4-25'	full sun-part shade	Philadelphia County	C	acidic soil, compaction sensitive
shrub	Rhododendron periclymenoides	pinxterbloom azalea	FAC	4, 5, 6	seasonal	M	N	4-7'	4-6'	full sun-part shade	Philadelphia County	C	pink flowers open before leaves are out; moist, acid, well-drained soil
shrub	Rhododendron viscosum	swamp azalea	FACW+	(3, 4) 5	saturated	M	N	6-12'	5-8'	full sun-part shade	Philadelphia County	C	compaction resistant, showy pink and white flowers
shrub	Rhus aromatica	fragrant sumac		5, 6	no	M	U	6-10'	2-4'	full sun-part shade	Pennsylvania	C	spicy smelling leaves; good fall color
shrub	Rhus copallina	winged sumac		6	no	H	M	10-20'	7-15'	full sun	Philadelphia County	C	compaction sensitive; flood intolerant

Table 8.2: Native and Recommended Non-invasive Plants (continued)

Type	Latin Name	Common Name	National Wetland Indicator *	Hydrologic zone **	Inundation tolerance	Drought tolerance(N=none; L=low; M=medium; H=high)	Salt tolerance (N=none; L=low; M=medium; H=high; U=unknown)	Mature canopy spread	Mature height	Light requirement	Nativity	Commercial availability (C=container; P=plug; S=seed	Notes
shrub	Rhus glabra	smooth sumac		4 (5, 6)	no	M	N	9-15'	9-15'	full sun	Philadelphia County	C	grows well in poor soils; flood and compaction intolerant
shrub	Rhus typhina	staghorn sumac		6	no	H	M	15-25'	15-25'	full sun	Philadelphia County	C	flood intol., compaction sensitive
shrub	Rosa carolina	pasture rose	UPL	5, 6	no	H	M	5-10'	4-6'	full sun	Philadelphia County	C	compaction tolerant; flood intolerant
shrub	Rosa palustris	swamp rose	OBL	2 (3, 4)	saturated	L	N	4-6'	6'	full sun	Philadelphia County	C	easy to establish
shrub	Rosa virginiana	wild rose	FAC	3 (4, 5)	seasonal	L	N	3-5'	4-6'	full sun	Philadelphia County	C	very pretty; low maint; tolerant of poor soils
shrub	Rubus allegheniensis	common blackberry	FACU-	4, 5, 6	no	H	N	6-12'	3-6'	full sun-part shade	Philadelphia County	C	compaction tolerant; edible fruit
shrub	Rubus occidentalis	blackcap raspberry		6	no	M	N	5-11'	3-4'	full sun-part shade	Pennsylvania	C	tasty fruits; purple & white stems provide winter interest; forms thickets
shrub	Salix discolor	pussy-willow	FACW	3, 4, 5	seasonal	L	N	10-12'	10-15'	full sun	Philadelphia County	C	compaction resistant, roots easily from cuttings
shrub	Salix exigua	sandbar willow	OBL	3, 4, 5	seasonal	M	L	10-15'	10'	full sun	Philadelphia County	C	found on sandy, gravelly bars or shores
shrub	Salix sericea	silky willow	OBL	3, 4, 5	seasonal	L	N	10-15'	10'	full sun-part shade	Philadelphia County	C	found in swamps, bogs, and on stream banks
shrub	Sambucus canadensis	american elder	FACW	(3, 4) 5, 6	seasonal	M	M	5-12'	5-12'	full sun-shade	Philadelphia County	C	compaction resistant
shrub	Spiraea tomentosa	steeplebush	FACW-	4, 5, 6	seasonal	M	N	3-6'	3-6'	full sun	Philadelphia County	C	compaction resistant
shrub	Vaccinium angustifolium	low-bush blueberry	FACU-	4, 5, 6	seasonal	H	N	2'	1-3'	full sun-part shade	Philadelphia County	C	compaction sensitive; very sweet berries; very flood tolerant; needs acidic soil
shrub	Vaccinium corymbosum	highbush blueberry	FACW-	3, 4, 5, 6	seasonal	L	H	8-12'	6-12'	full sun-part shade	Philadelphia County	C	compaction resistant, acidic soils
shrub	Vaccinium pallidum	early low blueberry	FACU-	4, 5, 6	seasonal	H	U	2-3'	1-3'	full sun-part shade	Philadelphia County	C	white flowers; sweet edible fruit; wildlife value; compaction sensitive, very flood tol
shrub	Vaccinium stamineum	deerberry	FACU	6	no	H	N	5-10'	5-10'	full sun-part shade	Pennsylvania	C	white flowers; edible fruit; high wildlife value; dry to moist soil
shrub	Viburnum acerifolium	maple-leaved viburnum	UPL	5, 6	no	H	N	2-4'	4-6'	full sun-part shade	Philadelphia County	C	creamy white flowers; blue berries; dry to moist soil; wildlife value
shrub	Viburnum dentatum	southern arrow-wood	FAC	3 (4, 5)	seasonal	M	M	6-12'	6-12'	full sun-part shade	Philadelphia County	C	compaction tolerant; heat resistant
shrub	Viburnum lentago	nannyberry	FAC	4, 5, 6	no	H	N	6-12'	15-18'	full sun-part shade	Philadelphia County	C	white flowers; sweet black berries; very adaptable; high wildlife value
shrub	Viburnum nudum	possum haw	OBL	3, 4, 5	seasonal	L	N	12-20'	12-20'	full sun-part shade	Philadelphia County	C	white flowers; glossy leaves; high wildlife value; compaction resistant
shrub	Viburnum prunifolium	black haw	FACU	4, 5, 6	no	M	N	6-12'	15-20'	full sun-part shade	Philadelphia County	C	white flowers; black berries; very adaptable; high wildlife value
shrub	Viburnum trilobum	american cranberry	FACW	3, 4, 5	seasonal	M	N	8-12'	8-12'	full sun-part shade	Philadelphia County	C	white flowers; edible red berries; moist to boggy soil; high wildlife value
tree	Acer rubrum	red maple	FACW	3 (4, 5)	seasonal	L	N	30-50'	40-60'	sun-shade	Philadelphia County	C	tolerant of many soils, tolerates acidic soil, rapid growth; suitable street tree
tree	Acer saccharinum	silver maple	FACW	3 (4, 5)	seasonal	L	N	35-70'	50-70'	full sun-part shade	Philadelphia County	C	very tolerant of poor soils
tree	Acer saccharum	sugar maple	FACU	4, 5, 6	no	M	N	30-60'	60-75'	full sun-part shade	Philadelphia County	C	intolerant of crowding, pollution, and drought
tree	Amelanchier laevis	smooth serviceberry		4, 5, 6	seasonal	M	M	15-40'	25'	full sun-part shade	Philadelphia County	C	compaction sensitive
tree	Asimina triloba	paw paw	FACU+	4, 5, 6	no	L	N	15-30'	15-20'	full sun-part shade	Philadelphia County	C	unusual maroon flower; very large leaves; moist soil; compaction sensitive
tree	Betula lenta	sweet birch	FACU	4, 5, 6	seasonal	M	N	40-60'	40-55'	full sun-part shade	Philadelphia County	C	sensitive to soil compaction
tree	Betula nigra	river birch	FACW	(3, 4) 5	seasonal	L	N	40-60'	40-70'	full sun	Philadelphia County	C	good bank stabilizer; acidic soils
tree	Betula populifolia	gray birch	FAC	(4, 5) 6	seasonal	M	N	10-20'	20-40'	full sun	Philadelphia County	C	poor soils, short lived tree, early successional species
tree	Carpinus caroliniana	hornbeam	FAC	3 (4, 5) 6	seasonal	L	N	20-35'	50-75'	heavy shade	Philadelphia County	C	compaction sensitive
tree	Carya cordiformis	bitternut hickory	FACU+	5, 6	seasonal	H	N	50-75'	50-75'	full sun-part shade	Philadelphia County	C	dry, moist, or wet soil; high wildlife value; good fall color; compaction tolerant
tree	Carya glabra	pignut hickory	FACU-	4 (5, 6)	no	H	N	35-50'	50-60'	full sun-part shade	Philadelphia County	C	compaction sensitive, warm south-facing slopes
tree	Carya ovata	Shagbark hickory	FACU	4 (5, 6)	no	M	N	50-70'	75-100'	full sun-part shade	Philadelphia County	C	compaction tolerant, distinctive peeling bark
tree	Celtis occidentalis	hackberry	FACU	4, 5, 6	no	H	M	40-60'	40-60'	full sun-part shade	Philadelphia County	C	fruit persists into winter; deep-rooting; good street tree
tree	Cercis canadensis	eastern redbud	FACU-	4, 5, 6	no	H	N	25-35'	20-30'	full sun-part shade	Philadelphia County	C	not good in acidic soils; nitrogen fixer
tree	Chamaecyparis thyoides	atlantic white cedar	OBL	(1, 2) 3, 4	saturated	N	N	20'	50'	part sun-shade	Pennsylvania	C	usually found in areas with fluctuating water tables
tree	Cornus florida	flowering dogwood	FACU-	4, 5, 6	no	M	N	15-30'	30-50'	sun-shade	Philadelphia County	C	understory tree; nice ornamental
tree	Crataegus crus-galli	cockspur hawthorn	FACU	5, 6	seasonal	H	M	20-25'	20-30'	full sun-part shade	Philadelphia County	C	keeps berries all winter; tolerant of many soils
tree	Crataegus pruinosa	frosted hawthorn		4, 5	seasonal	M	U	20-24'	24'	full sun-part shade	Pennsylvania	C	white flowers; adaptable; high wildlife value
tree	Fagus grandifolia	american beech	FACU	4 (5, 6)	no	H	N	40-80'	50-70'	sun-shade	Philadelphia County	C	compaction intolerant; intolerant of poorly-drained soils
tree	Fraxinus americana	white ash	FACU	4 (5, 6)	no	L	N	60-80'	50-80'	full sun-part shade	Philadelphia County	C	well-drained soils; compaction tolerant
tree	Fraxinus pennsylvanica	green ash	FACW	3, 4, 5	seasonal	M	L	35-50'	50-60'	full sun	Philadelphia County	C	good bank stabilizer, compaction resistant; good street tree, but may develop surface roots with age
tree	Gleditsia triacanthos	honeylocust		3, 4, 5	seasonal	H	L	50-75'	50-75'	full sun	Philadelphia County	C	gold fall color; very adaptable; compaction tolerant; taproot; good street tree
tree	Ilex opaca	american holly	FACU	4, 5, 6	no	M	L	10-20'	40-50'	full sun-part shade	Philadelphia County	C	acidic well drained soils; intolerant of wind
tree	Juglans nigra	black walnut	FACU	5, 6	seasonal	L	N	75-100'	50-75'	full sun	Philadelphia County	C	flood and compaction tolerant; yellow-green flowers give way to edible nuts
tree	Juniperus virginiana	eastern red cedar	FACU	4, 5, 6	no	H	M	8-25'	50-75'	full sun	Philadelphia County	C	flood and shade intolerant; very tolerant of many soils; beautiful reddish bark
tree	Liquidambar styraciflua	sweetgum	FAC	3, 4, 5	seasonal	L	M	20-30'	60-75'	full sun	Philadelphia County	C	heat and flood tolerant; outstanding fall color; good street tree
tree	Liriodendron tulipifera	tulip tree	FACU	4, 5, 6	no	M	L	30-50'	70-100'	full sun-part shade	Philadelphia County	C	heat and compaction sensitive; rapid growth
tree	Magnolia virginiana	sweetbay magnolia	FACW+	3, 4, 5	seasonal	N	M	10-20'	10-20'	sun-shade	Philadelphia County	C	sandy-peaty acidic soil; attractive, fragrant flowers

Selected Native Plants for BMP's

Table 8.2: Native and Recommended Non-invasive Plants (continued)

Type	Latin Name	Common Name	National Wetland Indicator *	Hydrologic zone **	Inundation tolerance	Drought tolerance(N=none; L=low; M=medium; H=high)	Salt tolerance (N=none; L=low; M=medium; H=high; U=unknown)	Mature canopy spread	Mature height	Light requirement	Nativity	Commercial availability (C=container; P=plug; S=seed	Notes
tree	Nyssa sylvatica	sourgum	FAC	2 (3, 4) 5	seasonal	L	M	20-30'	30-50'	full sun	Philadelphia County	C	compaction tolerant; heat resistant
tree	Pinus rigida	pitch pine	FACU	4, 5, 6	no	M	M	30-50'	40-60'	full sun	Philadelphia County	C	acidic soils; compaction sensitive; heat resistant
tree	Pinus strobus	white pine	FACU	4, 5, 6	no	N	N	20-40'	50-100'	full sun-part shade	Philadelphia County	C	heat and compaction sensitive; long-lived; tolerant of poor soils
tree	Pinus virginiana	scrub pine		5, 6	no	H	N	10-20'	15-40'	full sun	Philadelphia County	C	tolerant of poor sterile soils; beautiful golden foliage in winter
tree	Platanus occidentalis	sycamore	FACW-	3, 4, 5	seasonal	L	N	75-100'	75-100'	full sun-part shade	Philadelphia County	C	compaction resistant
tree	Populus deltoides	cottonwood	FACU-	3, 4, 5	seasonal	L	L	35-60'	75-100'	full sun	Philadelphia County	C	compaction resistant; pioneer species
tree	Populus grandidentata	large-toothed aspen	FACU-	4, 5, 6	no	L	N	20-30'	50-70'	full sun	Philadelphia County	C	compaction sensitive; pioneer species
tree	Populus tremuloides	quaking aspen	FACU	4, 5, 6	seasonal	L	N	20-30'	35-50'	full sun	Philadelphia County	C	compaction sensitive; pioneer species
tree	Prunus serotina	black cherry	FACU	4, 5, 6	no	M	N	30-60'	50-60'	full sun	Philadelphia County	C	compaction intolerant; pioneer species
tree	Quercus alba	white oak	FACU	4, 5, 6	no	M	M	50-80'	50-80'	full sun-part shade	Philadelphia County	C	compaction very sensitive; acidic soils; long lived
tree	Quercus bicolor	swamp white oak	FACW+	2, 3, 4, 5	seasonal	L	L	50-60'	50-60'	full sun-part shade	Philadelphia County	C	compaction resistant
tree	Quercus coccinea	scarlet oak		5, 6	no	M	N	40-50'	50-75'	full sun	Philadelphia County	C	compaction intolerant, long lived, nice fall color
tree	Quercus falcata	southern red oak	FACU-	6	no	H	N	50-60'	70-80'	full sun-part shade	Philadelphia County	C	high winter wildlife value; found in dry to moist woods
tree	Quercus marilandica	blackjack oak		5, 6	no	H	L	15-40'	30-40'	full sun	Philadelphia County	C	very flood intolerant; compaction sensitive
tree	Quercus palustris	pin oak	FACW	(3) 4, 5, 6	seasonal	L	N	40-60'	60-70'	full sun	Philadelphia County	C	acidic well drained soils; compaction resistant; good street tree
tree	Quercus phellos	willow oak	FACU-	(3, 4) 5	seasonal	N	N	25-50'	40-60'	full sun-part shade	Philadelphia County	C	acidic soils; tolerates poor drainage; compaction tolerant
tree	Quercus rubra	red oak	FACU-	5, 6	no	M	M	50-75'	60-75'	full sun	Philadelphia County	C	acidic soils; compaction and pollution tolerant
tree	Quercus velutina	black oak		5, 6	no	L	N	40-50'	50-60'	full sun-part shade	Philadelphia County	C	compaction intolerant; acidic soils
tree	Salix nigra	black willow	FACW+	(2, 3) 4	seasonal	L	N	20-35'	35-50'	full sun	Philadelphia County	C	compaction resistant
tree	Sassafras albidum	sassafras	FACU	6	no	H	N	25-40'	30-60'	full sun-part shade	Philadelphia County	C	compaction intolerant; pioneer species; flood intolerant
tree	Tilia americana	basswood	FACU	(4, 5) 6	no	M	N	30-50'	60-80'	full sun-part shade	Philadelphia County	C	compaction sensitive; fragrant pale yellow spring flowers
tree	Ulmus americana	american elm	FACW-	(3) 4, 5, 6	seasonal	H	H	50-75'	60-90'	full sun	Philadelphia County	C	rare due to Dutch elm disease; new resistant stock; graceful vase form
tree	Ulmus rubra	slippery elm	FAC-	(3) 4, 5, 6	seasonal	H	H	50-75'	60-90'	full sun-part shade	Philadelphia County	C	seeds are eaten by birds and small mammals; shade tolerant

*** WETLAND INDICATOR (probability of occurring in a wetland):**

OBL	Obligate wetland species	99%
FACW	Facultative wetland species	67-99%
FAC	Facultative species	34-66%
FACU	Facultative upland species	1-33%
UPL	Upland species	1%
(+)	indicates that the species occurs in the higher portion of the range	
(-)	indicates that the species occurs in the lower portion of the range	

Those species with no wetland indicator are virtually intolerant of flooding or prolonged soil saturation during the growing season.

**** HYDROLOGIC ZONES**

Zone 1: Open water - Permanent pool (12 inches - 6 feet)

This zone is best colonized by submergent plants, if at all. This deep water zone is not usually planted for several reasons: there are few species that can grow in this zone, and many are not commercially available; open water areas provide unique habitat; and deep water aquatic plants may clog the stormwater facility outlet structure. The benefits of planting in this zone include the absorption of nutrients in the water column; enhanced sediment deposition; improved oxidation; and the creation of additional habitat.

Zone 2: Shallow water terrace/Aquatic bench (6 inches -1 foot)

This zone offers ideal conditions for a wide variety of emergent wetland plants. These areas typically fringe the ponding area and are permanently inundated.

Zone 3: BMP Fringe - Low marsh (0-6 inches regular inundation)

This zone is typically the shoreline of a pond or wetland - its width determined by the

Table 8.2: Native and Recommended Non-invasive Plants (continued)

Type	Latin Name	Common Name	National Wetland Indicator *	Hydrologic zone **	Inundation tolerance	Drought tolerance(N=none; L=low; M=medium; H=high)	Salt tolerance (N=none; L=low; M=medium; H=high; U=unknown)	Mature canopy spread	Mature height	Light requirement	Nativity	Commercial availability (C=container; P=plug; S=seed	Notes
	design slope. This zone is usually inundated except during periods of drought and is the												
	interface between the emergent wetland plantings and the upland plantings. Plants must												
	be able to withstand periods of inundation as well as periods of drought and should												
	have some capacity for slope stabilization.												
	Zone 4: BMP Fringe - High Marsh (periodic inundation, saturated soils)												
	This zone extends upslope from zone 3 and may be inundated after storms. It constitutes												
	the majority of the temporary extended detention area. Plants selected should be able												
	to withstand periodic inundation after storms as well as significant drought during the												
	summer.												
	Zone 5: Floodplain terrace (infrequent inundation, temporarily saturated soils)												
	Zone 5 is infrequently saturated by floodwaters that quickly recede in a day or less.												
	Plants should be able to withstand infrequent inundation as well as drought and should												
	offer some slope stabilization.												
	Zone 6: Upland (never inundated)												
	This zone extends above the maximum design water surface elevation. Plant												
	selection should be based on local soil and light conditions, and on the amount												
	of available space for plantings.												
	REFERENCES:												
	The Plants of Pennsylvania: An Illustrated Manual , Ann Rhoads, Timothy Block, Anna Anisko												
	Fairmount Park Commission: Selected Trees & Shrubs Native to Philadelphia County (brochure)												
	Fairmount Park Commission: Selected Wildflowers, Ferns, Grasses, Sedges, & Rushes Native to Philadelphia County (brochure)												
	Website: U.S. Department of Agriculture, Natural Resources Conservation Service: PLANTS Database http://plants.usda.gov/												
	Website: The Kemper Center for Home Gardening: PlantFinder http://www.mobot.org/gardeninghelp/plantfinder/Alpha.asp												
	Website: Plants of the North: http://www.rook.org/earl/bwca/nature/flora.html												
	Website: NC State University Plant Factsheets http://www.ces.ncsu.edu/depts/hort/consumer/factsheets/index.html												
	Website: University of Connectict Plant Database http://www.hort.uconn.edu/plants/index.html												
	Website: USDA Forest Service: Silvics of North America http://www.na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm												

8.4 Prohibited Non-native and Invasive Plants

Invasive non-native plants reproduce rapidly, degrade and take over natural ecosystems and have few, if any natural controls to keep them in check. Brought in to new areas by people for a specific purpose or by accident these species have characteristics that allow them to grow out of control and usually favor disturbed sites like areas of new construction. Under no circumstance should they be planted in a SMP. Because of appealing characteristics, some of these plants are available for sale and care should be taken not to purchase them. Additionally, the ability to identify and remove them before they can establish themselves is important as they almost always invade due to their gregarious reproductive strategies. They can be especially hard to get rid of once they take hold. Table 3 lists common invaders for the Mid-Atlantic region.

Table 8.3: Common Invasive Species of the Mid-Atlantic Region

Type	Latin Name	Common Name	Availability
forb	*Hemerocallis fulva*	Common daylily	commercially available
forb	*Alliaria petiolata*	Garlic mustard	
forb	*Polygonum cuspidatum*	Japanese knotweed	
forb	*Ranunculs ficaria*	Lesser celadine	
forb	*Lythrum salicaria*	Purple loosetrife	
forb	*Cirsium arvense*	Canada thistle	
forb	*Lespedeza cuneata*	Chinese lespedeza	
forb	*Heracleum mantegazzianum*	Giant hogweed	
forb	*Murdannia keisak*	Marsh dewflower	
forb	*Centaurea biebersteinii*	Spotted knapweed	
grass	*Bambusa, Phyllostachys, Pseudosassa*	Bamboo	commercially available
grass	*Microstegium vimineum*	Japanese stiltgrass	
grass	*Miscanthus sinensis*	Chinese silvergrass	
grass-like	*Phragmites australis*	Common reed	
grass-like	*Arundo donax*	Giant reed- wild cane	
shrub	*Berberis thunbergii*	Japanese barberry	commercially available
shrub	*Ligustrum spp.*	Privets	commercially available
shrub	*Euonymus alata*	Winged burning bush	commercially available
shrub	*Buddleja davidii*	Butterfly bush	commercially available
shrub	*Spiraea japonica*	Japanese spiraea - Japanese meadowsweet	commercially available
shrub	*Elaeagnus umbellata*	Autumn olive	
shrub	*Lonicera spp.*	Bush honeysuckles	commercially available
shrub	*Rosa multiflora*	Mulitflora rose	
shrub	*Rubus phoenicolasius*	Wineberry	
shrub	*Rhodotypos scandens*	Jetbead	
Tree	*Pyrus calleryana 'Bradford'*	Bradford pear	commercially available
Tree	*Acer platanoides*	Norway maple	commercially available
Tree	*Quercus acutissima*	Sawtooth oak	commercially available
Tree	*Paulownia tomentosa*	Princess tree	
Tree	*Ailanthus altissima*	Tree of Heaven	
Tree	*Albizia julibrissin*	Silk tree - mimosa tree	commercially available
Tree	*Broussonetia papyrifera*	Paper mulberry	
Tree	*Morus alba*	White mulberry	
Vine	*Hedera helix*	English Ivy	commercially available
Vine	*Wisteria sinensis, W. floribunda*	Wisteria, exotic	commercially available
Vine	*Eunonymus fortunei*	Creeping euonymus	commercially available
Vine	*Lonicera japonica*	Japanese honeysuckle	commercially available

Table 8.3: Common Invasive Species of the Mid-Atlantic Region (continued)			
Type	**Latin Name**	**Common Name**	**Availability**
Vine	*Pueraria montana v. lobata*	Kudzu	
Vine	*Polygonum perfoliatum*	Mile-a-minute	
Vine	*Celastrus orbiculatus*	Oriental bittersweet	
Vine	*Ampelopsis brevipedunculata*	Porcelain berry	commercially available
Vine	*Akebia quinata*	Five-leaved akebia	
Vine	*Cynanchum louiseae*	Louis' swallowwort	

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Appendices

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A

Hotspot Investigation Procedures

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Appendix A: Hotspot Investigation Procedures

A.1 Justification

This policy is intended to encourage infiltration on most sites while addressing potential contamination of groundwater and surface water caused by infiltration on sites with contaminated soils.

A.2 Required Steps

Step 1: Determine the prior land use at the site to be developed, and review any data on soil or groundwater quality.

- For larger development sites, a formal Phase I site assessment is often required by the lender in order to determine if any environmental hazard exists on the site. A determination of prior land use is part of this assessment.

- On sites where a formal Phase I is not conducted, methods to determine prior land use may include a title search, aerial photographs, soil surveys, topographic maps, city and state regulatory databases, and a review of state and local records.

Step 2: Determine the potential for contamination based on available data and prior land use.

- The following land uses are considered to have a potential for contaminated soil which may adversely affect the quality of groundwater discharging to surface water. Infiltration is prohibited on these site unless the applicant can show that there is no potential for contaminant migration due to infiltration.

    - Sites designated as CERCLA (Superfund) sites
    - Auto recycler facilities and junk yards
    - Commercial laundry and dry cleaning
    - Commercial nurseries
    - Vehicle fueling stations, service and maintenance areas
    - Toxic chemical manufacturing and storage
    - Petroleum storage and refining
    - Public works storage areas
    - Airports and deicing facilities, railroads and rail yards, marinas and ports
    - Heavy manufacturing and power generation
    - Metal production, plating and engraving operations
    - Landfills and hazardous waste material disposal
    - Sites on subsurface material such as fly ash known to contain mobile heavy metals and toxins

- Perform due diligence to determine whether any contamination is present on-site if the site has a history of hotspot usage. It is not sufficient to rule out infiltration based on historical site uses alone. Testing must be performed to determine whether the site is contaminated and in what areas any contamination is concentrated. Even if the site is contaminated, infiltration may still be feasible. Contamination should be evaluated per PADEP guidelines, including, but not limited to, comparing MSC levels, evaluating contaminant solubility, and conducting SPLP testing.

Step 3:

For sites that do not qualify as hotspots, proceed with design of infiltration facilities for Water Quality, including pre-treatment.

For sites that qualify as hotspots, determination of infiltration feasibility is still required. An infiltration waiver can be requested if sufficient proof of soil contamination is provided based on soil sampling results. If an infiltration waiver is requested due to contamination, environmental reports for any testing completed, as well as a justification letter from the geotechnical engineer or environmental professional, must be submitted, as well. If appropriate justification that contamination will preclude the site from infiltration is provided, an impervious liner must be incorporated into the site's basin design.

B

Soil Infiltration Testing Procedures

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Appendix B: Soil Infiltration Testing Procedures

B.1 Justification

This policy is intended to provide standard methods for use in determining the infiltration rate of liquid into soils.

B.2 Required Steps

Designers are required to use the soil infiltration testing procedures described by American Standard Testing Methods (ASTM) in their “Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer” or as set forth by the Pennsylvania Stormwater Best Management Practices Manual.

B.3 Summary of Acceptable Soil Infiltration Testing

The purpose of **Appendix B** is to provide potential field infiltration testing methods to be utilized for the design of infiltration facilities. In an effort to maintain congruency between the Pennsylvania Department of Environmental Protection (PADEP) and the Philadelphia Water Department (PWD) regarding stormwater/infiltration practices, **Appendix C**: Site Evaluation and Soil Testing of the Pennsylvania Stormwater Management Manual has been attached and is incorporated into this document.

There are a variety of field tests available to determine the design field infiltration rate at a given site. This Appendix outlines the procedures to perform two methods of infiltration: Double-Ring Infiltrometers and Percolation Tests.

A double-ring infiltrometer test estimates the vertical movement of water through the bottom of the test area, while a percolation test allows water movement through both the bottom and sides of the test area. As such, double-ring infiltrometer tests are considered to more accurately model the potential infiltration capacity of a soil. However, it is understood that for a large site with multiple test locations, double-ring infiltrometer tests can be cost prohibitive.

Key points for the two methods are summarized below.

Double-Ring Infiltrometer

- Double-Ring infiltrometer testing methodology is provided in ASTM D 3385.
- Two concentric metal rings are driven into the ground and filled with water. The outer ring helps to reduce lateral movement of water in the soil while the inner ring is used to calculate an infiltration rate.
- Test holes must be presoaked immediately prior to testing. The presoaking procedure is intended to simulate saturated conditions in the environment and to minimize the influence of unsaturated flow.
- The test must be performed for at least 6 hours or a length of time adequate for the infiltration rate to stabilize.
- It is strongly advised that a double-ring infiltration test be performed instead of a percolation test for proposed infiltration basins.

Percolation Tests

- Percolation test methodology is based on the criteria written in Chapter 73 of the Pennsylvania Code. The procedure is also included in the Pennsylvania Stormwater Manual included with this Appendix.

- A percolation test allows water movement through both the bottom and sides of the test area. Percolation tests are generally utilized in areas where both horizontal and vertical infiltration is expected.

- Percolation tests carried out betwen June 1 and December 31 should use a 24 hour presoaking before the testing.

- All test holes should be presoaked immediately prior to testing. The presoaking procedure is intended to simulate saturated conditions in the environment and to minimize the influence of unsaturated flow.

- The test infiltration rate from a percolation test is obtained by dividing the percolation rate by the appropriate reduction factor. This calculation is explained in detail in the following section.

Generally, a minimum of two tests should be performed per infiltration area. At least one test should be conducted within 1 foot of the proposed bottom elevation of an infiltration SMP. More tests may be warranted if the results for the first two tests are substantially different. The highest infiltration rate from the test results should be discarded when more than two are employed for design purposes. The geometric mean should be used to determine the average rate following multiple tests.

Soils underlying infiltration practices must have a tested infiltration rate between 0.5 and 10 inches per hour. Infiltration is to be considered infeasible in soils with tested infiltration rates of less than 0.5 inches per hour.

Soils with tested infiltration rates in excess of 10 inches per hour will require soil amendments. Upon achieving final subgrade elevations, a 2-foot thick layer of amended soil must be placed across the entire cross-section of the infiltrating SMP, below the bottom elevation of the SMP, and a minimum of two infiltration tests must be performed within the amended soil layer. The procedure utilized must be the double-ring infiltrometer test, and it must be in compliance with the current Philadelphia Stormwater Management Guidance Manual. The engineer must provide a signed and sealed infiltration testing report with a testing location plan and summary of results. All information must be submitted to PWD for review and approval before proceeding with construction. If soil amendments are installed and the tested infiltration rate is determined to be outside of the PWD-allowable range of 0.5 to 10 inches per hour or varies significantly from the design infiltration rate, additional soil amendments and/or a system redesign will be required.

The presence of massive rock in relatively close proximity to the point of infiltration may result in lateral, as opposed to vertical infiltration if the rock is not sufficiently jointed and/or fissured to infiltrate. This can potentially result in water migrating and then reappearing at topographic low areas. Therefore, if rock is present within 5 feet of the proposed base of the infiltration basin, the designer must provide adequate information to document that the water is infiltrating vertically and not traveling laterally along the top of rock surface.

Other testing procedures may be used if site conditions make double-ring infiltrometer and percolations tests infeasible. In such cases, a waiver requesting approval of an alternate testing procedure must be submitted. It is recommended that this waiver be submitted before the testing is performed. Refer to the Technical Library at http://www.pwdplanreview.org/ for the most recent waiver forms.

Pennsylvania Stormwater Best Management Practices Manual

Appendix C – Site Evaluation and Soil Testing

Protocol 1
Site Evaluation and Soil Infiltration Testing

A. Purpose of this Protocol

The purpose of the *Site Evaluation and Soil Infiltration Testing Protocol* is to describe evaluation and field testing procedures to:

a. Determine if Infiltration BMPs are suitable at a site, and at what locations.
b. Obtain the required data for infiltration BMP design.

B. When to Conduct Testing

Designers are encouraged to conduct the Soil Evaluation and Investigation early in the site planning and design process. The Site Development process outlined in Chapters 4 and 5 of this Manual describe a process for site development and BMPs. Soil Evaluation and Investigation should be conducted early in the preliminary design of the project so that information developed in the testing process can be incorporated into the design. Adjustments to the design can be made as necessary. It is recommended that Soil Evaluation and Investigation be conducted following the development of an early Preliminary Plan. The Designer should possess a preliminary understanding of potential BMP locations prior to testing. Prescreening test may be carried out in advance to site potential BMP locations.

C. Who Should Conduct Testing

Qualified professionals who can substantiate by qualifications/experience their ability carry out the evaluation should conduct test pit soil evaluations. A professional, experienced in observing and evaluating soils conditions is necessary to ascertain conditions that might affect BMP performance, which can not be thoroughly assessed with the testing procedures. Such professionals must conduct these evaluations in risk areas, or areas indicated in the guidance as non-preferred locations for testing or BMP implementation.

D. Importance of Stormwater BMP Areas

Sites are often defined as unsuitable for Infiltration BMPs and soil based BMPs due to proposed grade changes (excessive cut or fill) or lack of suitable areas. Many sites will be constrained and unsuitable for infiltration BMPs. However, if suitable areas exist, these areas should be identified early in the design process and should not be subject to a building program that precludes infiltration BMPs. An exemption should not be provided for "full build-outs" where suitable soils otherwise exist for infiltration.

E. Safety

As with all field work and testing, attention should be given to all applicable OSHA regulations and local guidelines related to earthwork and excavation. Digging and excavation should never be conducted without adequate notification through the Pennsylvania One Call system (**PA OneCall** 1-800-242-1776 or www.paonecall.org). Excavations should never be left unsecured and unmarked, and all applicable authorities should be notified prior to any work.

INFILTRATION TESTING: A MULTI-STEP PROCESS

Infiltration Testing is a four-step process to obtain the necessary data for the design of the stormwater management plan. The four steps include:

1. Background Evaluation
    - Based on available published and site specific data
    - Includes consideration of proposed development plan
    - Used to identify potential BMP locations and testing locations
    - Prior to field work (desktop)
    - On-site screening test
2. Test Pit (Deep Hole) Observation
    - Includes Multiple Testing Locations
    - Provides an understanding of sub-surface conditions
    - Identifies limiting conditions
3. Infiltration Testing
    - Must be conducted on-site
    - Different testing methods available
    - Alternate methods for - additional-Screening and Verification testing
4. Design Considerations
    - Determination of a suitable infiltration rate for design calculations
    - Consideration of BMP drawdown
    - Consideration of peak rate attenuation

Step 1. Background Evaluation

Prior to performing testing and developing a detailed site plan, existing conditions at the site should be inventoried and mapped including, but not limited to:

- Existing mapped individual soils and USDA Hydrologic Soil Group classifications.
- Existing geology, including the location of any dikes, faults, fracture traces, solution cavities, landslide prone strata, or other features of note.
- Existing streams (perennial and intermittent, including intermittent swales), water bodies, wetlands, hydric soils, floodplains, alluvial soils, stream classifications, headwaters and 1st order streams.
- Existing topography, slope, and drainage patterns.
- Existing and previous land uses.
- Other natural or man-made features or conditions that may impact design, such as past uses of site, existing nearby structures (buildings, walls), etc.

A sketch plan or preliminary layout plan for development should be evaluated, including:

- The preliminary grading plan and areas of cut and fill.
- The location and water surface elevation of all existing and location of proposed water supply sources and wells.
- The location of all existing and proposed on-site wastewater systems.
- The location of other features of note such as utility right-of-ways, water and sewer lines, etc.
- Existing data such as structural borings, drillings, and geophysical testing.

- The proposed location of development features (buildings, roads, utilities, walls, etc.). In Step 1, the Designer should determine the potential location of infiltration BMPs. The approximate location of these BMPs should be located on the proposed development plan and should serve as the basis for the location and number of tests to be performed on-site.

Important: If the proposed development program is located on areas that may otherwise be suitable for BMP location, or if the proposed grading plan is such that potential BMP locations are eliminated, the Designer is *strongly* encouraged to revisit the proposed layout and grading plan and adjust the development plan as necessary. Full build-out of areas suitable for infiltration BMPs should *not* preclude the use of BMPs for volume reduction and groundwater recharge.

Step 2. Test Pits (Deep Holes)

A Test Pit (Deep Hole) allows visual observation of the soil horizons and overall soil conditions both horizontally and vertically in that portion of the site. An extensive number of Test Pit observations can be made across a site at a relatively low cost and in a short time period. The use of soil borings as a substitute for Test Pits strongly is discouraged, as visual observation is narrowly limited in a soil boring and the soil horizons cannot be observed in-situ, but must be observed from the extracted borings. Borings and other procedures, however, might be suitable for initial screening to develop a preliminary plan for testing, or verification testing.

A Test Pit consists of a backhoe-excavated trench, 2-1/2 to 3 feet wide, to a depth of between 72 inches and 90 inches, or until bedrock or fully saturated conditions are encountered. The trench should be benched at a depth of 2-3 feet for access and/or infiltration testing.

At each Test Pit, the following conditions shall be noted and described. Depth measurements should be described as depth below the ground surface:

___ Soil Horizons (upper and lower boundary)

___ Soil Texture and Color for each horizon

___ Color Patterns (mottling) and observed depth

___ Depth to Water Table

___ Depth to Bedrock

___ Observance of Pores or Roots (size, depth)

___ Estimated Type and Percent Coarse Fragments

___ Hardpan or Limiting Layers

___ Strike and dip of horizons (especially lateral direction of flow at limiting layers)

___ Additional comments or observations

The Sample Soil Log Form at the end of this protocol may be used for documentation of each Test Pit.

At the Designer's discretion, soil samples may be collected at various horizons for additional analysis. Following testing, the test pits should be refilled with the original soil and the surface replaced with the original topsoil. A Test Pit should *never* be accessed if soil conditions are unsuitable for safe entry, or if site constraints preclude entry. OSHA regulations should always be observed.

It is important that the Test Pit provide information related to conditions at the bottom of the proposed Infiltration BMP. If the BMP depth will be greater than 90 inches below existing grade, deeper excavation will be required. However, *such depths are discouraged, especially in Karst topography.* Except for surface discharge BMPs (filter strips, etc.) the designer is cautioned regarding the proposal of systems that are significantly lower than the existing topography. The suitability for infiltration may decrease, and risk factors are likely to increase. *Locations that are not preferred* for testing *and* subsurface infiltration BMPs include swales, the toe of slopes for most sites, and soil mantels of less than three feet in Karst topography.

The designer and contractors should reducing grading and earthwork as needed to reduce site disturbance and compaction so that a greater opportunity exists for testing and stormwater management.

The number of Test Pits varies depending on site conditions and the proposed development plan. General guidelines are as follows:

- For single-family residential subdivisions with on-lot BMPs, one test pit per lot is recommended, preferably within 25 feet of the proposed BMP area. Verification testing should take place when BMPs are sited at greater distances.
- For multi-family and high density residential developments, one test pit per BMP area or acre is recommended.
- For large infiltration areas (basins, commercial, institutional, industrial, and other proposed land uses), multiple test pits should be evenly distributed at the rate of four (4) to six (6) tests per acre of BMP area.

The recommendations above are guidelines. Additional tests should be conducted if local conditions indicate significant variability in soil types, geology, water table levels, bedrock, topography, etc. Similarly, uniform site conditions may indicate that fewer test pits are required. Excessive testing and disturbance of the site prior to construction is not recommended.

Step 3. Infiltration Tests/Permeability Tests

A variety of field tests exist for determining the infiltration capacity of a soil. Laboratory tests are strongly discouraged, as a homogeneous laboratory sample does not represent field conditions. Infiltration tests should be conducted in the field. Tests should not be conducted in the rain or within 24 hours of significant rainfall events (>0.5 inches), or when the temperature is below

freezing. However, the preferred testing *is* between January and June, the wet season. This is the period when infiltration is likely to be diminished by saturated conditions. Percolation tests carried out between June 1 and December 31 should use a 24 hour presoaking before the testing. This procedure is not required for Infiltrometer testing, or permeometer testing

At least one test should be conducted at the proposed bottom elevation of an infiltration BMP, and a minimum of two tests per Test Pit is recommended. More tests may be warranted if the results for first two tests are substantially different. The highest rate (inches/hour) for test results should be discarded when more than two are employed for design purposes. The geometric mean should be used to determine the average rate following multiple tests.

Based on observed field conditions, the Designer may elect to modify the proposed bottom elevation of a BMP. Personnel conducting Infiltration Tests should be prepared to adjust test locations and depths depending upon observed conditions.

Methodologies discussed in this protocol include:

- Double-ring Infiltrometer tests.
- Percolation tests (such as for on-site wastewater systems and described in Pa Code Chapter 73).

There are differences between the two methods. A Double-ring Infiltrometer test estimates the vertical movement of water through the bottom of the test area. The outer ring helps to reduce the lateral movement of water in the soil. A percolation test allows water movement through both the bottom and sides of the test area. For this reason, the measured rate of water level drop in a percolation test must be adjusted to represent the discharge that is occurring on both the bottom and sides of the percolation test hole.

For *infiltration basins*, it is *strongly* advised that an Infiltration Test be carried out with an infiltrometer (not percolation test) to determine the saturated hydraulic conductivity rate. This precaution is taken to account for the fact that only the surface of the basin functions to infiltrate, as measured by the test. Alternatively, permeability test procedures that yield a saturated hydraulic conductivity rate can be used (see formulas developed by Elrick and Reynolds (1992), or others for computation of hydraulic conductivity and saturated hydraulic conductivity).

Other testing methodologies and standards that are available but not discussed in detail in this protocol include (but are not limited to):

- Constant head double-ring infiltrometer
- Testing as described in the Maryland Stormwater Manual Appendix D.1 using 5-inch diameter casing.
- ASTM 2003 Volume 4.08, Soil and Rock (I): Designation D 3385-03, Standard Test Method for Infiltration Rate of Soils in Field Using a Double-Ring Infiltrometer.
- ASTM 2002 Volume 4.09, Soil and Rock (II): Designation D 5093-90, Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring.
- Guelph Permeameter
- Constant Head Permeameter (Amoozemeter)

a. Methodology for Double-Ring Infiltrometer Field Test

A Double-ring Infiltrometer consists of two concentric metal rings. The rings are driven into the ground and filled with water. The outer ring helps to prevent divergent flow. The drop in water level or volume in the inner ring is used to calculate an infiltration rate. The infiltration rate is determined as the amount of water per surface area and time unit that penetrates the soils. The diameter of the inner ring should be approximately 50% to 70% of the diameter of the outer ring, with a minimum inner ring size of 4-inches, preferably much larger. (Bouwer, 1986). Double-ring infiltrometer testing equipment that is designed specifically for that purpose may be purchased. However, field testing for stormwater BMP design may also be conducted with readily available materials.

Equipment for Double-Ring Infiltrometer Test:

___ Two concentric cylinder rings 6-inches or greater in height. Inner ring diameter equal to 50% - 70% of outer ring diameter (i.e., an 8-inch ring and a 12-inch ring). Material typically available at a hardware store may be acceptable.

___ Water supply

___ Stopwatch or timer

___ Ruler or metal measuring tape

___ Flat wooden board for driving cylinders uniformly into soil

___ Rubber mallet

___ Log sheets for recording data

Procedure for Double-Ring Infiltrometer Test

___ Prepare level testing area.

___ Place outer ring in place; place flat board on ring and drive ring into soil to a minimum depth of two inches.

___ Place inner ring in center of outer ring; place flat board on ring and drive ring into soil a minimum of two inches. The bottom rim of both rings should be at the same level.

___ The test area should be presoaked immediately prior to testing. Fill both rings with water to water level indicator mark or rim at 30 minute intervals for 1 hour. The minimum water depth should be 4-inches. The drop in the water level during the

last 30 minutes of the presoaking period should be applied to the following standard to determine the time interval between readings:

- If water level drop is 2-inches or more, use 10-minute measurement intervals.
- If water level drop is less than 2-inches, use 30-minute measurement intervals.

___ Obtain a reading of the drop in water level in the center ring at appropriate time intervals. After each reading, refill both rings to water level indicator mark or rim. Measurement to the water level in the center ring shall be made from a fixed reference point and shall continue at the interval determined until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of 1/4 inch or less of drop between the highest and lowest readings of four consecutive readings.

___ The drop that occurs in the center ring during the final period or the average stabilized rate, expressed as inches per hour, shall represent the infiltration rate for that test location.

b. Methodology for Percolation Test

Equipment for Percolation Test:

___ Post hole digger or auger

___ Water supply

___ Stopwatch or timer

___ Ruler or metal measuring tape

___ Log sheets for recording data

___ Knife blade or sharp-pointed instrument (for soil scarification)

___ Course sand or fine gravel

___ Object for fixed-reference point during measurement (nail, toothpick, etc.)

Procedure for Percolation Test

This percolation test methodology is based largely on the Pennsylvania Department of Environmental Protection (PADEP) criteria for on-site sewage investigation of soils (as described in Chapter 73 of the Pennsylvania Code). This should include the 24 hour presoak procedure between June 1 and December 31. The presoak is done primarily to simulate saturated conditions in the environment (generally Spring) and to minimize the influence of

unsaturated flow. If a presoak procedure is not employed between June1 and December 31, than the rate reduction formula described by Elrick and Reynolds (1992), or Fritton, et.,al. (1986) is recommended to account for the influence of unsaturated conditions in the test.

Prepare level testing area.

___ Prepare hole having a uniform diameter of 6 to 10 inches and a depth of 8 to 12-inches. The bottom and sides of the hole should be scarified with a knife blade or sharp-pointed instrument to completely remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Loose material should be removed from the hole.

___ (Optional) two inches of coarse sand or fine gravel may be placed in the bottom of the hole to protect the soil from scouring and clogging of the pores.

___ Test holes should be presoaked immediately prior to testing. Water should be placed in the hole to a minimum depth of 6 inches over the bottom and readjusted every 30 minutes for 1 hour.

___ The drop in the water level during the last 30 minutes of the final presoaking period should be applied to the following standard to determine the time interval between readings for each percolation hole:

- If water remains in the hole, the interval for readings during the percolation test should be 30 minutes.
- If no water remains in the hole, the interval for readings during the percolation test may be reduced to 10 minutes.

___ After the final presoaking period, water in the hole should again be adjusted to a minimum depth of 6-inches and readjusted when necessary after each reading. A nail or marker should be placed at a fixed reference point to indicate the water refill level. The water level depth and hole diameter should be recorded.

___ Measurement to the water level in the individual percolation holes should be made from a fixed reference point and should continue at the interval determined from the previous step for each individual percolation hole until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of 1/4 inch or less of drop between the highest and lowest readings of four consecutive readings.

___ The drop that occurs in the percolation hole during the final period, expressed as inches per hour, shall represent the percolation rate for that test location.

___ The average measured rate must be adjusted to account for the discharge of water from both the sides and bottom of the hole and to develop a representative infiltration rate. The average/final percolation rate should be adjusted for each percolation test according to the following formula:

Infiltration Rate = (Percolation Rate) / (Reduction Factor)

Where the Reduction Factor is given by**:

$$R_f = \frac{2d_1 - \Delta d}{DIA} + 1$$

With:

d_1	=	Initial Water Depth (in.)
Δd	=	Average/Final Water Level Drop (in.)
DIA	=	Diameter of the Percolation Hole (in.)

The Percolation Rate is simply divided by the Reduction Factor as calculated above or shown in the table below to yield the representative Infiltration Rate. In most cases, the Reduction Factor varies from about 2 to 4 depending on the percolation hole dimensions and water level drop – wider and shallower tests have lower Reduction Factors because proportionately less water exfiltrates through the sides. For design purposes additional safety factors are employed (see Protocol 2, Infiltration Systems Design and Construction Guidelines)

*** The area Reduction Factor accounts for the exfiltration occurring through the sides of percolation hole. It assumes that the percolation rate is affected by the depth of water in the hole and that the percolating surface of the hole is in uniform soil. If there are significant problems with either of these assumptions then other adjustments may be necessary.*

Table 1. Sample Percolation Rate Adjustments

Perc. Hole Diameter, DIA (in.)	Initial Water Depth, d_1 (in.)	Ave./Final Water Level Drop, Δd (in.)	Reduction Factor, $\mathbf{R_f}$
6	**6**	0.1	3.0
		0.5	2.9
		2.5	2.6
	8	0.1	3.7
		0.5	3.6
		2.5	3.3
	10	0.1	4.3
		0.5	4.3
		2.5	3.9
8	**6**	0.1	2.5
		0.5	2.4
		2.5	2.2
	8	0.1	3.0
		0.5	2.9
		2.5	2.7
	10	0.1	3.5
		0.5	3.4
		2.5	3.2
10	**6**	0.1	2.2
		0.5	2.2
		2.5	2.0
	8	0.1	2.6
		0.5	2.6
		2.5	2.4
	10	0.1	3.0
		0.5	3.0
		2.5	2.8

Step 4. Design Considerations beginning with *Protocol 2 – Infiltration System Design and Construction Guidelines*

ADDITIONAL POSSIBLE TESTING - BULK DENSITY, OTHERS

Other testing methods are acceptable to assess a soil's suitability for infiltration for early screening and occasionally for verification. They can be especially helpful where consultants wish to cull out the better soils. Percolation testing can also be performed without presoaking as a *pre*-screening procedure.

Alternate tests or investigations can be used for verification. For instance, if the BMPs are not located precisely over the test locations, alternate testing or investigations can be used to verify that the soils are the same as the soils that yielded the earlier test results. However, consultants should document these verification test results or investigations. Professionals with substantiated qualifications should carry out verification procedures.

Bulk Density Tests measure the level of compaction of a soil, which is an indicator of a soils' ability to absorb rainfall. Developed and urbanized sites often have very high bulk densities and therefore possess limited ability to absorb rainfall (and have high rates of stormwater runoff). Vegetative and soil improvement programs can improve, (i.e. lower), the soil bulk density and improve the site's ability to absorb rainfall and reduce runoff.

Macropores occur primarily in the upper soil horizons and are formed by plant roots (both living and decaying), soil fauna such as insects, the weathering processes caused by the movement of water, the freeze-thaw cycle, soil shrinkage due to desiccation of clays, chemical processes, and other mechanisms. These macropores provide an important mechanism for infiltration prior to development, extending vertically and horizontally for considerable distances. It is the intent of good engineering and design practice to maintain these macropores in the installation of Infiltration BMPs as much as possible. Bulk Density Tests can help determine the relative compaction of soils before and after site disturbance and/or restoration and should be used at the discretion of the designer/reviewer.

Various procedures are available to conduct bulk density tests. The density measurements should be carried out in conjunction with a soil texture analysis. Sandy soils infiltrate well, but tend to have a somewhat higher bulk density than finer soils. Experienced personnel can do the texture analysis manually on site.

Sample Soil Log

Tested by: ____________

Test Pit: ____________ Date: ____________ Elevation: ____________ Equipment Used: ____________

Geology: ____________ Soil Type: ____________ Land Use: ____________ Weather: ____________

Additional comments: ________________________

Horizon	Upper Boundary	Lower Boundary	Soil Textural Class	Type, Size, Coarse Fragments, etc.	Soil Color	Color Patterns	Pores, Roots, Rock Structure	Depth to Bedrock	Depth to Water	Comments

Protocol 2
Infiltration Systems Design and Construction Guidelines

Role of Infiltration BMPs

The phrase “infiltration BMPs” describes a wide range of stormwater management practices aimed at infiltrating some fraction of stormwater runoff from developed surfaces into the soil horizon and eventually into deeper groundwater. In this manual the major infiltration strategies are grouped into four categories or types, based on construction and performance similarities:

- Surface Infiltration Basins
- Subsurface Infiltration Beds
- Bioretention Areas/Rain Gardens
- Other BMPs that support infiltration (vegetated filter/buffer strips, level spreaders, and vegetated swales)

Infiltration BMPs are one of the most beneficial approaches to stormwater management for a variety of reasons including:

- Reduction of the peak rate of runoff
- Reduction of the volume of runoff
- Removal of a significant portion of the particulate-associated pollutants and some portion of the solute pollutants.
- Recharge of groundwater and maintenance of stream baseflow.

Infiltration BMPs attempt to replicate the natural hydrologic regime. During periods of rainfall, infiltration BMPs reduce the volume of runoff and help to mitigate potential flooding events. During periods of reduced rainfall, this recharged water serves to provide baseflow to streams and maintain in-stream water quality. Qualitatively, infiltration BMPs are known to remove nonpoint source pollutants from runoff through a complex mix of physical, chemical, and biological removal processes. Infiltration promotes maintenance of the natural temperature regimes of stream systems (cooler in summer, warmer in winter), which can be critical to the aquatic ecology. Because of the ability of infiltration BMPs to reduce the volume of runoff, there is also a corresponding reduction in erosive “bankfull” conditions and downstream erosion and channel morphology changes.

Infiltration BMPs are designed to infiltrate some portion of runoff during every runoff event. During small storm events, a large percentage of the runoff may infiltrate, whereas during large storm events, the volume that infiltrates may only be a small portion of the total runoff. However, because most of the rainfall in Pennsylvania occurs in small (less than 1-inch) rainfalls, the annual benefits of an infiltration system may be significant.

Purpose of Protocol 2: Infiltration Systems Guidelines
The purpose of this protocol is to provide the designer with specific guidelines for the successful construction and long-term performance of Infiltration BMPs. These guidelines fall into three categories:

1. Site conditions and constraints
2. Design considerations
3. Construction requirements

All of these guidelines are important, and successful infiltration is dependent on careful consideration of site conditions, careful design, and careful construction.

1. SITE CONDITIONS and CONSTRAINTS

a) It is desirable to **maintain a 2-foot clearance above regularly occurring seasonally high water table**. This reduces the likelihood that temporary groundwater mounding will affect the system, and allows sufficient distance of water movement through the soil to allow adequate pollutant removal. Some minor exceptions for very shallow systems and on grade systems, filter strips, buffers, etc.

b) **Maintain a minimum depth to bedrock of 2-feet to assure adequate pollutant removal**. In special circumstances, filter media may be employed to remove pollutants if adequate soil mantle does not exist.

c) It is desired that **soils underlying infiltration devices should have infiltration rates between 0.1 and 10 inches per hour**, which in most development programs should result in reasonably sized infiltration systems. Where soil permeability is extremely low, infiltration may still be possible but the surface area required could be large, and other volume reduction methods may be warranted. Undisturbed Hydrologic Soil Groups B and C often fall within this range and cover most of the state. Soils with rates in excess of 6.0 inches per hour may require an additional soil buffer (such as an organic layer over the bed bottom) if the Cation Exchange Capacity (CEC) is less than 5 and pollutant loading is expected to be significant. In carbonate soils, excessively rapid drainage may increase the risk of sinkhole formation, and some compaction or additional soil may be appropriate.

d) **Infiltration BMPs should be sited so that any risk to groundwater quality is minimized**, at least 50 feet from individual water supply wells, and 100 feet from community or municipal water supply wells. Horizontal separation distances or buffers may also be appropriate from Special Geologic Features, such as fractures traces and faults, depending on water supply sources.

e) **Infiltration BMPs should be sited so that they present no threat to sub-surface structures**, at least 10 feet down gradient or 100 feet up gradient from building basement foundations, and 50 feet from septic system drain fields unless specific circumstances allow for reduced separation distances.

In general, soils of Hydrologic Soil Group D will not be suitable for infiltration. Similarly, areas of floodplains and areas of close proximity to wetlands and streams will generally not be suitable

for infiltration (due to high water table and/or low permeability). In developing areas that were previously used for agricultural purposes, the designer should consider the past patterns of land use. Areas that were suitable for cultivation will likely be suitable for some level of infiltration. Areas that were left out of cultivation often indicate locations that are too wet or too rocky, and will likely not be suitable for infiltration.

2. DESIGN CONSIDERATIONS

a) **Do Not Infiltrate in Compacted Fill.** Infiltration in native soil without prior fill or disturbance is preferred but not always possible**.** Areas that have experienced historic disturbance or fill are suitable for infiltration provided sufficient time has elapsed and the Soil Testing indicates the infiltration is feasible. In disturbed areas it may be necessary to infiltrate at a depth that is beneath soils that have previously been compacted by construction methods or long periods of mowing, often 18-inches.

b) **A Level Infiltration Area (1% or less slope) is preferred.** Bed bottoms should always be graded into the existing soil mantle, with terracing as required to construct flat structures. Sloped bottoms tend to pool and concentrate water in small areas, reducing the overall rate of infiltration and longevity of the BMP. Infiltration areas should be flat, nearly so, or on contour.

c) **The soil mantle should be preserved to the maximum extent possible**, and excavation should be minimized. Those soils that do not need to be disturbed for the building program should be left undisturbed. Macropores can provide a significant mechanism for water movement in infiltration systems, and the extent of macropores often decreases with depth. Maximizing the soil mantle also increases the pollutant removal capacity and reduces concerns about groundwater mounding. Therefore, excessive excavation for the construction of infiltration systems is strongly discouraged.

d) **Isolate “hot spot areas”**. Site plans that include ‘hot spots’ need to be considered. ‘Hot spots’ are most often associated with some industrial uses and high traffic – gasoline stations, vehicle maintenance areas, and high intensity commercial uses (fast food restaurants, convenience stores, etc.). These “hot spots” are defined in Section 3.3, Stormwater Standards for Special Areas. Infiltration may occur in areas of hot spots provided pretreatment is suitable to address concerns. Pretreatment requirements need to be analyzed, especially for ‘hot spots’ and areas that produce high sediment loading. Pretreatment devices that operate effectively in conjunction with infiltration include grass swales, vegetated filter strips, settling chambers, oil/grit separators, constructed wetlands, sediment sumps, and water quality inserts. The pollutants of greatest concern, site by site, should guide selection of pretreatment depending upon the nature and extent of the land development under consideration. Selection of pretreatment techniques will vary depending upon whether the pollutants are of a particulate (sediment, phosphorus, metals, etc.) versus soluble (nitrogen and others) nature. Types of pretreatment (i.e., filters) should be matched with the nature of the pollutants expected to be generated.

e) **The Loading Ratio of impervious area to bed bottom area must be considered**. One of the more common reasons for infiltration system failure is the design of a system that attempts to infiltrate a substantial volume of water in a very small area. Infiltration

systems work best when the water is "spread out". The Loading Ratio describes the ratio of imperious drainage area to infiltration area, or the ratio of total drainage area to infiltration area. In general, the following Loading Ratio guidelines are recommended:

- Maximum Impervious Loading Ratio of 5:1 relating impervious drainage area to infiltration area.
- A Maximum Total Loading Ratio of 8:1 relating total drainage area to infiltration area.
- Maximum Impervious Loading Ratio of 3:1 relating impervious drainage area to infiltration area for Karst areas.

f) **The Hydraulic Head or Depth of Water should be limited**. The total effective depth of water should generally not be greater than two feet to avoid excessive pressure and potential sealing of the bed bottom. Typically the water depth is limited by the Loading Ratio and Drawdown Time and is not an issue.

g) **Drawdown Time must be considered**. In general, infiltration BMPs should be designed so that they completely empty within the time period specified in Chapter 3.

h) **All infiltration BMPs should be designed with a positive overflow** that discharges excess volume in a non-erosive manner, and allows for controlled discharge during extreme rainfall events or frozen bed conditions. Infiltration BMPs should never be closed systems dependent entirely upon infiltration in all situations.

i) **Geotextiles should be incorporated into the design as necessary in certain infiltration BMPs**. Infiltration BMPs that are subject to soil movement and deposition must be constructed with suitably well-draining non-woven geotextiles to prevent to movement of fines and sediment into the infiltration system. The designer is encouraged to err on the side of caution and use geotextiles as necessary at the soil/BMP interface.

j) Avoid severe slopes (>20%), and toes of slopes, where possible. Specific on-site investigations by experienced personnel need to be made to determined acceptability of each case.

3. CONSTRUCTION REQUIREMENTS

a) **Do not compact soil infiltration beds during construction**. Prohibit all heavy equipment from the infiltration area and <u>minimize</u> all other traffic. Equipment should be limited to vehicles that will cause the least compaction, such as tracked vehicles.

b) **Protect the infiltration area from sediment until the surrounding site is <u>completely</u> stabilized.** Methods to prevent sediment from washing into BMPs should be clearly shown on plans. Where geo-textile is used as a bed bottom liner, this should be extended several feet beyond the bed and folded over the edge to protect from sediment wash into the bed during construction, and then trimmed. Runoff from construction areas should never be allowed to drain to infiltration BMPs. This can usually be accomplished by diversion berms and immediate vegetative stabilization. The infiltration area may be used as a temporary sediment trap or basin during earlier stages of construction. However, if an infiltration area is also to be utilized as a temporary

sediment basin, excavation should be limited to within 1 foot of the final bottom invert of the infiltration BMP to prevent clogging and compacting the soil horizon, and final grade removed when the contributing site is fully stabilized. All infiltration BMPs should be finalized at the end of the construction process, when upstream soil areas have a dense vegetative cover.

c) **Provide thorough construction oversight.** Long-term performance of infiltration BMPs is dependent on the care taken during construction. Plans and specifications must be followed precisely. The designer is encouraged to meet with the contractor to review the plans and construction sequence prior to construction, and to inspect the construction at regular intervals and prior to final acceptance of the BMP.

d) **Provide Quality Control of Materials.** As with all BMPs, the final product is only as good as the materials and workmanship that went into it. The designer is encouraged to review and approve materials and workmanship, especially as related to aggregates, geotextiles, soil and topsoil, and vegetative materials.

BMP Effectiveness

Infiltration BMPs produce excellent pollutant removal effectiveness because of the combination of a variety of natural functions occurring within the soil mantle, complemented by existing vegetation (where this vegetation is preserved). Soil functions include physical filtering, chemical interactions (e.g., ion exchange, adsorption), as well as a variety of forms of biological processing, conversion, and uptake. The inclusion of native vegetation for filter strips, rain gardens, and some vegetated infiltration basins, reinforces the work of the soil by reducing velocity and erosive forces, soil anchoring, and further uptake of nonpoint source pollutants. In some cases the more difficult-to-remove soluble nitrates can be reduced as well. It should be noted that infiltration BMPs tend to be excellent for removal of many pollutants, especially those that are in particulate form; however, there are limitations to the removal of highly solubilized pollutants, such as nitrate, which can be transmitted through the soil.

In addition to the removal of chemical pollutants, infiltration can address thermal pollution. Maintaining natural temperatures in stream systems is recognized as an issue of increasing importance for protection of overall stream ecology. Detention facilities tend to discharge heated runoff flows. The return of runoff to the groundwater through use of infiltration BMPs guarantees that these waters will be returned at natural groundwater temperatures, considerably cooler than ambient air in summer and warmer in winter, so that seasonal extreme fluctuations in stream water temperature are minimized. Fish, macroinvertebrates, and a variety of other biota will benefit as the result.

Although precise data on pollutant removal efficiencies is somewhat limited, infiltration BMPs have been shown to have excellent efficiencies for a wide range of pollutants. In fact, recent EPA guidance has suggested that infiltration BMPs can be considered 100 percent effective at removing pollutants from surface water for the fraction of water that infiltrates (EPA, 1999a). Other more conservative removals are reported in a variety of other sources. Estimated removals for all BMPs are contained in Section 9.

Fate of Infiltrated Contaminants

The protection of groundwater quality is of utmost importance in any PA watershed. The potential to contaminate groundwater by infiltrating stormwater in properly designed and constructed BMPs with proper pretreatment is low, if come common sense rules are followed, as discussed above. Numerous studies have shown that stormwater infiltration BMPs have a minor risk of contaminating either groundwater or soil. Perhaps the most comprehensive research was conducted by the U.S. Environmental Protection Agency, summarized in "Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration" (Pitt et al., 1994). The publication presents a summary table that identifies the potential of pollutants to contaminate groundwater as either low, low/moderate, moderate, or high. Of the 25 physical pollutants listed, only one has a "high" potential (chloride), and only two have even "moderate" potential (fluoranthene and pyrene) for polluting groundwater through the use of shallow infiltration systems with some sediment pretreatment. While chloride can be found in significant quantities due to winter salting, relatively high concentrations are generally safe for both humans and aquatic biota (in fact, chloride is not even included in U.S. EPA's primary drinking water standards and the secondary standard concentration is given as 250 mg/L at http://www.epa.gov/safewater/mcl.html#mcls). Pentachlorophenol, cadmium, zinc, chromium, lead, and all the pesticides listed are classified as having a "low" contamination potential. Even nitrate which is soluble and mobile (discussed further below) is only given a "low/moderate" potential.

Legret et al. (1999) simulated the long term effects of heavy metals in infiltrating stormwater and concluded that the "long-term pollution risks for both soil and groundwater are low," and "metals are generally well retained in the upper layers of the soil (0-20 cm) [0-8 inches]…" Barraud et al. (1999) studied a thirty year-old infiltration BMP and found that both metal and hydrocarbon concentrations in the soil under the infiltration device decreased rapidly with depth "to a low level after a few decimeters down [3 decimeters = 1 foot]…" A study concerning the infiltration of highway runoff (Dierkes and Geiger, 1999) found that polycyclic aromatic hydrocarbons (PAH) were effectively removed in the upper 4 inches of the soil and that runoff that had passed through 14 inches of soil met drinking water standards for cadmium, zinc, and copper. This extremely high pollutant removal and retention capacity of soils is the result of a multitude of natural processes including physical filtering, ion exchange, adsorption, biological processing, conversion, and uptake.

Several studies have also found that porous pavement and stone-filled subsurface infiltration beds can significantly reduce the pollutant concentrations (especially hydrocarbons and heavy metals) of stormwater runoff before it even reaches the underlying soil due to adsorption, filtering, sedimentation, and bio-degradation by a diverse microbial community in the pavement and infiltration beds (Legret and Colandini, 1999; Balades et al., 1995; Swisher, 2002; Newman et al., 2002; and Pratt et al., 1999).

Common Causes of Infiltration BMP "Failures"

The concept of failure is simple – a design no longer provides the benefit or performance anticipated. With respect to stormwater infiltration BMPs, the term requires some qualification, since the net result of "failure" may be a reduction in the volume of runoff anticipated or the discharge of stormwater with excessive levels of some pollutants. Where the system includes built structures, such as porous pavements, failure may include loss of structural integrity for the wearing surface, whereas the infiltration function may continue uncompromised. For infiltration

systems with vegetated surfaces, such as play fields or rain gardens, failure may include the inability to support surface vegetation, caused by too much or too little water.

The primary causes of reduced performance appear to be:

a) Poor construction techniques, especially soil compaction/smearing, which results in significantly reduced infiltration rates.
b) A lack of site soil stabilization prior to the BMP receiving runoff, which greatly increases the potential for sediment clogging from contiguous land surfaces.
c) Inadequate pretreatment, especially of sediment-laden runoff, which can cause a gradual reduction of infiltration rates.
d) Lack of proper maintenance (erosion repair, re-vegetation, removal of detritus, catch basin cleaning, vacuuming of pervious pavement, etc.), which can reduce the longevity of infiltration BMPs.
e) Inadequate design

Infiltration systems should always be designed such that failure of the infiltration component does not completely eliminate the peak rate attenuation capability of the BMP. Because infiltration BMPs are designed to infiltrate small, frequent storms, the loss or reduction of this capability may not significantly impact the storage and peak rate mitigation of the BMP during extreme events.

Consideration of Infiltration Rate in Design and Modeling Application

For the purposes of site suitability, areas with tested soil infiltration rates as low as 0.1 inches per hour may be used for infiltration BMPs. However, in the design of these BMPs and the sizing of the BMP, the designer should incorporate a safety factor. Safety factors between 1 (no adjustment) and 10 have commonly been used in the design of stormwater infiltration systems, with a factor of two being recommended for most cases.

The <u>minimum safety for design purposes that may used for any type of tests is two (2)</u>. For percolation tests this safety factor is only applicable for soils more coarse than a loam. It should be applied ***after*** (in addition to) using the reduction formula outlined in Protocol 1, Site Evaluation and Soil Infiltration Testing.

For Percolation tests in loams and finer soils (silty loam, clay loams, silty clay loams, sandy clay loams, clays) a <u>minimum design safety factor of three (3)</u> is recommended ***after*** using the reduction formula in Protocol 1, Site Evaluation and Soil Infiltration Testing. This higher factor is to account for the unwanted capillary suction force that can occur from *un*saturated conditions during percolation testing.

Therefore, a percolation rate of 0.5 inches per hour (***after*** reduction formula) should generally be considered as a rate of 0.25 inches per hour when designing an infiltration BMP for a sandy loam. The same rate for a loam would yield a *design* rate of 0.17 inches/hour.

For other test procedures a safety factor of 3 should also be considered for problem or less preferred locations, basins, swales, toe of slopes, loadings greater than 5:1 (drainage area to infiltration area) where saturated hydraulic conductivity rate (Ksat) was **not** determined (A raw infiltration rate was used. The Ksat rate will normally be less than the infiltration rate.)

As discussed in Section 9 of this Manual, infiltration systems can be modeled similarly to traditional detention basins. The marked difference with modeling infiltration systems is the inclusion of the infiltration rate, which can be considered as another outlet. For modeling purposes, it is convenient to develop infiltration rates that vary (based on the infiltration area provided as the system fills with runoff) for inclusion in the Stage-Storage-Discharge table.

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C

Procedures for Determining Effects of Infiltration on Subsurface Stability in Areas of Historic Fill

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Appendix C: Procedures for Determining Effects of Infiltration on Subsurface Stability in Areas of Historic Fill

C.1 Justification

This policy is intended to address three potential problems involving stormwater control on sites built on structural fill.

1. Some fill material such as fly ash may contain mobile metals and toxins. This issue is addressed in the hotspot policy.

2. Concentrated infiltration can lead to extensive erosion and subsidence in fill containing very fine material, such as ash. Diffuse infiltration may still be possible under these conditions.

3. Minor subsidence under concentrated infiltration facilities may threaten structures that are very close to those facilities. Minor subsidence of the infiltration facility itself is not sufficient reason to avoid infiltration. In no case shall new structures included as part of the site development be considered cause for avoiding the use of an infiltration system.

C.2 Required Steps

Step 1: Complete a conceptual site design, including drainage area and estimated area of the proposed infiltration facility.

Step 2: Determine whether the site is in an area of historic fill.

- The Design Professional is responsible to rule out or detect the presence of historic fill. This investigation may rely on historic maps, records of previous construction, local knowledge, or test pits conducted at the site. If no historic fill is present, steps 3 through 7 are not necessary.

Step 3: If the site is in an area of historic fill, conduct an investigation to determine the type and condition of fill.

- The site investigation should conduct test pits or test borings to confirm the depth and nature of the fill at the site. The explorations should extend through any organic materials at the site, into the naturally deposited inorganic materials below the site. An assessment of permeability of each of the onsite stratums should be made by direct field testing, laboratory testing of samples collected during the investigation or correlation with grain size or other physical properties of representative samples of each stratum. At least one exploration, test boring or test pit should be conducted for every 2500 sq. feet of infiltration area planned at the site. Based on this information, the lateral extent of the zone of influence of the infiltration system should be determined.

- As part of the site investigation, the potential for drain lines, rubble fill, former building foundations or other man-made features which could facilitate the migration of fine material from the site should be evaluated from historic maps, records of previous construction, local knowledge or test pits conducted at the site.

Step 4: If the site is in an area of historic fill, rate existing structures based on susceptibility to subsidence.

• The foundation bearing condition of adjacent structures, utilities and other surface features should be assessed. The depth of basement levels and anticipated foundation bearing soils should be determined. In particular, structures, utilities or other surface features which are suspected of bearing on historic fill soils must be identified.

• Low susceptibility are structures showing no signs of distress bearing on or in the naturally deposited inorganic strata below the fill and organic material or on prepared engineered fill after the removal of the historic fill and organic soils

• Moderate susceptibility are structures showing no signs of distress bearing on inorganic historic fill which are less than 10 feet in depth and contains little to no ash which was place directly over the naturally deposited inorganic stratums.

• High susceptibility are structures which either currently show signs of distress, are underlain by more than 10 feet of historic fill or historic fill containing significant amounts of ash or underlain by organic material. Any structure founded within the zone of influence as defined by a 1 vertical to 2 horizontal slope of an unfilled drain lines, rubble fill, former building foundations or other man-made features which could facilitate the migration of fine material from the site should be considered as a high susceptibility site.

Step 5: If the site is in an area of historic fill, determine feasibility of infiltration for the proposed design.

• Infiltrate for all cases where the adjacent structures of concern are outside of the zone of influence of the fluctuating water level caused by the infiltration system or where the support of the structures is rated as low susceptibility within the zone of influence.

• Strongly consider infiltration in areas affecting structures which can tolerate moderate subsidence where support of the structures is rated as moderate susceptibility within the zone of influence.

• Do not infiltrate in areas affecting structures in areas of high susceptibility within the zone of influence of the infiltration system unless special engineering evaluations indicate that the structures can tolerate the anticipated subsidence.

Step 6: If infiltration threatens existing structures, attempt to adjust the site design to remove any concerns.

• Determine whether the site can be redesigned to move infiltration facilities farther from structures.

• Determine whether the site can be redesigned to reduce the ratio of drainage area to infiltration area. Diffuse infiltration occurs when the infiltration area is equal in size to the impervious drainage area (for example, a gravel bed underlying the entire area of a parking facility). In this case, the infiltration facility will have no more effect on subsurface stability than if the site were completely pervious.

• As part of the submittal requesting a wavier from using an infiltration system on site, the Design Professional must evaluate the use of underpinning or other support of structures within the zone of influence illustrating that the cost of providing support below the depth of the fill and organic soils is prohibitive. In addition to evaluation of alternate locations of the infiltration system, the Design Professional will review the

feasibility of using cut off barriers to limit the zone of influence adjacent to susceptible structure.

• In no case shall new facilities included as part of the site development be considered cause for avoiding the use of an infiltration system. All new structures and facilities shall be designed to tolerate the anticipated subsidence or be adequately founded on non-susceptible engineered fill or on foundations extending though the historic fill and any organic soils.

Step 7: If, after completing steps 1 through 6, the Design Professional determines that there is no safe design for infiltration at the site, the Design Professional will proceed to design of water quality facilities. In this case, the Design Professional must provide sufficient data and calculations along with the Stormwater Management Control Plan to demonstrate that infiltration is infeasible.

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D

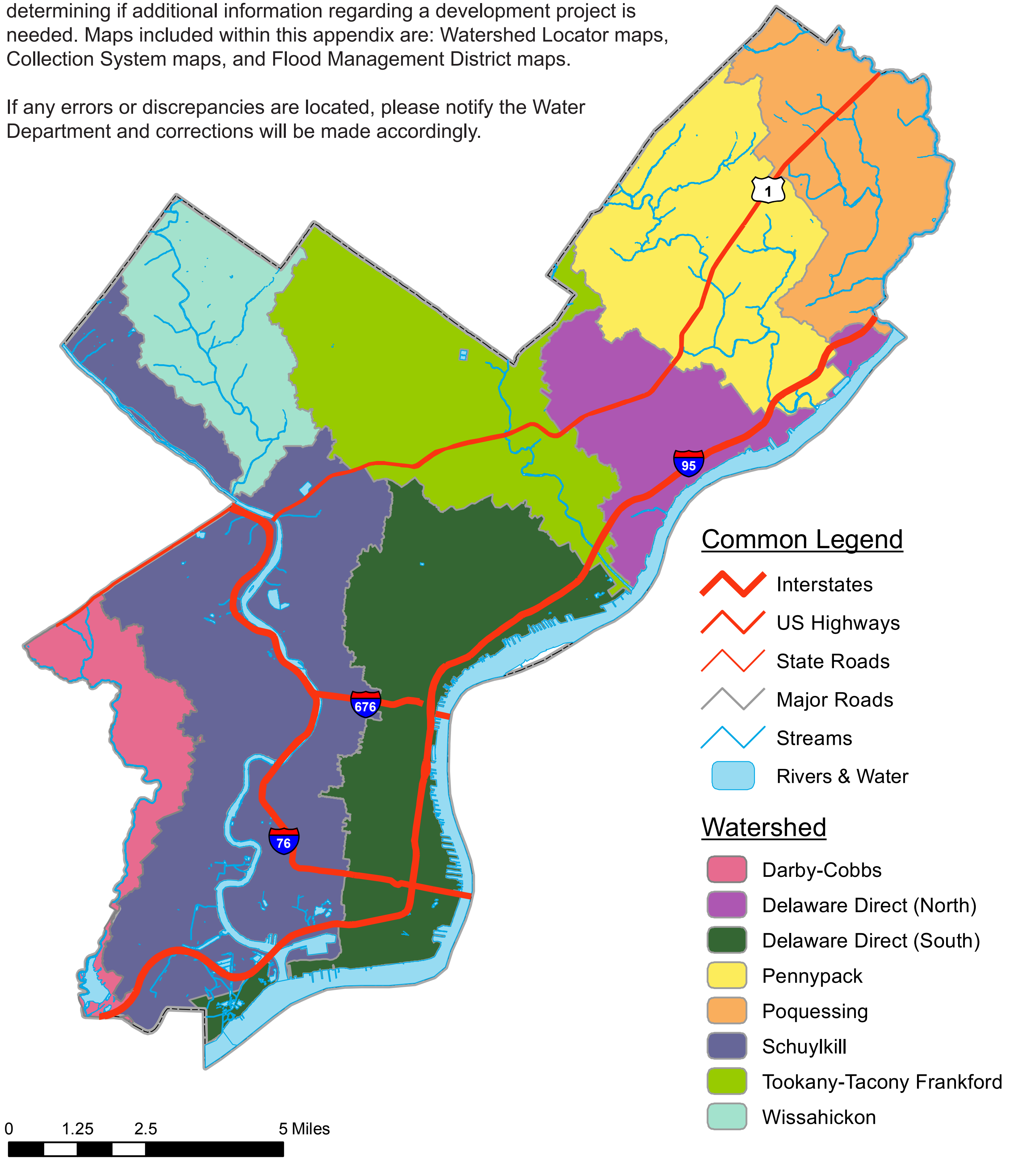
Maps: Zones for Acceptable Practices

Philadelphia Watersheds

Watershed Information Maps

The following maps are provided as a reference for site planning and for determining if additional information regarding a development project is needed. Maps included within this appendix are: Watershed Locator maps, Collection System maps, and Flood Management District maps.

If any errors or discrepancies are located, please notify the Water Department and corrections will be made accordingly.

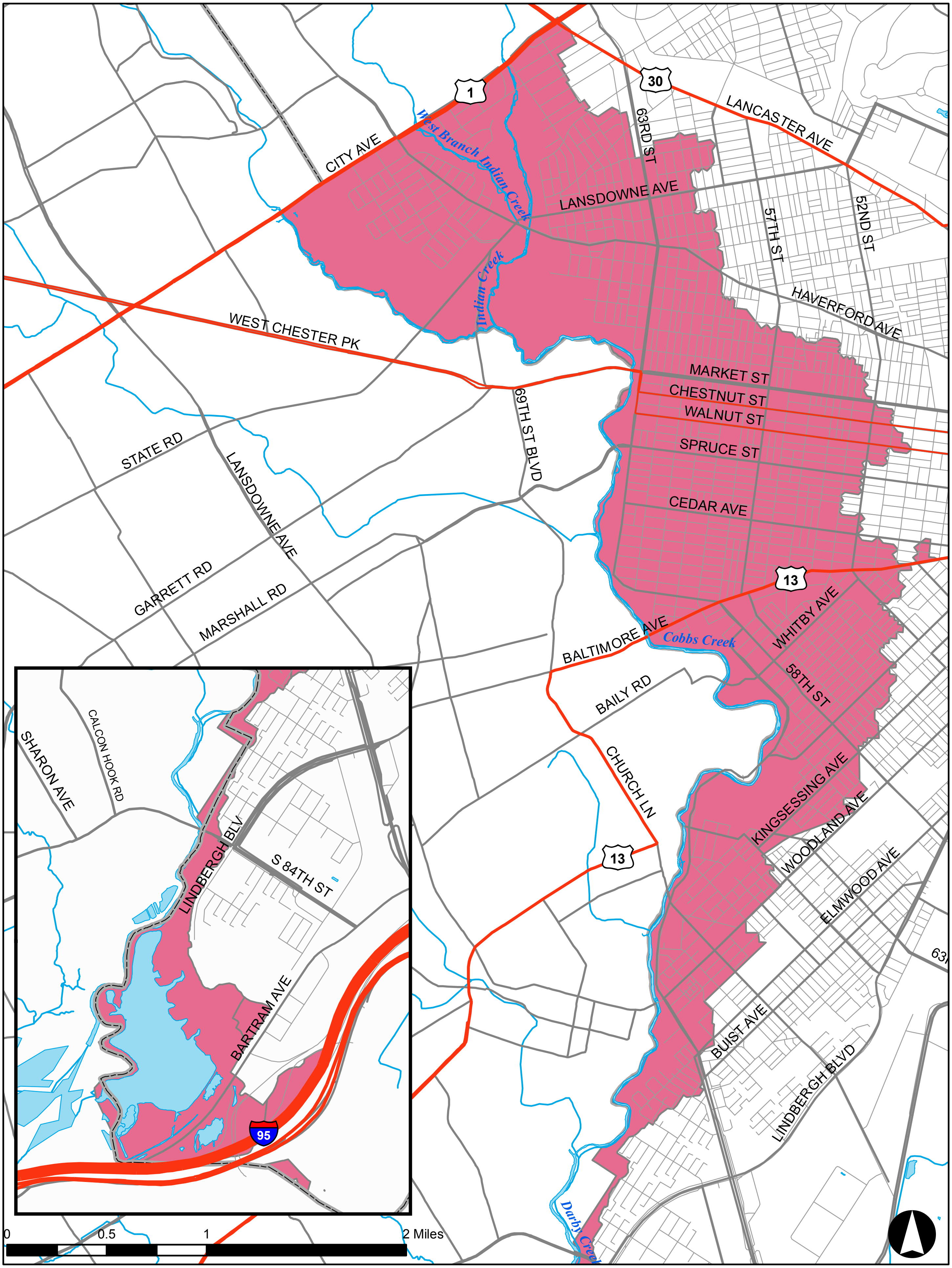


Philadelphia Water Department

Disclaimer: The suite of maps provides general reference information only. By no means are the provided maps to be used in scientific calculations, in lieu of site location mapping or for submittal with required plans. Use of the maps is at the discretion of the owner and or developer and should not replace any of the standard data acquisition and research processes involved with development.

Watershed Locator

Darby-Cobbs Watershed



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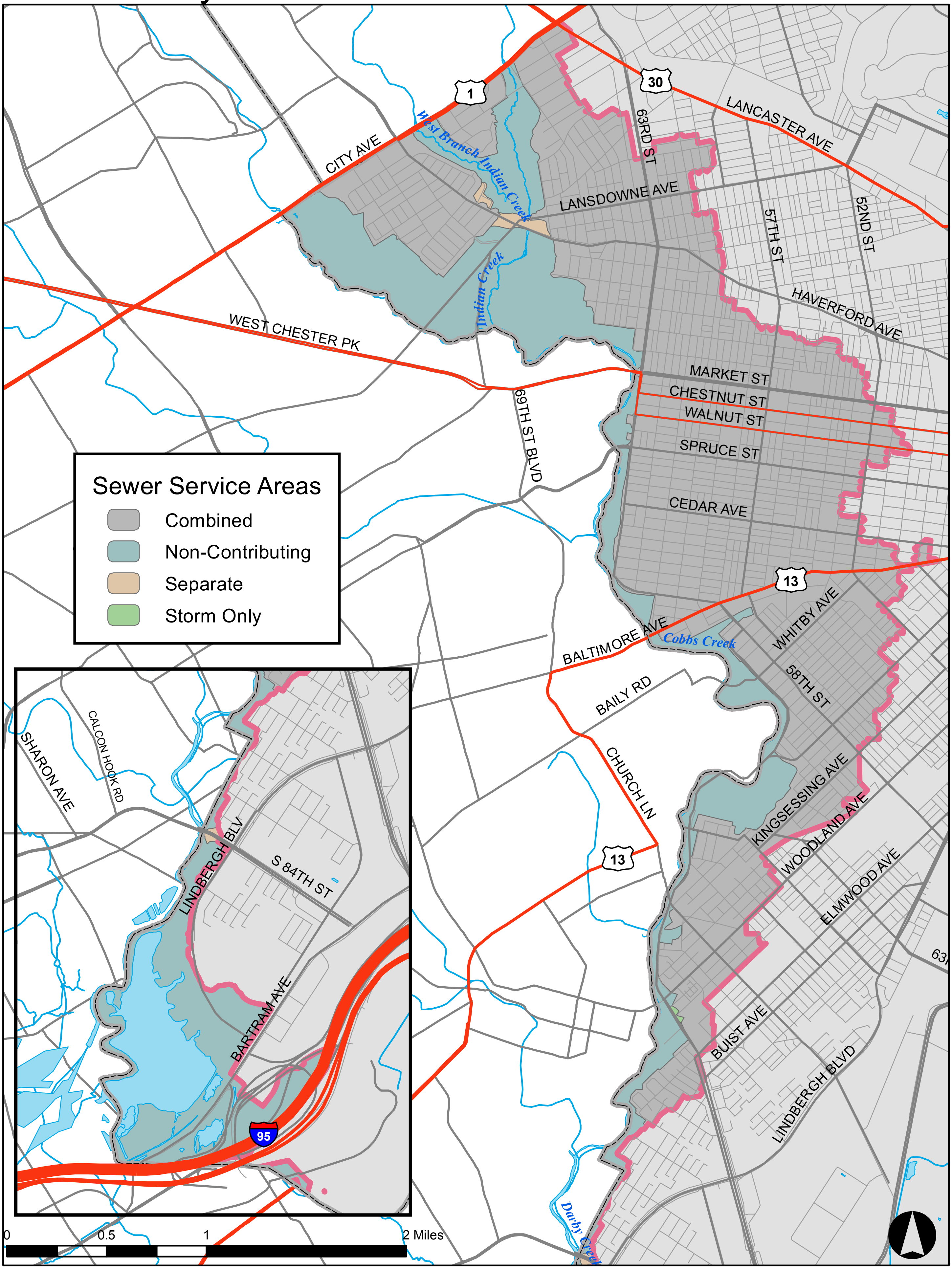
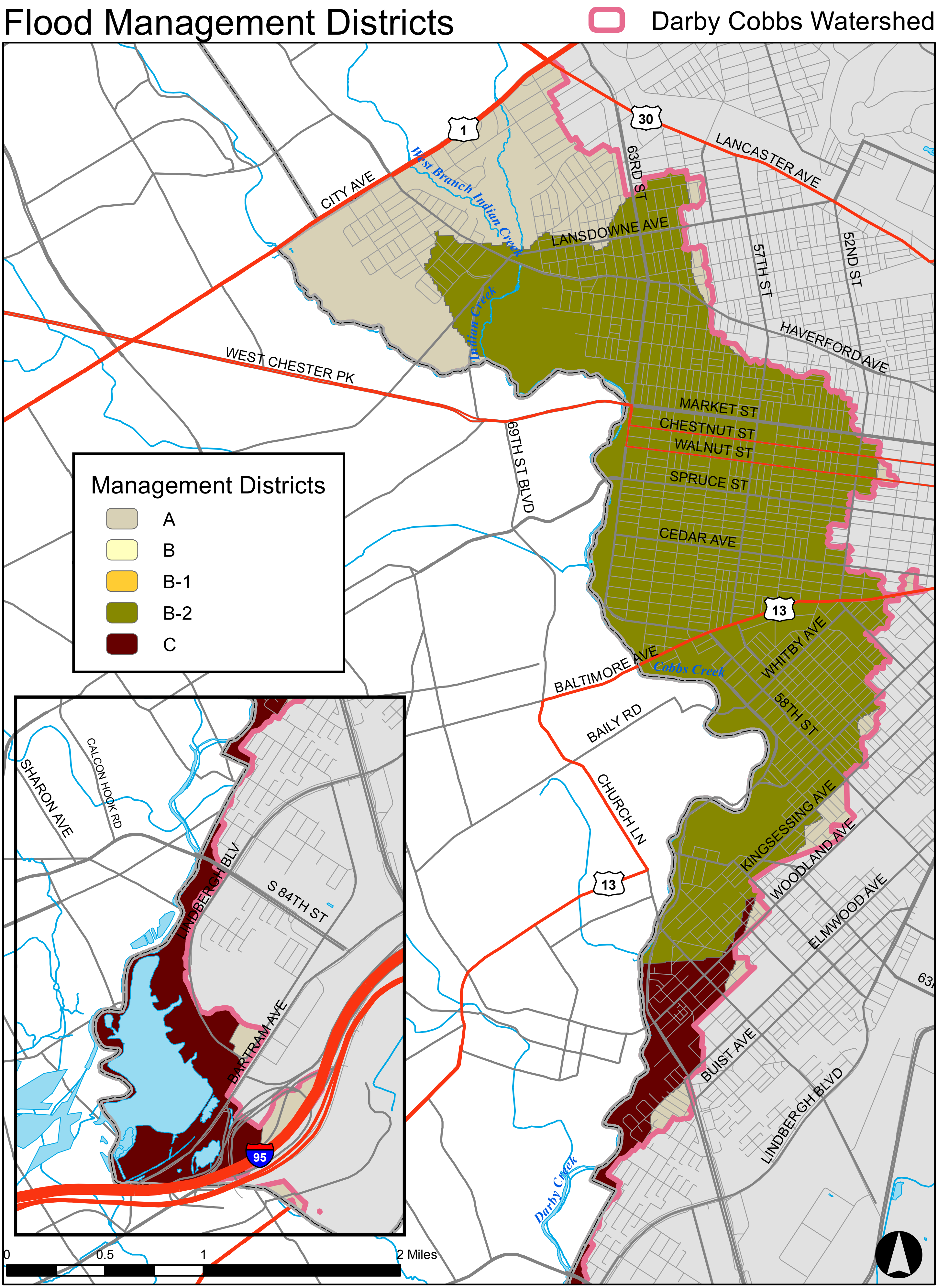


Flood Management Districts



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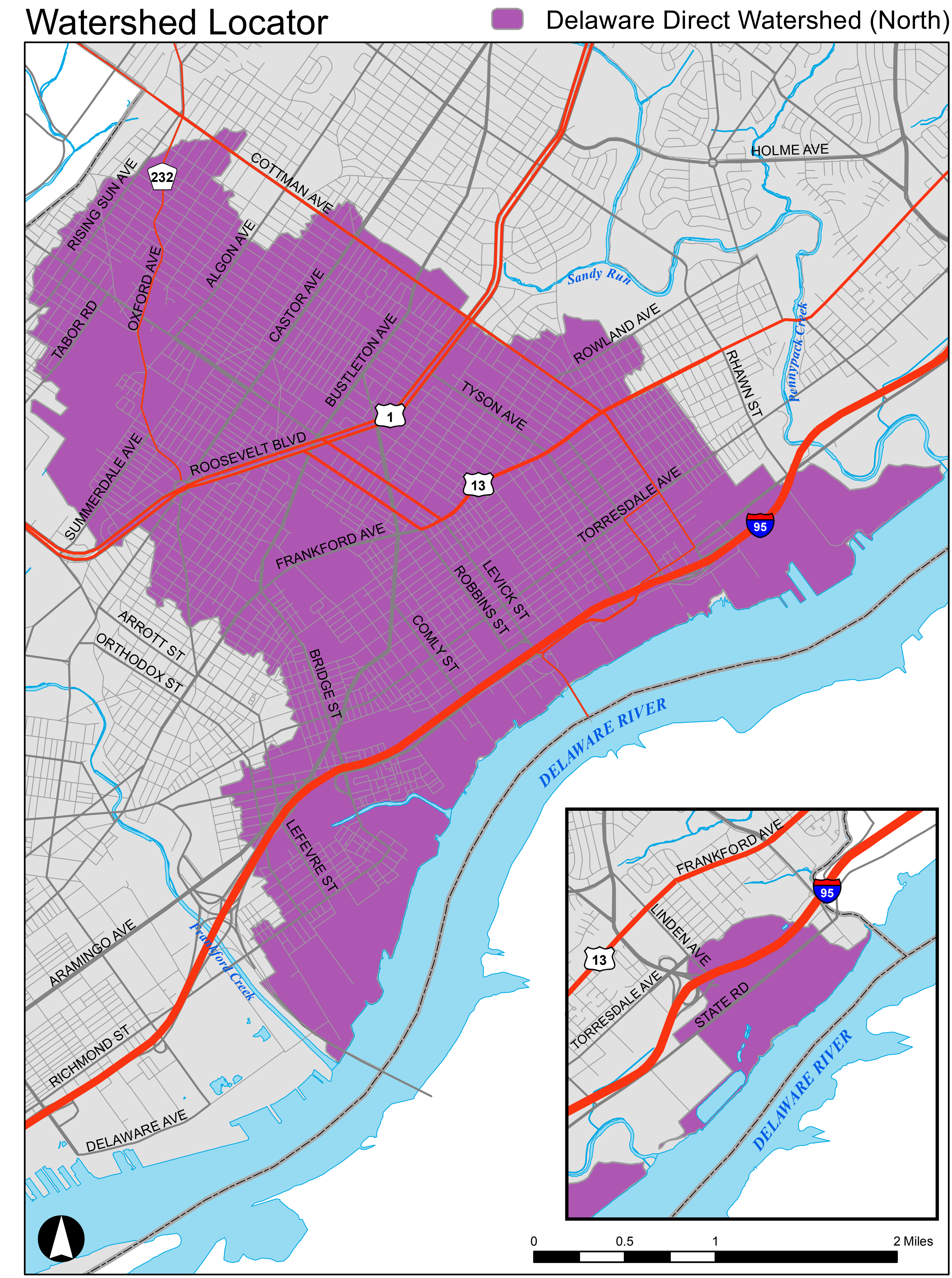

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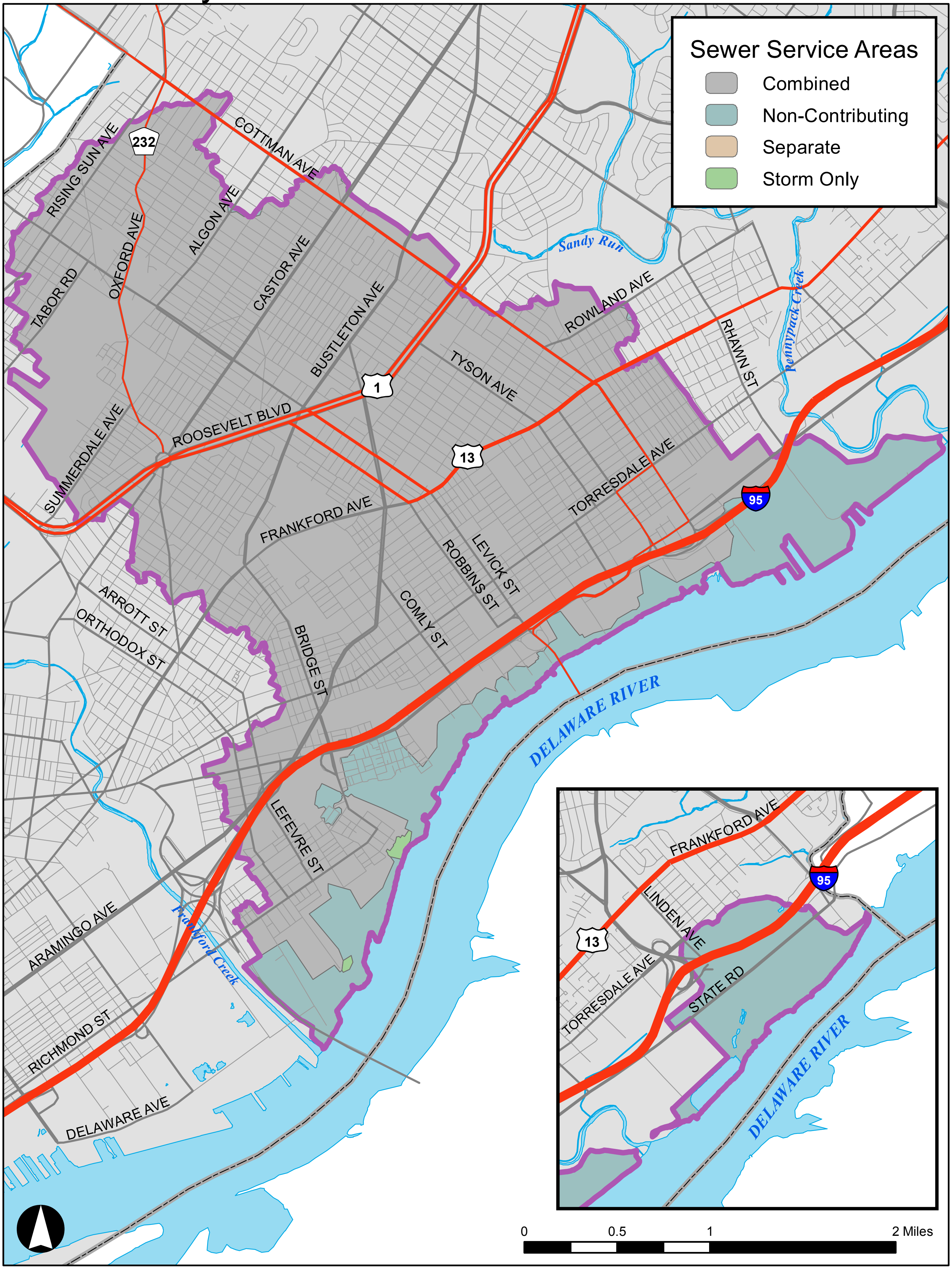

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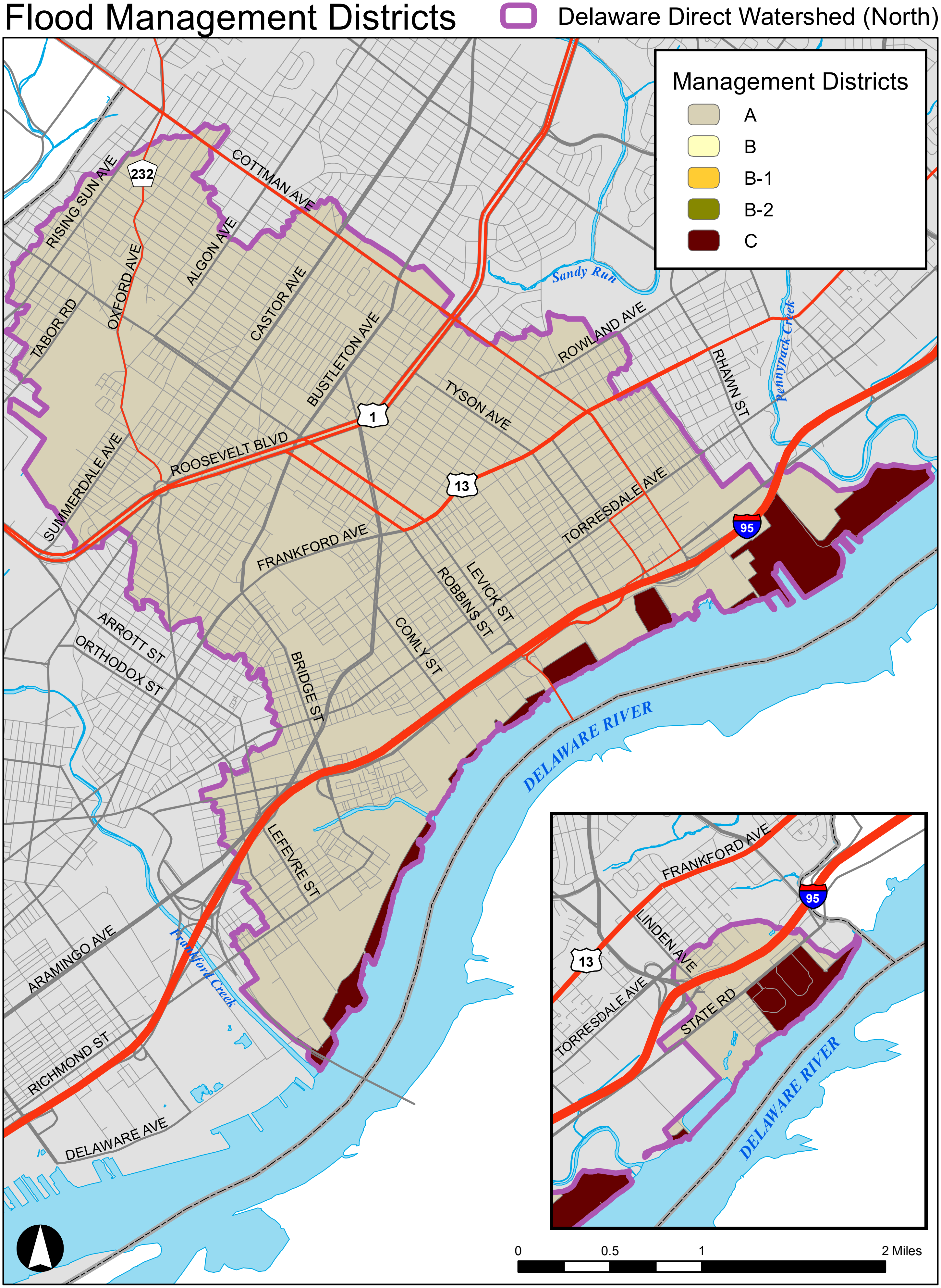

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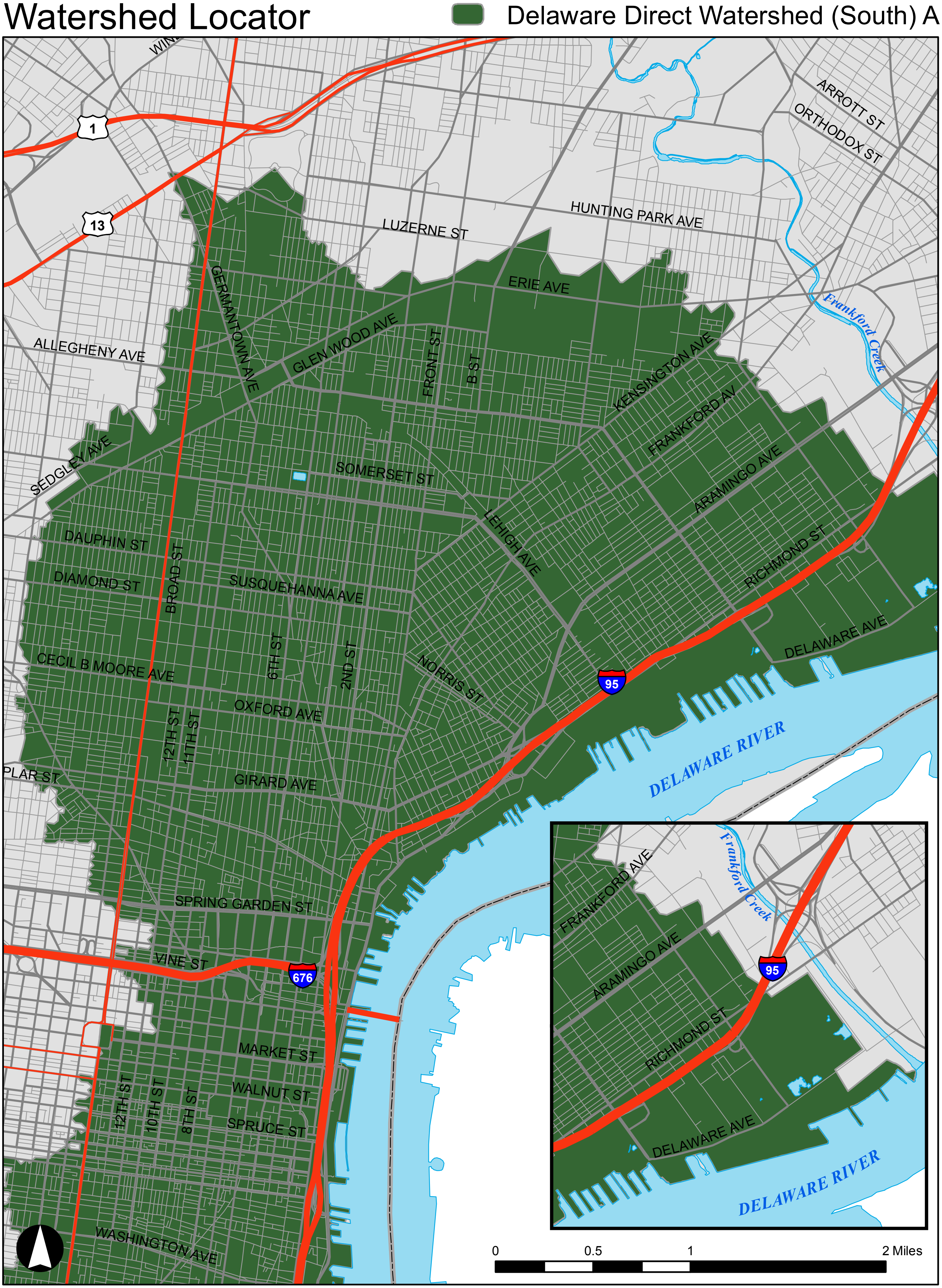
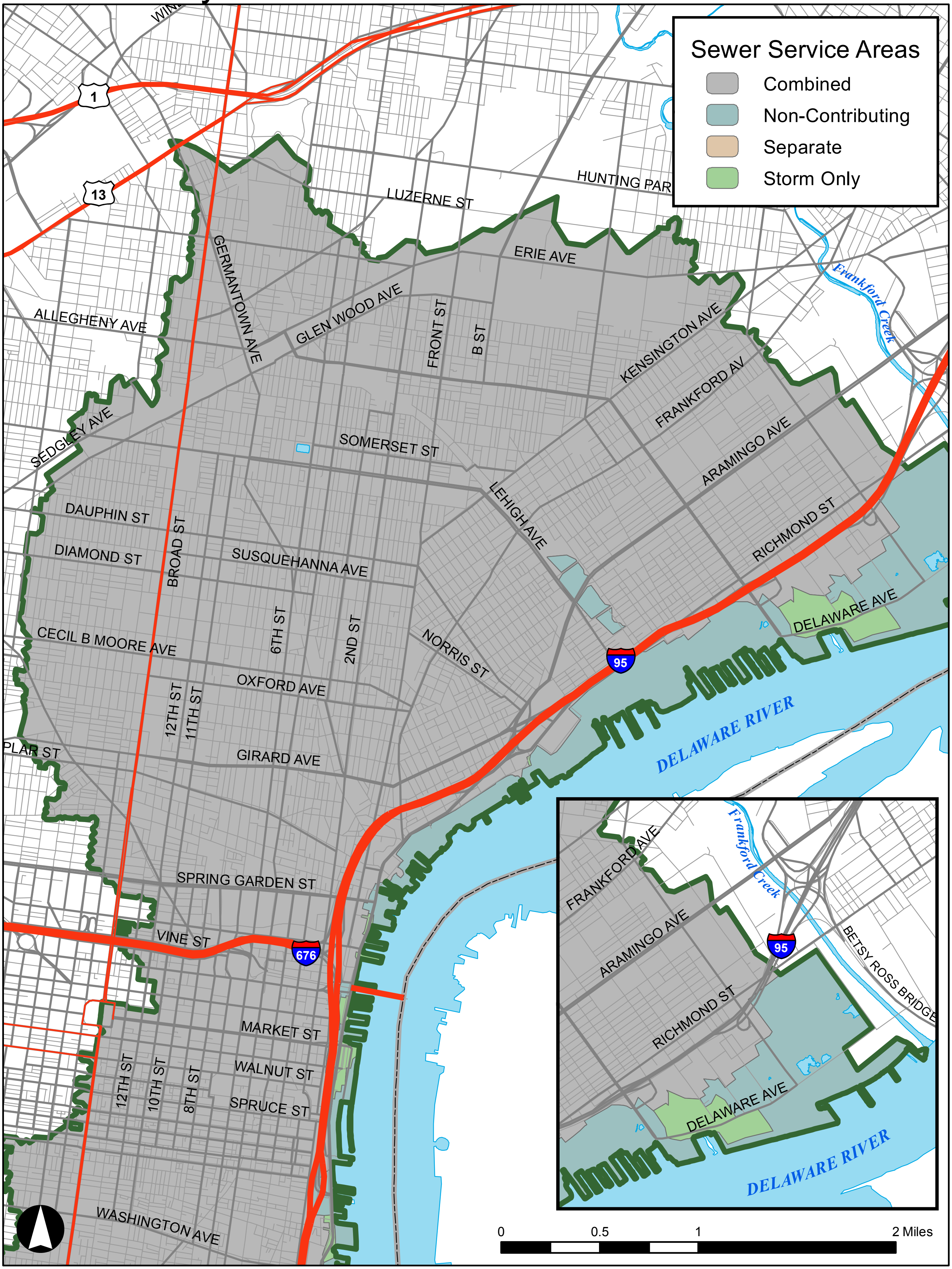


Collection System

Delaware Direct Watershed (South) A



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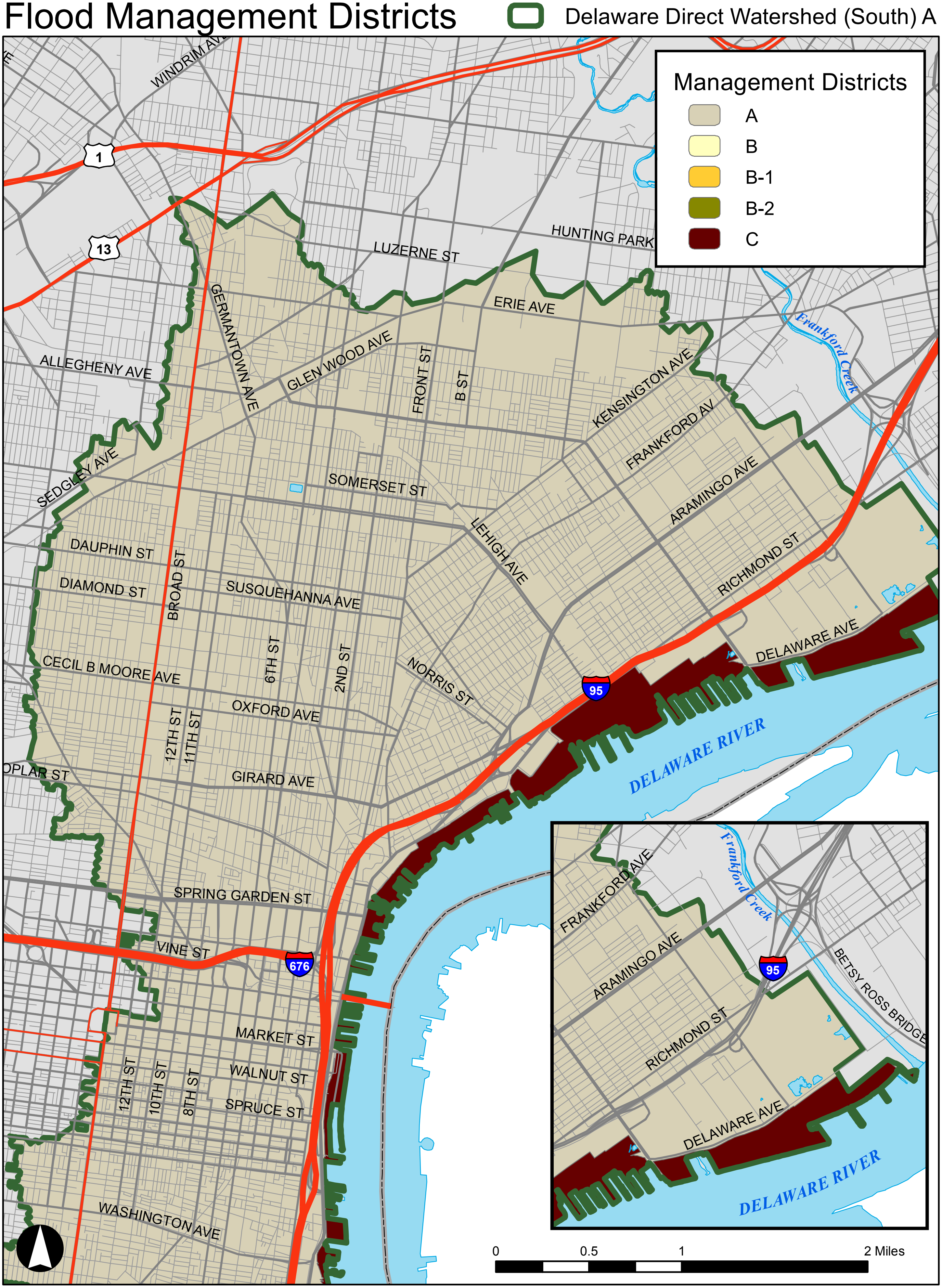
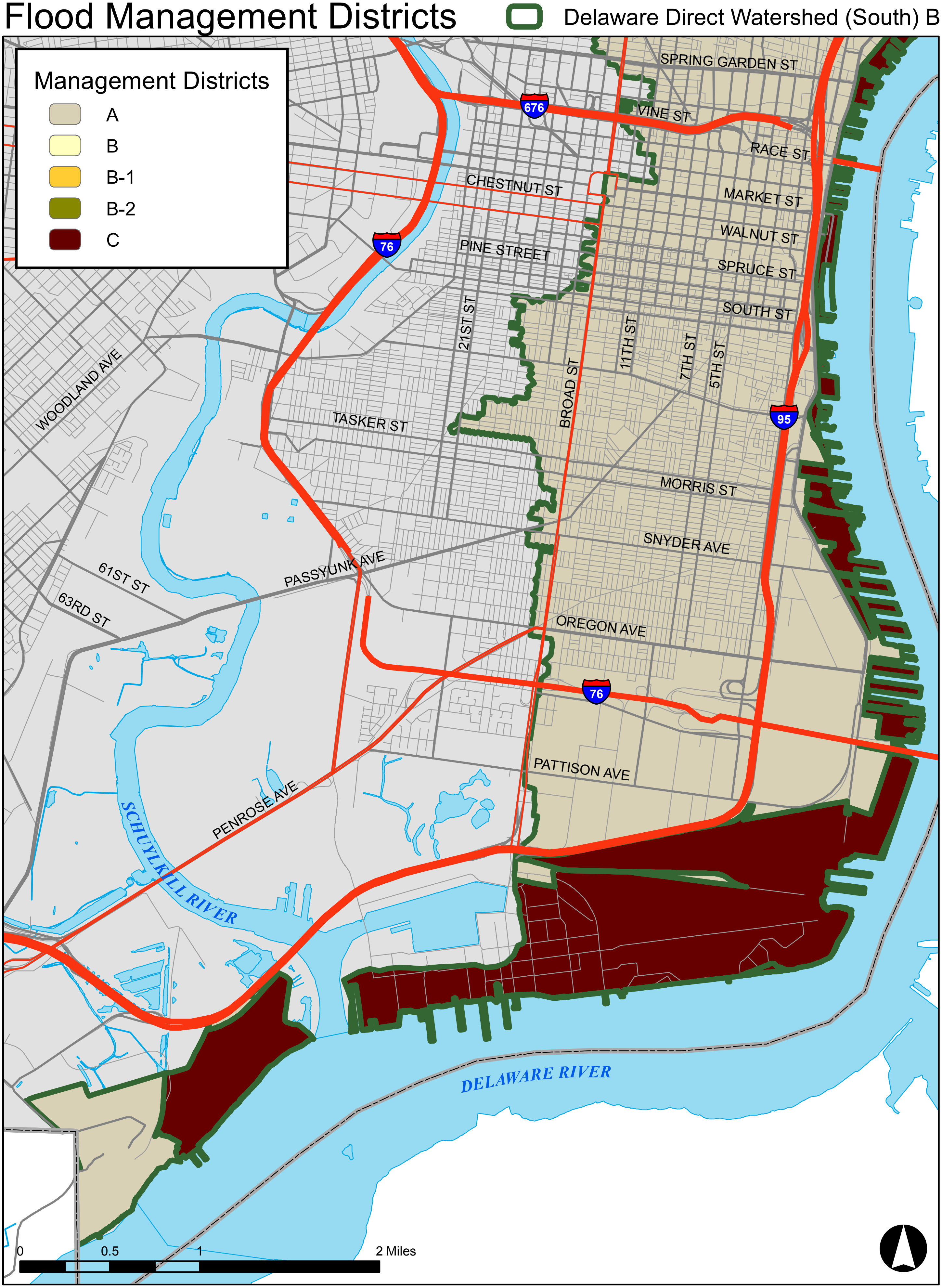


Watershed Locator

Collection System

Delaware Direct Watershed (South) B

Flood Management Districts



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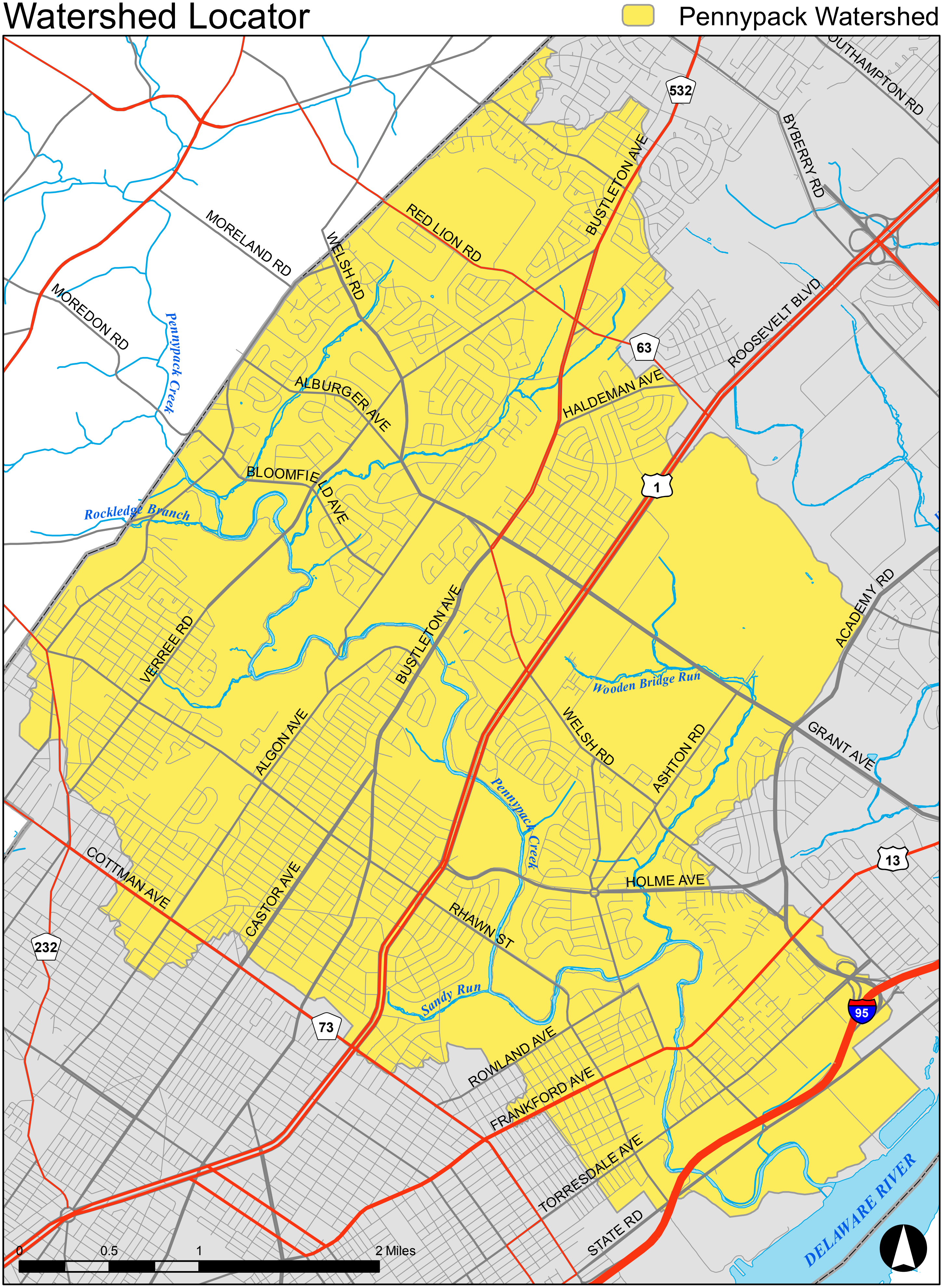

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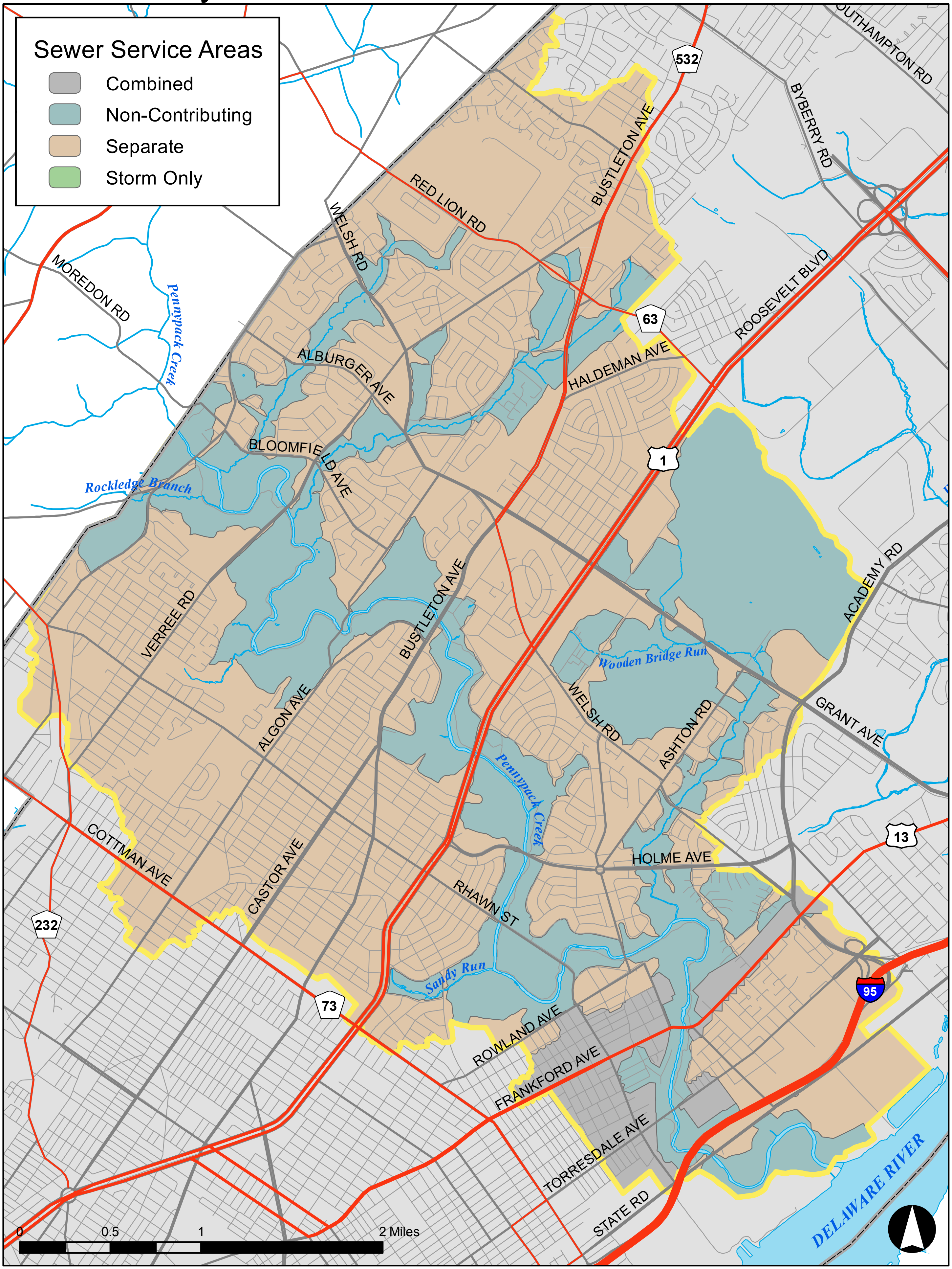
Pennypack Watershed



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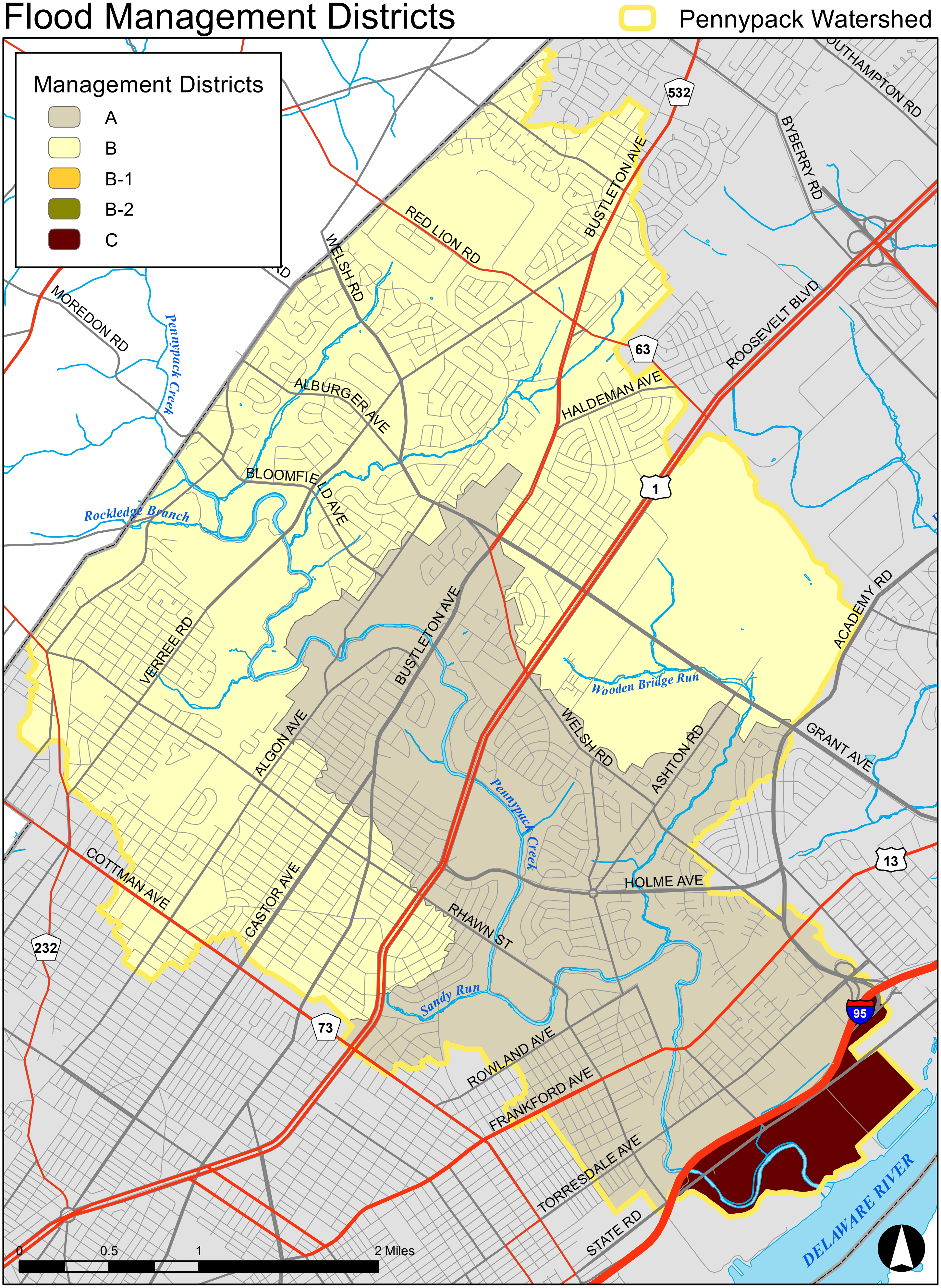

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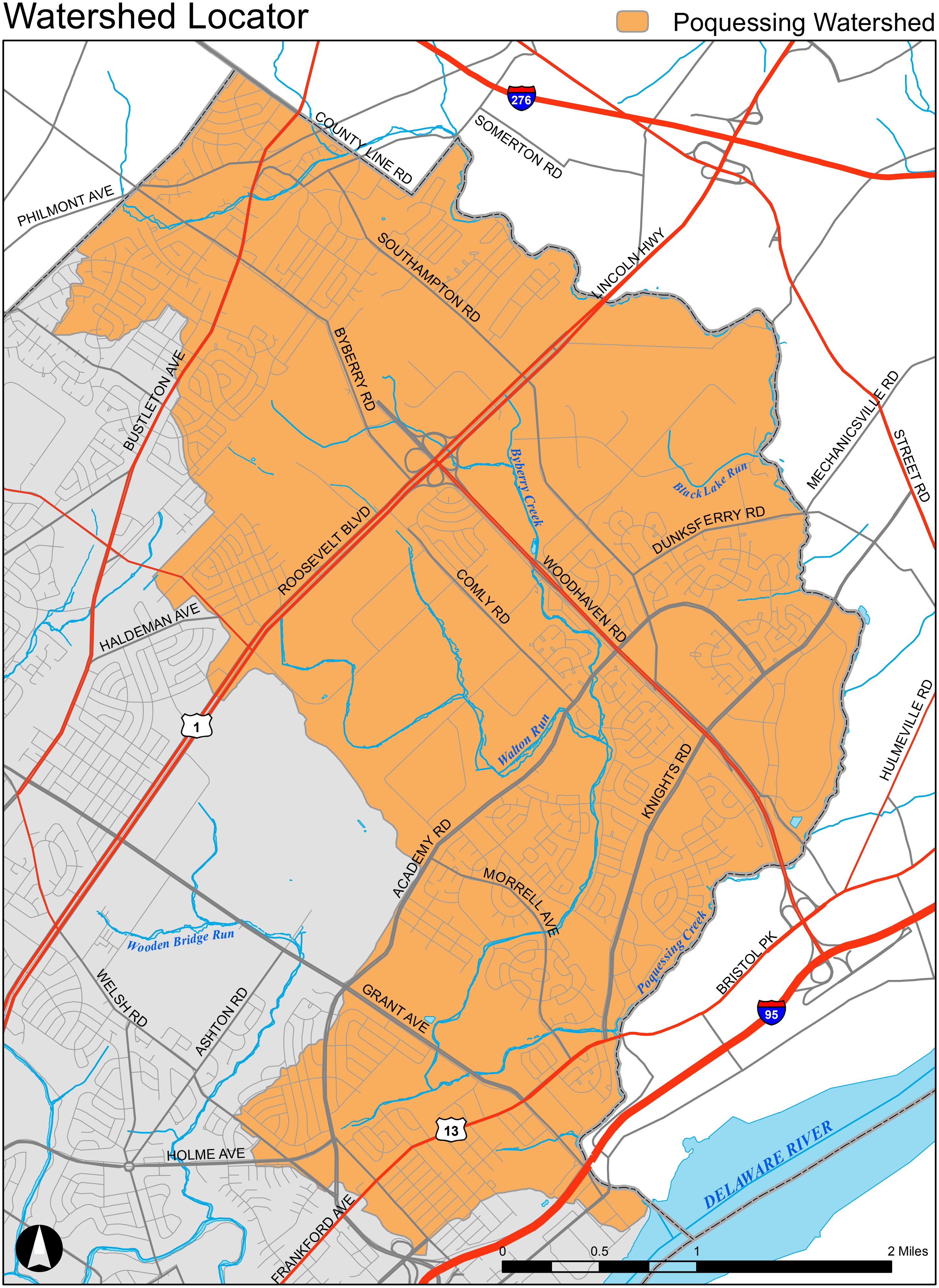

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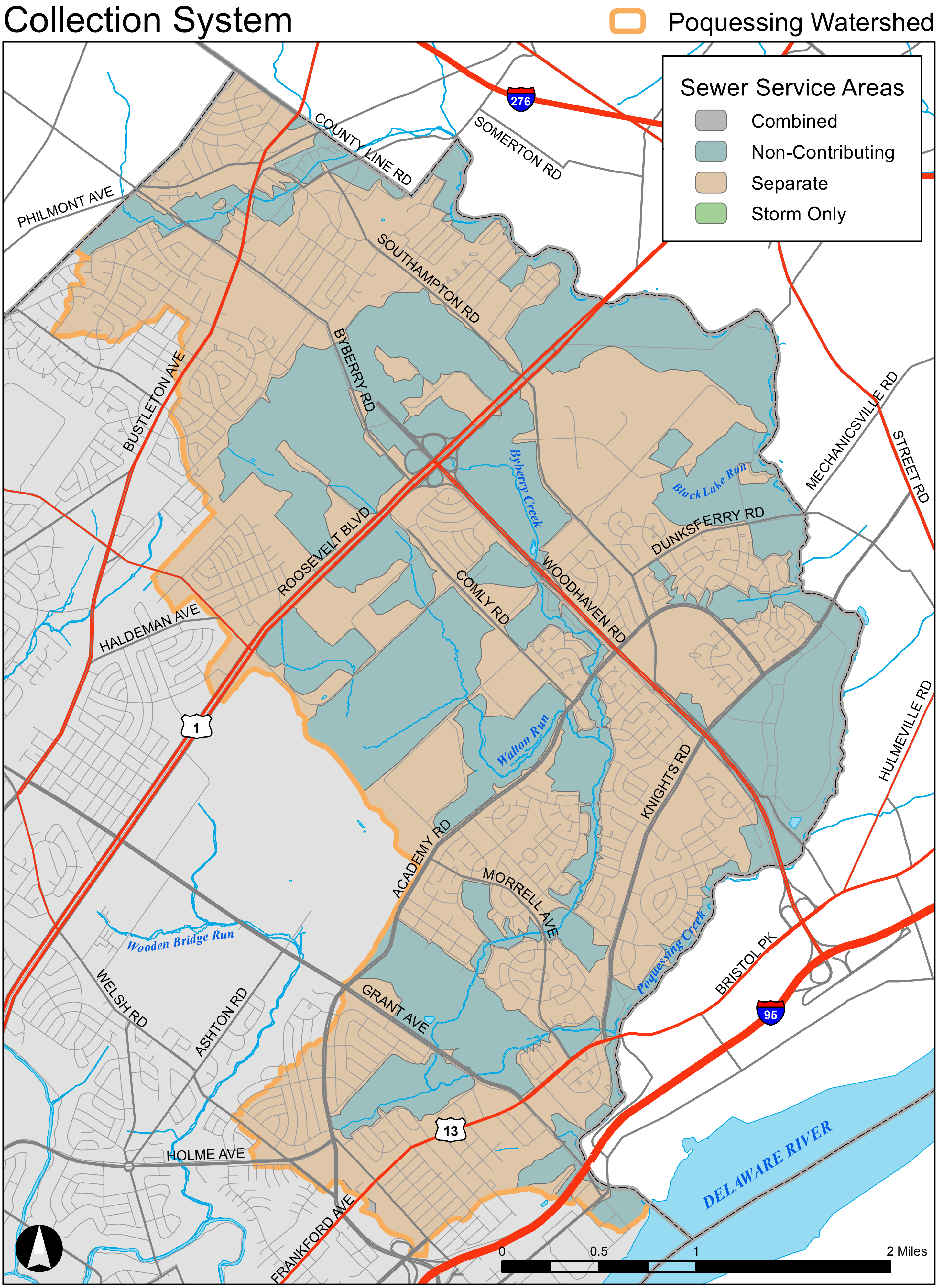

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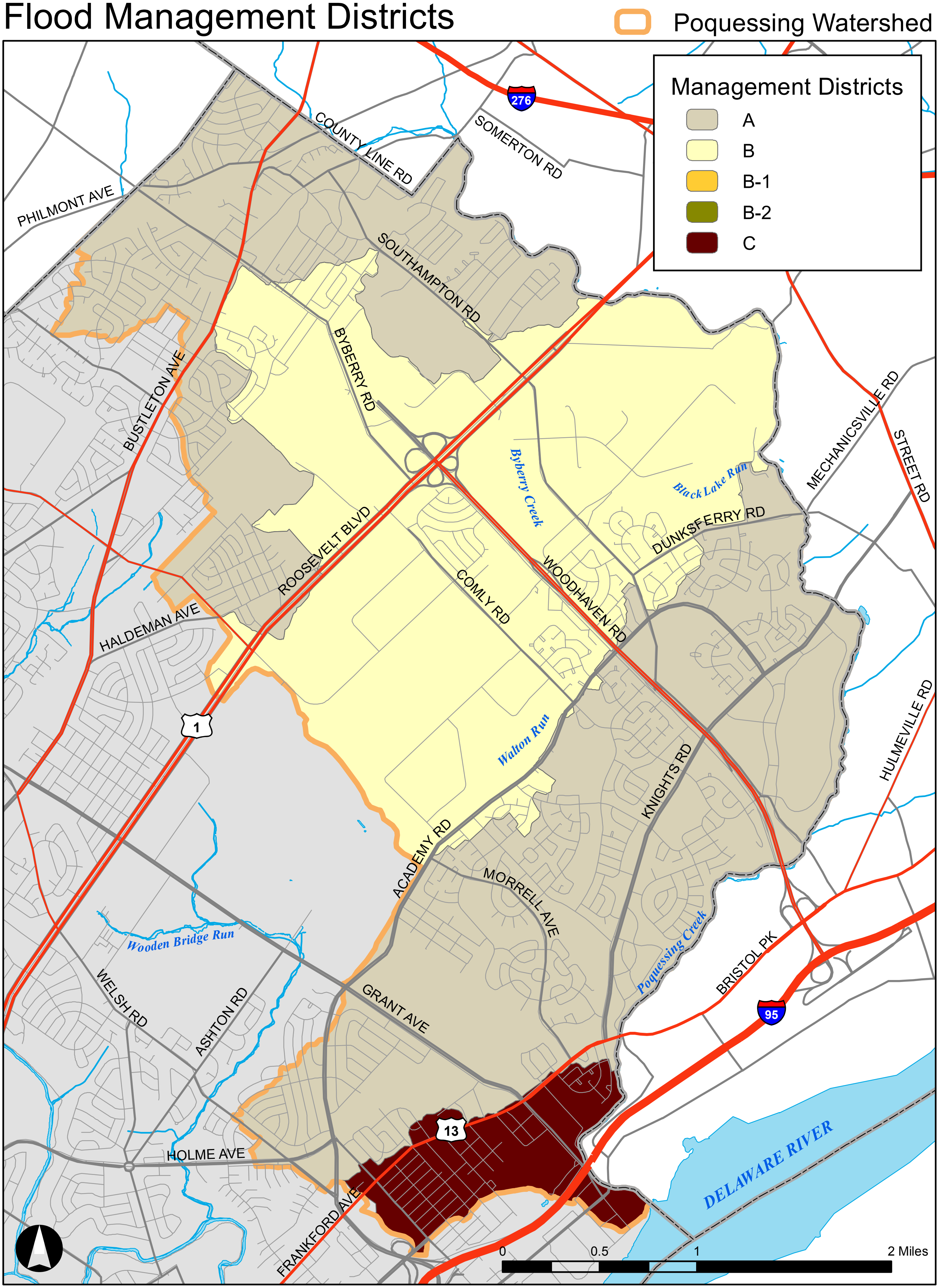

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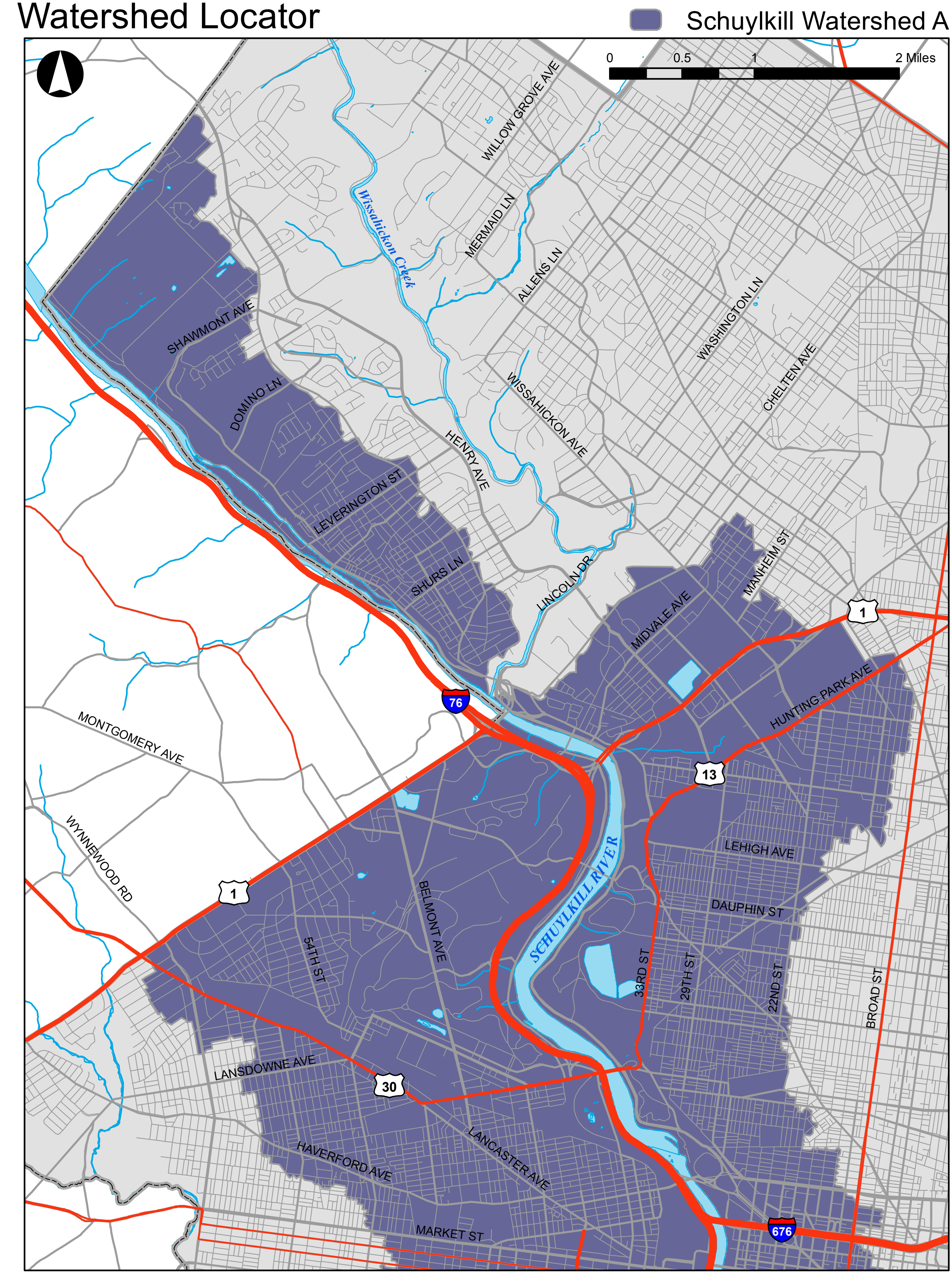

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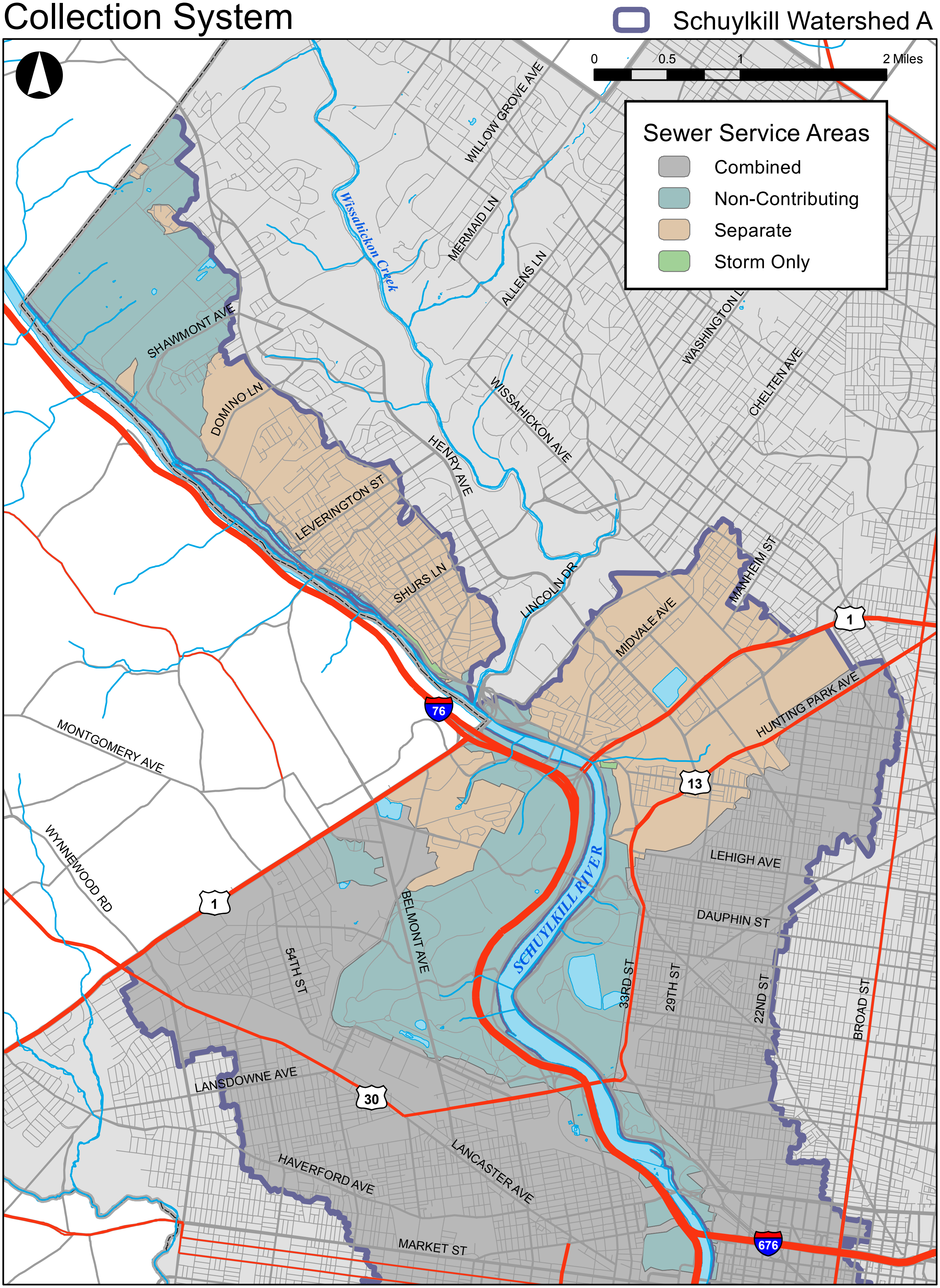

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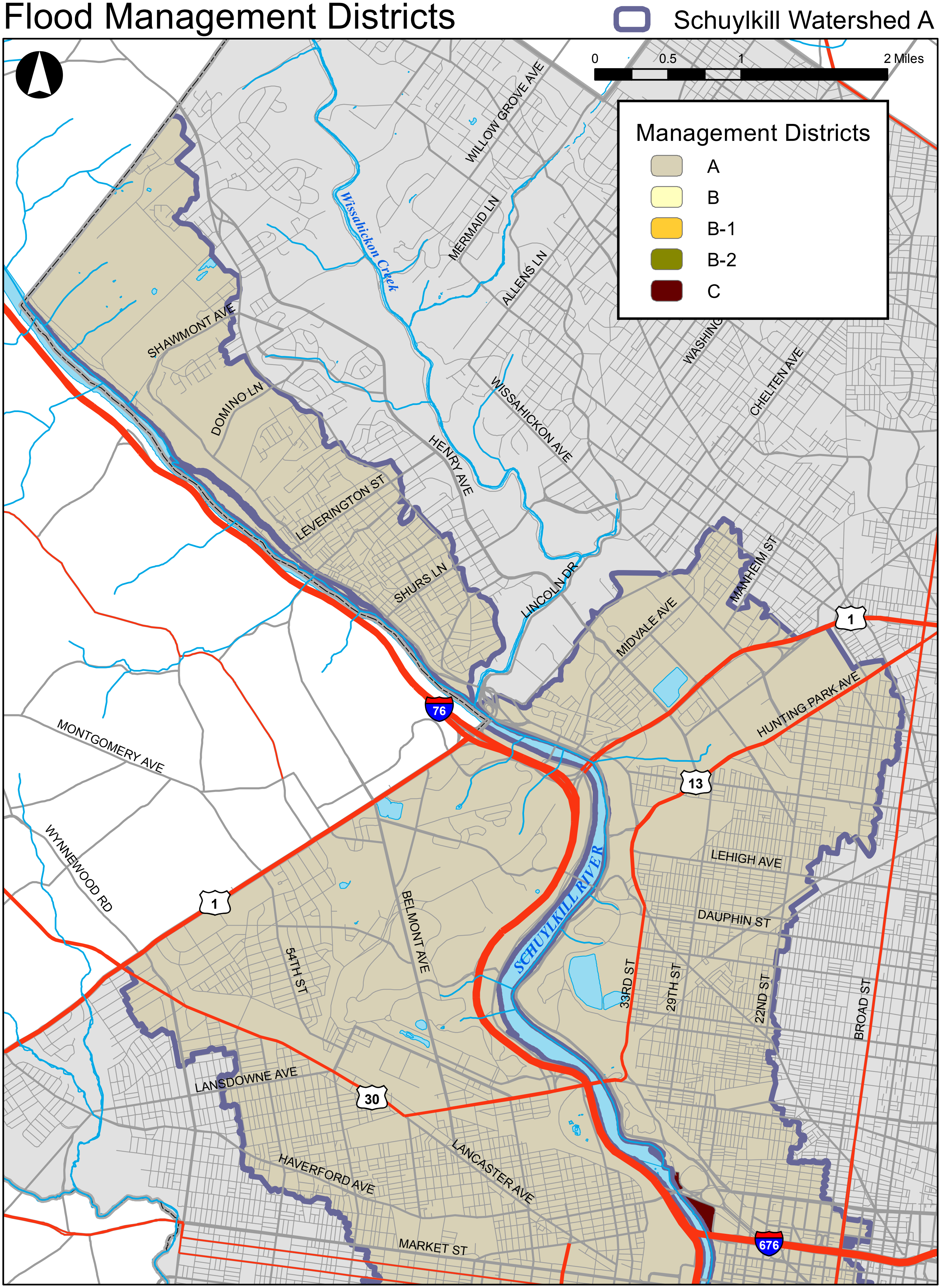

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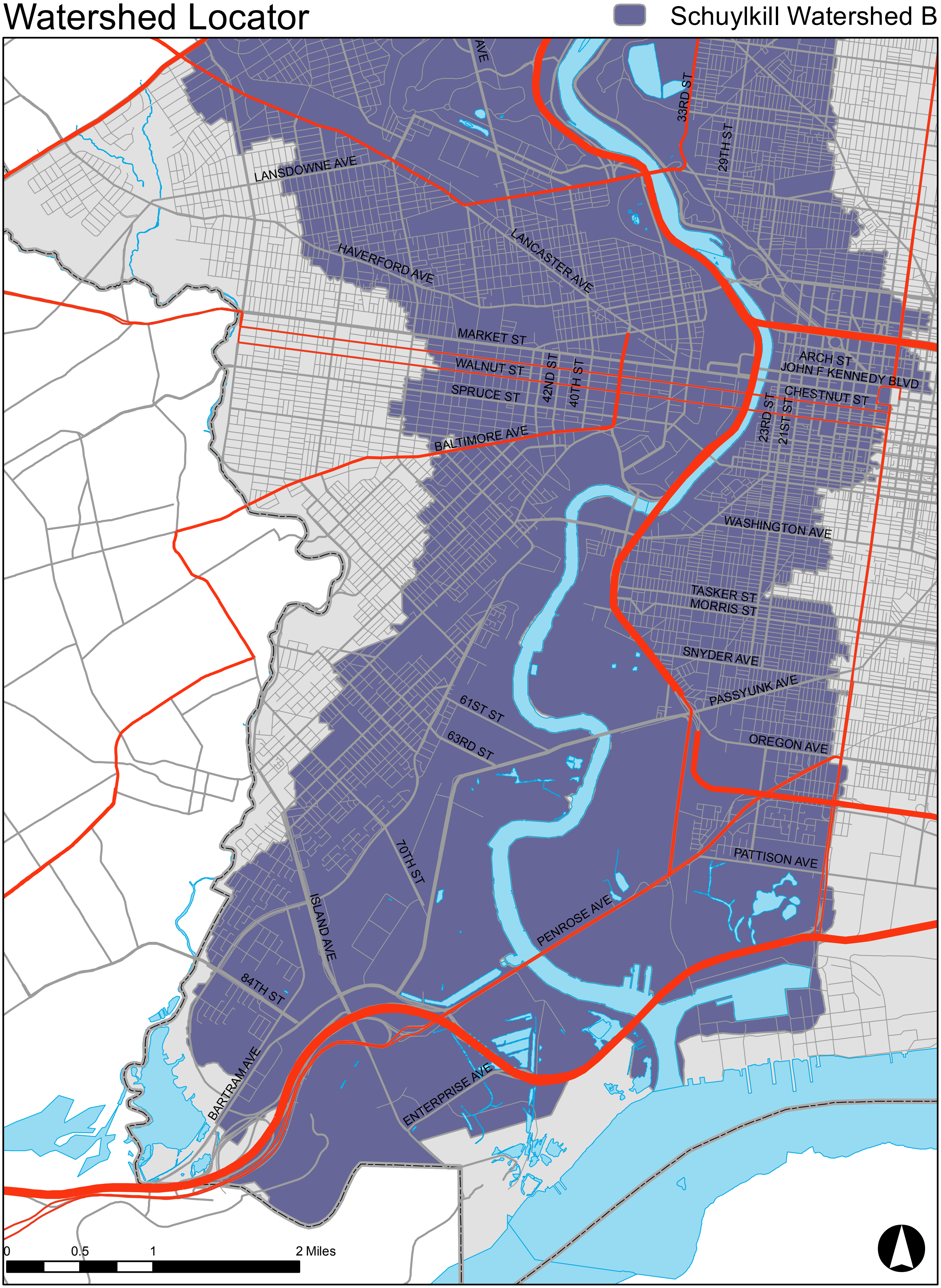
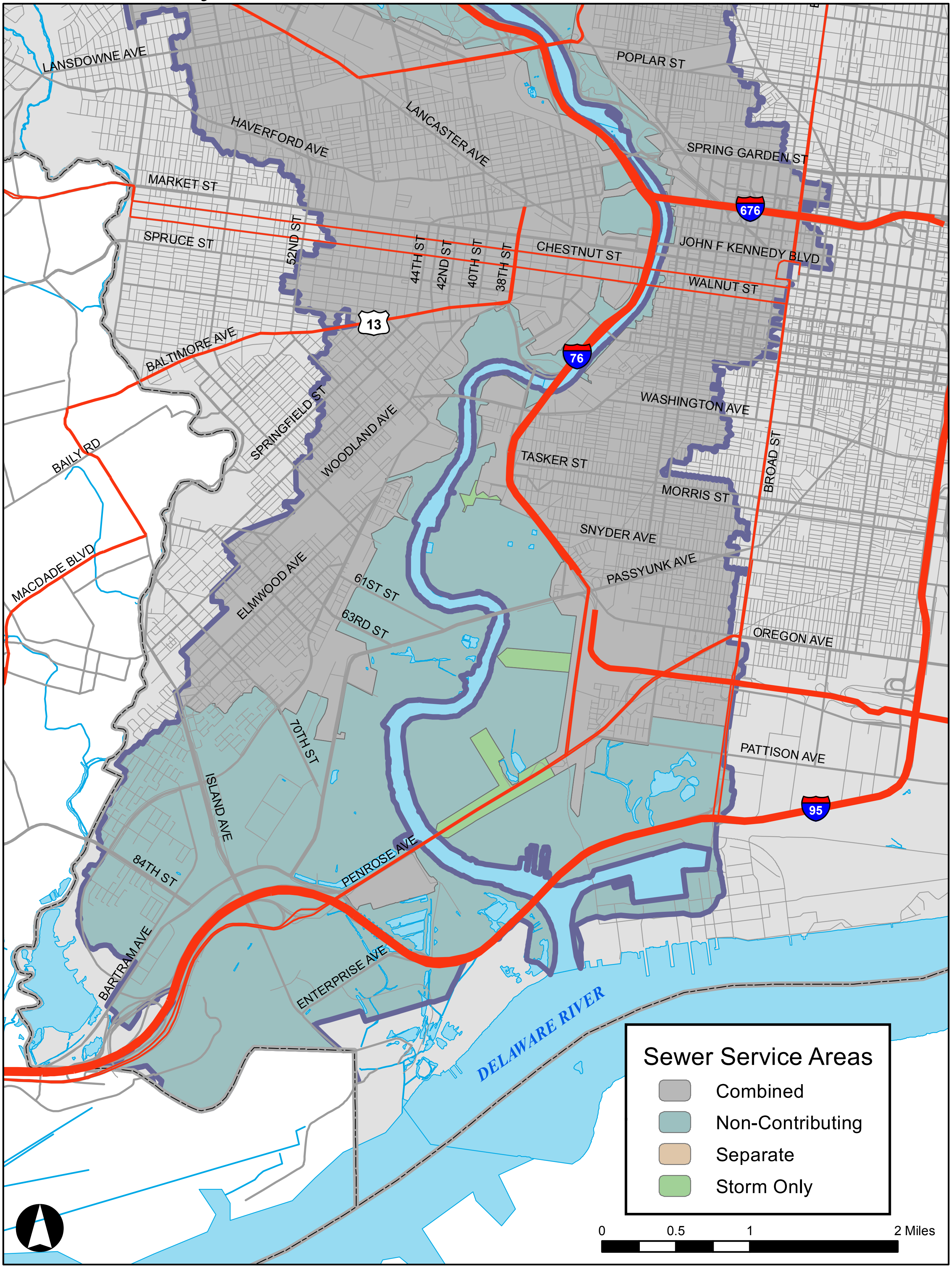


Collection System

Schuylkill Watershed B



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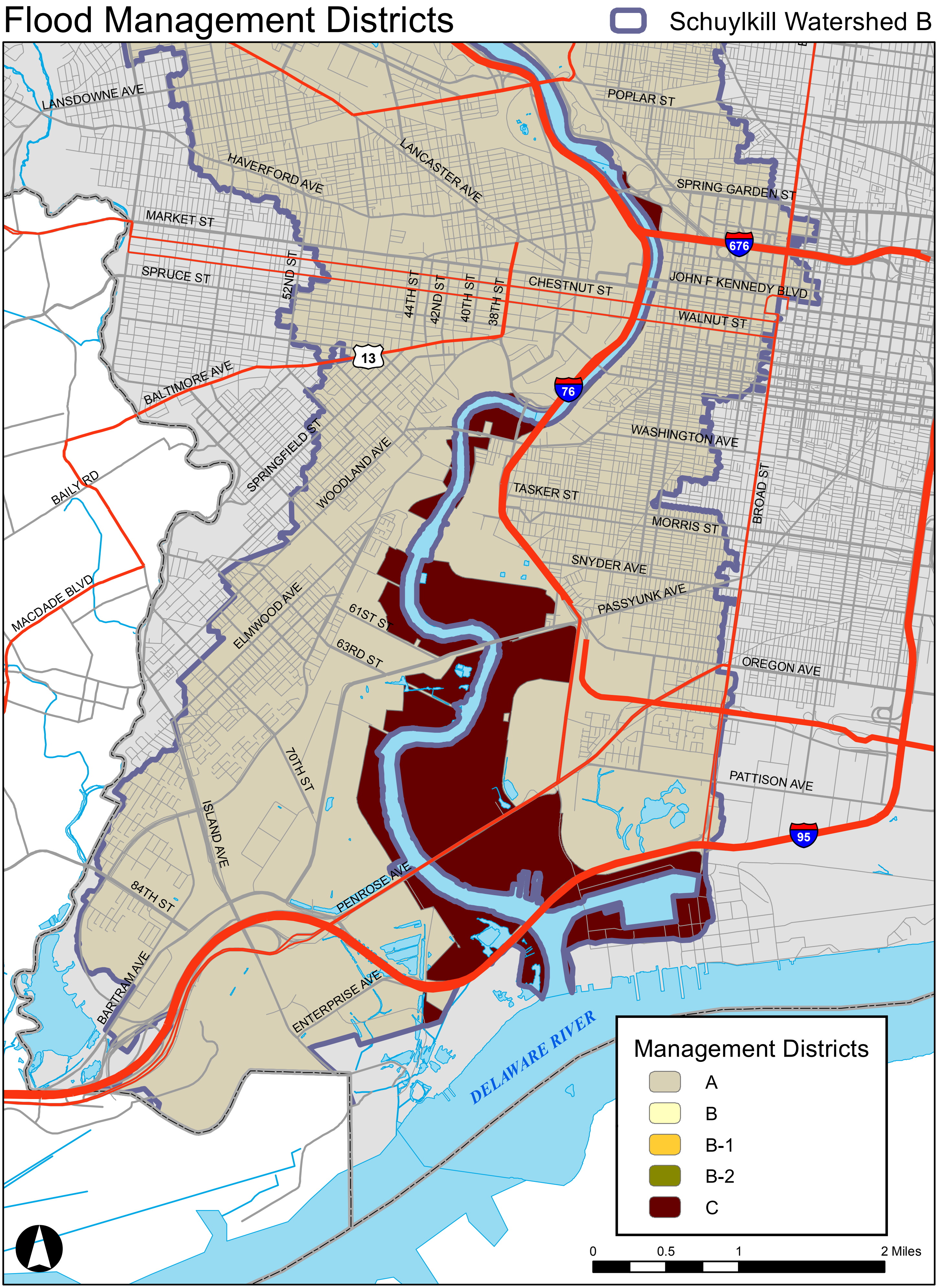

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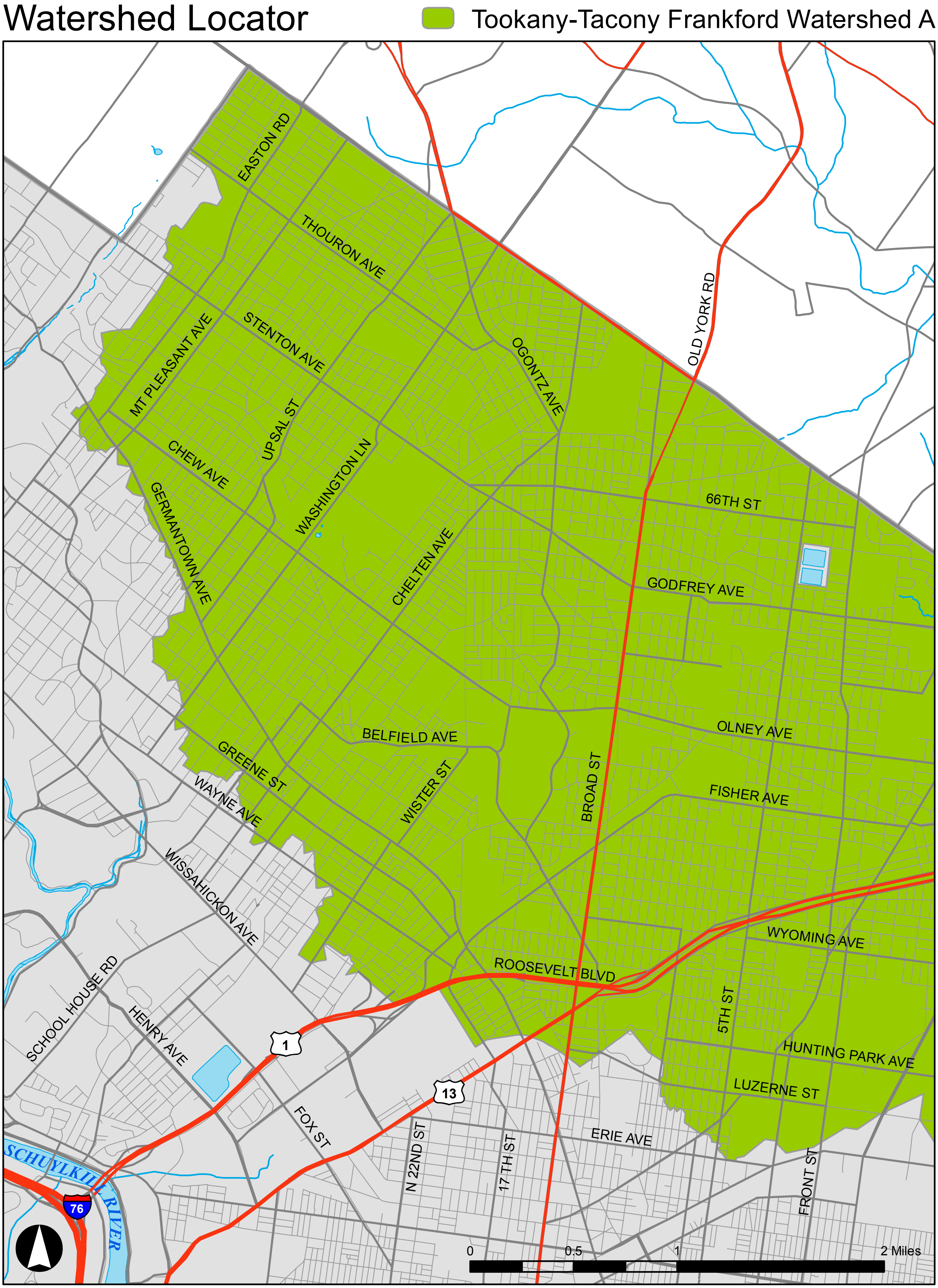

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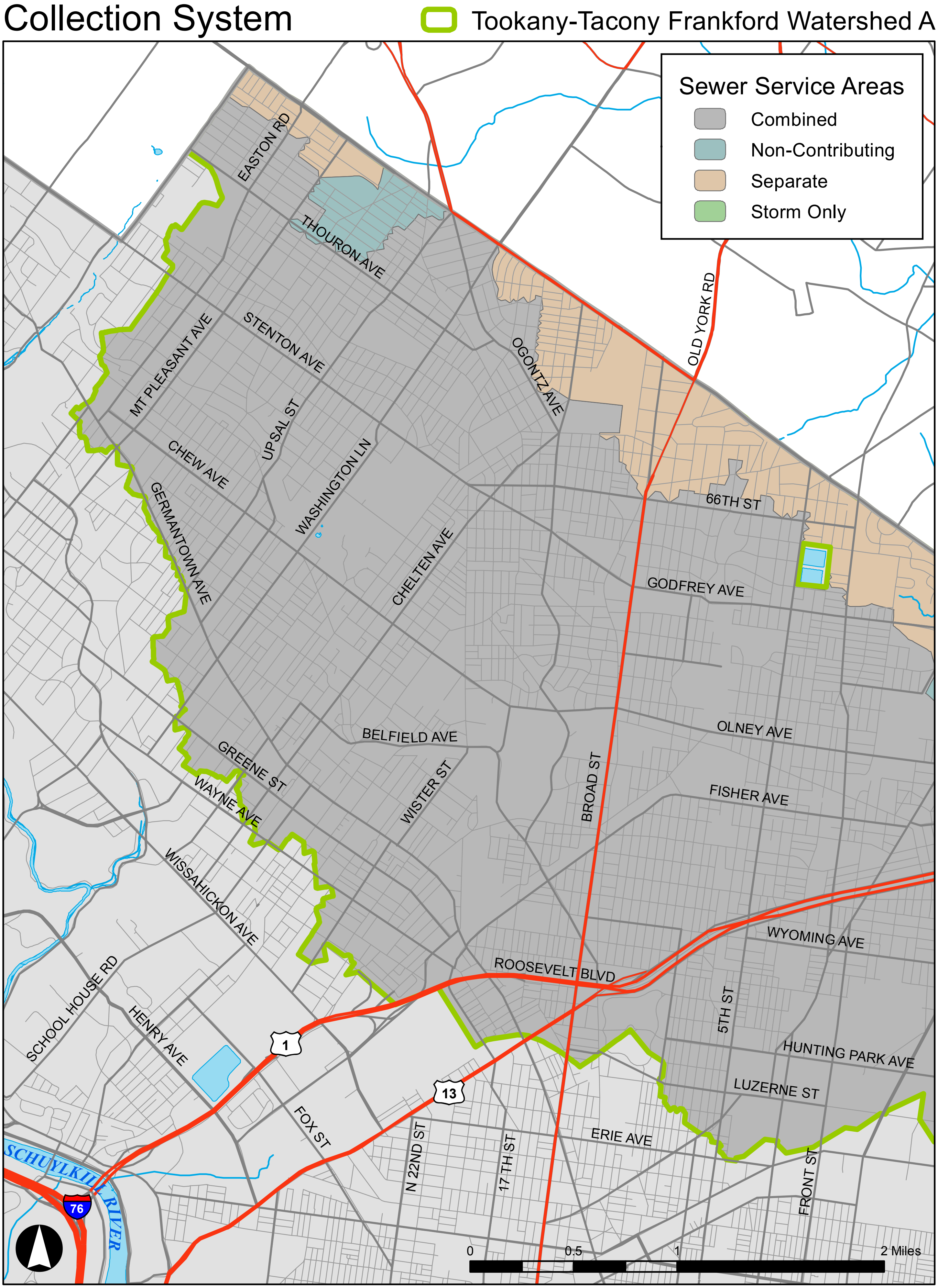
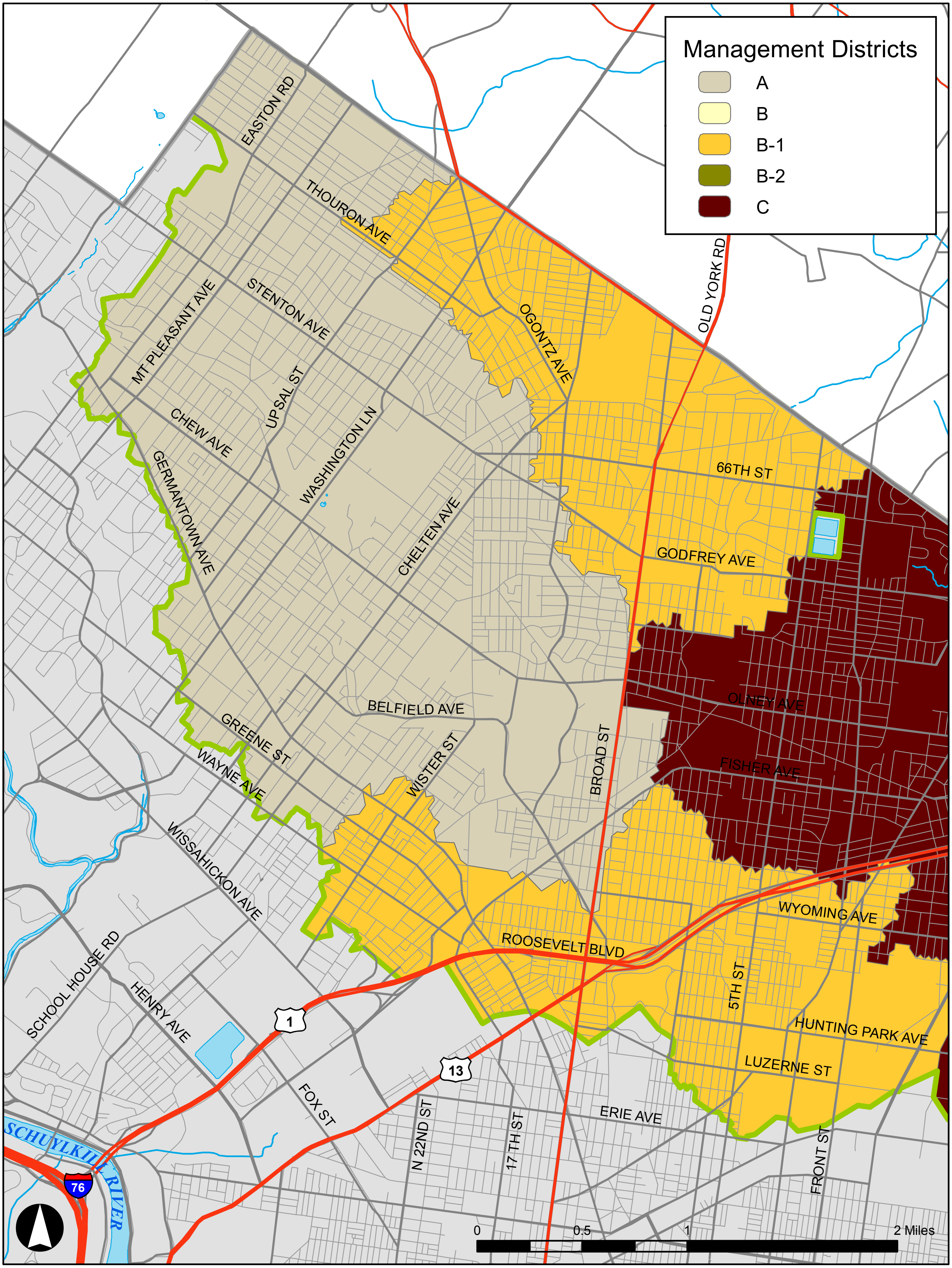


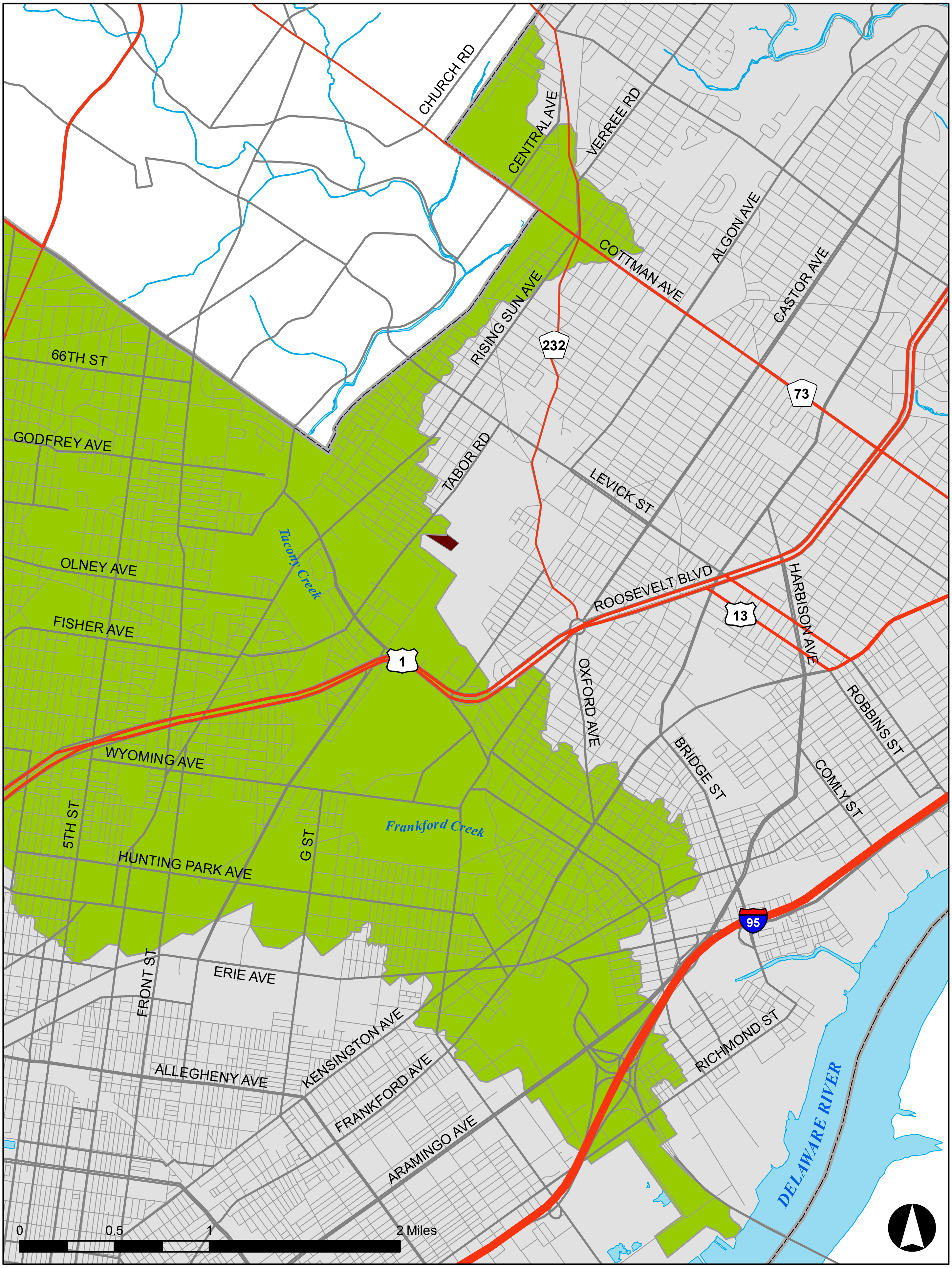
Flood Management Districts

Tookany-Tacony Frankford Watershed A



Watershed Locator

Tookany-Tacony Frankford Watershed B



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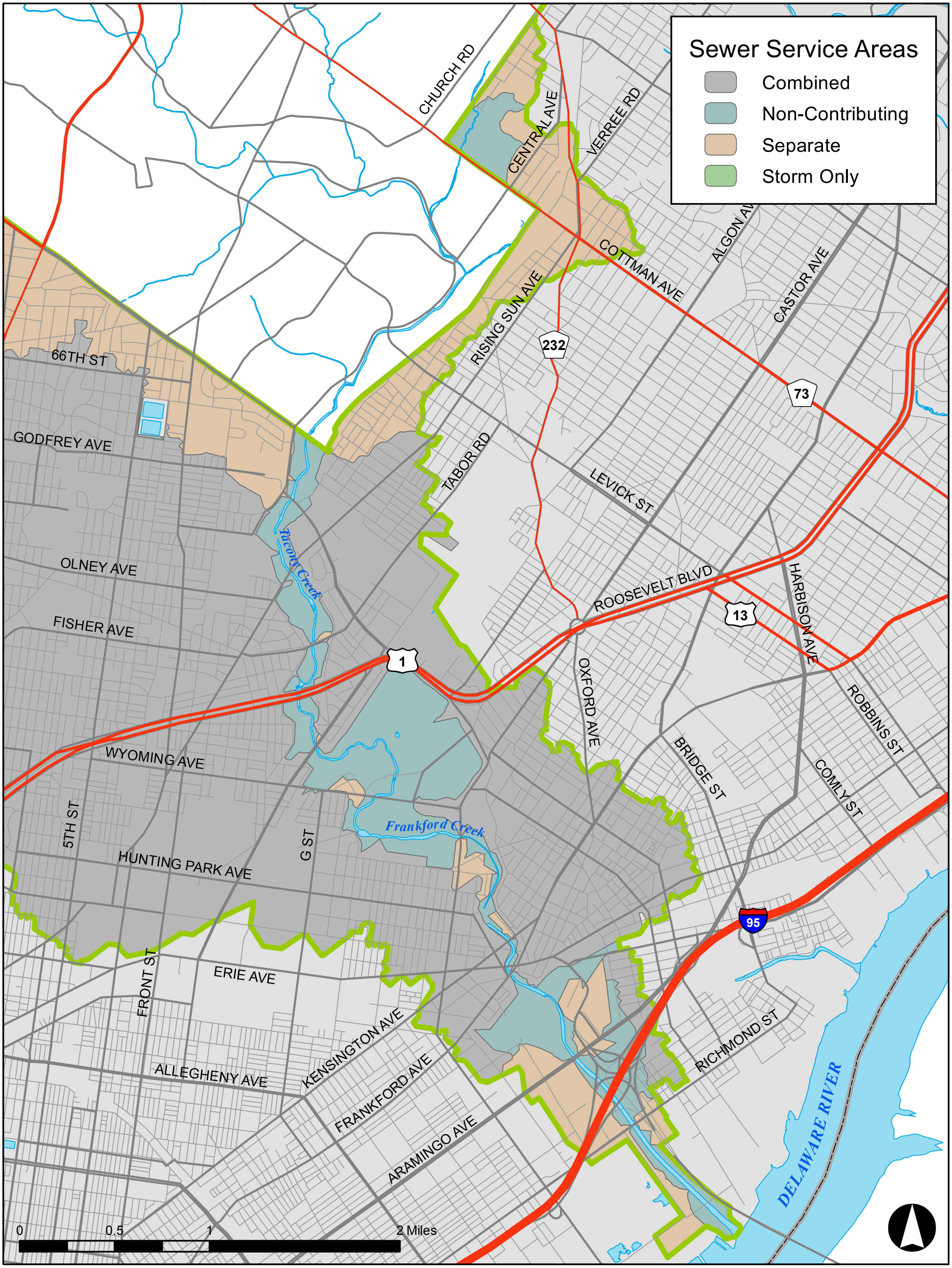
Tookany-Tacony Frankford Watershed B



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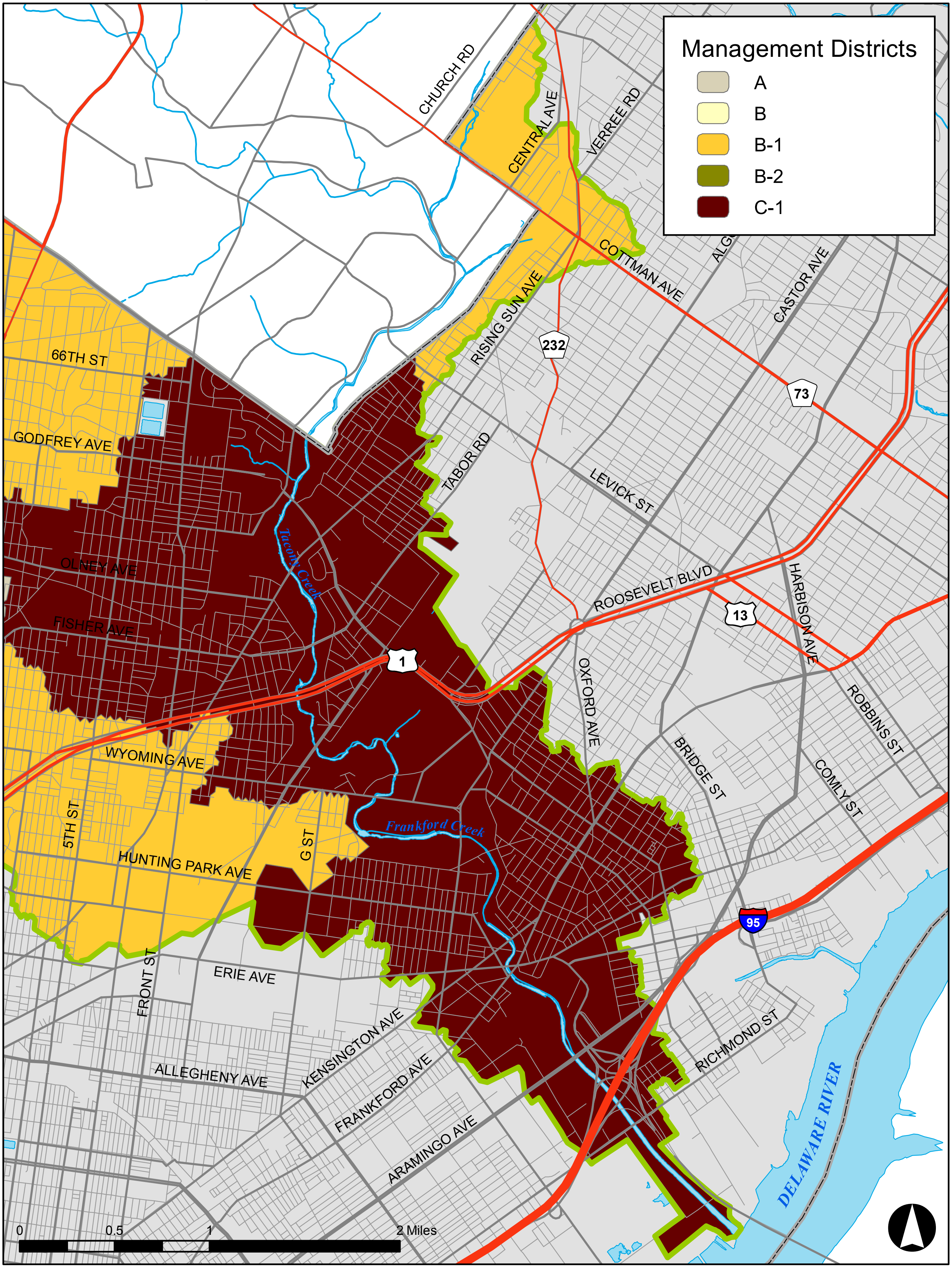

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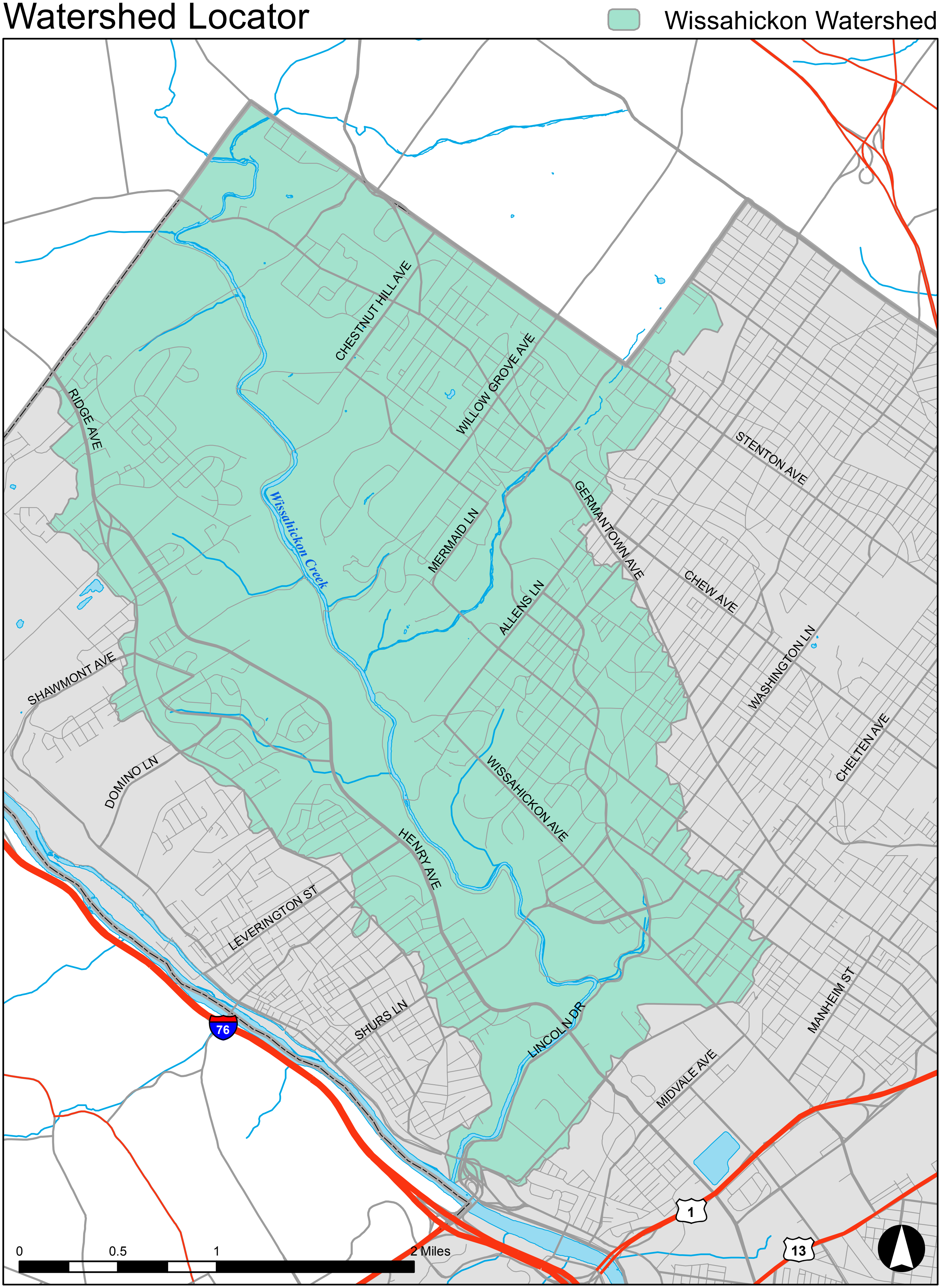

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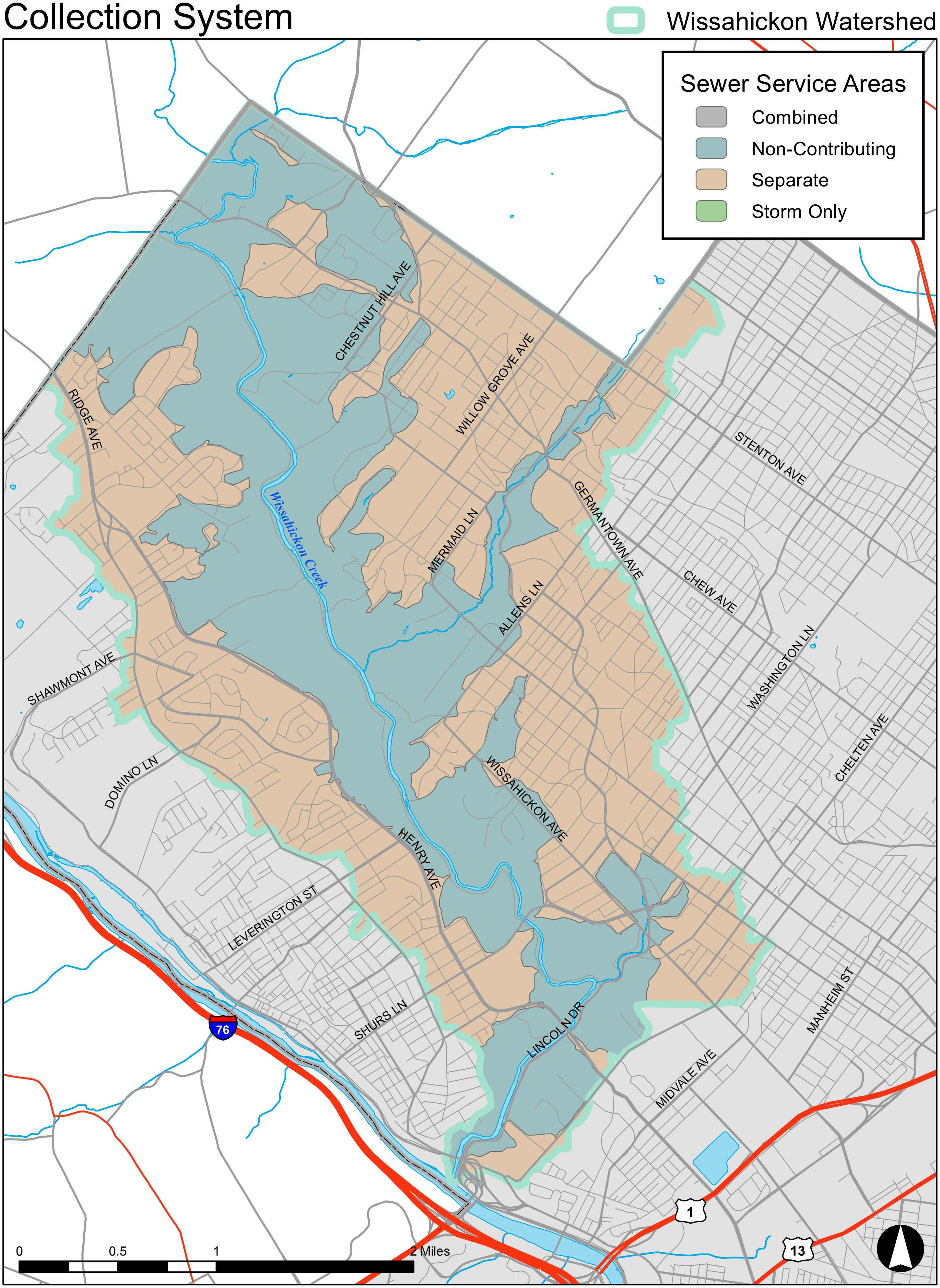

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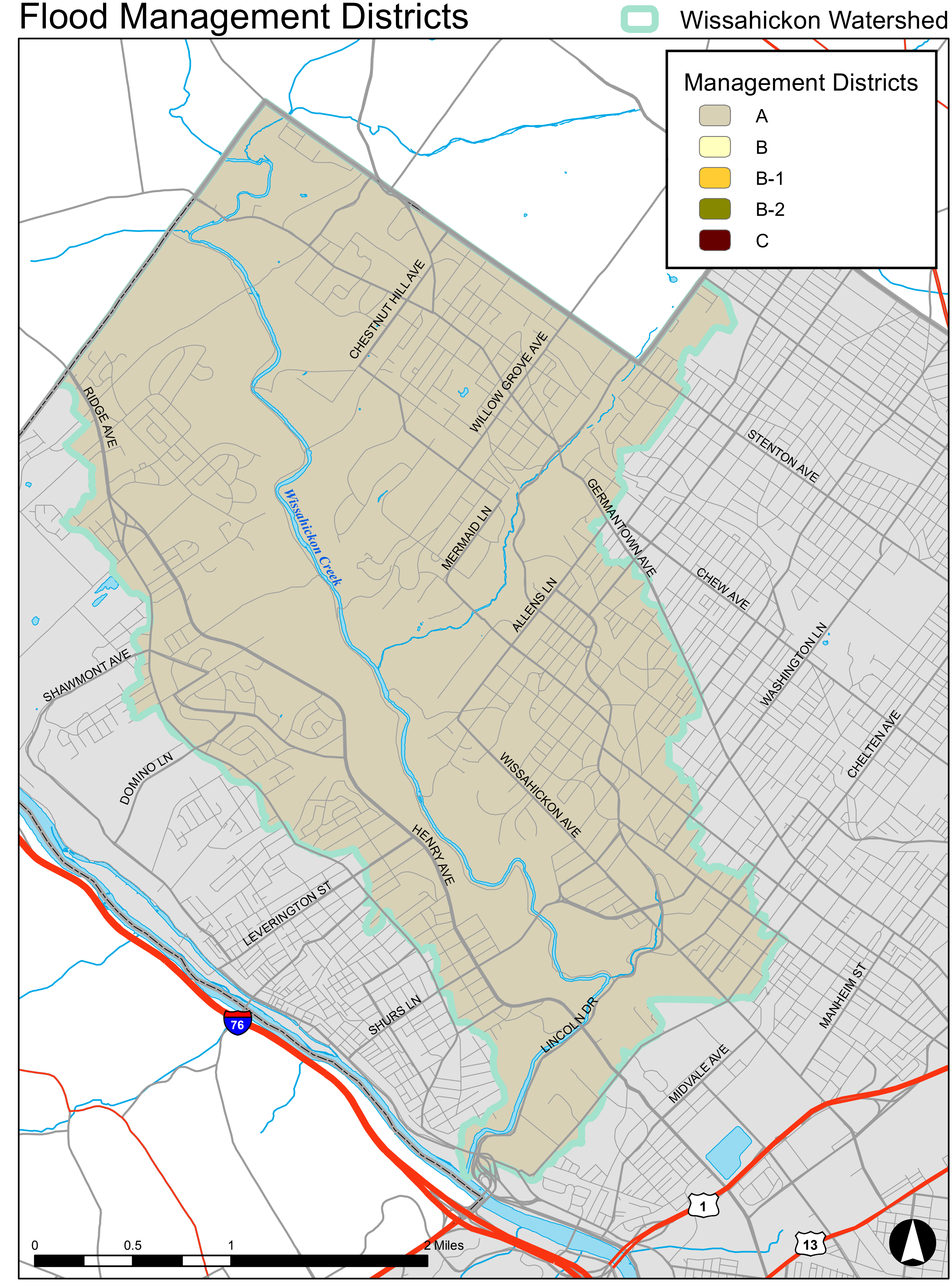

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Worksheets and Checklists

Refer to the Technical Library at http://www.pwdplanreview.org/
for the most recent Checklists and Worksheets

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F

Regulatory Guidance

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F.1

The Philadelphia Stormwater Management Regulations

CHAPTER 6
STORMWATER

600.0 STORMWATER MANAGEMENT

Water Department review of stormwater management plans is authorized by section 14-704 of the Philadelphia Code.

600.1 Definitions

(a) Applicant: Whenever used in this Chapter 6, a property owner, Developer, or other person who has filed an application to the Department for approval to engage in or be exempt from any Regulated Activity at a Development Site in the City of Philadelphia.

(b) Buffer: The area of land immediately adjacent to any surface water body measured perpendicular to and horizontally from the top-of-bank on both sides of a stream that must remain or be restored to native plants, trees, and shrubs.

(c) Conceptual Stormwater Management Plan: A preliminary stormwater management plan as described in these Regulations and in the Manual.

(d) Demolition: To tear down, raze, or remove an existing structure or impervious surface, whether in whole or in part.

(e) Design Storm: The magnitude and temporal distribution of precipitation from a storm event defined by probability of occurrence (e.g., five-year storm) and duration (e.g., 24-hours), used in the design and evaluation of stormwater management systems.

(f) Developer: Any landowner, agent of such landowner, or tenant with the permission of such landowner, who makes or causes to be made a subdivision of land or land Development project prior to issuance of the Certificate of Occupancy.

(g) Development: Any human-induced change to improved or unimproved real estate, whether public or private. As used in these Regulations, Development encompasses, but is not limited to, New Development, Redevelopment, Demolition, and Stormwater Retrofit. It includes the entire Development Site, even when the project is performed in phases.

(h) Development Site: The specific tract of land where any Development activities are planned, conducted, or maintained. It refers to a contiguous area of disturbance including across streets and other rights of way, regardless of individual parcel ownership, where lots are developed as one common project.

(i) Diffused Drainage Discharge: Drainage discharge not confined to a single point location or channel, such as sheet flow or shallow concentrated flow.

(j) Directly Connected Impervious Area (DCIA): An impervious or impermeable surface that is directly connected to the drainage system as defined in the Manual.

(k) Earth Disturbance: A construction or other human activity which disturbs the surface of land, including, but not limited to, clearing and grubbing, grading, excavation, embankments, land development, agricultural plowing or tilling, timber harvesting activities, road maintenance activities, mineral extraction, and the moving, depositing, stockpiling, or storing of soil, rock or earth materials or as otherwise defined in the Manual.

(l) Erosion and Sediment Control Plan: A site specific plan consisting of both drawings and a narrative that identifies

measures to minimize accelerated erosion and sedimentation before, during and after Earth Disturbance.

(m) Groundwater Recharge: The replenishment of existing natural underground water supplies from precipitation or overland flow without degrading groundwater quality.

(n) Management District: Sub-area delineations that determine peak rate attenuation requirements, as defined in the Manual. A Development Site located in more than one Management District shall conform to the requirements of the district into which the site discharges.

(o) Manual: The most recent version of the Philadelphia Stormwater Management Guidance Manual.

(p) New Development: Development project on an unimproved tract of land where structures or impervious surfaces were removed before January 1, 1970.

(q) Operations & Maintenance Agreement (O & M Agreement): Agreement between the Property Owner and the City which outlines the maintenance requirements associated with the Post Construction Stormwater Management Plan.

(r) Post Construction Stormwater Management Plan (PCSMP): A complete stormwater management plan set as described in these Regulations and in the Manual.

(s) Predevelopment Condition: For New Development and Redevelopment, Predevelopment shall be defined according to the procedures found in the Manual.

(t) Redevelopment: Development on an improved tract of land that includes, but is not limited to, the demolition or removal of existing structures or impervious surfaces and replacement with new impervious surfaces. This includes replacement of impervious surfaces that have been removed on or after January 1, 1970.

(u) Record Drawings: Construction drawings revised to represent the as-built conditions.

(v) Stormwater Management Practice (SMP): Any man-made structure that is designed and constructed to detain, infiltrate, or otherwise control stormwater runoff quality, rate, or quantity.

(w) Stormwater Pretreatment: Techniques employed to remove pollutants before they enter the SMP, including, but not limited to, the techniques defined and listed as pretreatment in the Manual.

(x) Stormwater Retrofit: The voluntary rehabilitation and/or installation of SMPs on a property to better manage stormwater runoff.

600.2 Regulated Activities

(a) A Regulated Activity under these Regulations is Development that results in an area of Earth Disturbance greater than or equal to 15,000 square feet, or as otherwise required by local, state, and federal requirements. The area of Earth Disturbance during the construction phase determines requirements for the erosion and sediment controls and post-construction stormwater management.

(b) The applicability of these Regulations is summarized in the Table of Applicable Stormwater Regulations in Philadelphia and in the Manual.

(c) These Regulations shall apply to the entire Development Site even if Development on that site is to take place in phases.

(d) Existing SMPs may be used on a Development Site if the SMPs meet all of the requirements of these Regulations.

600.3 Exemptions

(a) General Exemptions

The following cases are exempt from the specified requirements of these Regulations.

(1) Redevelopment that results in an area of Earth Disturbance greater than or equal to fifteen thousand (15,000) square feet, but less than one (1) acre, is exempt from the requirements of Section 600.5(b), Channel Protection Requirement.

(2) Redevelopment that results in an area of Earth Disturbance greater than or equal to fifteen thousand (15,000) square feet that can demonstrate a twenty percent (20%) reduction in DCIA from Predevelopment Conditions as described in the Manual, is exempt from the requirements of Section 600.5(b),Channel Protection Requirement and 600.5(c), Flood Control Requirement.

(b) Exemption Responsibilities

An exemption shall not relieve the Applicant, Developer or property owner from implementing such measures as are necessary to protect public health, safety, property, water quality, and the environment.

(c) Emergency Exemption

Emergency maintenance work performed for the protection of public health and safety is exempt from the requirements of these Regulations. A written description of the scope and extent of any emergency work performed shall be submitted to the Department within two (2) calendar days of the commencement of the activity. If the Department finds that the work is not an emergency, then the work shall cease immediately and the requirements of these Regulations shall be addressed as applicable.

(d) Special Circumstances

If conditions exist that prevent the reasonable implementation of water quality and/or quantity control practices on site, upon written request by the property owner, the Department may at its sole discretion accept off-site stormwater management practices, retrofitting, stream restorations, or other practices that provide water quality and/or quantity control equal or greater than onsite practices for the volume which the Applicant has demonstrated to be infeasible to manage and treat on site.

Table of Applicable Stormwater Regulations in Philadelphia				
		Earth Disturbance Associated with Development		
		0-14,999 sq. ft.	15,000 sq. ft.-1 acre	> 1 acre
Section 600.5(a) Water Quality Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Yes	Yes
Section 600.5(b) Channel Protection Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Exempt	Yes (Alternate Criteria)
Section 600.5(c) Flood Control Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Yes (Alternate Criteria)	Yes (Alternate Criteria)
Section 600.6 Nonstructural Project Design Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Yes	Yes
Section 600.8 Post-Construction Stormwater Management Plan Requirement	New Development	N/A**	Yes	Yes
	Redevelopment	N/A**	Yes	Yes

Yes (Alternate Criteria) – requirements of section may be waived depending on post-development site conditions (See Sections 600.3(a)(3), 600.5(b) and 600.5(c) for further details).

N/A - Not Applicable, development project is not subject to requirements of indicated Regulations section. Voluntary controls are encouraged.

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

Any local, state, or federal requirements still apply.

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

600.4 Erosion and Sediment Control during Earth Disturbance

(a) All Earth Disturbance must comply with the Erosion and Sediment Control requirements of the Pennsylvania Department of Environmental Protection (PADEP) as specified in 25 Pa. Code § 102.4.

(b) No Earth Disturbance greater than or equal to fifteen thousand (15,000) square feet and less than one (1) acre shall commence until the Department approves an Erosion and Sediment Control Plan conforming to the regulations of the PADEP.

600.5 Post-Construction Stormwater Management Criteria

(a) Water Quality Requirement: The Water Quality Requirement is designed to recharge the groundwater table and to provide water quality treatment for stormwater runoff.

(1) The following formula shall be used to determine the water quality volume (WQv) in cubic feet of storage for the development site:

$$WQ_v = \left(\frac{P}{12}\right) * (I) \qquad \text{Eqn: 600.1}$$

Where:
WQv = Water Quality Volume (cubic feet)
P = 1.0 inch
I = DCIA within the limits of earth disturbance (square feet)

(2) Groundwater Recharge Requirement: In order to preserve or restore a more natural water balance on a Development Site, the water quality volume shall be infiltrated on site. A list of acceptable practices for infiltration is provided in the Manual.

(A) The infiltration volume shall be equal to one (1) inch of rainfall over all DCIA within the limits of Earth Disturbance.

(B) To determine if infiltration is appropriate on the Development Site, follow the Hotspot Investigation, Subsurface Stability, and Suitability of Infiltration procedures found in the Manual.

(C) If the soil investigation report demonstrates that the soil is unsuitable for infiltration, the Applicant shall follow the Infiltration Waiver Request procedure requirements as defined in the Manual.

(3) Water Quality Treatment Requirement.

(A) Where it has been demonstrated, in accordance with section 600.5(a)(2) of these Regulations, that a portion or all of the water quality volume cannot be infiltrated on site, the water quality volume which cannot be infiltrated on site must be treated for water quality.

(B) Water quality treatment is attained differently in separate sewer areas and in combined sewer areas as specified in the Manual.

(b) Channel Protection Requirement: The Channel Protection Requirement is designed to minimize accelerated channel erosion resulting from stormwater runoff from Development Sites.

(1) To meet the Channel Protection Requirement, SMPs shall retain or detain the runoff from all DCIA within the limits of Earth Disturbance from a one-year, 24-hour

Natural Resources Conservation Service (NRCS) Type II design storm in the proposed site condition such that the runoff takes a minimum of 24 hours and a maximum of 72 hours to drain from the facility.

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

(3) Design criteria and a list of SMPs for channel protection are included in the Manual.

(c) Flood Control Requirement

(1) To prevent flooding caused by extreme events, the City of Philadelphia is divided into Management Districts that require different levels of stormwater attenuation depending on location. Management Districts shall be determined for the Development Site using the maps provided in the Manual.

(A) The Table of Peak Runoff Rates for Management Districts lists the attenuation requirements for each Management District.

(B) A Development Site located in more than one Management District shall conform to the requirements of the district where the discharge point is located.

(2) Predevelopment Conditions for New Development and Redevelopment are specified in the Manual.

Table of Peak Runoff Rates for Management Districts

District	Column A NRCS Type II 24-hour Design Storm applied to Proposed Condition	Column B NRCS Type II 24 –hour Design Storm applied to Predevelopment Condition
A	2 – year	1 - year
A	5 – year	5 - year
A	10 – year	10 - year
A	25 – year	25 - year
A	50 – year	50 – year
A	100-year	100-year
B	2 – year	1 – year
B	5 – year	2 – year
B	10 – year	5 – year
B	25 – year	10 – year
B	50 – year	25 – year
B	100 – year	50 – year
B-1	2 – year	1- year
B-1	5 – year	2 – year
B-1	10 – year	5 - year
B-1	25 – year	10 - year
B-1	50- year	25- year
B-1	100-year	100-year
B-2	2 – year	1- year
B-2	5 – year	2 - year
B-2	25 – year	5 - year
B-2	50- year	10- year
B-2	100 – year	100 - year
C*	Conditional Direct Discharge District	
C – 1**	Conditional Direct Discharge District	

SMPs shall be designed such that peak rates from Column A are less than or equal to Peak Rates from Column B.

* In District C, a Development Site that can discharge directly without use of City infrastructure may do so without control of proposed conditions peak rate of runoff.

** In District C-1, a Development Site which can discharge directly to the Tookany/Tacony-Frankford main channel or major tributaries without the use of City infrastructure may do so without the control of proposed conditions peak rate of runoff greater than the 5 – year storm.

For Conditional Direct Discharge Districts, the proposed conditions peak rate of runoff for a

Development Site that discharges to City infrastructure must be controlled to the Predevelopment Conditions peak rate as required in District A provisions for the specified Design Storms.

The Predevelopment Condition shall be defined according to the procedures found in the Manual.

600.6 Nonstructural Project Design and Sequencing to Minimize Stormwater Impacts

(a) An Applicant is required to find practicable alternatives to the surface discharge of stormwater, the creation of impervious surfaces, and the degradation of Waters of the Commonwealth.

(b) All Development shall include the following steps in sequence to comply with water quality requirements of these Regulations. The goal of the sequence is to minimize the increases in stormwater runoff and impacts to water quality resulting from the proposed regulated activity.

(1) Prepare an Existing Resource and Site Analysis (ERSA) plan and worksheet, showing environmentally sensitive areas including, but not limited to: steep slopes, ponds, lakes, streams, suspected wetlands, hydric soils, vernal pools, land development, any existing recharge areas, and any other requirements of the worksheet available in the Manual;

(2) establish the required Buffer in accordance with federal, state and/or local law;

(3) prepare a Conceptual Stormwater Management Plan avoiding the sensitive areas identified in ERSA;

(4) evaluate nonstructural stormwater management alternatives as described in the Manual;

(5) minimize Earth Disturbance during the construction phase;

(6) use site design techniques described in the Manual to minimize the impervious surfaces within the limits of Earth Disturbance;

(7) use techniques in the Manual to minimize DCIA within the limits of Earth Disturbance;

(8) design appropriate SMPs according to the Manual;

(A) meet Water Quality Requirement and provide for Stormwater Pretreatment prior to infiltration or water quality treatment in accordance with Section 600.5(a) of these Regulations and the Manual;

(B) meet Channel Protection Requirement in accordance with Section 600.5(b) of these Regulations;

(C) meet Flood Control Requirement for the appropriate Management District in accordance with Section 600.5(c) of these Regulations; and

(9) adjust the site design as needed to meet all requirements of these Regulations.

600.7 Requirements for the Design of SMPs

(a) General Requirements

(1) In order to provide for the protection of public health and safety and to more effectively manage stormwater in Philadelphia, all SMPs shall meet the requirements of these Regulations.

(2) The existing points of concentrated drainage that discharge onto adjacent land shall not be altered in any manner that could cause property damage without written permission of the owner of the adjacent land.

(3) The design of all SMPs shall incorporate sound engineering principles and practices as detailed in the Manual. The Department reserves the right to reject any

design that would result in the creation or continuation of a stormwater problem area.

(4) All stormwater runoff in excess of any volume infiltrated on site must be routed through a dedicated stormwater pipe and conveyed to the approved connection or point of discharge.

(5) When the Development Site is located within a combined sewer area and adjacent to a receiving water body, stormwater shall be discharged directly to receiving waters after requirements of these Regulations and any applicable local, state or federal requirements are met.

(6) Areas of existing diffused drainage discharge shall be subject to any applicable discharge criteria in the general direction of existing discharge, whether proposed to be concentrated or maintained as diffused drainage areas, except as otherwise provided by these Regulations. If diffused drainage discharge is proposed to be concentrated and discharged onto adjacent land, the Applicant must document that adequate downstream conveyance facilities exist to safely transport the concentrated discharge, or otherwise prove that no erosion, sedimentation, flooding or other impacts will result from the concentrated discharge.

(7) All SMPs shall incorporate maximum ponding and/or draw down requirements consistent with the Manual.

(8) Acceptable calculation methods for the design of SMPs are provided in the Manual.

600.8 PCSMP Requirements

(a) General Requirements

For any activities regulated by these Regulations and the Philadelphia Code Section §14-704(3):

(1) No zoning permit may be issued until the Water Department has approved a Conceptual Stormwater Management Plan.

(2) No Earth Disturbance may commence and no building permit will be issued until the Department has approved a PCSMP.

(b) Conceptual Approval

To obtain conceptual approval from the Department, the Applicant must complete the ERSA worksheet, and prepare an ERSA plan and Conceptual Stormwater Management Plan.

(c) PCSMP Approval

(1) The PCSMP shall include a general description of the Development project, project sequence, calculations, maps and plans as described in Section 600.6(b) of these Regulations. A list of required contents of the PCSMP is located in the Manual.

(2) For any activities that require state or federal permits, proof of application or approval of those permit(s) shall be included as part of the PCSMP.

(3) All PCSMP materials shall be submitted to the Department in accordance with submittal procedures as outlined in the Manual.

(d) Miscellaneous Stormwater Management Charges

Applicability and requirements for Stormwater Plan Review Fees and Stormwater Management in Lieu are described in Section 308.0 of these Regulations.

(e) Project Expirations

Conceptual Stormwater Management Plan and PCSMP approvals and rejections shall

be subject to the Department's expiration policy, set forth in the Manual.

600.9 Permit Requirements by Other Government Entities

(a) Other government entities may require permits for certain regulated Earth Disturbance activities.

(b) Requirements for these permits must be met prior to commencement of Earth Disturbance.

600.10 Inspections

(a) The Department or its designee may inspect any phase of the installation of the SMPs.

(b) An onsite meeting between the Department and the Applicant is required prior to the start of construction.

(c) During any stage of the work, if the Department or its designee determines that any component of the PCSMP is not being installed as approved by the Department, the Department shall issue a "Stop Work Order" preventing other on-site construction from proceeding until the deficiencies are corrected.

(d) Record Drawings for all PCSMP components must be submitted to the Department.

(e) A final inspection of all PCSMP components shall be conducted by the Department or its designee to confirm compliance with the approved PCSMP prior to the issuance of Certificate of Occupancy, or other equivalent issuance, or use of the Development Site.

600.11 Construction, Operations and Maintenance of SMPs

(a) No regulated Earth Disturbance activities shall commence until the Department has approved a PCSMP in accordance with the requirements set forth in the Manual.

(b) All SMPs shall be constructed in accordance with the PCSMP.

(c) Operation and Maintenance responsibilities are defined in the O & M Agreement between the property owner and the City and in the Manual. SMPs and other stormwater management controls shall be maintained by the property owner or designee to design function.

(d) There shall be no alteration or removal of any SMP or other stormwater management control required by an approved PCSMP and the O & M Agreement, and the property owner shall not allow the property to remain in a condition which does not conform to an approved PCSMP and O & M Agreement.

(e) The Department reserves the right to accept or reject the operations and maintenance responsibility for any SMPs.

(f) The Department or its designee may inspect the long term operation of the SMPs and other stormwater management controls.

600.12 Stormwater Management Easements

(a) Stormwater management easements or rights of way are required for all areas used for off-site SMPs or stormwater conveyance, unless a waiver is granted by the Department.

(b) Stormwater management easements shall be provided by the property owner if necessary for access for inspections and maintenance, or for the preservation of stormwater runoff conveyance, infiltration, detention areas and/or other stormwater controls and SMPs, by persons other than the property owner.

(c) The stormwater management easement and its purpose shall be specified when recorded in accordance with section 600.13 of these Regulations.

600.13 Recording of O & M Agreement

(a) The owner of any land upon which SMPs will be placed, constructed or implemented as described in the PCSMP shall be responsible for the recording of the following documents with the Philadelphia Department of Records:

(1) The O & M Agreement, which shall be included as part of the PCSMP submitted under Section 600.8, and

(2) Easements under Section 600.12 of these Regulations. Recordings shall be at the property owner's expense.

600.14 Prohibited Discharges

(a) No person shall allow, or cause to allow, a stormwater discharge into the City's separate storm sewer system that is not composed entirely of stormwater.

(b) In the event that the Department determines that any discharge to a storm sewer is not composed entirely of stormwater, the Department will notify the responsible person to immediately cease the discharge.

(c) Nothing in this Section shall affect a discharger's responsibilities under state law.

600.15 Prohibited Connections

(a) The following connections are prohibited, except as otherwise provided:

(1) Any drain or conveyance, whether on the surface or subsurface, which allows any non-stormwater discharge including sewage, groundwater, process wastewater, and wash water, to enter the separate storm sewer system.

(2) Any connections to the storm drain system from indoor drains and sinks.

(3) Any drain or conveyance connected from a commercial or industrial land use to the separate storm sewer system that has not been documented in plans, maps, or equivalent records, and approved by the City.

600.16 Enforcement

(a) Whenever a property owner, Applicant, Developer, or other responsible party has engaged in conduct prohibited by, or failed to meet a requirement of this Chapter 6, the Department may order compliance by notifying the responsible party.

(b) Such notification shall set forth the nature of the violation(s) and establish a time limit for correction of the violation(s).

(c) Failure to comply within the time specified may subject the responsible party to any and all available penalty provisions. Such penalties shall be cumulative and shall not prevent the City from pursuing all remedies available in law or equity.

(d) The Department may suspend or revoke any approvals granted for the Development Site upon discovery of the failure of the property owner, Applicant or Developer to comply with these Regulations.

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F.2

Local Permitting Requirements

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F. 2. Local Permitting Requirements

In order to disturb earth in the City of Philadelphia, developers may be required to obtain permits and/or approvals from various City agencies and departments. The list below is provided for convenience, however, this list is only current as of June 2007. and it is subject to change. Developers should consult with the Department of Licenses and Inspections for the most up to date guidance on permit requirements in the City of Philadelphia.

* Licenses and Inspections (http://www.phila.gov/LI)
    * Zoning Permit
    * Building Permit
* City Planning Commission (http://www.philaplanning.org/)
    * Plat Approval
* Philadelphia Water Department (http://www.phila.gov/water)
    * Act 537
    * Sewer
    * Water
    * Stormwater
    * Groundwater Discharge Permit
    * Industrial Waste
* Fairmount Park (http://www.phila.gov/fairpark/)
* Streets Department (http://www.phila.gov/streets)
* Fire Commissioner (http://www.phila.gov/fire/)
* Historical Commission (http://www.phila.gov/historical/)

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F.3

Federal and State Permitting Requirements

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F. 3 State and Federal Permitting Requirements

In addition to City Permits and approvals as described in F3, land development may be subject to state and federal regulations. Each project is likely to have slightly different requirements. This Manual contains information that was valid as of June 2007 which is subject to change. Developers should consult with the appropriate regulatory agency to determine applicable plan and/or permitting requirements for development or earth disturbance activities. Some common requirements include:

- Pennsylvania Department of Transportation (PENN DOT): Highway Occupancy Permit
- Pennsylvania Department of Environmental Protection (PADEP): Construction Erosion and Sedimentation Control Plan
- Pennsylvania Department of Environmental Protection (PADEP): West Nile Virus Control Plan and Guidance Documents
- National Pollutant Discharge Elimination System (NPDES): General PAG-2 or Individual Permit for Stormwater Discharges Associated with Construction Activities
- PADEP and US Army Corps of Engineers (USACE) Joint Permit: Pennsylvania Water Obstruction and Encroachment Permit and a USACE Section 404 Permit
- PADEP Bureau of Waterways Engineering, Division of Dam Safety: Dam Permit
- PADEP Bureau of Watershed Management: General Permit BDWM-GP-4 Intake and Outfall Structures

For information on Pennsylvania Department of Environmental Protection (PADEP) requirements see the PADEP Guide to Permits for Land Development and/or contact the:

PADEP
Southeast Regional Office
2 East Main Street,
Norristown, PA 19401.
http://www.dep.state.pa.us/

For further information on Federal Regulations:

- Clean Water Act (http://www.epa.gov/region5/water/cwa.htm)
- United States Environmental Protection Agency (USEPA) Region 3

  USEPA Region 3
  1650 Arch Street (3PM52)
  Philadelphia, PA 19103-2029
  (http://www.epa.gov/reg3wapd/programs.htm)

- National Pollutant Discharges Elimination System (NPDES) (http://cfpub.epa.gov/npdes/)
- Pennsylvania Department of Environmental Protection

  PADEP
  Bureau of Water Supply and Wastewater Management
  Permits Section
  PO Box 2063
  Rachel Carson State Office Building
  Harrisburg, PA 17105-2063

- Army Corps of Engineers

  USACE
  Wanamaker Building, Rm 600
  100 Penn Square East
  Philadelphia, PA 19107-3390

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F.4

Special Circumstances and Waiver Requests

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F.4. Special Circumstances and Waiver Requests

F.4.1 Special Circumstances

The Philadelphia Stormwater Management Regulations state:

> *600.3 (d) If conditions exist that prevent the reasonable implementation of water quality and quantity control practices on site, upon written request by the Owner, the Office of Watersheds of the Philadelphia Water Department, may at its sole discretion accept off-site SMPs, retrofitting, stream restorations, or other practices that provide water quality and quantity control equal or greater than onsite practices for the volume that the Owner has demonstrated to be infeasible to treat on site.*

The Philadelphia Water Department (PWD) recognizes that there may be circumstances on a proposed site that make it impractical to implement on-site stormwater management practices to the standards specified in this manual. Applicants who ask to have their projects considered for special circumstances must demonstrate the extent to which onsite Stormwater Management Practices (SMPs) are infeasible.

PWD will review a complete Post Construction Stormwater Management Plan (PCSMP) to determine if special circumstances warrant treatment of a portion or all of the stormwater from a site. The PWD may at its sole discretion accept:

- off-site SMPs,
- retrofitting,
- stream restorations, or
- other practices

that provide water quality control equal or greater than onsite practices for the volume that the Owner has demonstrated to be infeasible to treat on site. The developer shall account for the management of all stormwater runoff from the site unless they can demonstrate that it is infeasible to do so. The developer shall provide stormwater management to the maximum extent practicable, as approved by PWD, in all cases before any off-site facilities or practices as noted above will be allowed. Date

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F.4.2 Waiver Request Process

Infiltration Waiver Requests

A waiver from the infiltration requirement **must** be requested at any site where infiltrilration is infeasible. To request a waiver form the infiltration requirement send the following form letter, a complete infiltration waiver request worksheet and stamed and signed geotechnical report for the project area to:

Projects Control
Philadelphia Water Department
1101 Market Street, 2nd Floor
Philadelphia, PA 19107

It is strongly recommended that all waiver requests be submitted before the PCSMP is submitted as the site design may be significantly affected. A copy of the waiver request approval should be submitted with the PCSMP. Please note that all waivers may be revoked should information become available which contradicts the original request. Electronic versions of all waiver request form letters and worksheets can be downloaded from the Technical Library at http://www.pwdplanreview.org/.

Small Orifice Waiver Request

A waiver from the 3-inch minimum orifice design **must** be requested when use of a smaller orifice is being proposed. To request a waiver form the 3-inch minimum, send the following form letter and a complete small orifice request worksheet to:

Projects Control
Philadelphia Water Department
1101 Market Street, 2nd Floor
Philadelphia, PA 19107

It is strongly recommended that all waiver requests be submitted before the PCSMP is submitted as the site design may be significantly affected. A copy of the waiver request approval should be submitted with the PCSMP. Please note that all waivers may be revoked should information become available which contradicts the original request. Electronic versions of all waiver request form letters and worksheets can be downloaded from the Technical Library at http://www.pwdplanreview.org/.

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Abbreviations & Acronyms

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Abbreviations & Acronyms

CERM	Civil Engineering Reference Manual
CSO	Combined Sewer Overflow
DCIA	Directly Connected Impervious Area
DIC	**Disconnected Impervious Cover**
PADEP	Pennsylvania Department of Environmental Protection
E & S	Erosion and Sediment
ERSA	Existing Resource and Site Analysis
HSG	Hydrologic Soil Group
L & I	Department of Licenses & Inspections
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resources Conservation Service
O & M	Operations and Maintenance
PASMM	Pennsylvania Stormwater Management Manual
PA SBMPM	Pennsylvania Stormwater BMP Manual
PCPC	Philadelphia City Planning Commission
PCSMP	Post-Construction Stormwater Management Plan
PWD	Philadelphia Water Department
SMP	Stormwater Management Practice
SWTR	Surface Water Treatment Rule
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
ZBA	Zoning Board of Adjustments

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Glossary

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Glossary Terms

Buffer: The area of land immediately adjacent to any surface water body measured perpendicular to and horizontally from the top-of-bank on both sides of a stream that must remain or be restored to native plants, trees, and shrubs.

Design Professional: A licensed professional engineer registered in the Commonwealth of Pennsylvania.

Design Storm: The magnitude and temporal distribution of precipitation from a storm event measured in probability of occurrence (e.g., five-year storm) and duration (e.g., 24 hours), used in the design and evaluation of stormwater management systems.

Developer: Any landowner, agent of such landowner, or tenant with the permission of such landowner, who makes or causes to be made a subdivision of land or land development project prior to issuance of the Certificate of Occupancy.

Development: Any human-induced change to improved or unimproved real estate, whether public or private, including but not limited to land development, construction, installation, or expansion of a building or other structure, land division, street construction, and site alteration such as embankments, dredging, grubbing, grading, paving, parking or storage facilities, excavation, filling, stockpiling, or clearing. As used in these Regulations, development encompasses both new development and redevelopment. It includes the entire development site, even when the project is performed in stages.

Development Site: The specific tract of land where any earth disturbance activities are planned, conducted, or maintained.

Diffused Drainage Discharge: Drainage discharge not confined to a single point location or channel, such as sheet flow or shallow concentrated flow.

Directly Connected Impervious Area (DCIA): An impervious or impermeable surface, which is directly connected to the drainage system as defined in the Philadelphia Stormwater Management Guidance Manual.

Earth Disturbance: Any human activity which moves or changes the surface of land, including, but not limited to, clearing and grubbing, grading, excavation, embankments, land development, agricultural plowing or tilling, timber harvesting activities, road maintenance activities, mineral extraction, and the moving, depositing, stockpiling, or storing of soil, rock or earth materials.

Existing Conditions: Physical conditions on the site including land use, impervious surface, topography, vegetation, soils, and hydrology that exist on the site on the date the owner starts the development process.

Erosion and Sediment Control Plan: A plan for a project site that identifies stormwater detention and retention structures that will minimize accelerated erosion and sedimentation during the construction phase.

Groundwater Recharge: The replenishment of existing natural underground water supplies without degrading groundwater quality.

Hotspots: Areas where land use or activities have contaminated the soil underlying the site such that infiltration of stormwater would likely cause groundwater contamination through leaching of the soil.

Impervious Surface: A surface that prevents the infiltration of water into the ground. Examples of impervious surface include roofs, streets, sidewalks, and parking or driveway areas that are covered with impervious paving materials such as asphalt or concrete.

Management District: Sub-area delineations that determine peak rate attenuation requirements, as defined in the Manual. Sites located in more than one management district shall conform to the requirements of the district into which the site discharges

Manual: The 2005 or most recent edition of the Philadelphia Stormwater Management Guidance Manual. A comprehensive technical stormwater management reference for use in the City of Philadelphia.

New Development: Any development project that does not meet the definition of redevelopment as defined in these Regulations or any development project at a site where structures or impervious surfaces were removed before January 1, 1970.

Owner: Any person, landowner, developer, or tenant with the permission of such landowner who holds legal title to a property subsequent to issuance of the Certificate of Occupancy.

Post Construction Stormwater Management Plan (PCSMP): A complete stormwater management plan as described in these regulations and in the Manual.

Predevelopment Condition: for the purpose of new development, the predevelopment condition shall be the existing condition of the site. For redevelopment, predevelopment shall be defined according to the procedures found in the Manual.

Redevelopment: Any development on a site that requires demolition or removal of existing structures or impervious surfaces and replacement with new impervious surfaces. This includes replacement of impervious surfaces that have been removed on or after January 1, 1970 with new impervious surfaces. Maintenance activities such as top-layer grinding and re-paving are not considered redevelopment. Interior remodeling projects are also not considered redevelopment.

Stormwater Management Practice (SMP): Any man-made structure that is designed or constructed to convey, store, or otherwise control stormwater runoff quality, rate, or quantity. Typical SMPs include, but are not limited to, detention and retention basins, swales, storm sewers, pipes, and infiltration structures.

Stormwater Pretreatment: Techniques employed in SMPs to remove pollutants before they enter the structure, limited to techniques defined and listed as pretreatment in the Manual.

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References

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Homeowner's Guide to Stormwater Management

A Homeowner's Guide to Stormwater Management

You can make a difference!

Learn what you can do on your property and in your community to improve the health of your watershed.

Prepared by: **Office of Watersheds**
Philadelphia Water Department

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The information contained in this guide is being offered by the City of Philadelphia (City) through its Water Department (PWD) for the use of residents of the City. Please note that the stormwater management projects or Best Management Practices (BMPs) in this guide are voluntary projects recommended strictly for homeowners. They are not designed for professionals required to comply with the City's Stormwater Regulations.

If you plan to install any of the following structural projects on your property in the City, please notify PWD via its e-mail address (WaterShedsPWD@phila.gov): Rain Barrels, Rain Gardens, or Dry Wells. PWD would like to register your project with the City's Department of Licenses & Inspections (L&I). Also, PWD encourages you to take photographs of your project and to send them to PWD via the above e-mail address

If you experience problems with any water or sewer piping on your property, you should contact a registered plumber.

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A Homeowner's Guide to Stormwater Management

Table of Contents

Introduction

The Office of Watersheds of the Philadelphia Water Department has a vision for Philadelphia—"Clean Water—Green City." We want to unite the City with its water environment, creating a green legacy for future generations while incorporating a balance between ecology, economics and equity.

In order to achieve the goal of "Clean Water-Green City," we must work together with our partners, local residents, homeowner associations and municipalities on managing stormwater in a manner that will restore our watersheds. We can all play a part in taking an active role in converting our streams, creeks and surrounding green spaces into healthy systems that local residents, along with native fish and wildlife, can use as amenities, sanctuaries and habitats. As a homeowner, your part can be as simple as maintaining your car properly or building a rain garden on your lawn. This guide provides you with the steps and actions you can take to improve stormwater management on your property or in your community. These stormwater management projects will not only help protect our invaluable drinking water sources, but they will help green the city, restore our waterways and improve quality of life for all residents.

For more information, please visit www.PhillyRiverInfo.org or e-mail WaterShedsPWD@phila.gov.

Vehicle Maintenance

By maintaining your car properly you can prevent oil leaks, heavy metals and toxic materials from traveling from your car onto the street. Rain washes oil and other hazardous chemicals from the street into the nearest storm drain, ultimately draining into the Delaware and Schuylkill Rivers, the source of drinking water for many. Just imagine the number of cars in our region and the amount of oil that finds its way into our local waterways! It has been estimated that each year over 180 million gallons of used oil is disposed of improperly (Alameda CCWP, 1992), and that a single quart of oil can pollute 250,000 gallons of drinking water (NDRC, 1994). Please follow proper automotive maintenance.

Maintaining your Vehicle

- Maintain your car and always recycle used motor oil.
- Check your car or truck for drips and oil leaks regularly and fix them promptly. Keep your vehicle tuned to reduce oil use.
- Use ground cloths or drip pans under your vehicle if you have leaks or if you are doing engine work. Clean up spills immediately and properly dispose of clean up materials.
- Collect all used oil in containers with tight-fitting lids. Old plastic jugs are excellent for this purpose.
- Recycle used motor oil. Many auto supply stores, car care centers, and gas stations will accept used oil. Do not pour liquid waste down floor drains, sinks or storm drains.
- Do not mix waste oil with gasoline, solvents, or other engine fluids. This contaminates the oil which may be reused, increases the volume of the waste, and may form a more hazardous chemical.
- Never dump motor oil, antifreeze, transmission fluid or other engine fluids into road gutters, down the storm drain or catch basin, onto the ground, or into a ditch.
- Many communities have hazardous waste collection days where used oil can be brought in for proper disposal. Find out about your program. Recycling just one gallon of used oil can generate enough electricity to run the average household for almost 24 hours.
- Try to use drain mats to cover drains in case of a spill.
- Store cracked batteries in leak proof secondary containers.

Lawn & Garden Care

When fertilizing lawns and using other common chemicals, such as pesticides and herbicides, remember you're not just spraying the lawn. When it rains, the rain washes the fertilizers, pesticides and herbicides along the curb and into storm drains, which ultimately carry runoff into the Schuylkill and Delaware Rivers, our drinking water source. In addition to degrading the water quality of our streams and rivers, pesticides can kill critters in the stream and fertilizers can cause algal blooms, which rob our waterways of oxygen that fish need to survive. If you have to use fertilizers, pesticides, and herbicides, carefully read all labels and apply these products sparingly.

Many homeowners are unaware of the actual nutrient needs of their lawns. According to surveys conducted by the Center for Watershed Protection, over 50% of lawn owners fertilize their lawns, yet only 10 to 20% of lawn owners take the trouble to perform soil tests to determine whether fertilization is even needed (CWP, 1999). *Organic lawn care practices (no chemical pesticides and fertilizers) can also be a wise environmental choice and will save you money.* Conduct a soil test on your lawn and follow the below practices to reduce the need to fertilize on your lawn and garden.

Caring for your Lawn and Garden

- Use fertilizers sparingly. Lawns and many plants do not need as much fertilizer or need it as often as you might think. Test your soil to be sure!
- Consider using organic fertilizers; they release nutrients more slowly.
- Never fertilize before a rain storm (the pollutants are picked up by stormwater during rain events).
- Keep fertilizer off of paved surfaces—off of sidewalks, driveways, etc. If granular fertilizer gets onto paved surfaces, collect it for later use or sweep it onto the lawn.
- Use commercially available compost or make your own using garden waste. Mixing compost with your soil means your plants will need less chemical fertilizer and puts your waste to good use. Another alternative is to use commercial compost, called Earthmate, which is available for free through PWD. Call 215-685-4065 or visit the website to learn more about Earthmate: www.phila.gov/water/brc/brchow2get.html
- Let your grass clippings lay! Don't bag the grass. Use a mulching lawn mower to cut one-third of the blade length each week and naturally fertilize your lawn in the process.

Lawn & Garden Care

- Wash your spreader equipment on a pervious (penetrable) vegetated area, like the lawn, to allow for the natural absorption of excess fertilizer.
- Never apply fertilizer to frozen ground or dormant lawns.
- Maintain a buffer strip of unmowed natural vegetation bordering waterways and ponds to trap excess fertilizers and sediment from lawns/gardens.
- Grow an organic garden (no pesticides or fertilizers). Call the Organic Landscape Alliance at 1-866-820-0279 or visit www.organiclandscape.org.

Pet Waste

When animal waste is left on the ground, rainwater or melting snow washes the pet waste into our storm drains or directly into our local creeks. The disease-causing bacteria found in pet waste eventually flows from our local waterways into the Delaware and Schuylkill Rivers, our drinking water source. In addition to contaminating waterways with disease-carrying bacteria, animal waste acts like a fertilizer in the water, just as it does on land. This promotes excessive aquatic plant growth that can choke waterways and promote algae blooms, robbing the water of vital oxygen.

Scooping Up the Poop

- Bag it! When going for dog walks, take a shopping bag or sandwich bag. When doggy makes a deposit, turn the baggie inside out over your hand and use it as a glove to pick up the waste.
- Flush the pet waste down the toilet because then it is treated at a sewage treatment plant.
- If flushing down the toilet is not a viable option, put the pet waste in the trash, but never put waste into storm drains.
- Encourage your neighbors to provide pet waste stations for collection and disposal of waste. Check to see if the parks in your neighborhood have them.
- Dig a small trench in your yard where your pets tend to defecate and toss the waste in the trench, cover with a layer of leaves, grass clippings, and dirt.
- Dispose waste in disposal units called Doggy Loos where they are installed into the ground. Decomposition occurs within the unit.
- At the park, set up a pooch patch which has a pole surrounded by a light scattering of sand around it. Dog owners can introduce their dog to the pole upon entry to the park. Dogs will then return to the patch to defecate and then you can place the pet waste in special bins for disposal.

Vehicle Washing

Car washing is a common routine for residents and a popular way for organizations, such as scout troops, schools, and sports teams to raise funds. However, most of the time, cars are washed in driveways and parking lots which allow wash water (dirty water) to finds its way to the nearest storm drain, ultimately draining into our drinking water sources, the Delaware and Schuylkill Rivers. The wash water often contains pollutants, such as oils and grease, phosphates (from the soap), and heavy metals—all of which are unhealthy for people and fish.

Washing Your Car Properly

- The best action is to take your vehicle to a commercial car wash, especially if you plan to clean the engine or the bottom of the car. Most car washes reuse water several times before sending it for treatment at a sewage treatment plant.

If you still want to wash your car at home...

- Wash your car on gravel, grass or another permeable surface, so the ground can filter the water naturally.
- Use soap sparingly. Try to use non-phosphate detergents. Phosphates are nutrients that can cause problems for nearby waterways.
- Use a hose that is high pressure, low volume. Use a hose with a nozzle that automatically turns off when left unattended or one that has a pistol grip or trigger nozzle to save water. Wash one section of the car at a time and rinse it quickly.
- When you're done, empty your bucket of soapy water down the sink, not the street.
- Block off the storm drain during charity car wash events or use an insert with a vacuum pump to catch wash water and empty it into the sink, not the street.

Tree Planting

If you have any tree planting questions and need to ask an expert, go to www.pennsylvaniahorticulturalsociety.org/garden/ask_gardener

Trees are not only a beautiful addition to the landscape, but they also provide invaluable benefits to cities. They reduce heat by cooling and shading homes during the hot summer months, decreasing the amount of energy required to cool a home and its related electric bills. Mature trees can actually cut summer cooling costs by 40% and tree-lined blocks can even decrease local temperatures. Trees naturally clean the air of pollutants and create a neighborhood noise buffer. Trees also improve stormwater management, reducing the amount of polluted stormwater that normally would go directly into storm drains. Tree roots also allow rainwater to filter back into the soil, recharging the often thirsty water table. A 2005 study by the University of Pennsylvania found that trees can increase property values. Planting a tree within 50 feet of a house can increase its sale price by 10 to 15%. Some studies even indicate that the mere presence of trees can create stronger neighborhood ties and reduce crime.

Planting a Tree

Before getting started, you may be interested in participating in the TreeVitalize rebate program where you may be eligible to receive up to a $25 rebate on the purchase of a tree. Whether you are planting a tree in your yard or hiring a contractor to plant a street tree, you may qualify. For more information, visit www.treevitalize.net and www.pennsylvaniahorticulturalsociety.org/phlgreen/tree-pledge.html.

Also, the Pennsylvania Horticultural Society's Tree Tenders Program offers a basic training course designed to teach general tree-care skills to organized community groups and individuals in Philadelphia. If you are interested in the course or a free copy of the *Tree Tenders Handbook* or *Mini-Guide to Tree Planting,* visit www.pennsylvaniahorticulturalsociety.org/phlgreen/treetenders.

1. Now, if you are ready to get started with your tree planting, select a site appropriate for your tree.
2. Dig the hole at least 1½ to 2 times the width of the root ball (container) to be installed, and no deeper than the height of the root ball so that the root flare (the top of the root mass) is flush with the existing ground. The planting pit should be dug so the walls of the pit are angled like a bowl or sloping outward in heavy soils.
3. Break up the walls of the pit after digging, so that fine roots can penetrate the soil. The soil that you dig out of the hole is what you will use to backfill around the root ball. Soil amendments are not recommended when planting a tree; therefore, no compost, moss, or shredded pine bark should be added to the backfill.

Tree Planting

You can also volunteer to plant trees elsewhere in the city—along creeks and streams in Fairmount Park and at local schools. The more trees in Philadelphia, the healthier we will be! Contact Fairmount Park, Greater Philadelphia Cares and UC Green to learn how you can volunteer to plant trees.

4. Remove all debris from the pit and gently tightly pack the loose soil in the bottom of the pit by hand.
5. Cut and remove the rope and burlap from around the trunk and check for root flare. Remove all nails. Drop the burlap down to the bottom of the hole.
6. Do not handle the plant by the branches, leaves or stem. Place the plant straight in the center of the planting pit, carrying the plant by the root ball. Never carry a plant by the trunk or branches.
7. After the tree is in the pit, carefully cut and remove the top third of the wire basket and as much burlap as possible using the least amount of disturbance.
8. Backfill planting pit with existing soil and pack it in there tightly to fill all voids and air pockets. Do not over compact soil. Make sure plant remains straight during backfilling/packing procedure.
9. The top of the root mass (root flare) of the tree should be flush with the final grade. Do not cover stem with soil. If your tree has soil over the trunk flare (where the trunk cures outward into the root system), it is essential to plant the trunk flare above soil. Remove the soil from the root ball if the flare is buried by it.
10. Water plant thoroughly and slowly, immediately after planting to saturate backfill. For the first year after planting, water the tree with 15 gallons per week. Use your index finger to check the soil moisture under the mulch. If the soil is cool to the touch, do not water. If it is warm and dry, then water. A layer of mulch (i.e. shredded bark, compost) should be placed around the tree, at a depth between 3 to 4 inches and with a radius of approximately 2 to 4 inches from the tree stem. Do not rest the mulch directly against the tree stem. The mulch makes it easier to water the tree and reduces weed competition.
11. Remove all tags, labels, strings and wire form the plant material.

Many homeowners ask how a newly planted tree can affect the sewer, water lines, sidewalk and/or building's foundation? If you choose the correct tree, site, and planting conditions, your tree shouldn't interfere with your sewer, waterline, etc. Most tree roots grow in the soil's top 12 inches and spread well beyond the tree's canopy in search of water and nutrients. They don't "attack" underground mains, unless these are already damaged, providing entrances for developing roots. An adequate and generous tree pit, or long, narrow continuous "tree lawn" will provide the best conditions for establishing and maintaining a "well behaved" tree with the environment needed to survive in the city.

Tree Planting

Street Trees

If you do not have a yard, but you would like to have a tree in front of your property —on your sidewalk—you have several options in Philadelphia.

You can get a tree for free and installed at no cost by **Fairmount Park**, however, this may involve being placed on a waiting list

You or a group from your neighborhood can sign up for a **Tree Tenders program** through the Pennsylvania Horticultural Society, where you can get trained to care for your tree, learn how to organize a tree planting project and receive free tree care tools in exchange for your participation.

Lastly, you can **hire a contractor** approved by Fairmount Park to plant a tree in front of your house. However, the contractor you hire must apply for a Street Tree Permit from Fairmount Park before any work can be done. The private planting could cost you up to $500 (not including the price of the tree).

Talk to your neighbors and find out if there is a neighborhood organization or Tree Tenders group organizing a street tree planting project. Some local groups that do tree plantings, include The South of South Neighborhood Organization, UC Green and Citizens Alliance.

Recommended Street Tree List for Philadelphia

The Fairmount Park Commission recommends the below list of approved trees which will thrive in an urban setting, have a good track record, and won't interfere with overhead wires in Philadelphia.

Small Trees—Under 30 feet

Acer buergeranum—Trident Maple

Acer campestre—Hedge Maple

Acer ginnala—Amur Maple

Acer tataricum—Tartarian Maple

Crataegus crus-galli 'Inermis'—Thornless Hawthorn, tree form

Crataegus laevigata 'Superba'—Crimson Cloud Hawthorn tree form

Crataegus phaenopyrum—Washington Hawthorn, tree form

Crataegus viridis—Winter King Hawthorne

Prunus triloba—Flowering Plum

Malus (selected varieties)—Crabapple

Syringa reticulata—Japanese Tree Lilac

Medium Trees 30–46 feet

Aesculus x carnea 'Briotii'—Ruby Red Horsechestnut

Cercidiphyllum japonica—Katsura tree

Cladrastis lutea—Yellowwood

Crataegus lavallei—Lavalle Hawthorn

Koelreuteria paniculata—Golden Rain Tree

Malus (selected varieties)—Crabapple

Ostrya virginiana—Hop Hornbeam

Phellodendron amurense—Amur Cork Tree

Prunus x yedoensis—Yoshino Cherry

Ulmus parvifolia—Chinese Elm

Quercus acutissima—Sawtooth Oak

Large Trees Over 47 feet

Acer rubrum (selected cultivars)—Red Maple

Celtis occidentalis—Hackberry

Corylus colurna—Turkish Filbert

Fraxinus pennsylvanica 'Patmore'—Patmore Green Ash

Gleditsia triacanthos (selected cultivars)—Honey Locust, a) Halka, b) Moraine, c) Shademaster

Ginkgo biloba (male selections only)—Ginkgo

Liquidambar styraciflua—Sweetgum

Quercus rubra—Red Oak

Quercus macrocarpa—Bur Oak

Quercus palustris—Pin Oak

Sophora japonica—Japanese Pagoda Tree

Tilia cordata—Little Leaf Linden

Zelkova serrata (selected cultivars)—Japanese Zelkova—a) Green Vase, b) Village Green

Columnar Trees for Narrow Streets

Acer rubrum 'Armstrong'—Armstrong Columnar Red Maple

Carpinus betulus fastigiata—Pyramidal European Hornbeam

Ginkgo biloba 'Princeton Sentry'—Princeton Sentry Ginkgo Grafted Male Variety

Prunus sargentii 'Columnaris'—Columnar Sargent Cherry

Quercus robur 'Rose Hill'—Rose Hill English Oak

Backyard Stream

Establish a streamside (riparian) buffer—a vegetated area along the edge of the stream that protects it from pollution and erosion. This buffer zone absorbs pollutants and nutrients that would otherwise end up running directly into the stream. Plant material slows runoff and filters out pollutants and sediments. Well-planted streamside buffers are also a great low-cost way to control erosion. While plants slow runoff, filter pollutants, and help control erosion, trees cast shade on the stream, cooling the water, reducing algae growth and improving fish habitat. A buffer with trees and shrubs also becomes a home to birds, butterflies and other creatures. Trees and plants that grow in the buffer play a critical role in keeping streams healthy.

Caring for Your Stream

- Begin with a "no mow" or "no graze" zone along your stream banks. Make your buffer as wide as possible.
- Plant trees and shrubs in your buffer zone. They provide many long-lasting benefits and can be quite inexpensive to establish and maintain.
- Using shrubs will give your buffer a quick start; many reach full size in just a few years.
- Set your mower blades at least three inches high. Taller grass slows runoff, resists drought and needs less fertilizer
- Use hay bales or a special silt fence to prevent soil from washing off your site and into the stream while establishing your stream buffer.
- Cover piles of soil with tarps to protect them from rain.
- Use good farm practices by not cultivating the soil and planting winter cover crops to conserve soil.
- Contact your local DEP office or county conservation district if you see soil runoff in the stream from a nearby construction site.
- Limit your overall use of pesticides and herbicides, and use extreme caution when using them near streams.
- Keep grazing and other farm animals out of and away from the stream. Contact your county conservation district or the U.S. Fish and Wildlife Service to find out about farm fencing programs.
- Compost yard waste. Don't bag lawn trimmings or throw them into the stream; leave them in place for effective recycling of nutrients.
- Store firewood, trash and other materials well away from streams.

Winter De-icing

As snow piles up in the winter, we oftentimes turn to salt to melt snow and ice. Salt, however, causes adverse environmental impacts, especially on our streams and rivers, our drinking water source in Philadelphia. Excess salt can saturate and destroy a soil's natural structure and result in more erosion to our waterways. High concentrations of salt can damage and kill vegetation. Salt poses the greatest danger to fresh water ecosystems and fish. Studies in New York have shown that as salt concentrations increase in a stream, biodiversity decreases. Excess salt can seep into groundwater and stormwater runoff. Effective ice control can help prevent excess salt runoff to our waterways.

De-icing in the Winter

There are many alternatives to salt including potassium chloride, calcium chloride and magnesium chloride, corn processing byproducts, and calcium magnesium acetate (CMA). Most can be found in your local hardware stores under various trade names, so check the labels for chemical content. While these alternatives can be spread in a dry form or sprayed as a liquid, their best use occurs when they are used with salt. They tend to increase the efficiency of salt thereby reducing the amount that needs to be applied. When over-applied, all chloride compounds can be harmful to the environment. Non-chloride corn byproducts recycled from mills and breweries have been shown to be effective de-icers as well. While they are often advertised as organic or natural, they can have extremely high phosphorus content, a major water pollutant. Numerous studies have shown calcium magnesium acetate (CMA) to be the most environmentally benign de-icer. Many northern states use CMA on roads in sensitive areas (wetlands, endangered species' habitat, drinking water supply, etc.). A couple of disadvantages with CMA however, is that it does not work well below 25° Fahrenheit and it is the most expensive de-icer. Because all de-icers can be harmful to the environment when applied in excess, the best strategy is to reduce the use of these chemicals as much as possible.

- The first line of defense should simply be to shovel sidewalks and pathways to keep them clear and to prevent ice from forming. Also, consider that salt and de-icers are not effective when more than 3 inches of snow have accumulated.
- Consider the temperature. Salt and calcium magnesium acetate (CMA) have a much slower effect on melting snow and ice at temperatures below 25° Fahrenheit.

Winter De-icing

- Track winter weather and only use salt and de-icers when a storm is about to come through. If a winter storm does not occur, sweep up any unused material, store, and reuse for the next big storm.
- Apply de-icing products discriminately, focusing on high-use areas and slopes where traction is critical. Apply the least amount necessary to get the job done. This will save money in product costs and will also help minimize property damage to paved surfaces, vehicles, and vegetation.
- Reduce salt and other chemicals by adding sand for traction.
- Become familiar with various de-icing products and wetting agents such as magnesium chloride and calcium chloride, which can improve the effectiveness of salt and reduce the amount needed.
- If you observe ongoing issues of ineffective ice management or examples of poor application, such as excess piles of road salt left to disperse, share your concerns with the property manager of your residence or business, or with the City of Philadelphia Streets Department. The Streets Department Hotline is 215-686-5560 and their website is www.phila.gov/streets.
- Plant native vegetation that is salt tolerant in stormwater drainage swales and ponds that may receive salt-laden runoff. Not only will these native species have a greater chance for survival, but they will continue to act as an effective buffer for our local waterways.
- Store salt and other products on an impervious (impenetrable) surface, such as a basement floor, to prevent ground contamination. Also store products in a dry, covered area to prevent stormwater runoff.

Planters (Container Gardens)

Planters reduce impervious cover (impenetrable surfaces, such as concrete sidewalks, parking lots, etc.) by retaining stormwater runoff rather than allowing it to directly drain into nearby sewers and creeks. Planters offer "green space" in tightly confined urban areas by providing a soil/plant mixture suitable for stormwater capture and treatment. They can be used on sidewalks, parking areas, back yards, rooftops and other impervious areas.

Contained Planters

Contained planters are used for planting trees, shrubs, and ground cover. The planter is either prefabricated or permanently constructed and has a variety of shapes and sizes. Planters may range from large concrete planters to potted plants arranged on an impervious surface like the roof garden shown in the bottom photos to left. Planters can be placed on impervious surfaces like sidewalks, back yards, rooftops, or along the perimeter of a building in order to catch stormwater runoff from the roof. Contained planters may drain onto impervious surfaces through holes in their base or by an overflow structure so the plants do not drown during larger rain events.

Plants should be hardy and self-sustaining native species with little need for fertilizers or pesticides. Planters can be made of stone, concrete, brick, wood, or any other suitable material. However, treated wood should be avoided if it leaches any toxic chemicals.

Planters can be permanently fixed in place or easily moved around to enable you to change the look of the planter garden that you have created. Numerous manufactured pots and planters are available at your local hardware or landscaping store. You can create a "do-it-yourself" planter or use recycled items to create planters. Homemade planters may be constructed by stacking and fastening wood beams or laying and mortaring stones. There are many websites with detailed instructions to help with this type of project, such as www.taunton.com, www.hgtv.com, www.diynetwork.com.*

Creating a Contained Planter

- Purchase planters at the local hardware or landscaping store, if you are not building your own planter box.
- Drill holes in the bottom of the planter if they are not already there.
- Fill the planter with soil and leave a 12 inch area from the soil to the top of the planter.
- Choose native drought and saturation tolerant plants and trees to plant in the planter.
- Occasionally turn or till the soil to improve infiltration.

*These are just a few of the websites PWD came across during our research. These particular companies are not endorsed by PWD, nor can PWD verify any information on these companies.

Rain Barrels

Please read the Disclaimer on the inside cover, if you are interested in installing this project.

A rain barrel collects and stores stormwater runoff from rooftops. By detaining (temporarily holding) the stormwater runoff during a rain event, you can help add capacity to the city's sewer system and reduce sewer overflows to our creeks and rivers, our drinking water source. Also, the collected rain water can be reused for irrigation to water lawns, gardens, window boxes or street trees.

Rain barrels can be purchased on-line or they can be built. If you would like to purchase a rain barrel on-line, view the list of retailers we came across in our research.*

Whether you buy or build a rain barrel, the most important thing to remember is that they are only effective at stormwater management when the stored water is emptied in between storms, making room in the barrel for the next storm.

Building a Rain Barrel

- Rain barrels help lower water costs when the stored water is recycled for lawn irrigation, for example.
- Rain barrels help reduce water pollution by reducing stormwater runoff, which oftentimes picks up pollutants in its path, such as oil, grease and animal waste, and transports these pollutants to the nearest creek, river or stormdrain.
- Storing rainwater for garden and lawn use helps recharge groundwater naturally.

Materials Needed for Building a Rain Barrel

- One 55 gallon drum
- One 5 foot section vinyl garden hose
- One 4 foot diameter atrium grate (basket used in garden ponds and pool skimmers)
- One ½ inch PVC male adapter
- One ¾ inch x ½ inch PVC male adapter
- One 5 foot section of drain hose, drain line, or sump pump line (1¼ inch)
- One 1¼ inch female barbed fitting and
- One 1¼ inch male threaded coupling
- One vinyl gutter elbow
- Drill (or a hole saw)
- Router, jig saw or coping saw
- Measuring tape

Optional:

- Waterproof sealant (silicone caulk, PVC glue)
- Teflon tape
- Fiberglass window screen material or mosquito netting
- Cinder blocks or wooden crate

Rain Barrels

*Rain Barrel Distributors

Clean Air Gardening

Composters.com

Day's Garden

ENVIRO ENERGY International Inc.

Gardener's Supply Company

GARDENWARe

Green Culture

Green Venture

Jerry Baker

Lee Valley Tools

Midwest Internet Sales

New England Rain Barrel and Composter Company

RainCatcher 4000

Plow&Hearth

Rain King

Rainsaver USA

Real Goods

Riversides

The Rain King

Spruce Creek Rainsaver

The Rain Pail

Urban Garden Center

This is not a comprehensive list of rain barrel distributors or suppliers. This is a list of rain barrel distributors that PWD came across during our rain barrel research. The particular companies are not endorsed by PWD, nor can PWD verify any information on these companies.

Instructions for Building a Rain Barrel

Step 1. Cut Holes in Rain Barrel:

- Cut lower drain hole: Measure about 1 inch above the bottom of the barrel (55 gallon drum) where the barrel side begins to rise toward the top. Using a ¾ inch bit (or hole saw), drill a hole through the barrel.
- Cut upper drain hole: Mark the upper drain hole according to where you want the overflow to be in the upper region of the barrel and in relationship to the lower drain. Use a 1⅜ inch hole saw to cut out the overflow hole.
- Cut top hole for atrium grate (filter): Using the atrium grate as a template for size, mark a circle at the center of the top of the drum (locating the rainwater inlet in the center of the barrel lets you pivot the barrel without moving the downspout). Drill a ½ inch hole inside of the marked circle. Use a router, jigsaw or coping saw to cut until the hole is large enough to accommodate the atrium grate, which filters out large debris. Don't make the hole too big—you want the rim of the atrium grate to fit securely on the top of the barrel without falling in.
- Cut notch to hold hose: Using a ½ inch bit or hole saw, cut out a notch at the top of the barrel rim (aligned so that it is above the lower drain hole). The notch should be large enough so that the end of the hose with the adapter will firmly snap into place.

Step 2. Set Up Barrel and Modify Downspout:

- Set up barrel: Since water will only flow from the garden hose when the hose is below the barrel, place the barrel on high ground or up on cinder blocks or a sturdy wooden crate underneath your downspout, making sure the barrel is level.
- Modify your downspout: Cut your existing downspout using a saw so that the downspout's end can be placed over the top of your rain barrel. Use a vinyl downspout elbow that fits the size of your downspout (usually 3 inch or 4 inch) to aim the stormwater into the rain barrel or just simply place the barrel right under the downspout.

Step 3. Assemble Parts:

- Attach garden hose to lower drain hole: Screw in the ½ inch PVC male adapter to the lower drain hole. The hard PVC threads cut matching grooves into the soft plastic of the barrel. Unscrew the ½ inch PVC male adapter from the hole. Wrap threads tightly with teflon tape (optional). Coat the threads of the coupler with waterproof sealant (optional). Screw the coated adapter back into the hole and let it sit and dry for 24 hours (optional). Attach 5 foot garden hose to the PVC male adapter. Attach the ¾ inch x ½ inch PVC

Rain Barrels

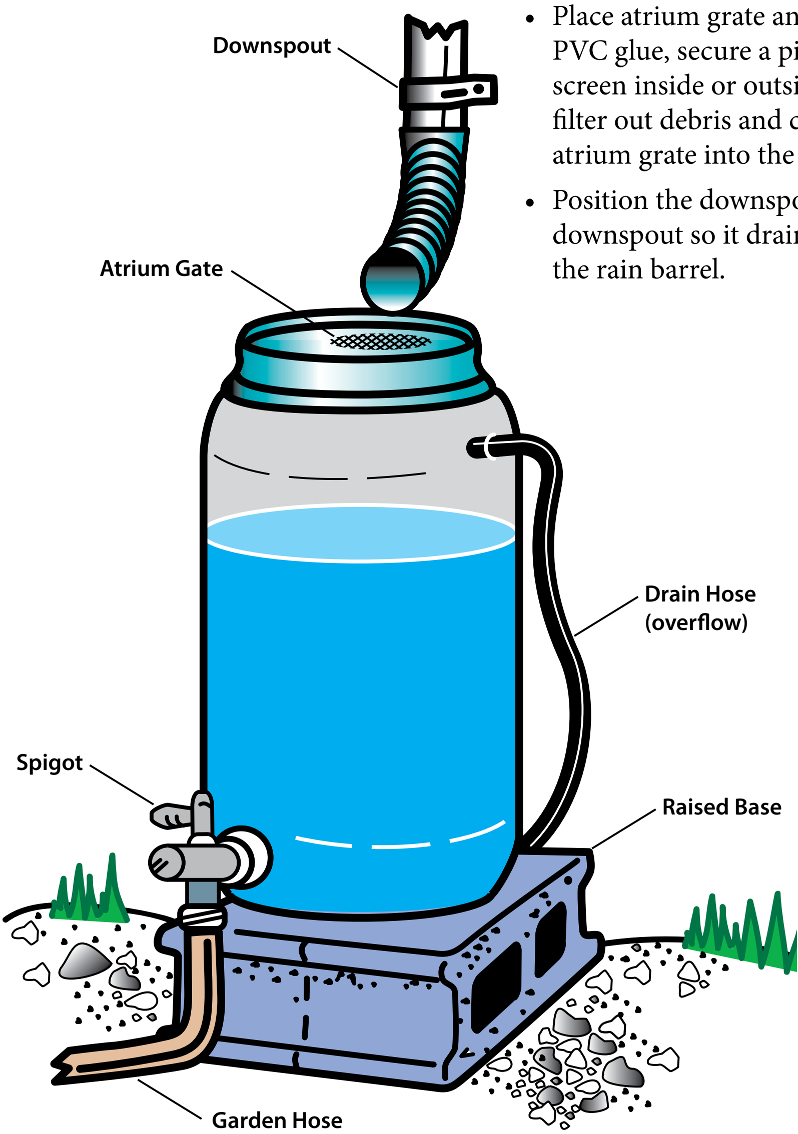
Don't forget to empty your rain barrel after the storm!

male adapter to the other end of the hose (this can be readily adapted to fit a standard garden hose).

- Attach drain hose (overflow hose) to upper drain hole: Put the 1¼ inch male threaded coupling inside the barrel with the threads through the hole. From the outside, screw the 1¼ inch female barbed fitting onto the threaded coupling. Use silicone on the threads (optional). Attach 5 foot section of drain hose to upper fitting and connect it to where the original downspout was connected (sewer riser) in order to transport the overflow into the sewer.

The overflow must be conveyed safely away from your property and your neighbor's property. If your downspout was not originally connected to the sewer, place a splash pad on the ground under the overflow hose to direct the flow away from the foundation of your home.

- Place atrium grate and screen in top hole: Using PVC glue, secure a piece of fine mesh window screen inside or outside of the atrium grate to filter out debris and control mosquitoes. Place the atrium grate into the hole (basket down).
- Position the downspout: Position the end of your downspout so it drains onto the atrium grate on the rain barrel.



Rain Gardens

Please read the Disclaimer on the inside cover, if you are interested in installing this project.

A rain garden uses native plants and landscaping to soak up rain water (stormwater) that flows from downspouts or simply flows over land during a rain event. The center of the rain garden holds several inches of water, allowing the stormwater to slowly seep into the ground instead of flow directly from your roof, yard or driveway into the nearest storm drain, creek or river.

Creating a Rain Garden

- A rain garden allows 30% more water to seep into the ground than a conventional lawn (South River Federation & Center for Watershed Protection, 2002). This increase helps replenish the groundwater supply (important during a drought!), and also helps hold back stormwater from contributing to the stormwater and sewage overflows into nearby creeks and rivers.
- A rain garden reduces the amount of water pollution that would otherwise eventually reach the streams and rivers through stormwater runoff. Scientific studies have demonstrated that the first inch of rainfall is responsible for the bulk of the pollutants in stormwater runoff. A rain garden is designed to temporarily hold this one-inch of rainfall and slowly filter out many of the common pollutants in the water, such as oil, grease, and animal waste, that would otherwise flow into the waterways via the nearest stormdrain or stormwater runoff.
- The native plants used in rain gardens require less water and less fertilizer than conventional lawns. They also require less maintenance and provide habitat for birds and other wildlife.

Materials

- Plants for the garden (see plant list)
- Hose, rope or string
- Level
- Shovel or spade
- Measuring tape
- Humus or other soil amendments (optional)
- Downspout extension (also optional).

Instructions

Before starting this project, please conduct an Infiltration Test (pages 26–27) to determine if your soil conditions are adequate for a rain garden.

Step 1. Size and Locate your Rain Garden:

- First, measure the footprint of your house by getting the area (length x width) of your house and then determine how much of your rooftop area drains to the downspout you are disconnecting to your garden (for gutters with a downspout at

Sizing Example

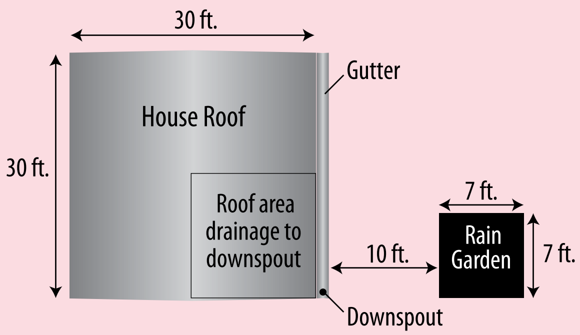
If the area of the house is 30 ft. x 30 ft. and ¼ of this area drains to one downspout:

15 ft. x 15 ft. = 225 ft.^{2}

20% of 225 ft.^{2} = 45 ft.^{2}

30% of 225 ft.^{2} = 67.5 ft.^{2}

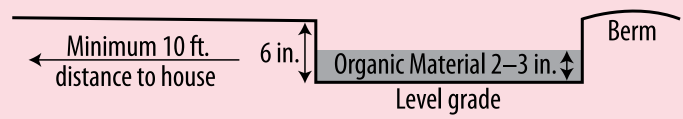
The rain garden area should be between 45 and 67.5 square feet, depending on soil type (use 20% for sandier soils).



each end, assume that half the water goes to each downspout). Refer to the sizing example for guidance. Be sure you measure the house footprint only, but include the area of any driveway or patio areas that will drain to the rain garden (do not take the roof slope into account). The surface area of your rain garden should be between 20% and 30% of the roof area that will drain into the rain garden.

- Locate the garden at least 10 feet away from your house and your neighbor's house (to prevent water leakage), and create the garden in the lowest point of this section of your lawn, maintaining a minimum 1% slope from the house down to the rain garden. If your yard drain is also located in this section of the lawn, you can build the rain garden around the drain. The bottom of the rain garden would be a few inches lower than the drain and the overflow would actually be in the middle of the rain garden.
- If you build the rain garden around your yard drain, when it fills up with water, the water that overflows from the garden will be conveyed safely to the yard drain. If you are not building around the yard drain, it is imperative that the overflow is safely conveyed to a drain nearby to prevent it from flowing into your neighbor's property.
  Make sure the drain is in a suitable location in relation to the rain garden in order to effectively manage the garden's overflow.

Garden Cross Section



- When finding the right spot for your rain garden, keep in mind that you will want to create a shallow ditch or swale that carries the stormwater runoff from the disconnected downspout to the rain garden. The swale will help slow the runoff before it reaches the rain garden.
- Finally, lay out the boundary of the garden with a rope.

Step 2. Dig the Rain Garden:

- To enable the rain garden to hold several inches of water during a storm, you'll have to dig a hole 3 to 4 inches deep across the entire surface of the rain garden. If the soil lacks organic material, you can improve it by digging the hole 5 to 6 inches deep, and adding 2 to 3 inches of humus or other organic material. Make sure the bottom is level, but gently slopes from the bottom to the ground level around the edges. If the drop at the edge is too steep, you might get some erosion around the edges.

Rain Gardens

- Next, test how the garden will hold water during a storm by letting water flow into the rain garden from a hose placed at the downspout. Based on this test, make any necessary adjustments (e.g., create a berm on the lower side of the garden using the diggings—the soil that was excavated).

Step 3. Add Plants to the Rain Garden:

- Choose native plants that won't require much watering, but make sure they can withstand wet soils for up to 24 hours. (Refer to the list of native plants below.)
- Also, take into account how much sun your garden receives. It's often helpful to draw out a planting plan before you start, and mark planting areas within the garden with string. After planting, weeding may be required until the plants become established. You may also need to periodically prune some of the plants to let others grow. In the winter, leave dead or dormant plants standing and cut back in the spring.
- Your garden may need a bit more maintenance than a lawn in the beginning, but in the long run it will be easier to care for and provide many added benefits!

Native Plants Recommended by Fairmount Park for Rain Gardens

Perennials

Bee-balm—*Monarda didyma*

Black-eyed Susan—*Rudbeckia hirta*

Blazing star—*Liatris spicata*

Blue flag iris—*Iris versicolor*

Boneset—*Eupatorium perfoliatum*

Butterfly weed—*Asclepias tuberosa*

Cardinal flower—*Lobelia cardinalis*

Early goldenrod—*Solidago bicolor*

Golden alexander—*Zizia aurea*

Joe-pye weed—*Eupatorium purpureum*

New England aster—*Aster novae-angliae*

New York ironweed—*Veronia novaborescensis*

Obedient plant—*Physostegia virginiana*

Ox-eye—Heliopsis helianthoides

Solomon's seal—*Polygonatum biflorum*

White snakeroot—*Eupatorium rugosum*

Grasses and Grass-like plants

Big bluestem—*Andropogon gerardii*

Bottle brush grass—*Elymus hystrix*

Canada wild rye—*Elymus canadensis*

Path rush—*Juncus tenuis*

Purple-top—*Tridens flavus*

Soft rush—*Juncus effusus*

Switch-grass—*Panicum virgatum*

Virginia wild rye—*Elymus virginicus*

Ferns

Christmas fern—*Polystichum acrostichoides*

Hay-scented fern—*Dennstaedtia punctilobula*

Rattlesnake fern—*Botrychium virginianum*

Sensitive fern—*Onoclea sensibilis*

Shrubs

Gray dogwood—*Cornus racemosa*

Highbush blueberry—*Vaccinium corymbosm*

Mountain laurel—*Kalmia latifolia**

Ninebark—*Physocarpus opulifolius*

Pasture rose—*Rosa carolina*

Red osier dogwood—*Cornus sericea*

Spicebush—*Lindera benzoin*

Sweet pepperbush—*Clethra alnifolia*

*Pennsylvania's state flower

When purchasing plants, pay close attention to the scientific names to ensure the correct species are selected.

Wildflower Meadow

Wildflower meadows present excellent opportunities for stormwater management, promoting ground-water infiltration, water quality treatment, and even flood control. Also, when using native plants in a meadow you are not only providing an aesthetically pleasing landscape, but preserving native species and biodiversity, and creating habitat for wildlife. Meadows allow you to spend less time mowing, less time applying fertilizers and lawn chemicals, and less time watering in the summer months. This low maintenance structure helps protect our nearby local streams from pollutants and other chemicals, in addition to flooding conditions, thereby helping to protect the Delaware and Schuylkill Rivers, the source of our drinking water in Philadelphia.

Creating a Wildflower Meadow

Step 1. Site Selection: First, you need to choose a suitable location, preferably an open sunny site that gets at least six hours of sun every day. It should have good air movement. This helps keep diseases down, and the movement caused by wind will make plants sturdier, and stems stronger. The site should have few weeds. An already cultivated site such as a field or garden plot is ideal. A lawn can work too. The hardest is an overgrown garden bed, or old field full of aggressive weeds and grasses. A site next to such an area to transform is also difficult, due to weed seeds blowing in. A site next to a formal landscape may also be a hard sell. In such formal areas, an informal transition area may be necessary.

Step 2. Plant Selection: Plant selection is important for long bloom, as noted already, but more importantly for species that will last under your conditions. Soil type is not as important as whether the site is dry or moist. A dry site is best. The key is to have a diversity of species, as found in nature, with a mix of graminoides (grasses and grass-like plants) and forbs (flowering meadow wildflowers). If you don't create your own mixture, buy a good quality seed mix from a reputable supplier. When it comes to these seeds, you truly get what you pay for. Inexpensive mixes often contain mainly annuals which are gone after the first year, contain non-native species, seeds that have poor germination, potential weedy species, or just a lot of seed debris. Another consideration under species selection, whether you buy a mix or make your own mixture, is whether you want a short term (1 to 5 years) or longer term meadow. In the former you may have more annuals for color up front, but keep in mind that they may be out competed with weeds after a few years. A long term meadow may have mainly perennials which may take several years to begin a good display, but will last and out compete many weeds.

Wildflower Meadow

The number of plants of any one type will depend on how you will be viewing the meadow. If seeing it from a distance, you'll want to use larger numbers of each plant type, and place them in sweeping masses. If creating a small area, or one viewed at close range, you may have few of any one type plant, and have them all mixed.

Step 3. Site Preparation: This is the step often overlooked, yet the key to success or failure. Since these wildflowers are usually less competitive than weeds, the site should contain no weeds or weed seeds. Unless the site has been cultivated already, with few to no weeds, there are several methods you may use.

You may smother vegetation with black plastic for a whole growing season. You may also smother existing growth with thick layers of leaves, grass clippings, or newspapers. Another method is to plant a summer buckwheat crop, cut and tilled in before going to seed, followed by fall planting of winter wheat, cut and tilled in late winter. You may need to repeat this a second season. Or you may repeat deep soil tillage every three weeks for a full growing season. If it's a lawn with no weeds, remove the sod using a sod-cutter that can be rented from equipment rental firms. Many use a systemic herbicide, but avoid those that are residual (last in the soil).

Step 4. Sowing or Planting: You may sow in spring or early summer, which favors grasses over the forbs. Keep the spring-sown meadow watered as you would a newly seeded lawn, often for a month or two. Sowing in early fall favors the forbs, as some grass seeds rot then. Since many seeds will either not germinate until the following spring, or germinate and not grow until then, you should also use annual rye as a winter cover crop with fall sowings. Avoid sowing in mid to late summer when there may be droughts or seeds drying out before germinating. For sowing, aim for about 80 seeds per square foot. In several years this will result in one or two plants in this space. Of this number per square foot, for spring sowing use about 60 forb and 20 grass seeds. This is about 9 lbs. and 3 lbs. per acre. For fall sowing, use a higher proportion of grass seeds.

For small areas (for instance under 1000 square feet), consider using already-germinated small plants you can buy in trays as "plugs." These are more costly than seeds, but will establish more quickly. You can find these at specialty suppliers, either local, mail-order, or online.

Step 5. Post-planting management: In the first two years, seeds of annual and biennial weeds still in the soil or blown in will grow faster than your perennial wildflowers. Don't allow such weeds the first year to get above one foot tall before cutting back to four to six inches high. The wildflowers will, for the most part, remain short and below this height. The second year, cut back to about one foot high since plants will be larger. A weed or string trimmer works well for this. Don't pull weeds, as this may also disturb wildflower seedlings. Don't use herbicides as these may drift, killing large patches of both weeds and wildflowers!

In the third and future years, mow it close to the ground. This should be done in late fall or early spring, removing the debris from mowing. This exposes the soil to the rapid warmth from the sun in spring, encouraging your wildflowers over cool-season weeds. Learn your wildflowers, and over the years you can selectively weed out any weeds or woody plant seedlings.

Dry Well

Please read the Disclaimer on the inside cover, if you are interested in installing this project.

Materials

- Measuring tape
- Shovel
- Saw
- Wheelbarrow
- Vinyl downspout elbow to fit your downspout (typically 3 in. or 4 in.)
- Landscape non-woven geotextile fabric
  - Make sure the fabric is porous enough to allow water to pass through it.
- Crushed stone
  - Use stone that is approximately 1–1½ in. diameter.
  - Wash the stone to make sure that it is clean. You can use a sieve to remove fine material if the stone seems to have a lot of small particles.
  - It is important that the stone is washed (no dust or particles) and that the stone is uniformly the same size.
  - The stone does not have to be very large; it just has to be roughly of a similar size to get the maximum amount of void space in the stone while maintaining the structure of the well.

Dry wells are small, excavated pits, filled with stone or gravel that temporarily stores stormwater runoff until it infiltrates (soaks) into the surrounding soil. The stormwater can come straight off of the roof of your house via a downspout that either indirectly or directly connects to the dry well. It can travel indirectly to the dry well through a grassy swale or it can travel directly into the well through a pipe. This design guide describes how you can disconnect your downspout to a swale and dry well that is sized based on the included sizing table (noted below). Dry wells help protect our rivers and streams in combined and separate sewered areas. They help add capacity to Philadelphia's sewer system during heavy rainfalls by helping prevent the stormwater runoff from reaching the system and instead allowing the runoff to soak into the surrounding soil. In separate sewered areas, the impact of stormwater runoff on neighborhood streams, is reduced. By infiltrating the stormwater runoff on land, the combined (sewage and stormwater) sewer overflows into the Delaware and Schuylkill Rivers are reduced, thereby decreasing pollution in our streams, lessening flooding impacts and improving water quality in our rivers, our drinking water source. Dry wells also recharge groundwater through infiltration, which leads to more flow in streams during dry weather (when it is not raining) and less streambank erosion during wet weather (when it is raining).

Building a Dry Well

Site Preparation

- Conduct an Infiltration Test (see pages 24–25) to determine if your soil conditions are suitable for a dry well.
- Make sure buried electrical, telephone, and TV cables and gas piping are not going to be a problem in the area that you will be digging your dry well. If you don't know where they are located, call PA One Call at 1-800-242-1776 at least three days before you dig.
- Install leaf guards to prevent leaves and other plant material from entering the downspout and clogging the dry well.
- Determine the size of the well. Read through the Dry Well Sizing section of this fact sheet.
- Determine the volume of crushed stone you will need.
  Volume of Stone = Dry Well Area x 1½ feet
  For example: 33 square feet x 1½ feet = 49.5 cubic feet of stone.

Dry Well

Dry Well Sizing

- Refer to the sizing table. Decide what size storm you would like to store and infiltrate in your dry well. Find the closest number in Column A. About one-third of storms in the Philadelphia area are 0.25 inches or less, 60% are 0.5 inches or less, and 85% are 1.0 inch or less.
- Estimate the roof area draining to the dry well (length [ft.] x width [ft.] = area in square feet). Find the closest value in Column B for the storm depth you have chosen. At this point, you have narrowed your choice down to just one line of the table.
- Find the area required for your dry well in Column D. When you multiply your dry well length and width, the resulting number (area) needs to be at least as great as the number in Column D. Columns E and F show examples of lengths and widths that will work.
- Determine whether your yard and budget will allow you to build a dry well of this size with a safe overflow. If not, choose a smaller storm and repeat the steps. Storing a larger storm provides a greater benefit, but also requires more space and costs more. Storing even the smallest storm in the table will provide benefits.
- **The dry well should have a safe overflow**, such as an overflow to your yard drain. In larger storms, your dry well will fill up, and you need to make sure that the overflow doesn't damage your property or your neighbors' properties. Keep in mind that the yard drain has to be slightly downhill from the dry well.
- **The dry well should be at least 10 feet from your house** and any other buildings that are level with yours. It should be at least 25 feet from buildings that are downhill from the dry well.

Example

Storm Depth =
0.5 inches (Lines 4-6, Column A)

Roof Area =
250 square feet (Line 5, Column B)

Dry Well Area =
19 square feet (Line 5, Column D)

Possible Dimensions:
7 feet long by 3 feet wide =
21 square feet
(Line 5, Columns E and F)

4 feet long by 5 feet wide =
20 square feet

6 feet long by 3.5 feet wide =
21 square feet

	A Storm Depth (in.)	B Roof Area Draining to Dry Well (sq. ft.)	Dry Well Dimensions			
			C Depth (ft.)	D Area (sq. ft.)	E Example Length (ft.)	F Example Width (ft.)
1	0.25	100	1.5	3.8	2	3
2	0.25	250	1.5	9.4	4	3
3	0.25	500	1.5	19	7	3
4	0.5	100	1.5	7.5	3	3
5	0.5	250	1.5	19	7	3
6	0.5	500	1.5	38	13	3
7	1.0	100	1.5	15.1	6	3
8	1.0	250	1.5	38	13	3
9	1.0	500	1.5	75	26	3

Dry Well

Step 1. Modify your downspout. Cut your existing downspout close to the ground using a saw so that a vinyl downspout elbow can fit over the disconnected downspout (usually 3 or 4 inches). The elbow should aim the stormwater runoff into the swale

Step 2. Dig a swale—a small channel or ditch starting from the point below the disconnected downspout to the dry well location. The swale should be just a few inches deep and wide. The swale should slope downward from the downspout to the dry well. The runoff draining from the disconnected downspout through the swale should drain readily toward the dry well.

Step 3. After preparing the site and determining the size of your well, shape the well, using the Dry Well Sizing Table.

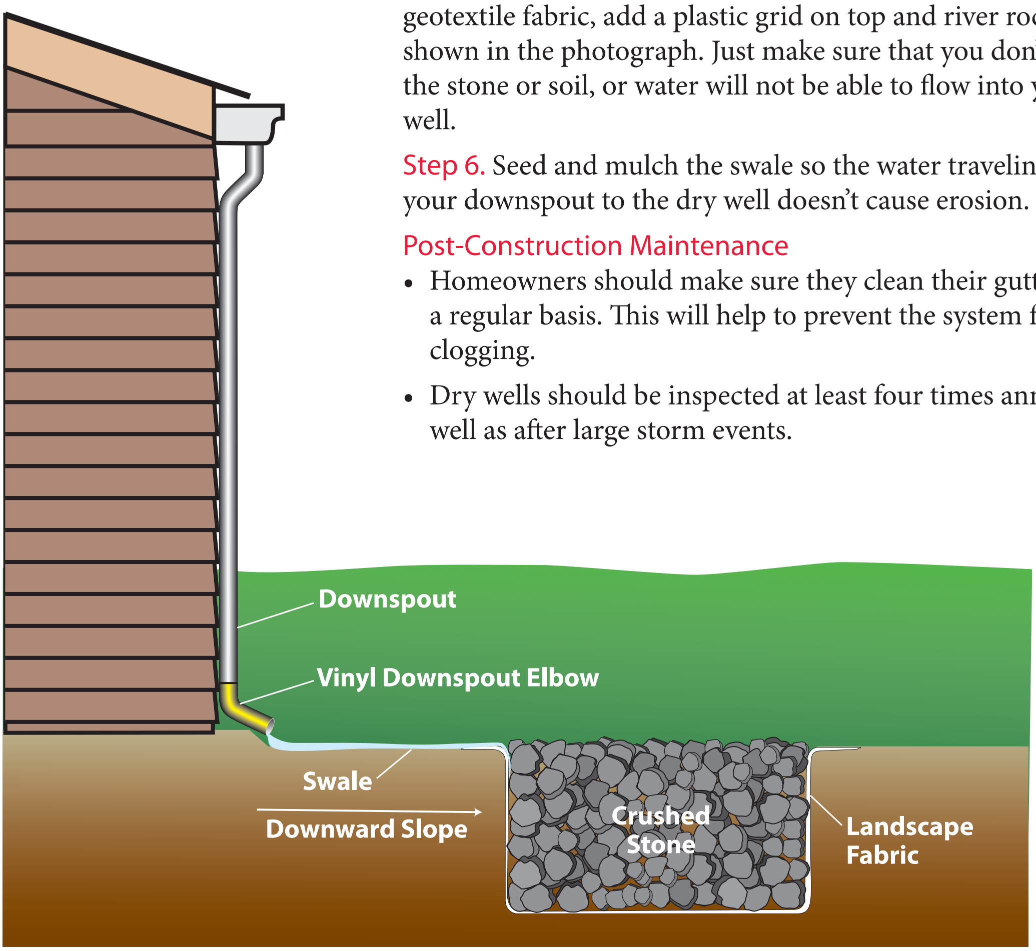
Step 4. Line the well with landscape fabric (non-woven geotextile fabric or filter cloth). Make sure it is porous enough to allow water to pass through it. Also, excess fabric should be folded over the edges of the well. The fabric prevents surrounding soil from getting into the system and clogging it up.

Step 5. Fill the well with the crushed stone. You can either a) fill the well with stones all of the way to the top until flush with the surrounding soil, b) fill the well with stones just a few inches from the top of the well, add a layer of geotextile fabric and backfill over the well with soil to plant in it (make sure the layer of fabric is between the stone and soil), or c) fill the well with stones just a few inches from the top of the well, add a layer of geotextile fabric, add a plastic grid on top and river rocks, as shown in the photograph. Just make sure that you don't mound the stone or soil, or water will not be able to flow into your dry well.

Step 6. Seed and mulch the swale so the water traveling from your downspout to the dry well doesn't cause erosion.

Post-Construction Maintenance

- Homeowners should make sure they clean their gutters on a regular basis. This will help to prevent the system from clogging.
- Dry wells should be inspected at least four times annually as well as after large storm events.



Infiltration Test

It is important that water infiltrate well even during saturated conditions. Conduct your infiltration test after a rain storm.

An infiltration test will help you determine if the soil on your property is suitable for certain types of stormwater management measures, such as a dry well or rain garden. An infiltration test measures how quickly water can soak in and flow through the soil. It is important to know how your soil infiltrates water before building a dry well, rain garden or any other stormwater management structure.

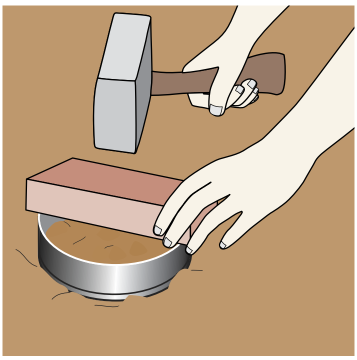
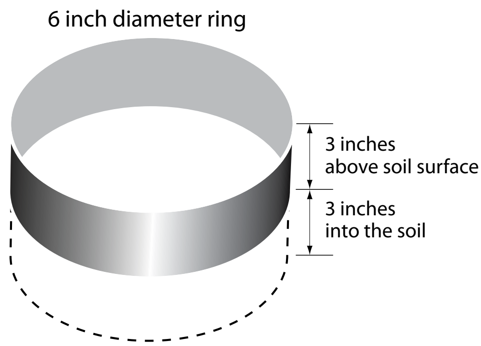


Figure 1
Using the hand sledge and block of wood, drive the 6 inch diameter ring, beveled edge down, to a depth of three inches.

Materials

- 6 inch diameter ring
- Hand sledge and wood block
- Plastic wrap
- 500 mL plastic bottle or graduated cylinder
- Water
- Stopwatch or timer
- Pen and paper



Step 1. Drive Ring into Soil:

- Clear the sampling area of surface residue, etc. If the site is covered with vegetation, trim it as close to the soil surface as possible.
- Using the hand sledge and block of wood, drive the 6 inch diameter ring, beveled edge down, to a depth of three inches (see Figure 1).
- If the soil contains rock fragments, and the ring cannot be inserted to the depth, gently push the ring into the soil until it hits a rock fragment.

Figure 2
Pour the 444 mL of water (1 inch of water) into the ring lined with plastic wrap.

Step 2. Firm Soil:

- With the 6 inch diameter ring in place, use your finger to gently firm the soil surface only around the inside edges of the ring to prevent extra seepage. Minimize disturbance to the rest of the soil surface inside the ring.

Step 3. Line Ring with Plastic Wrap:

- Line the soil surface inside the ring with a sheet of plastic wrap to completely cover the soil and ring as shown in Figure 2. This procedure prevents disturbance to the soil surface when adding water.

Infiltration Test

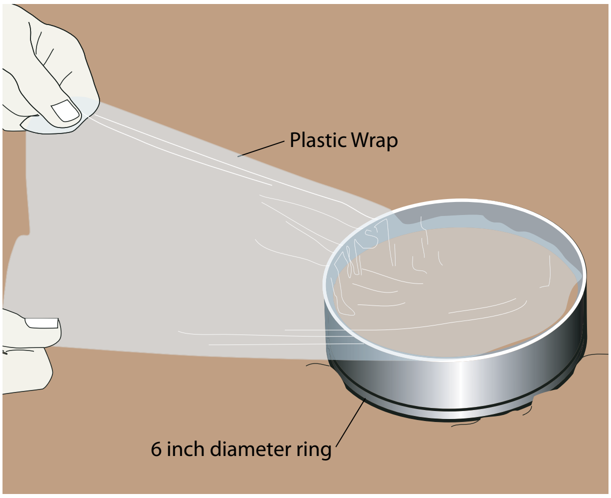


Figure 3
Remove the plastic wrap by gently pulling it out, leaving the water in the ring.

Step 4. Add Water:

- Fill the plastic bottle or graduated cylinder to the 444 mL (1 inch) mark with water. Pour the 444 mL of water (1 inch of water) into the ring lined with plastic wrap as shown in Figure 2.

Step 5. Remove Wrap and Record Time:

- Remove the plastic wrap by gently pulling it out, leaving the water in the ring (Figure 3). Note the time. Record the amount of time (in minutes) it takes for the 1 inch of water to infiltrate the soil. Stop timing when the surface is just glistening. If the soil surface is uneven inside the ring, count the time until half of the surface is exposed and just glistening. Record the time.

Step 6. Repeat Infiltration Test:

- In the same ring, perform Steps 3, 4, & 5 with a second inch of water. Record the number of minutes elapsed for the second infiltration measurement. Repeat the test (Steps 3, 4, & 5) a few more times. All of the tests should be conducted consecutively. If the test continues to yield the same results, you will have a good idea of the saturated infiltration rate. If the soil infiltrates the water under 1 hour, your soil is ready for a dry well, rain garden or any of the other structural projects in this manual.

Photo Credits

Vehicle Maintenance
Washington State Puget Sound Action Team

Lawn & Garden Care
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Pet Waste
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Tree Planting
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Backyard Stream
NAM Planning & Design

Winter De-Icing
Chuck Leonard

Planter Boxes
Multiple planters – Miriam Manon
Single planter – Clint Bautz

Rain Barrels
page 15 – Three Rivers Wet Weather Demonstration Program
page 16 – Michael Pickel

Rain Gardens
page 19-20 – Roger Bannerman, Wisconsin Department of Natural Resources

Creating a Wildflower Meadow
Robin Sasek, CDM

Dry Wells
Wissahickon Valley Watershed Association

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