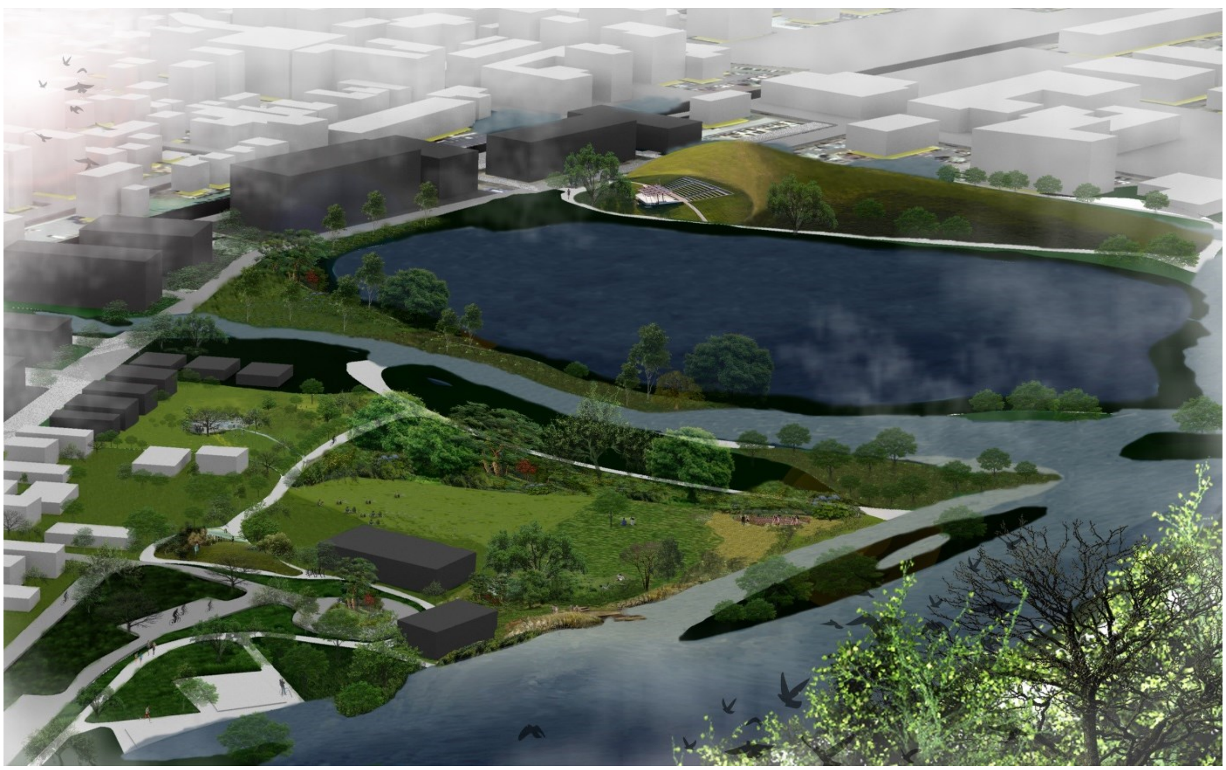




Flooding and Stormwater Management Plan for Ambler Area Watersheds



Temple University Ambler

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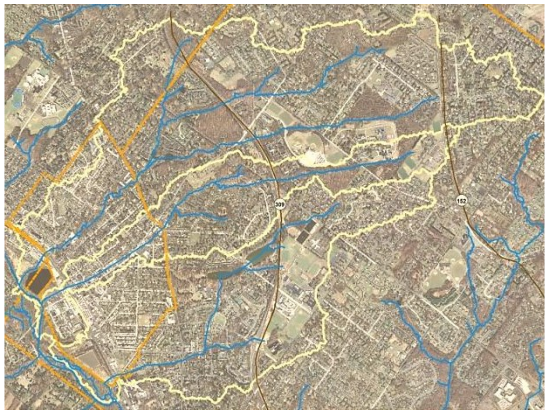

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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the funding agencies at the time of publication. This report does not constitute a standard, specification, or regulation.

In January 2015, a digital copy of this document will be posted on the Center for Sustainable Communities website at http://www.temple.edu/ambler/csc.

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Executive Summary

The 4.1 square-mile study area lies in the center of the Wissahickon Creek watershed, consisting of portions of four municipalities (Ambler Borough, Lower Gwynedd Township, Upper Dublin Township, and Whitpain Township). Three sub-watersheds are included in the study area (Rose Valley Creek, Tannery Run, and Honey Run & Stuart Farm Creek). The study area faces problems with water quality and flooding, particularly in the West Ambler section of Whitpain Township. The purpose of the *Flooding and Stormwater Management Plan for Ambler Area Watersheds* was to mitigate water quality and flooding concerns through identifying and prioritizing stormwater improvements. The study was undertaken by a multi-disciplinary research team from Temple University's Center for Sustainable Communities (CSC).

An Advisory Committee was formed consisting of representatives from government agencies, municipal authorities, environmental associations, and local residents. Primary data were created through field and municipal surveys, and secondary data were collected from various sources. A stakeholder meeting was held where residents shared their experiences with recent flooding events. Several GIS analyses were conducted regarding watershed characteristics and runoff, including flash flood potential, land use, and precipitation. Analyses were also conducted in order to further understand stormwater and flooding issues in the area. Both Hydrologic and Hydraulic models were used to generate new flood maps and evaluate improvements from stormwater infrastructure facilities. New 100-Yr. and 500-Yr. preliminary floodplains were developed as a result.

Five general types of recommendations were proposed:

1. *Extended Detention Basins (including retrofitting)* – The Project Team looked for opportunities to increase volume and naturalize basins to hold water longer. Thirty-six (36) sites were recommended for either expansion or new construction of basins resulting in an additional potential storage volume of 90.3 acre-ft.
2. *Infiltration Sites* – These recommended sites were based on inspections of areas that can provide storage for runoff from large rooftops, parking lots, and/or athletic fields. Seventeen (17) sites were recommended for infiltration resulting in an additional potential storage volume of 5.5 acre-ft.
3. *Riparian Buffer Restoration* – The total additional potential storage volume resulting from riparian buffer restoration would be 2.84 acre-ft.
4. *Site-Specific Recommendations* – There were six site-specific recommendations proposed, including (a) daylighting and channelization of the Rose Valley Creek, (b) maintaining operating level at Loch Alsh Reservoir four feet lower than in past and reconstruction of Loch Linden Dam (St. Mary's Lake) & replacement of the lake with a constructed wetland, (c) creation of additional wetland area, excavation, and/or construction of a dam at Ambler Park, (d) continuation of EPA and ACE remediation and mitigation of the BoRit asbestos site, and (e) Church Street and Main Street: channel widening and bridge replacement.
5. *Low-Impact Green Stormwater Infrastructure Projects* – These include measures such as rain gardens, rain barrels, green roofs, and permeable pavement. While the implementation of these projects will not impact flood control to a great extent, they have proven to significantly improve water quality on a local scale.

There are several strategies the municipalities can undertake for implementation, including the adoption and enforcement of new Flood Insurance Rate Maps (FIRMs), implementation of the stormwater improvements and flood control projects, adoption of municipal stormwater ordinances, institution of a flood warning system, and participation in FEMA's Community Rating System (CRS).

1. Introduction

This stormwater management plan has been developed for three urban watersheds that drain several municipalities in southeastern Pennsylvania, including the Ambler Borough, Lower Gwynedd Township, Upper Dublin Township and Whitpain Township. The plan has identified and prioritized stormwater improvements to mitigate (i) water quality problems, derived primarily from non-point source pollutions, and (ii) flooding problems that the lower-income and minority residents have been facing for many years. The project team, consisted of researchers at Temple University's Center for Sustainable Communities (CSC), formed partnerships with local governments, environmental groups and community organizations. Specific tasks included field data collection and verification, modeling, stormwater management facilities inventory and an assessment of stormwater improvements, including their impact on water quality and flood hazard mitigation, and their implementation strategies. The project developed new preliminary floodplain maps and a high-quality GIS database that are now available to township engineers and other interest groups. Implementation strategies included cost estimation and possible funding sources so that municipalities can take actions following the priority list.

Parts of this study were funded by the following municipalities and government agencies:

- Ambler Borough, Upper Dublin Township, and Whitpain Township
- US Army Corps of Engineers (ACE)
- US Department of Environmental Protection Agency (EPA) – Urban Waters Small Grant
- US Department of Housing and Urban Development (HUD) – Community Development Block Grant

1.1. Study Location and Community Issues

The 4.1 square-mile study area is located at the center of the 64 square-mile Wissahickon Creek Watershed and includes three tributaries – Rose Valley, Honey Run/Stuart Farm, and Tannery Run. These three watersheds drain Ambler Borough and Lower Gwynedd, Whitpain, and Upper Dublin Townships (see Figures 1 and 2). The center of the study area is Ambler Borough. With approximately 6,000 people and 7,500 people/square-mile density, Ambler is a vibrant and diverse urban community that offers a social, cultural and business hub just 16 miles north of Philadelphia. The borough has a walkable downtown commercial district, affordable housing and convenient public transit that make it ideal for living, working and socializing. The borough has the densest population immediately adjacent to the main channel of Wissahickon Creek[1]. The densely-developed West Ambler neighborhood, located in bordering Whitpain Township and characterized by a low-income and minority population, has vacant and flood-damaged properties. The neighborhood faces environmental justice issues that include air pollution, surface water pollution and groundwater contamination[2]. Sections of Ambler Borough and the West Ambler section of Whitpain Township are located at the downstream end of the tributary watersheds and are subject to the accumulated effects of increased runoff from upstream areas. In addition, these areas are impacted by flooding from the main stem of the Wissahickon Creek.

[1] Philadelphia Water Department (PWD). 2007. Wissahickon Creek Watershed Comprehensive Characterization Report.

[2] CDM Federal Programs Corporation, Preliminary Phase 2 Groundwater Report, Borit Asbestos Super fund Site, Operable Unit 1, Ambler, PA, A review by Gordon Chase for Borit CAG members, May 13th 2011.

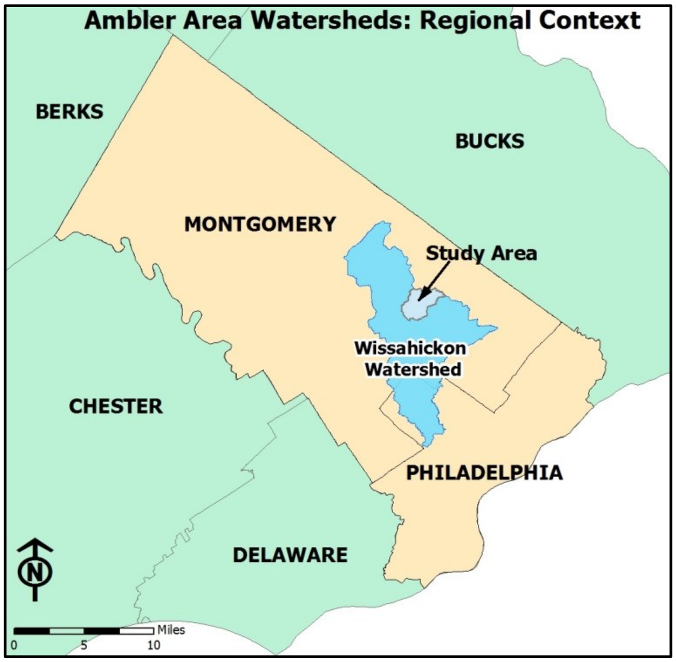

Figure 1: Study area: Regional context

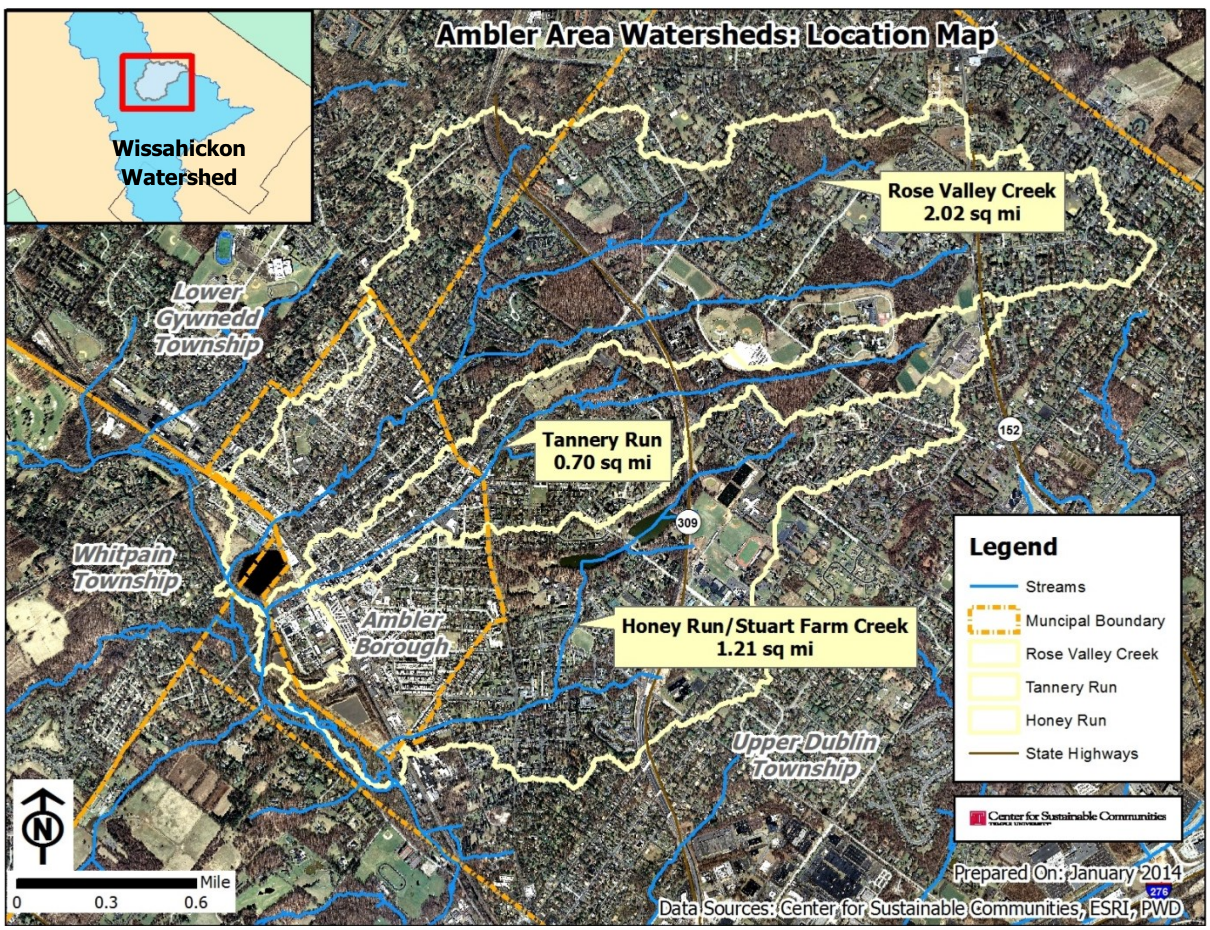

Figure 2: Study area: Local context

In the Wissahickon Watershed, the increasing presence of impermeable surfaces has amplified the volume and frequency of runoff and led to a number of problems, including increased incidence of flooding, impaired water quality, and ecological degradation[3]. Considering both national and state criteria, the Wissahickon Creek main stem and tributary stream reaches do not meet water quality standards and are designated as "impaired" due to nutrients and siltation[4]. The creek pollution is due to both nonpoint and point sources. Of paramount concern is the increase in the amount of impervious cover (i.e., roads, rooftops, turf grass), which has contributed to the escalation of runoff and flood levels. Increased volume of runoff is not only the result of increases in impervious surfaces, but also from the substantial areas of natural landscape converted to lawns or playing fields on highly compacted soil. Furthermore, stormwater runoff is subject to many pollutants such as nutrients (in fertilizers), pesticides and bacteria that it encounters as it makes its way to the nearest water body.

Communities in the Wissahickon Watershed have faced devastating effects from major flood events (Floyd 1999, Allison 2001, Ivan 2004, Irene 2011 and Lee 2011), and have faced millions of dollars' worth of damage as well as loss of life. For the main stem of the Wissahickon Creek in Montgomery County, each of these events produced peak flows larger than the 100-Yr flood used for the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs). While flooding is a natural process and occurs in both developed and undeveloped watersheds, land conversion to less-permeable surfaces in the absence of stormwater controls leads to higher flood peaks, flood volumes, and frequency of flooding. This is the case for large storm events, and in particular for smaller but more frequent storms. Figure 3 is a collage of pictures demonstrating the flooding damage in the West Ambler neighborhood. Figure 4 is a collage of media coverage and citizen journalism on flooding damages.

1.2. Project Rationale and Research Design

Being located within the study area, the project team was confident that the proposed strategies were relevant to community priorities. At the very early stage of this project, the team met with officials of the three municipalities, and representatives of environmental groups and community organizations. Ambler Borough officials indicated that mitigating recurrent flooding, managing stormwater and improving water quality are critical challenges to achieve a better quality of life for its residents. Whitpain Township officials said that emergency response, flooding mitigation and community revitalization are community priorities. Stormwater management and flood mitigation are longstanding priorities of Upper Dublin Township, which is implementing several stormwater improvements identified in a previous CSC project. According to the Wissahickon Creek Watershed Partnership website, a number of new BMPs are being constructed throughout the watershed and a number of stormwater basins are being retrofitted[5]. The Ambler Environmental Advisory Council prioritizes local streams for watershed protection and riparian buffer restoration[6]. The Upper Dublin

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[3] Philadelphia Water Department (PWD). 2007. Wissahickon Creek Watershed Comprehensive Characterization Report.

[4] United States Environmental Protection Agency (US EPA). 2000. Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion IX. EPA 822-B-00-019. Office of Water, U.S. Environmental Protection Agency, Washington D.C., and
Pennsylvania Department of Environmental Protection (PA DEP). 2001. Pennsylvania Code Title 25. Environmental Protection. Chapter 93. Water Quality Standards, p. 226.

[5] Wissahickon Creek Watershed Partnership http://www.phillywatersheds.org/wiss_working

[6] Ambler EAC http://amblereac.org

Environmental Protection Advisory Board has specific goals to protect the quality of water, land and air resources that involve such matters as stormwater and erosion control[7]. The project team's discussions with community groups indicated that the disadvantaged West Ambler neighborhood faces severe flooding and poor water quality due to contamination from the asbestos site, posing a serious environmental justice problem in this watershed.

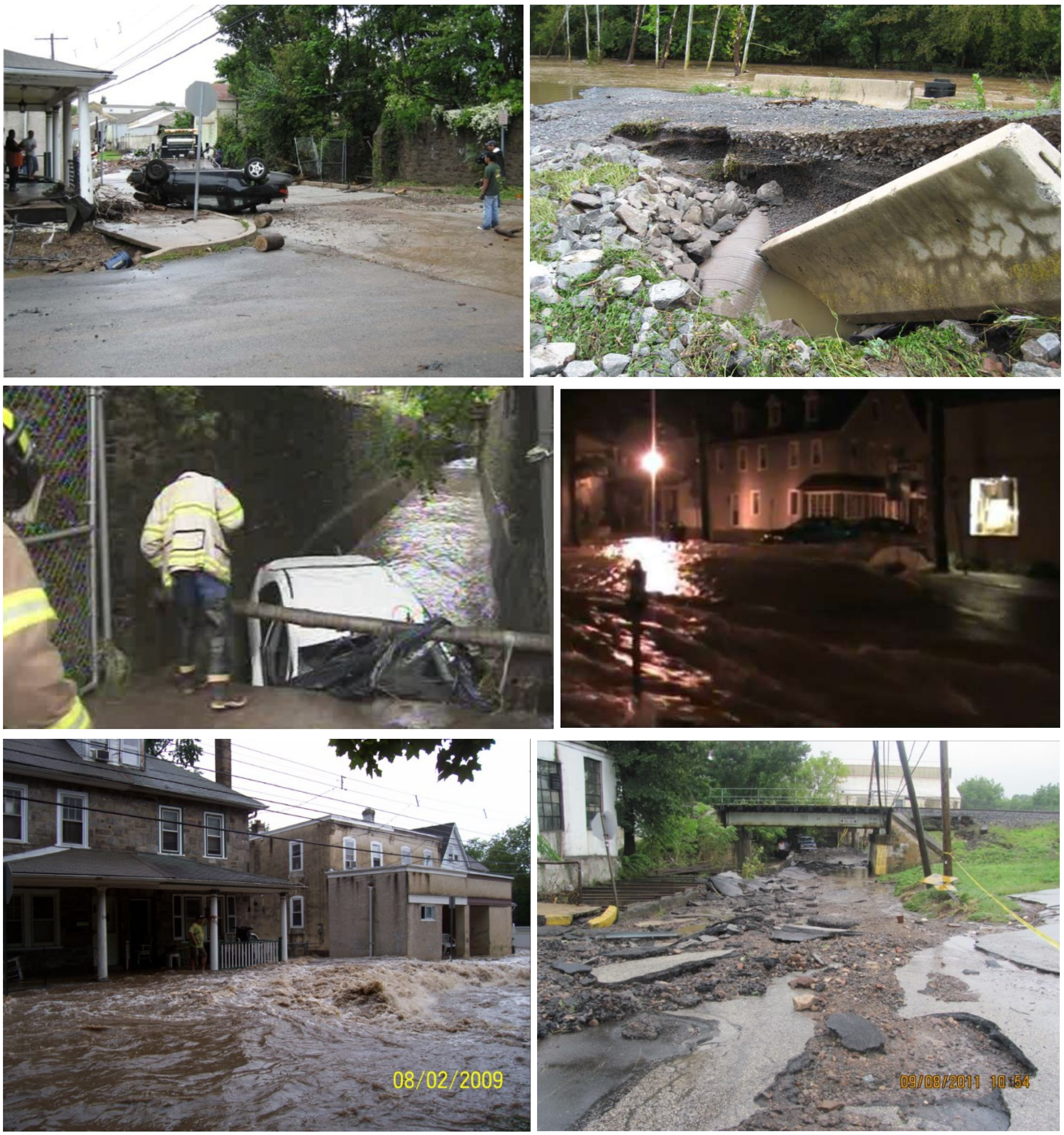

Figure 3: A collage of six photographs showing the West Ambler neighborhood and downtown Ambler during and after large storm events, 2009 – 2011
Photo Credit: Whitpain Township

[7] Upper Dublin Township http://www.upperdublin.net/boards/epa.aspx

Figure 4: A collage of media coverage and resident reporting in the study area
Sources: ABC news story http://abclocal.go.com/wpvi/story?section=news/local&id=6728664
Montgomery media story: Six foot of water drowns West Ambler
http://www.montgomerynews.com/articles/2011/09/09/ambler_gazette/news/doc4e68d0655cd97755519226.txt
NBC 10 Philadelphia story on flooding in Ambler
http://www.nbcphiladelphia.com/news/local/Your-Photos-Flooding-Around-the-Area-52309442.html
YouTube Video Screenshot http://www.youtube.com/watch?v=l9XQzsydgKE

Urban runoff can negatively impact stormwater quality. Reducing storm volumes and runoff can reduce erosion and sedimentation and improve water quality. In a normal year about 80% of annual runoff volume is produced by smaller storms with runoff of one inch or less[8]. Capturing the first inch of runoff can significantly improve water quality and reduce flash flooding. Hydrologic and hydraulic modeling is necessary to evaluate the impact of stormwater improvements as to their potential for flood mitigation and water-quality improvement. In addition, the modeling can generate new floodplain maps to replace existing FIRMs. According to existing FIRMs, many areas that are subjected to recurrent flooding are not included in the 100-Yr floodplains. These maps need to be updated so that residents, businesses and municipalities could take better precautions. FEMA has enlisted the CSC as a cooperating technical partner (CTP) and has approved floodplain maps

[8] Fromuth, Richard. (ed). 2011. Pennypack Creek Watershed Stormwater Management Plan - Act 167. Prepared for Philadelphia Water Department. http://www.temple.edu/ambler/csc/research/documents/Act167_mainreport.pdf

that the CSC project team has created in recent years for other watersheds (i.e., Pennypack and Sandy Run).

Ambler Borough is classified as a MS4 community by the US EPA and will be required to implement stormwater improvements to improve water quality in the streams[9]. Upper Dublin and Whitpain Townships are also MS4 communities that are committed to improving stormwater facilities. The implementation of a stormwater management plan and a stormwater ordinance would reduce stormwater problems in the watershed, reduce flooding in non-point and point-source areas, reduce erosion and sedimentation, improve water quality and contribute to community revitalization[10]. Possible state level funding sources for stormwater Best Management Practices (BMPs) construction include Growing Greener watershed grants, Clean Water Act Section 319 and PennVEST grants, and low-income loans.

Based on prior research in this region, the CSC project team strongly endorsed the use of stormwater BMPs as the preferred means to achieve improved water quality through groundwater recharge and retention, stream bank protection and volume control[11]. As this watershed is essentially "built-out," the project team concentrated much of its research on identifying opportunities for retrofitting existing stormwater facilities and finding locations for new BMPs in areas not currently served by them. The study recommended facilities that would allow for settling and storage of sediment from runoff and reduce sediment loading in the watershed. Various types of BMPs were evaluated, such as infiltration basins, infiltration galleries and trenches, stormwater wetlands, rain gardens, pervious paving, day-lighting streams, and riparian buffer. Additional flood mitigation options for the West Ambler neighborhood were evaluated and presented. The options for West Ambler include structural flood control measures. Because structural measures such as channel expansion and culvert enlargement can reduce floodplain storage, it is important that these measures be completed in combination with other stormwater control measures that increase upstream storage, such as the recommended BMPs. This approach helps prevent adverse downstream impacts.

The Project Team used GIS software (ArcGIS) and the ACE software for hydrologic and hydraulic modeling (HEC-HMS and HEC-RAS) to do a watershed assessment, understand stormwater and flooding issues in the study area and develop engineering models. The Team also used outreach activities and stakeholder meetings throughout the project period.

< See Next Page >

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9 MS4: Stormwater Discharges From Municipal Separate Storm Sewer Systems (MS4s) http://cfpub.epa.gov/npdes/stormwater/munic.cfm

10 DeBarry, Paul. 2004. Watersheds: Processes, Assessment, and Management. New Jersey: John Wiley & Sons.

11 Meenar, Mahbubur. (ed.). 2006. Pennypack Creek Watershed Study. Report submitted to FEMA, William Penn Foundation, and participating municipalities of the Pennypack Creek Watershed. http://www.temple.edu/ambler/csc/research/projects/documents/PP_Creek_Study_Report.pdf

The study included the following tasks:

Project Initiation and Community Input

- Project Initiation and Outreach
- Data Collection and Verification
- Local Plans, Projects and Initiatives
- Community Input

GIS-Based Watershed Assessment

- Watershed Characteristics and Runoff
- Understanding Stormwater and Flooding Issues

Engineering Models and Results

- The Hydrologic Model
- The Hydraulic Model
- New Floodplain Maps

Assessment and Recommendations of Stormwater Infrastructure Facilities

- Detention Storage Facilities
- Potential Infiltration Sites
- Riparian Buffer Restoration
- Hydrologic and Water Quality Impact of the Proposed Improvements
- Improvement Site Ranking
- Site-Specific Recommendations
- Low-Impact Green Stormwater Infrastructure (GSI) Projects

Implementation Strategies

- Adoption and Enforcement of New Flood Insurance Rate Maps (FIRMs)
- Implementation of Stormwater Improvements and Flood Control Projects
- Adoption and Enforcement of Municipal Stormwater Ordinances
- Participation in FEMA's Community Rating System
- Flood Warning in the Ambler Area Watersheds

2. Project Initiation and Community Input

2.1. Project Initiation and Outreach

An Advisory Committee was formed on September 21, 2012 at the Temple University Ambler campus, located inside the watershed. The members represent government officials, municipal authorities, professionals, environment advisory councils, civic associations, environmental associations, business community and local residents. Here is the list of initial Advisory Committee members and their affiliations:

1. Bob Adams, Wissahickon Valley Watershed Association (WVWA), Community Advisory Group (CAG)
2. Maggie Allio, Philadelphia Water Department (PWD)
3. Mary Aversa, Borough of Ambler.
4. Frederick Bailey, West Ambler Civic Association (WACA)
5. James Blanch, Township of Whitpain
6. Susan Curry, Ambler Environmental Advisory Council (EAC)
7. Bernadette Dougherty, CAG, Ambler business owner
8. Jeffrey Featherstone, Ph.D., Center for Sustainable Communities (CSC), Temple University
9. Otis Hightower, WACA
10. Deborah Fries, Department of Environmental Protection (DEP), WACA
11. Richard Fromuth, CSC, Temple University
12. Mark Hintenlang, Township of Upper Dublin
13. Paul Leonard, Township of Upper Dublin
14. Kristine Matzko, Environmental Protection Agency (EPA)
15. Julie McCabe, Upper Dublin Environmental Protection Advisory Board (EPAB)
16. Sue McDowell, Ambler EAC
17. Mahbubur Meenar, Ph.D., CSC, Temple University
18. Diane Morgan, CAG
19. Paul Racette, Pennsylvania Environmental Council (PEC)
20. Erik Rourke, U.S. Army Corps of Engineers (ACE)
21. Michael Stokes, Montgomery County Planning Commission
22. Charles T. "Bud" Wahl, Borough of Ambler
23. Steve Ware, Ambler Borough Planning Commission, Townshapes LLC.
24. Alice Wright, DEP

A project website (http://amblerwatersheds.wordpress.com) was launched in mid-September 2012. The site included project-related basic information, community priorities and challenges, and an online form for public input. By mid-January 2013, the site received 1,383 views. On October 19, 2012, it received 183 views, when the site published a photo feature of the first stakeholder meeting. Public comments were accepted via this web site and email. The final report and an overview of the second stakeholder meeting will be featured in this website.

Figure 5: A screenshot of the project website

2.2. Data Collection and Verification

Primary data were created by the CSC and its vendors or sub-contractors (Aero2, BAE, and NTM). Secondary data were collected from various sources. Field verification of data was complete by January 2013. The following table shows important data sets collected or created for this project.

Table 1: Data

Data	Type	Source	Year	Note
Stream	GIS – Line	PWD, PAMAP	2008	Original File from PWD edited using 2008 LiDAR contours and enhanced TIN.
Stream – Integrated List Non-Attaining	GIS – Line	PADEP via PASDA	2014	Under the Clean Water Act, the PA DEP protects four stream water uses: aquatic life, fish consumption, potable water supply, and recreation. If a stream segment is non-attaining for any of the four causes, it is deemed impaired.
Elevation	GIS DEM	PAMAP	2008	DEM based on LiDAR
Elevation	GIS TIN	BAE, Inc.	2012	Enhanced TIN and Break Lines based on PAMAP LiDAR.
Elevation	GIS Contours	Aero2, Inc.	2012	Elevation reference checks and updates based on -660 scale Ortho flown in April 2012.
Soils	GIS – Polygon	NRCS	1967 (Montgomery County data); 1975 (Philadelphia data)	Digitized soil polygons from Montgomery and Philadelphia County Soil Surveys.
Land Use	GIS – Polygon	DVRPC	2005	Data purchased by the CSC, Temple University. Latest Land Use data (2010) is not available yet.

Ortho-Photos	GIS – Raster	PAMAP	2003-2006, 2008	Downloaded from PASDA web site (www.pasda.psu.edu)
Ortho-Photos	GIS – Raster	DVRPC	2010	Downloaded from PASDA web site (www.pasda.psu.edu)
Ortho-Photos	GIS – Raster	Aero2	2012	Primary data created by Aero2, a Temple University vendor.
Parcel	GIS – Polygon	Montgomery County – Information and Technology Solutions	2012	The cost of this data, $625.91, was waived by Montgomery County.
Sub-Watershed Boundaries	GIS – Polygon	Delineated with ArcMap 9.3 using LiDAR DEM from PAMAP	2008	DEM downloaded from PASDA web site (www.pasda.psu.edu)
Bridges, Culvert Locations	GIS- Point	PWD, CSC	2010-2012	Original File from PWD supplemented with CSC field measurements.
Bridge, Culvert Elevations	HEC-RAS	BAE, Inc.	2008	Break Lines based on LiDAR data and Ortho from PAMAP.
Bridge, Culvert Elevations	HEC-RAS	Aero2, Inc.	2012	Elevation reference checks and updates based on -660 scale Ortho flown in April 2012. Cost was paid through a different grant.
Bridge, Culvert Dimensions	HEC-RAS	CSC	2011-2012	Field measurement.
Channel Cross Sections	HEC-RAS	CSC	2008	Determined using HEC-GeoRas and enhanced TIN from BAE, Inc. based on 2008 LiDAR.
Channel Roughness	HEC-RAS	CSC	2008-2012	Manning's roughness values assigned using ortho-photography, Table 3.1 of HEC-RAS Hydraulic Reference Manual and FWHA guidance manual.
Detention Basins	GIS- Polygon	PWD	2008	Data provided by the PWD.
Detention Basins	GIS - Polygon	CSC	2009-2012	Based on field survey to determine opportunities for new and retrofit detention sites.
Infiltration Sites	GIS -Polygon	CSC	2009-2012	Field inspection, orthos, photographs.
Peak Flow Calibration	HEC-HMS	NTM, Inc. for CSC	2012	HEC-HMS hydrologic model calibrated using USGS Gage record for Wissahickon Creek at Fort Washington; Regional regression equations for watershed lag time; Precipitation frequency data from NOAA Atlas 14. Cost was paid through a different grant.
Existing Floodplains	GIS-Polygon	FEMA	1990	Digital Flood Insurance Rate Maps (dFIRMs) from FEMA.

Note: PAMAP – The Digital Base Map of Pennsylvania, Pennsylvania Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey, Elevation Data Web Page: http://www.dcnr.state.pa.us/topogeo/pamap/elevationdata/index.htm

Elevation Data Enhancement
PAMAP LiDAR elevation data were enhanced for five map tiles covering the study area. Break lines were added for small streams and structures. Contours were smoothed in stream channels. A merged TIN was provided with break line shape files. Aero2 Inc. and BAE Systems Inc., was retained by Temple University for this work.

Scope of work – Aero2

- New black and white aerial photography (1" = 660' negative scale, 4 lines 32 exposures, 32 exposures scanned at 14um, AGPS aerial control)
- Ground control survey (10 aerial targets, PA SOUTH NAD 83 format)
- Air Trig (32 frames)
- Digital Ortho Photography (0.5' pixel resolution)
    - Developed in-house DTM for Ortho Photo Rectification
    - Created Ortho Photos and mosaic photos seamlessly
    - Provided rectified mosaicked photos in the standard PA SPSC sheet format
- Strategic Conventional Photogrammetry
    - Provided necessary data to center on an as needed basis
    - Work consisted of verifying bridge elevations
    - Captured job-specific bridges – headwalls, and other critical base features surrounding the bridge
    - Mapped selected acreage blocks, as needed
    - Mapped selected linear streams, as needed
    - Provided all necessary consulting and workflow expertise when integrating the "new Aero2 data" to the existing PAMAP datasets (spot elevation check comparisons to the PAMAP LiDAR data)
    - Created 2-ft interval contours for selected areas such as the BoRit Site and Rt. 309
    - Delivered all files to the CSC in AutoCad

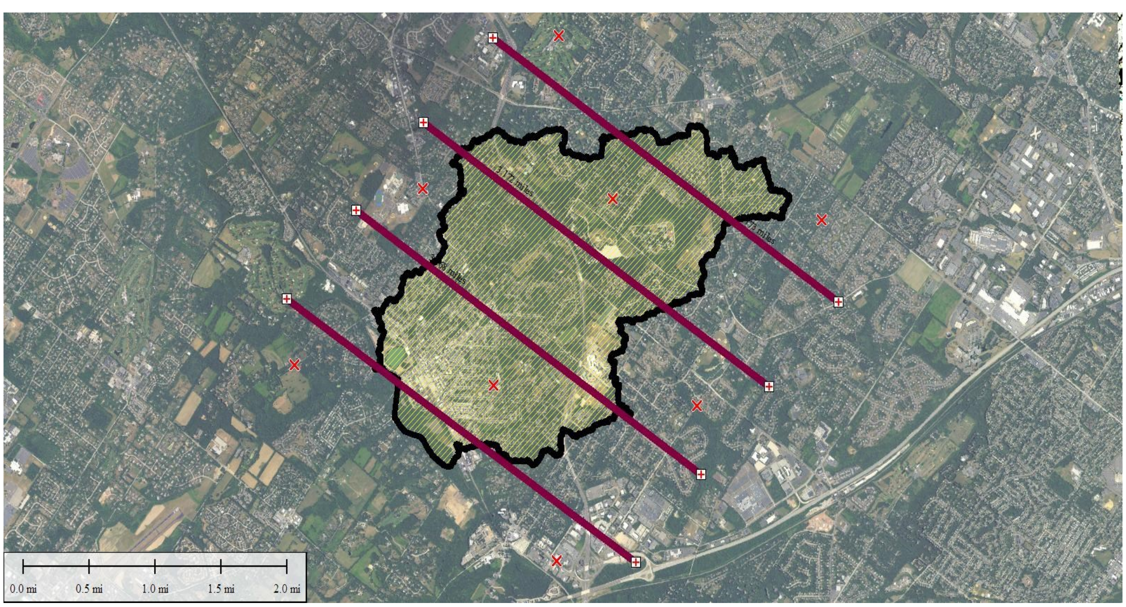

Figure 6: Aero2 flight paths for aerial image capturing process

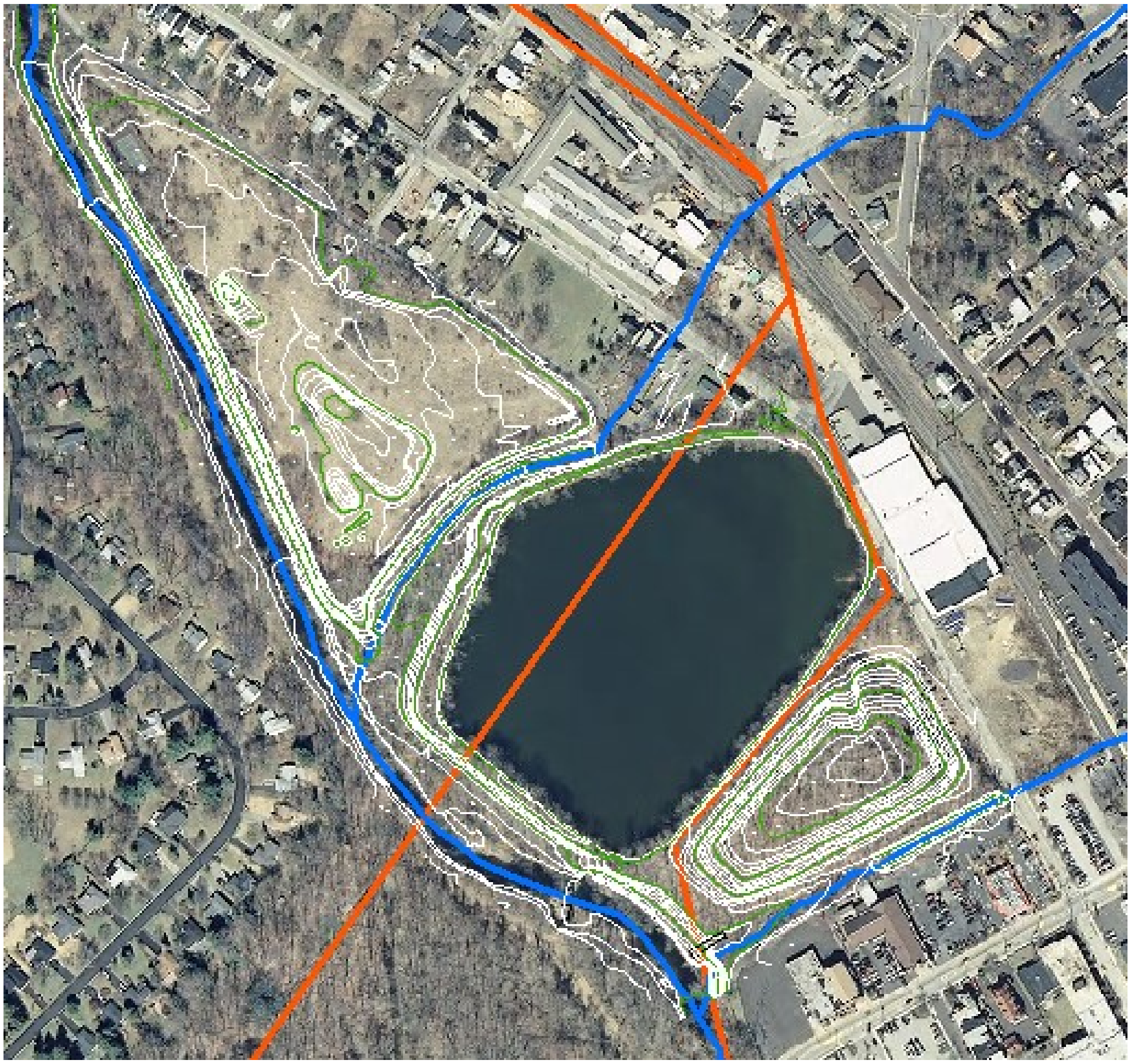

Figure 7: LiDAR data was checked against imagery based elevation data from Aero 2 in selected areas such as the asbestos site

Scope of work – BAE Systems Inc.

The CSC project team found some problems with the PAMAP LiDAR data in the study area. These included inaccurate TIN and contours, and missing break lines. BAE Systems Inc. was hired to fix these problems. BAE provided improved contour definition at streams, improved break lines with elevations of streets and a few headwalls, and an enhanced merged TIN data that proved crucial to the hydraulic modeling. BAE Systems processed the existing (4) 10K x 10K PAMAP LiDAR tiles by hydro-enforcing break lines for single line drains for 3.93 square miles covering the study area and provided PAMAP specification deliverables of this data. Per tile deliverables included:

- LAS ver. 1.1
- 2' Contour 3D shapefile
- Break lines in 3D shapefile
- 3.2' post spacing DEM in Geotiff format

Break lines were provided as shapefiles (a GIS file format) so elevations could be read more easily in ArcGIS software. Figure 8 shows examples of the work done by BAE Systems.

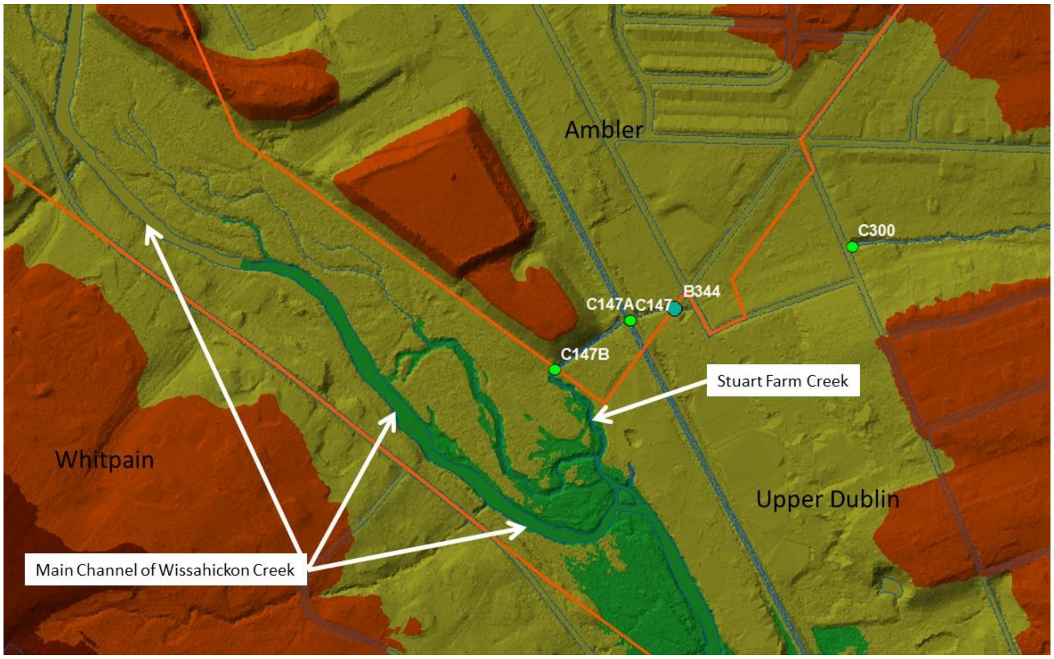

Figure 8: TIN near the Wissahickon Creek confluence with Stuart Farm Creek

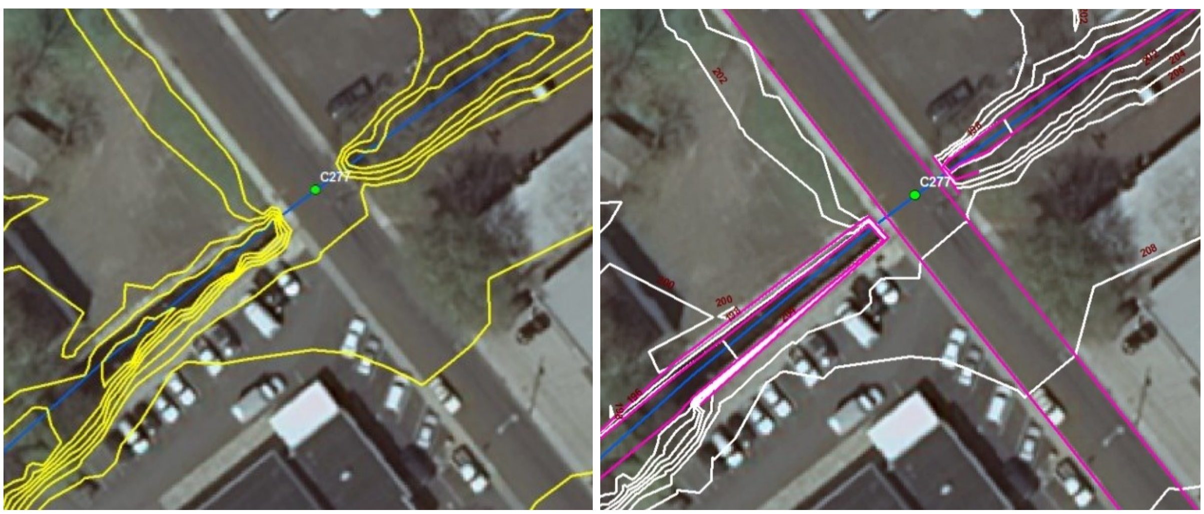

Figure 9: BAE Systems refined contours and added break lines for streams and roadways.

Municipal Problem Area Survey

A survey of municipalities located in the watershed was conducted in 2012. Municipalities identified locations where flooding, erosion and sedimentation were occurring. These locations are shown in Figure 10 as red lines or dots along stream segments. The survey was run for the whole Wissahickon Watershed and its 16 municipalities. Information on drainage problems and proposed solutions was solicited from each municipality by providing forms for each Watershed Plan Advisory Committee (WPAC) member. Overall, 163 problem areas were identified by the municipalities. Only 10 were reported in this study area (see Table 2).

Table 2: Ambler Area Watersheds Problem Identification by Municipalities

Types of Problems	Source	# of Reported Problems
Flooding	Ambler Borough	4
	Upper Dublin Township	1
	Whitpain Township	1
Erosion Sites	Ambler Borough	4

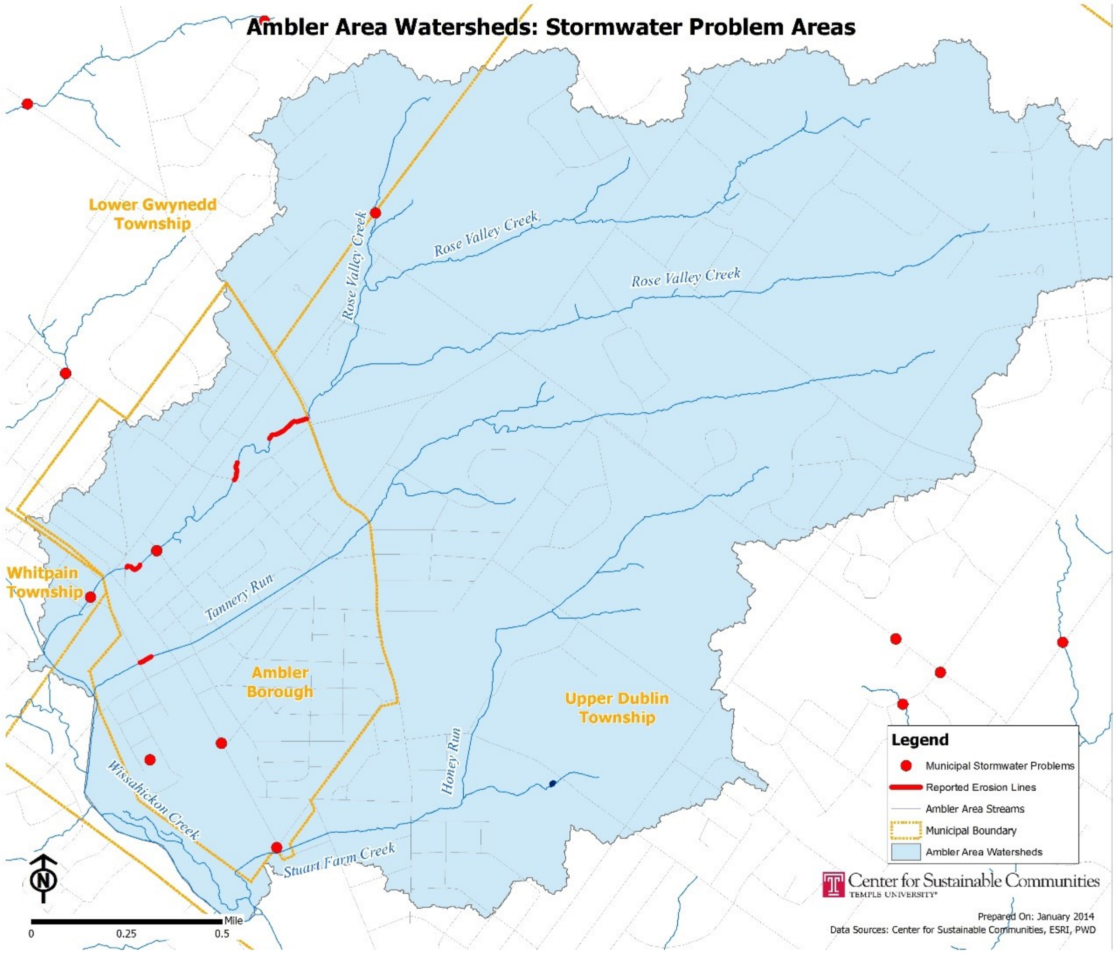

Figure 10: Municipal Problem Areas

CSC Field Survey

Obstructions field data were collected by the project team from 2009 to 2012. Data included (i) photos with 1 ft. Philadelphia Rod; (ii) dimensions; (iii) channel conditions; and (iv) reference to road or headwall. Obstructions to flow were measured for current dimensions. Figure 11 shows a collage of pictures from field surveys. As shown in Figure 12, 94 sites, including bridges (n = 16), culverts (n = 63), and dams (n = 15), were inspected and photographed. High water marks were checked. Sketches were prepared for entering obstruction data. See Figure 13 for an overview of the work-flow.

Figure 11: A collage of photographs measuring obstructions and high water marks in Rose Valley Creek, Tannery Run, and Honey Run/ Stuart Farm Creek

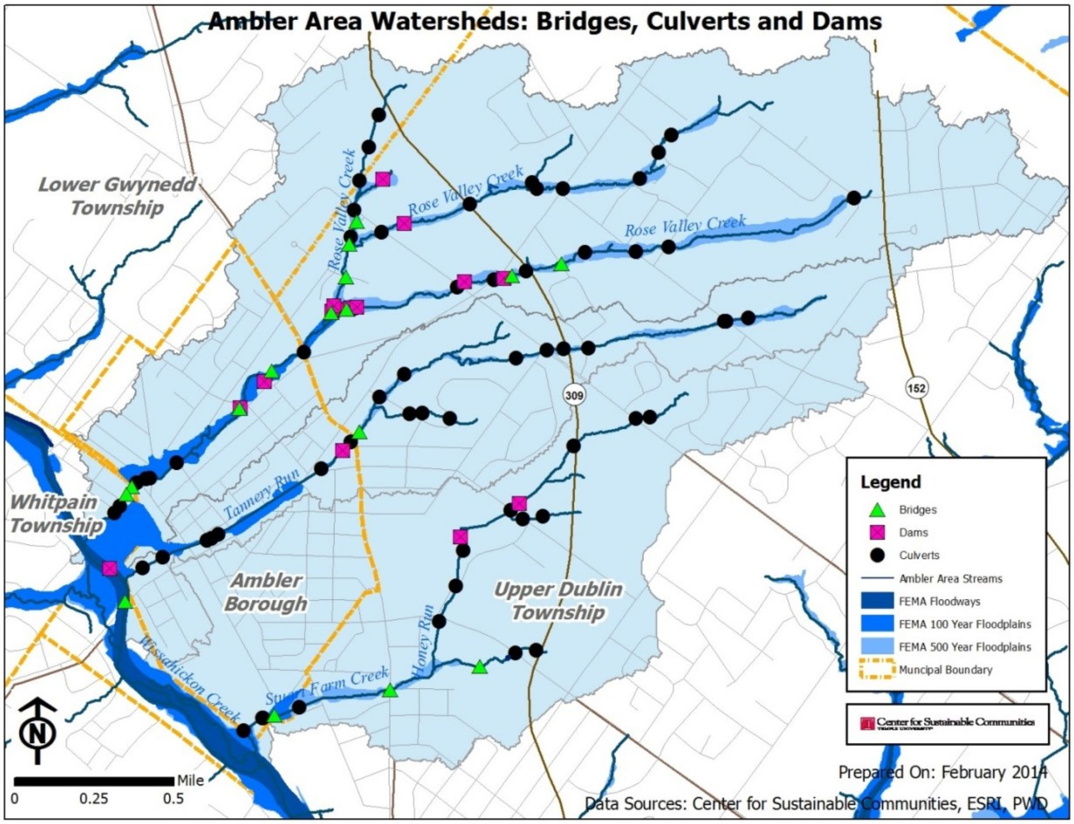

Figure 12: Field survey locations by the CSC project team

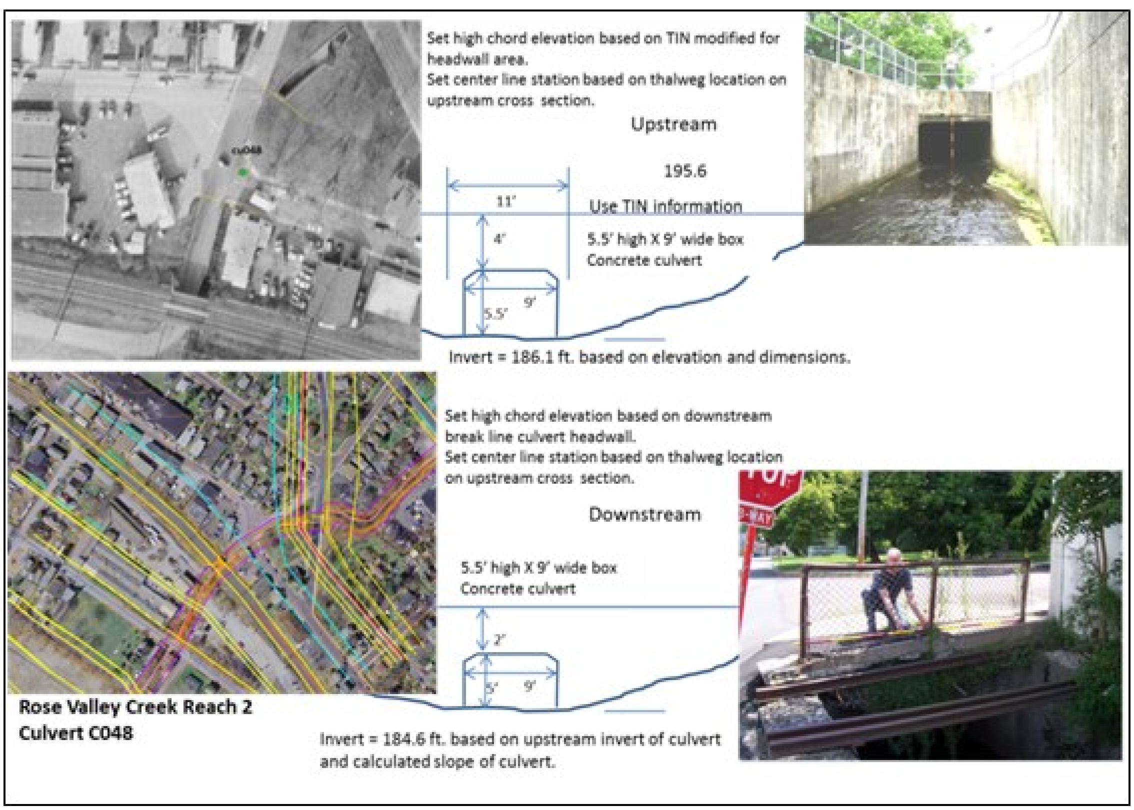

Figure 13: Overview of work-flow – field survey data

2.3. Local Plans, Projects, and Initiatives

Local municipalities, environmental advisory committees and nonprofit organizations have various projects addressing stormwater management and flooding issues throughout the study area. A few selected projects are briefly described here.

Ambler 100 Rain Gardens

The Ambler Borough Environmental Advisory Council (EAC), an all-volunteer citizen committee appointed by the local government, embarked on a campaign to bring 100 rain gardens to the borough. While an EAC is appointed, much of the work is volunteer based. Citizens are engaged through rain garden workshops when they learn how to design, build and maintain a rain garden on their property. EAC members also perform free site visits for residents interested in determining feasibility. The campaign rallies free labor from volunteers and mulch and plant supplies to assist the homeowner in installing the rain garden. At least five rain gardens have been installed on residential properties and in parks to date. Workshops will be held every fall and spring. News articles covered the effort, while the Greentreks Network produced a video documenting the program. In addition, the EAC publishes a website and an "Environmental Corner" section in Ambler's municipal newsletter, publicizing this and other programs and initiatives it sponsors.

Rose Valley Creek Riparian Buffer Restoration

A 3-year grant-funded project for Rose Valley Creek riparian buffer restoration was completed by Ambler EAC in 2011. They removed invasive plants, planted 850 trees and shrubs, and installed deer fencing, a rain garden and new wildflower meadows. The project reduced mowed areas in Borough Park and enhanced Ambler's only natural park. In 2012, they removed invasive plants, removed deer fencing downed by Hurricane Irene and Lee, planted nine more large trees, installed sleeves to protect saplings from deer rubbing and installed signage about the buffer project.

Upper Dublin Township SI Projects

In recent years, Upper Dublin Township has completed a number of SI projects such as retrofitting basins and channel stabilization. Projects include Dresherbrook Channel Stabilization, Dresherbrook Detention Basin Retrofit, Rose Valley Detention Basin Retrofit, Bell and Limekiln Detention Basin Retrofit, Pine Run Detention Basin Retrofit, Alden Lair Detention Basin Retrofit, Ardsley Detention Basin Retrofit, Route 309 / Highland Avenue Detention Basin Retrofit and Sheep Grazing, Upper Dublin Township Firehouse, Infiltration Basin and Sheep Grazing, and Pinetown / Highland Avenue Detention Basin Retrofit.

West Ambler Revitalization and Action Plan

This Action Plan was written on behalf of a neighborhood which straddles four different municipalities. Taking place over the course of nine months, The West Ambler Revitalization Planning Committee was composed of municipal officials, residents, community groups, environmental groups and government agencies (EPA, PA DEP), as well as the planning consultants hired by Whitpain Township. Five committee meetings were held at the Township building, which were open to the public, while four public meetings were held in the neighborhood. During these meetings, sketches and progress reports in the planning effort were presented, and comments and questions were taken. Because the BoRit Superfund Site is an integral part of the plan's focus, the Community Advisory Group (CAG), associated with the continued monitoring and remediation of the asbestos site, was involved as well. A series of "Goals, Facts, and Concepts" concerning the project were developed at the public meetings, which were subsequently incorporated into the plans.

This neighborhood revitalization plan has proposed channelization (or day-lighting) of the Rose Valley Creek, as shown in Figure 14 – location 20.

Figure 14: Concept Plan showing channelization of Rose Valley Creek[12]

Educational and Engagement Activities – Wissahickon Valley Watershed Association

The Wissahickon Valley Watershed Association (WVWA) performs a number of educational and engagement activities supporting the conservation of the Wissahickon Watershed. Educational opportunities are available to Boy Scout troops and in the form of academic enrichment programs. Students visit an historic mill on the Wissahickon, exploring the historical significance of the creek; in addition, students can visit WVWA's wetland preserves, as well as take part in water quality monitoring, learning about the techniques of collecting and analyzing stream data. In 2012 WVWA held a town-hall-style meeting entitled "Wissahickon: Creek in Crisis?" to educate local residents about the current conditions of the creek and the watershed. A panel of experts made presentations and concluded with a question-and-answer session with the attendees.

2.4. Community Input

The stakeholder meeting was organized by the Project Team with the help of the Advisory Committee. The event was announced through Temple University Ambler's website, local newspapers (including the Ambler Gazette and Enterprise) and municipal websites (see Figure 15). The event was also promoted free of charge by Ambler Gateway, an electronic billboard, for two weeks. Hundreds of flyers were distributed by local Environmental Advisory Committee members. More than 110 stakeholders attended the meeting, held in the First Presbyterian Church located in downtown Ambler. The event started with a 20-minute presentation by the Project Team, followed by a brief question-and-answer session. Then, the stakeholders of three municipalities (Ambler Borough, Upper Dublin Township, and Whitpain Township) visited three separate stations to share their experiences with recent flooding events. They responded to a number of questions included in a form. A brief summary of the responses from this session is presented here. This session was

[12] Simone Collins Landscape Architecture, Hunt Engineering, Urban Partners, and Environmental Standards. (2013). Revitalization and Action Plan. Prepared for Whitpain Township.

facilitated by 15 volunteers (from local municipalities and Temple University). The event received news coverage from NBC 10 Philadelphia (see Figures 16 and 17).

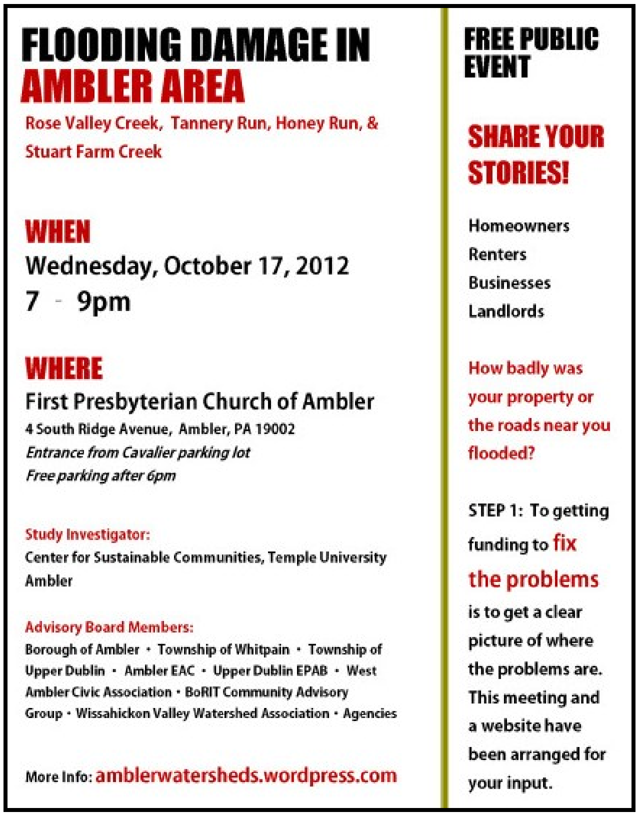

Figure 15: Meeting flyer

Figure 16: NBC 10 news coverage

Nearly all respondents were owners of the properties they were describing; most of these properties were residential, although three respondents identified their properties as businesses, all of whom reported substantial losses in inventory and equipment. Only one respondent explicitly self-identified as a residential tenant.

The overwhelming majority of respondents identified Tropical Storm Lee (September 2011) as their worst flooding event during the last five years, although some mentioned Hurricane Irene as well (August 2011). More than two-thirds of respondents described flooding of the basement, incurring the loss of various appliances and personal effects—most often including hot water heaters, furnaces, freezers, and other electrical appliances. Many respondents also detailed structural damage to their finished basements, including damage to drywall and carpeting. Damage to exterior features, including landscaping, sidewalks, or driveways was also described. For some, flooding was so severe that vehicles parked on the street and in driveways were totaled. Still others, although few in number, described damage resulting from sewage backups and not specifically from flood waters.

Nearly all of the respondents (90%) reported that their properties have been flooded at least twice in the past 10 years, with 52% of respondents reporting their properties have flood five times or more in the past 10 years. Some respondents even reported that their properties flooded twice a *year*.

Slightly more than 40% of respondents reported having flood insurance. Table 3 illustrates the full range of responses relating to flood insurance and claims. Some respondents (four) answered that they had filed a flood insurance claim although they had stated in the previous question that they in fact did *not* have flood insurance: it's possible that these respondents were referring to claims against a homeowner's insurance or other policy.

Table 3: Responses to Questions Related to Flood Insurance (n=31)

	Yes	No	Partially	No Answer
Flood Insurance?	13	18	-	-
Filed Claim?	13	16	-	2
Were Claims Paid?	8	8	4	11

Just over half of the respondents reported either taking action themselves to mitigate future flooding or knew that their municipality was taking action. Of these, 68% explicitly reported that they had taken action themselves on-site: some of these actions included the installation or upgrading of sump pumps, different types of drains and drain pipes, berms, and reinforced or glass-block basement windows. Actions taken by municipalities that respondents described included commissioning studies, widening riparian buffers and replacing culverts. More details on residents' responses can be found in Appendix E at the end of this report.

Many ideas and suggestions were offered as to what could be done to mitigate flooding in the future, ranging from the general to specific. Many respondents supported, in general, the restoration of riparian buffers and wetlands in the area, as well as improving existing detention basins. Some suggestions directly related to the pipes running under the SEPTA Regional Rail tracks, indicating that they should be replaced or redone. The installation of storm sewers on Norristown Road and a retention basin on Copper Drive was recommended by one respondent. Building detention basins in Ambler Borough Park was another suggestion offered. Two respondents made specific mention of the Loch Alsh reservoir—one suggested that opening the reservoirs caused the sewers to back up, while another suggested that leaving the reservoir below capacity before storms would have "saved property and aided evacuation."

After this initial stakeholder meeting, the Project Team attended or presented at a number of meetings, including the following:

- February 14, 2013 (West Ambler Revitalization Committee)
- February 25, 2013 (West Ambler Revitalization Committee)
- March 28, 2013 (Wissahickon Watershed Partnership Meeting) Progress report presented.
- June 4, 2013 (Whitpain Board of Supervisors) Progress Report presented.
- June 23, 2013 (Coordination Meeting with Army Corps Representatives)
- September 20, 2013 (Coordination Meeting with FEMA)
- October 11, 2013 (Coordination Meeting with Army Corps Representatives)
- October 25, 2013 (Coordination Meeting with Municipal Officials) Presentation given.
- November 26, 2013 (West Ambler Revitalization Committee) Presentation given.
- March 10, 2014 (Mapping Coordination Army Corps, FEMA, EPA) New maps to be presented.
- October 22, 2014 (West Ambler Revitalization Committee) Presentation given.

Figure 17: A collage of snap shots from the first stakeholder event, 2012
© *Mahbubur Meenar*

3. GIS-Based Watershed Assessment

3.1. Watershed Characteristics and Runoff

Stormwater management planning must take numerous surface features into account, including topography, soils, land use, and impervious cover, as well as existing stormwater collection and discharge. Since Ambler area watersheds are located at the center of Wissahickon Creek Watershed, a broader understanding of the Wissahickon Watershed would be helpful for the community, especially for continuous data sets such as precipitation. Precipitation characteristics for the central portion of Wissahickon Watershed would be representative of the Ambler area. This section describes the primary factors defining the stormwater runoff in the Wissahickon Watershed and the study area.

Precipitation Pattern

For the 30-year period from 1981 to 2010, precipitation at the National Weather Service (NWS) rain gage at the Springhouse area averaged 47.4 inches.[13] Similar annual totals were recorded for NWS stations near the watershed at Norristown (48.4 inches) and Conshohocken (48.7 inches). Additionally, a water budget analysis performed by the U.S. Geological Survey (USGS) for the period 1987-1998 reported an average annual total for the watershed of 47.2 inches.[14] This annual total, however, is not uniformly distributed over time, and extreme events can produce eight inches of rain or more in a single day. Flood events occur at any time of year, and may be caused by different types of weather events including severe thunderstorms, tropical storms, or even colder weather events when heavy rains can combine with snowmelt. Rainfall during individual storms is generally not distributed evenly across the watershed, and rarely occurs at a constant rate. Because of its location immediately northwest of the Coastal Plain, the Wissahickon Watershed is vulnerable to heavy rainfall from tropical weather events. Damaging tropical storms in recent years have included Floyd (1999), Allison (2001), Ivan (2004), Irene (2011) and Lee (2011).

Table 4 lists design rainfall totals that have been applied to the hydrologic analyses in this study. The design events are based on the Pennsylvania Department of Transportation (PennDOT) Intensity-Duration-Frequency (IDF) data for regions in Pennsylvania. These data were developed from the latest National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation frequency data. The precipitation totals for the various design events are weighted averages because the Wissahickon Watershed is situated at the boundary of PennDOT IDF Regions 4 and 5. Approximately 40% of the Wissahickon Watershed is in Region 4 and 60% in Region 5.

In terms of probability, the meaning of design storm frequency is as follows: a 5-year event would have a 20% chance of occurring in a given year; a 10-year event would have a 10% chance of occurring in a given year, etc. The rainfall totals in the table provide a means of predicting the magnitude of storms for planning and design purposes. They are a statistical product based on the population of events that have occurred in the past. They are not predictive of the timing or sequence of individual storm events or their rainfall distribution in the watershed. For example, the extreme precipitation events caused by tropical storms Floyd and Allison occurred less than two years apart.

13 NOAA, National Climatic Data Center, 1981-2010 Normals Data Access, http://www.ncdc.noaa.gov/land-based-station-data/climate-normals/1981-2010-normals-data.
14 Sloto, R. A., and Buxton, D. E. (2005). Scientific Investigations Report 2005-5113, U.S. Geological Survey.

In addition to total rainfall, the timing of rain during an event affects peak runoff rates. The design storms applied in this study include a period of heavy rain in the middle of the event. This is done to mimic the flashy runoff conditions that are usually a part of flood events in watersheds the size of the Wissahickon and its tributaries. Additionally, the same rainfall total and timing of rain is applied to the entire watershed simultaneously in the modeling. While this does not replicate any single historic event, it provides a means of evaluating the watershed under a range of runoff conditions and gives a measure of the effectiveness of potential stormwater improvements.

Although extreme storm events trigger the most damaging flooding in the Wissahickon Watershed, most storms produce less than one inch of rainfall. These smaller storms produce a significant portion of annual runoff. For this reason, stormwater management measures designed for infiltration or extended detention of these smaller runoff events are effective in reducing non-point pollution loadings and stream erosion. Daily precipitation data for 2010 at PWD rain gage No. 21 in the lower portion of the Wissahickon Watershed is presented in Figure 18. Of the 69 days when more than 0.1 inch of precipitation occurred, only 16 (23%) produced total rainfall exceeding one inch.

Table 4: Rainfall totals for 24-hour design storms

Storm Frequency	Total Precipitation (in)
1-Yr	2.75
2-Yr	3.30
5-Yr	4.10
10-Yr	4.80
25-Yr	5.90
50-Yr	6.91
100-Yr	8.11
500-Yr	11.83

Note: Based on PennDOT Intensity-Duration-Frequency (IDF) data for Regions 4 and 5 in Pennsylvania.

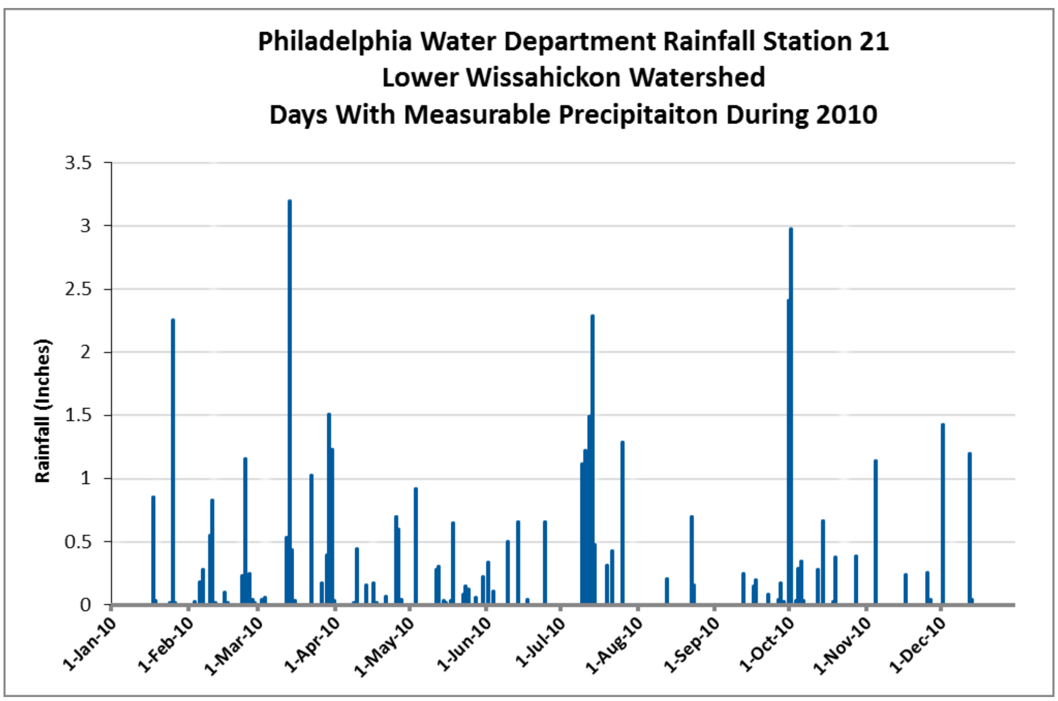

Figure 18: Precipitation events in the Wissahickon Watershed

Land Surface Features

The elevations over the watershed range from 155 feet to 397 feet. Ambler Borough and Whitpain Township portions of the watershed have the lowest elevation values. Figure 19 provides a graphical presentation of elevation from a Digital Elevation Model (DEM). The DEM was created from 2008 LiDAR flown for the PAMAP program of the Pennsylvania Department of Conservation and Natural Resources (DCNR), and was downloaded from the Pennsylvania Spatial Data Access website.[15] It includes high resolution, high-quality data with two-foot contours.

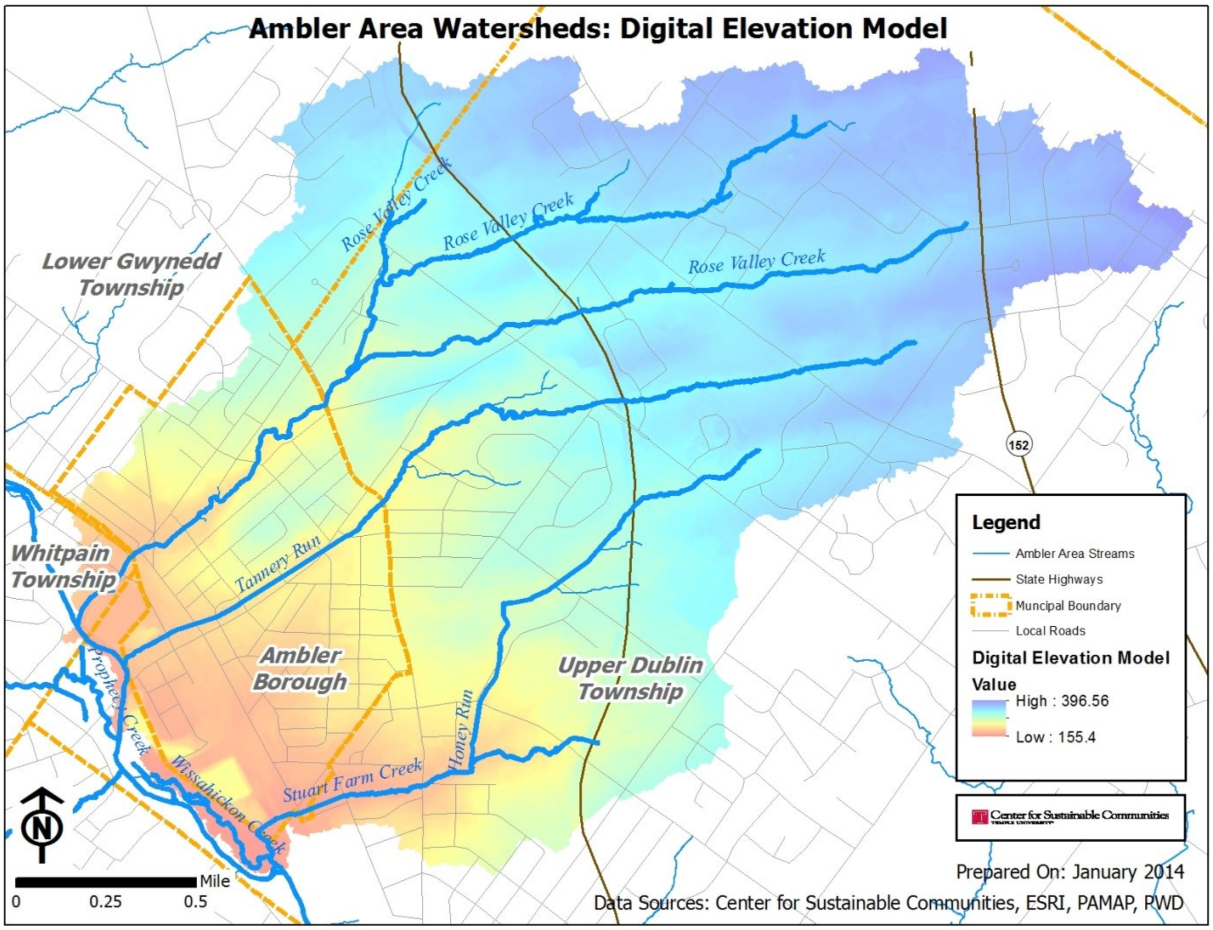

Figure 19: Study area elevation

Based on their runoff characteristics, soils of the U.S. are classified by the Natural Resource Conservation Service (NRCS) into four hydrologic groups A, B, C, and D. Group A soils have low runoff potential with high infiltration rates, while Group D soils have high runoff with very slow infiltration rates. The other two groups are in between. Runoff characteristics of various land uses vary with the underlying hydrologic soil group designation, and information on the location of hydrologic soils groups was used in the hydrologic modeling for this study. As noted in Figure 20, hydrologic soils in the Ambler area watersheds are predominately groups B and C soils with some

15 Pennsylvania State Data Access, Penn State Institutes of Energy and the Environment, Penn State University

Group D soils. The hydrologic soil groups in this area are predominantly Group C, followed by Group B, with slightly smaller areas of Group D. Ambler Borough itself is almost entirely Group C.

Group B soils have moderate infiltration rates even when thoroughly wetted, and consist chiefly of moderately deep to deep, moderately well drained to well drained soils with moderately fine to moderately coarse textures. Group C soils have slow infiltration rates even when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. Group D soils have the slowest infiltration rates of the four groups. Movement of water through this soil type is highly restricted due to the soil composition which generally more than 40 percent clay. All soils with a water table within 2 feet of the surface are included in Group D.[16]

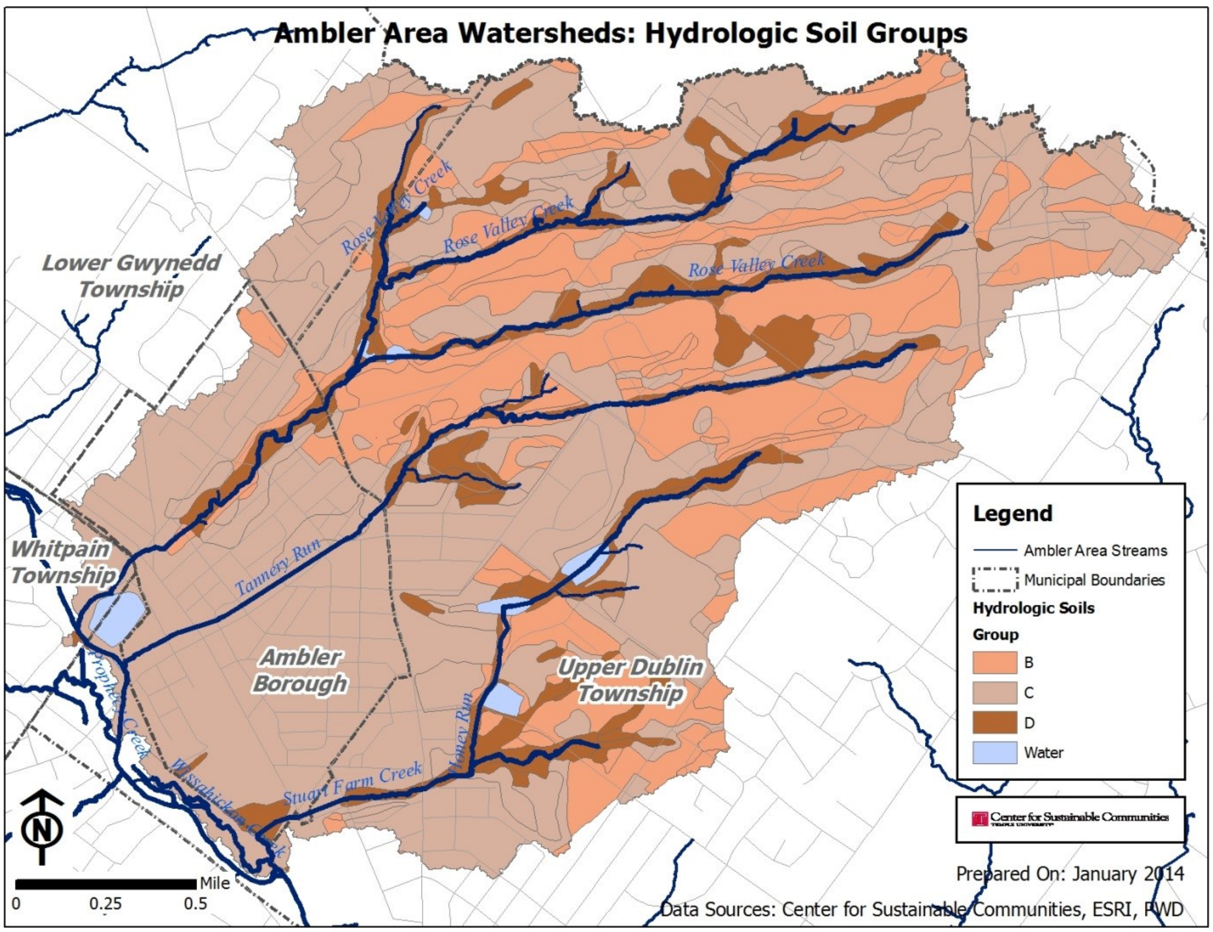

Figure 20: Hydrologic soil groups

Soil erodibility in the study area is depicted in Figure 21. There are no 'severe' erodibility zones in the Ambler area watershed. Erodibility ranges from mostly 'slight' to 'moderate' in areas of higher stream presence (more tributaries and stream convergence).

16 U.S. Department of Agriculture, Natural Resources Conservation Service, National Engineering Handbook, Part 630 – Hydrology, Chapter 7, pp. 7-2-7-3.

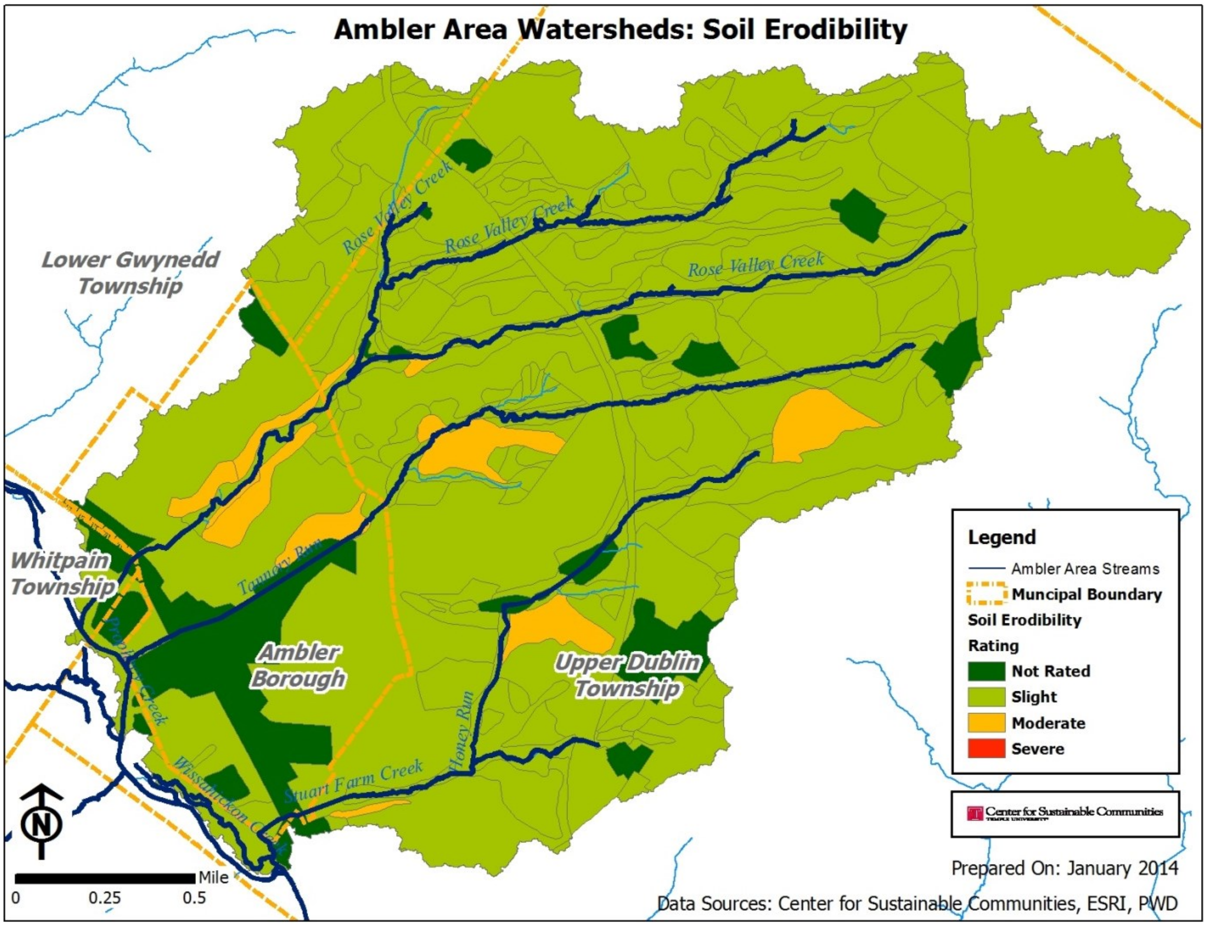

Figure 21: Soil erodibility

Current land use (2010) in the Ambler watersheds is shown in Figure 22 and Table 5. Almost half of the study area has single-family detached residential land use, and about 7% is multi-family residential. Wooded (15%), recreational (8%) and community services (6%) are the next most frequent land uses.

Table 5: Land Use, 2010

Land Use Type	Acres	% of Total Land
Agriculture	66.28	2.46%
Commercial	58.62	2.17%
Community Service	150.39	5.58%
Manufacturing: Light Industrial	35.64	1.32%
Parking (All Types)	91.19	3.38%
Recreation	205.46	7.62%
Residential: Multi-Family	178.44	6.62%
Residential: Row-Home	19.88	0.74%
Residential: Single-Family Detached	1,327.68	49.25%
Vacant	71.9	2.67%
Water	32.72	1.21%
Wooded	413	15.32%
Transportation and Utility	44.35	1.65%

Data Source: DVRPC, 2010

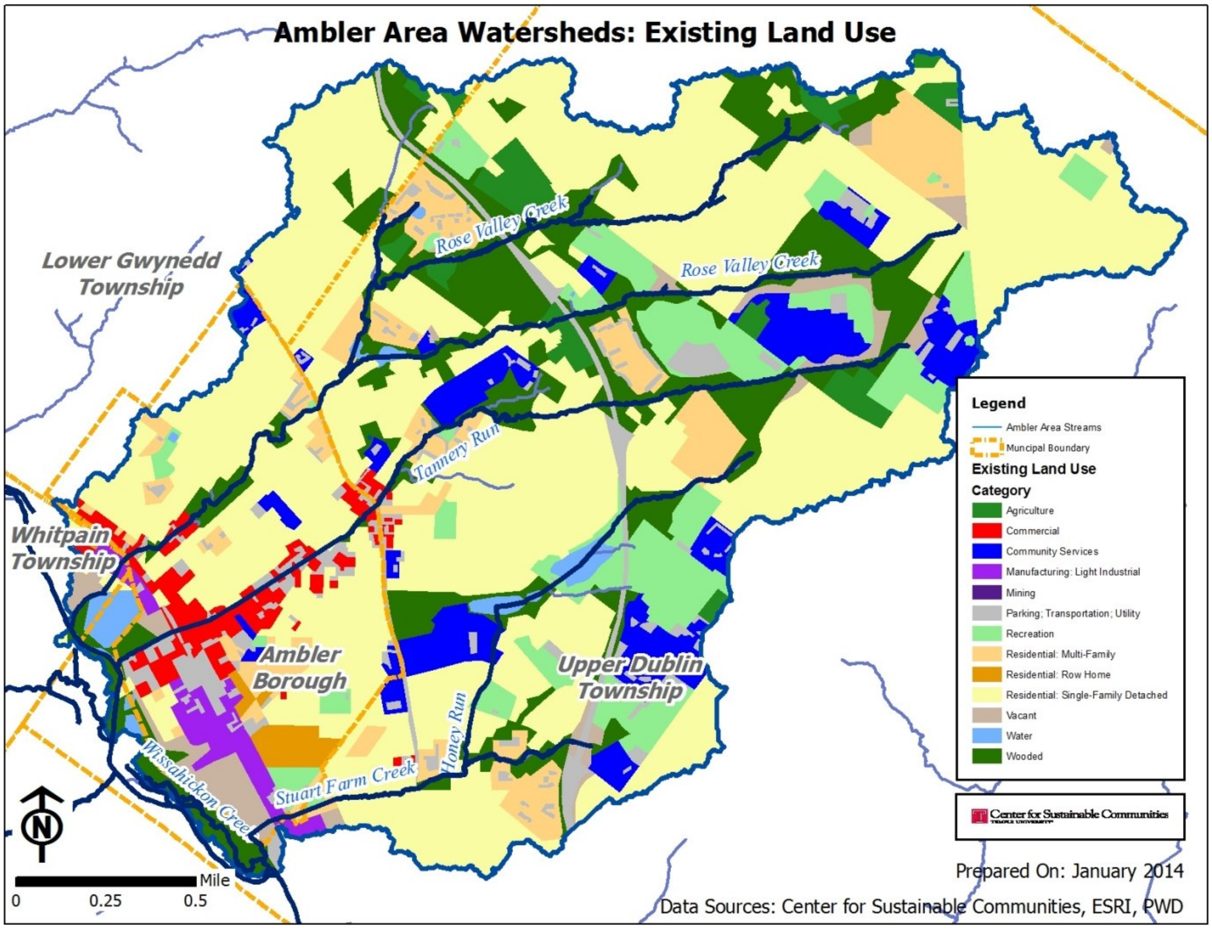

Figure 22: Land use, 2010

Taken together, the surface features of the study area, along with antecedent soil moisture conditions, define how it responds to rainfall. In order to provide more precise information about the potential for flash flooding in small watersheds, the National Weather Services' Mount Holly Weather Forecast Office has conducted a GIS-based analysis of flash flood potential for its forecast area. The product of the analysis is the map shown in Figure 23, which shows relative flash flood potential in the watershed based on digital data available for soils, slope, forest density, and land use. The map shows an index of the combined potential for these land-based parameters to generate flash flooding, with the highest index numbers representing the areas of highest flood potential. Comparison of this map with Figure 22 (land use) shows the close agreement with flash flood potential and land uses associated with impervious cover. The map provides a good picture of the areas in the watershed that would be expected to generate the largest runoff volumes, and is consistent with the representation of surface conditions by the hydrologic model described in this report.

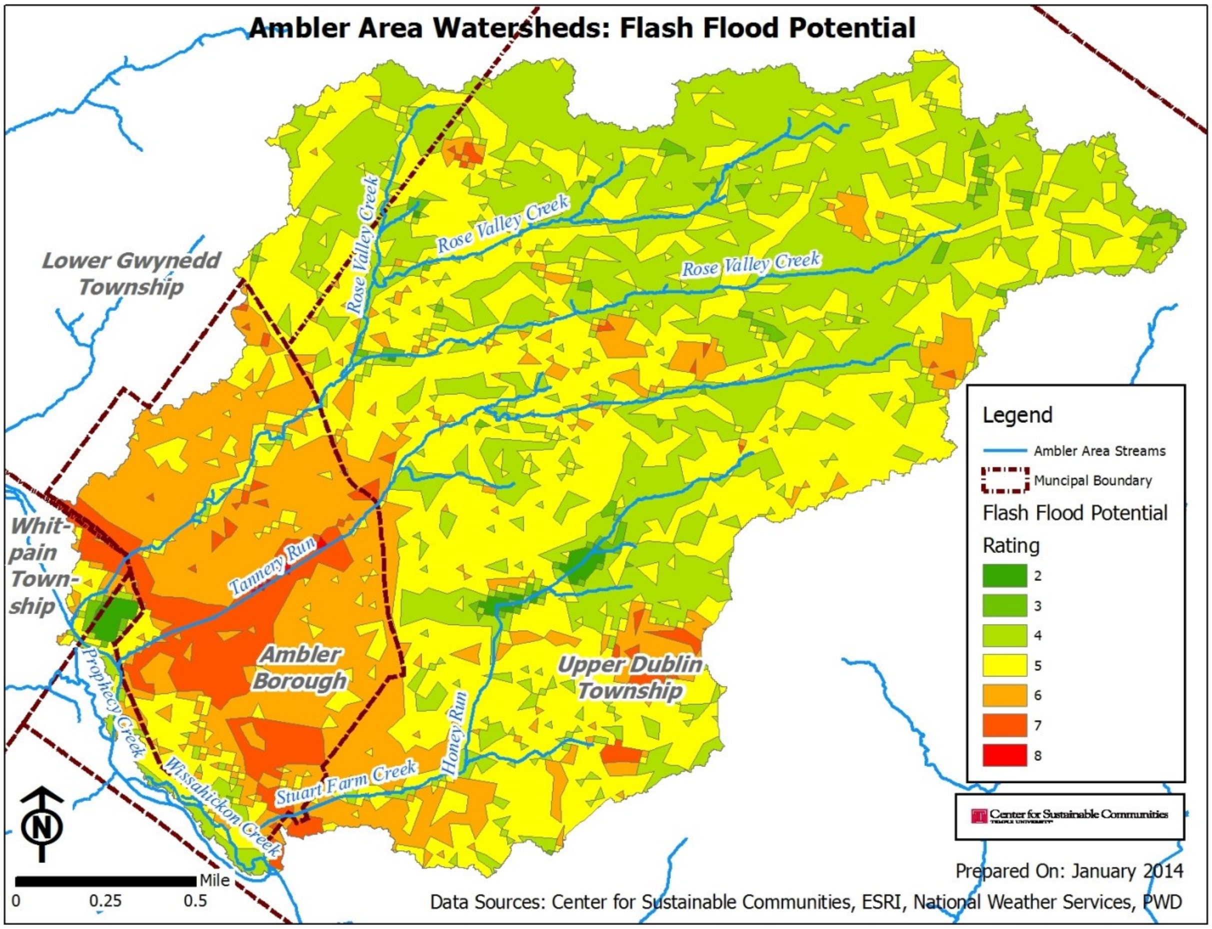

Figure 23: Flash flood potential in Ambler area watersheds

Once runoff occurs, constructed surface storage that intercepts and holds the runoff can delay flow and lower flood peaks. An inventory with 185 existing detention basins in the Wissahickon Watershed was provided by the PWD. This was supplemented by data collected by the CSC during field inspections of additional detention facilities and ponds in 2009. Figure 24 shows the distribution of these facilities only in the study area. The majority are located in the upper half of the watershed where there has been more new developments after the implementation of stormwater management regulations. The storage provided by these facilities was estimated and totals for each modeled sub-basin were included in the hydrologic model. The estimated total storage of all existing facilities is approximately 48 acre-ft. Most are local facilities designed to control site runoff from specific development sites. If spread over the entire study area, this storage total amounts to the equivalent of 0.22 inches of runoff. Many existing facilities are not designed for extended detention, and runoff from smaller storms passes directly through the facility. These structures represent opportunities for retrofitting to provide additional storage and extended detention.

Stormwater collection, piping and discharge through outfalls affect the pathway and timing of runoff in developed watersheds. Stormwater collection systems are located in each of the municipalities in the study area. The collection systems are located primarily in the residential, commercial, and industrial areas served by curbed streets, and along arterial and secondary roadways. Although a detailed survey of stormwater piping was not conducted as part of this study, estimates of the extent of coverage were made based on field observations, digital ortho-photos, land use data, and outfall and drainage shed data provided by the PWD. Based on this information, it is estimated that stormwater collection systems of various capacities have been installed in most of the study area.

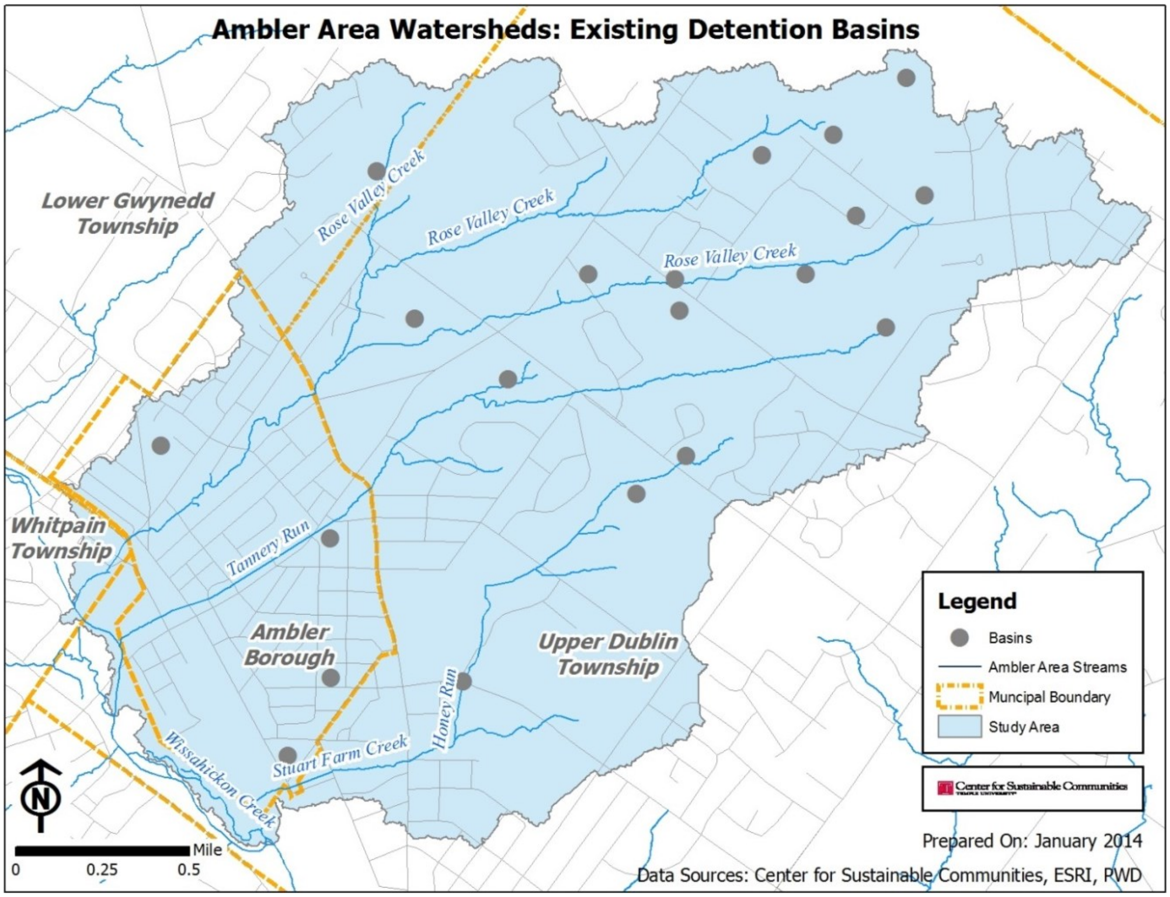

Figure 24: Existing detention basins in the study area

The single largest land use category in the watershed is single-family residential. In most residential areas, only a portion of the water falling on roofs and properties enters the street, and subsequently the storm inlets, depending on the slope of the property and gutter drainage onto the property. The remainder of roof and property drainage infiltrates into the soil, and as the soil becomes saturated, runoff flows at an increasing rate to the street or to other drainage basins offsite. As housing density increases, a larger proportion of each property's drainage enters storm inlets. In the most developed sections of the watershed with curbed roadways, the roadways channel runoff to the storm inlets during smaller storm events, and become stormwater channels once runoff exceeds the capacity of the inlets and/or pipe capacities. Development alters the local runoff pathway, particularly for smaller storms, and the runoff to stream channels is often controlled by the location of stormwater inlets, piping, detention basins, and outfalls. This situation is depicted in Figure 25. The watershed boundaries and outfall locations were used as guidance in delineating subareas for modeling. A map showing outfall locations in the watershed is shown in Figure 26. In addition, an example of a municipal stormwater system map, with stormwater piping, inlet and outlet locations provided by Upper Dublin Township, is shown in Figure 27.

Figure 25: Stormwater collection and outfalls

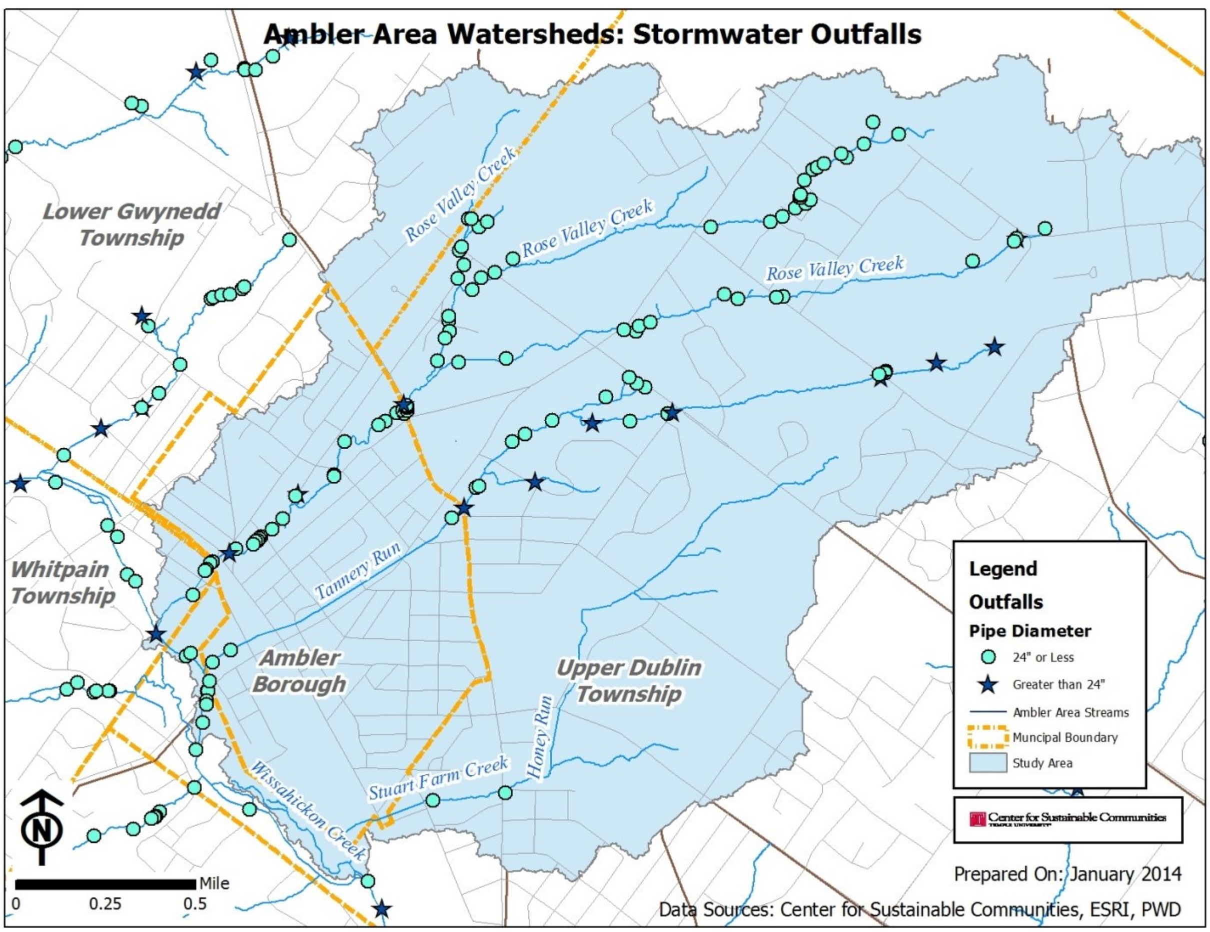

Figure 26: Stormwater outfalls

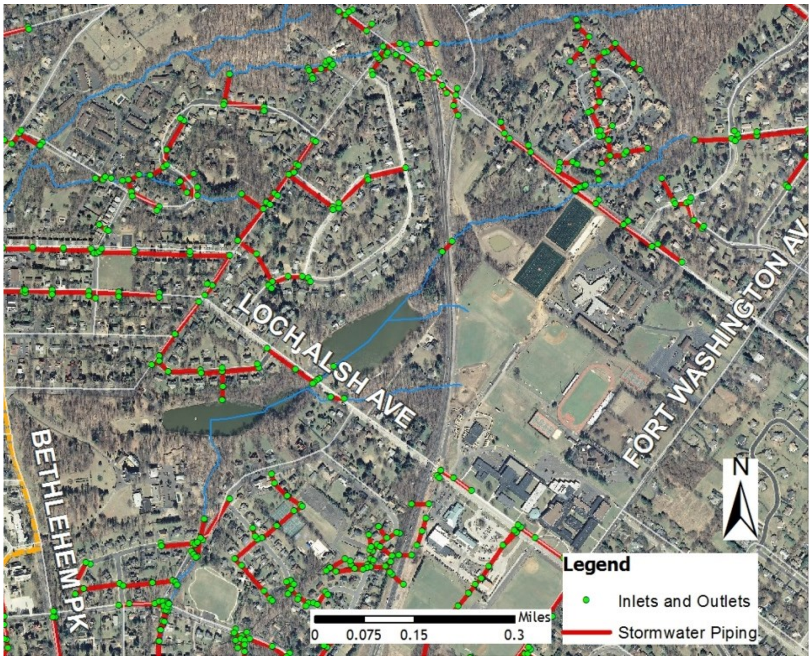

Figure 27: Stormwater collection system for a portion of Upper Dublin Township

3.2. Understanding Stormwater and Flooding Issues

Generally, stormwater problems in this study area are due to a number of reasons: floodplain development, loss of upstream storage, erosion, obstructions to flow and unmapped floodplains. Water quality problems are due to both point-source and nonpoint-source pollutions. This section describes some key issues related to stormwater and flooding in this watershed.

Nonpoint Source Pollution

All three creeks in the study area are designated as "impaired" in Pennsylvania's 303(d) list due to siltation, caused by urban runoff/storm sewers, and habitat modification. Surface water quality is impaired from a lack of stormwater runoff management and nonpoint source pollution control. The Ambler area was almost completely developed prior to the Pennsylvania Stormwater Management Act of 1978 and lacks suitable runoff controls[17]. As with many of the largely developed suburbs surrounding Philadelphia, ordinances that were in place during the suburban growth period did not adequately manage the increased volume of stormwater runoff resulting from the increase in impervious cover. It was not until the 1970s that municipalities began to recognize the need to get involved with this type of regulatory oversight. Impacts of uncontrolled urban runoff include: (1) faster timing of runoff, (2) non-point source pollution, (3) decreased groundwater recharge, and (4) increased stream temperatures, which result in increased flooding, increased stream bank erosion, impaired water quality and decreased aquatic diversity[18]. Stormwater problems are created because of increased impervious cover, destruction of riparian buffers, extensive floodplain development, more frequent extreme precipitation events, extensive channelization and piping, higher peak flows and higher runoff volumes. The study area has experienced severe flooding in many recent storm events,

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[17] Philadelphia Water Department (PWD). 2007. Wissahickon Creek Watershed Comprehensive Characterization Report.

[18] DeBarry, Paul. 2004. Watersheds: Processes, Assessment, and Management. New Jersey: John Wiley & Sons.

including Hurricane Irene and Tropical Storm Lee in 2011. Both storms produced peak flows larger than the 100-Yr flood used by FEMA as the basis for the current FIRMs[19].

Point Source Pollution
A large Superfund Site (BoRit Asbestos site), sitting next to Rose Valley Creek in the West Ambler neighborhood, includes a six acre private tract with asbestos piles, a 15-acre reservoir, and an 11-acre park that has been closed due to asbestos contamination (see Figure 30). In order to mitigate contamination from flooding, the EPA stabilized both sides of the creek. Unfortunately, the work was damaged in a recent flooding event. Another source of pollution is a wastewater treatment plant located in the flood zone, contributing to water contamination during storm events due to infiltration and inflow. Mean discharge of this wastewater treatment plant is 4.210 MGD, but increases substantially during storms[20].

Flooding
Figure 28 shows the floodway and the 100-Yr and 500-Yr floodplains for Ambler area streams. The floodplains shown are based on FEMA FIRMs. The number of buildings located within the 100-Yr floodway, 100-Yr floodplain, and 500-Yr floodplain is provided in Table 6, based on a GIS overlay of digital ortho-photos and floodplain data.

Table 6: Buildings affected by Floodways and 100- and 500-Year Floodplains

Municipality	**Building Footprints in Floodplains**		
	Floodway	**100 Year**	**500 Year***
Ambler	0	98	98
Lower Gywnedd	0	0	0
Upper Dublin	1	2	64
Whitpain	0	1	1
Total	**1**	**101**	**163**

Source: FEMA, PAMAP, PWD
**Includes buildings within 100-Yr floodplain*

< See Next Page >

[19] The total value of all flood insurance claims paid to Ambler Borough property owners is currently listed at $1.8 million by FEMA (January 1978 to March 2010) (http://bsa.nfipstat.com/reports/1040.htm#42). The CSC is conducting an Act 167 stormwater plan for the Wissahickon watershed. An initial analysis shows that 90 buildings fall within 100-Yr FEMA floodplains and another 91 buildings within 500-Yr floodplains. The project team suspects that actual numbers will be much higher, as FEMA floodplains in many parts of the study area are outdated and need revisions and many flood prone areas are not simply mapped.
[20] Philadelphia Water Department (PWD). 2007. Wissahickon Creek Watershed Comprehensive Characterization Report.

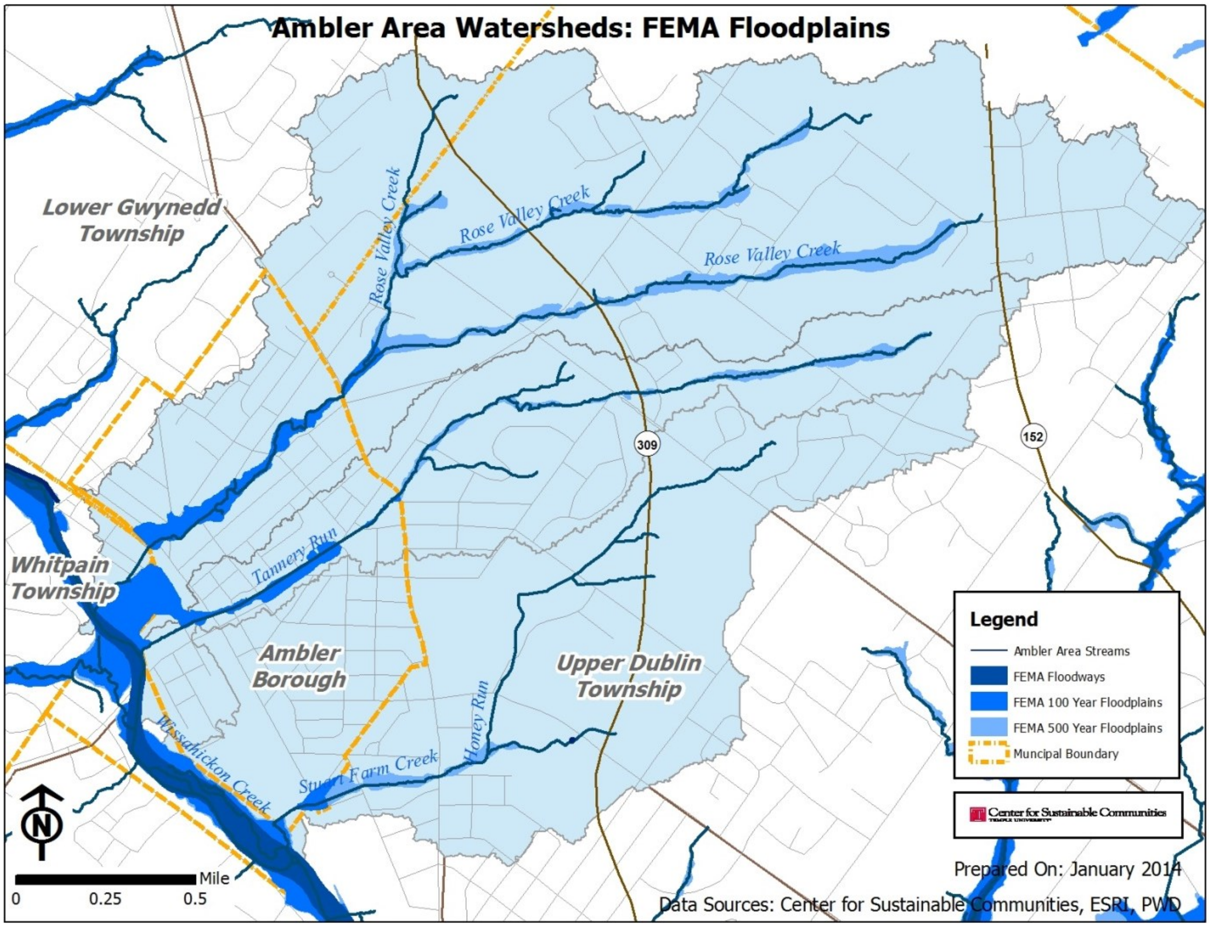

Figure 28: FEMA floodplains (FIRMs)

Flood insurance claims paid under FEMA's federal flood insurance program provide a partial measure of flood damage that has occurred since the late 1970s. This information can be used to indicate areas where flood damages are clustered, and also where repetitive flood claims have been filed. Based on individual flood insurance claims data provided by FEMA for the period of record through March 31st, 2010, the total number of flood insurance claims for the study area tributary watersheds was 116, with a total claims payment of $2.25 million. A total of 81 of these claims came from 23 repeat claim locations. The total payout for the repeat claims was $1.53 million. The highest density of claims has been in the lower reaches of the three tributaries within Ambler Borough, with very few occurring in the headwater areas. There have also been few, if any, claims along the main stem of the Wissahickon Creek adjacent to Ambler Borough.

Flood insurance claims and payments increased significantly with more recent flooding, particularly Tropical Storm Lee in September of 2011. According to FEMA statistics as of December 31, 2013, a total of 179 flood insurance claims had been filed in Ambler Borough alone with 157 of these claims paid, for a total payment of $4.02 million since the start of the flood insurance program in 1978.

Figure 29: West Ambler neighborhood after a flooding event. This area is not within existing FEMA floodplain boundaries.

Flooding problems can also occur at bridges and culverts. These structures can change the flow characteristics of waterways by restricting flows during flood events, which temporarily raises the upstream water surface elevation. Hazards associated with this include upstream flooding, bridge deck overtopping and flooding of low-lying approach roadways.

The PWD provided a comprehensive survey of 370 bridges and culverts in the Wissahickon Watershed that were considered to be significant obstructions to flow. These structures were re-measured by both the PWD and the Study Team to obtain current dimensions. The obstructions were then evaluated using the hydrologic model to determine flood events that would exceed their flow capacity. The analysis identified 34 structures where capacity would be exceeded by the 1-Yr design storm. These results are based on a watershed scale model, and problem culverts and bridges should be verified by the municipality based on the experience with historic flooding at the structure. A list of the structures is available from Wissahickon Creek Watershed Act 167 Plan, created by the CSC[21]. GIS files that can be used for mapping the structures are also available in digital format from the CSC. Profiles from the existing flood insurance study for the Wissahickon Creek in Montgomery County indicated that the major roadway bridges were not vulnerable to overtopping by smaller events.

There are many locations in this study area where existing FIRMs have become outdated. Figure 30 shows such as area (in a dotted circle) that has faced severe flooding in recent large storm events, but is not inside FIRM flood-zones.

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[21] Formuth, R. (ed). (2013). Wissahickon Creek Watershed Act 167 Plan. Temple University Center for Sustainable Communities. http://www.ambler.temple.edu/csc

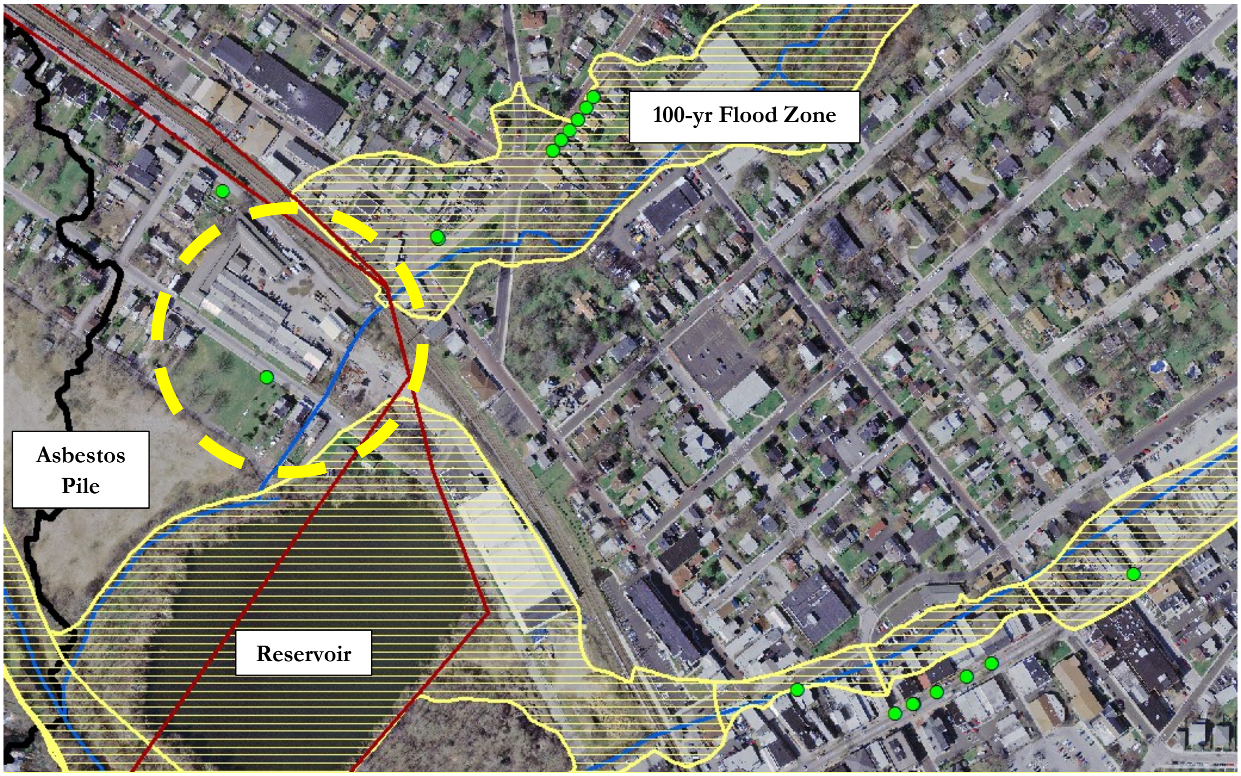

Figure 30: West Ambler Neighborhood, BoRIT site, and the reservoir. Locations of properties claimed flood insurance are shown in small dots. FEMA floodplain maps are shown in hatch pattern. Many properties in the dotted circle have faced recurrent flooding in recent years.

Stream Impairment

Surface water quality can become impaired from a lack of stormwater runoff management and inadequate nonpoint source pollution control.[22] Runoff from parking lots or other types of impervious surfaces increases stream temperatures and contributes to nonpoint source pollution. Pollutants come from automobile emissions, lawn and garden chemicals and litter.[23]

Increasing urbanization in the Wissahickon Watershed has also led to the destruction of riparian buffers, which has created additional pollution problems stemming from overland runoff into the watershed's streams, both the main stem Wissahickon Creek and its tributaries. The destruction of riparian buffers has also increased erosion and sediment loadings by exposing the stream bank soils to the velocity of the streams. It has led to the widespread loss of habitat for both aquatic and terrestrial species, as well as propagation of invasive plant species. A map of stream reaches in the study area lacking adequate riparian buffer is shown in Figure 31. This information is based on an updated inventory prepared in 2010 by the Heritage Conservancy.

[22] DeBarry, Paul. 2004. Watersheds: Processes, Assessment, and Management. New Jersey: John Wiley & Sons.

[23] Ibid.

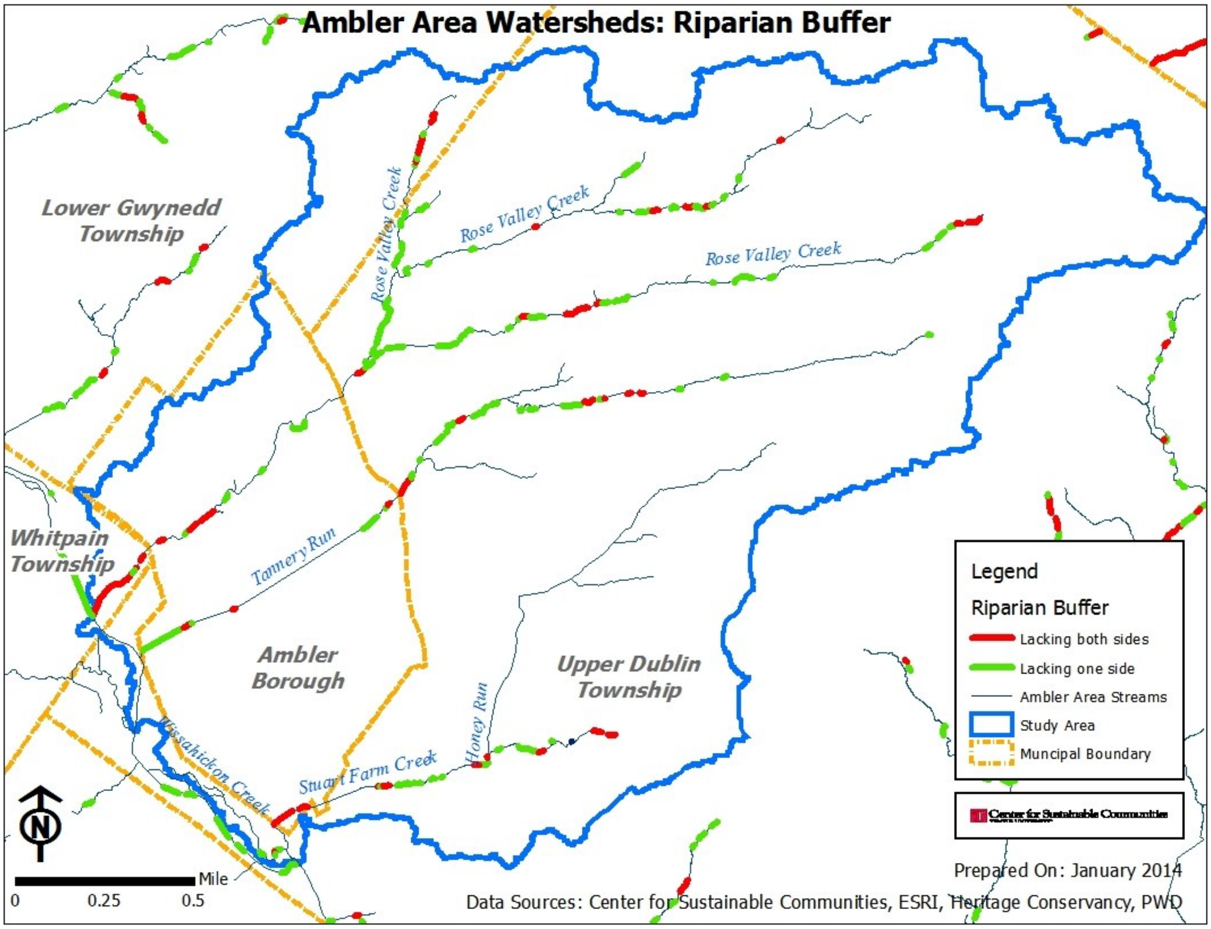

Figure 31: Stream reaches lacking sufficient riparian buffer

The Pennsylvania DEP and PWD have conducted several water quality studies and biological assessments in the Wissahickon Creek Watershed. Monitoring conducted by DEP has determined that about 83% of the Wissahickon Creek Watershed's stream miles are impaired for designated uses and have subsequently been listed on the Pennsylvania 303(d) list of impaired waters. The current designated use of the Wissahickon Creek is Trout Stocked Fishery. The impaired reaches in the study area are shown in Figure 32. The 303(d) list indicates that the majority of impairment is due to urban stormwater runoff, water flow variability, and flow and habitat alterations. Recent studies of the creek and watershed also identify stormwater runoff as a primary challenge to protecting and restoring the stream's ecosystem. Urban runoff is listed as the primary cause of impairment in 57% of the designated streams[24]. Given the state of the watershed and widespread impacts of stormwater, a major part of this study focused on measures to improve control of existing runoff, in addition to criteria for future development.

[24]Pennsylvania 303(d) Non-attaining Streams List

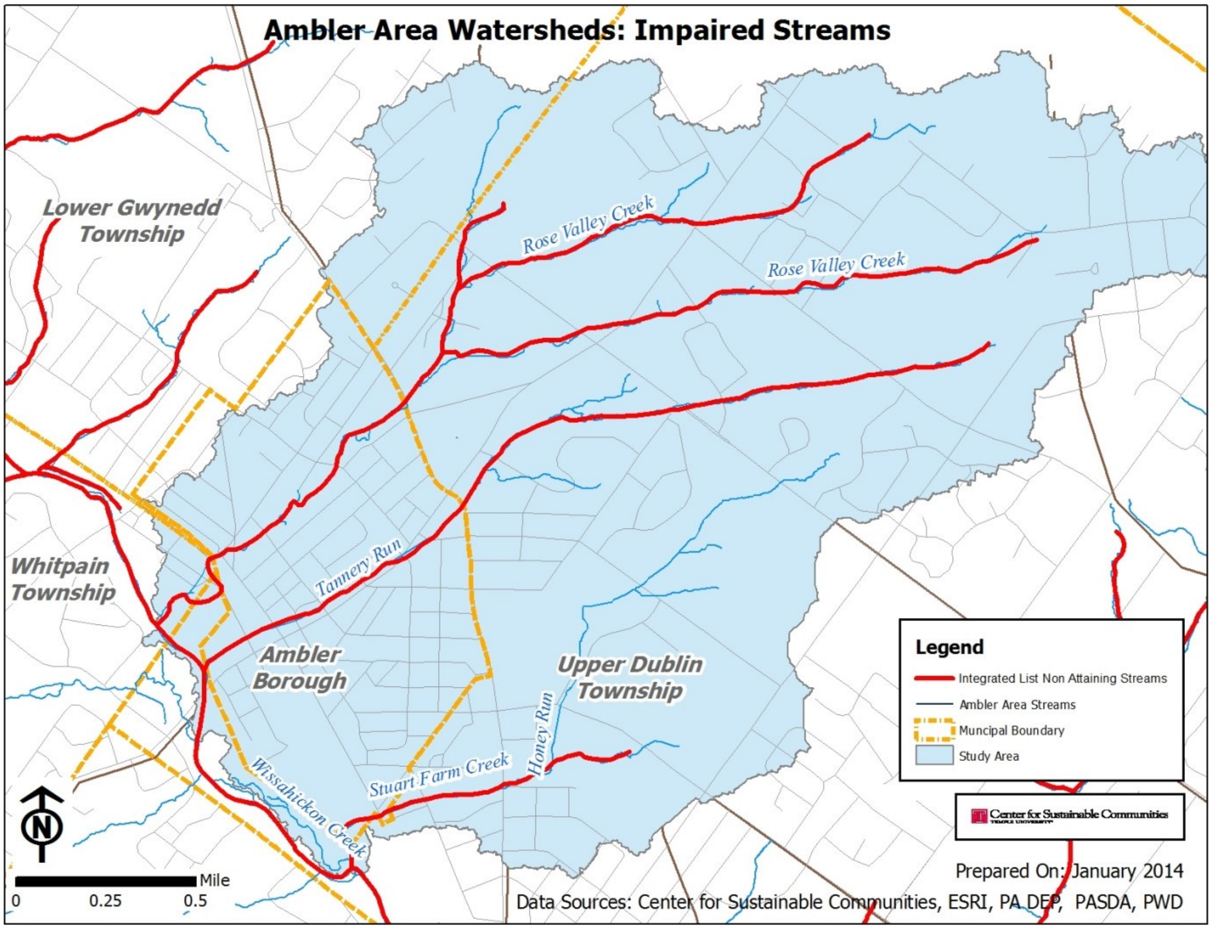

Figure 32: Impaired streams in the study area

Total Maximum Daily Load

In 2003, the EPA approved the Wissahickon Creek Total Maximum Daily Load (TMDL) to address the water quality impairments from point sources, in particular violations of standards for sediment and nutrients[25]. The TMDL sets waste load allocations (WLAs) for point sources for these contaminants. The TMDL established for sediment (2,823,095 lbs/year) was allocated among 15 municipalities and reported in Wissahickon Act 167 Plan[26]. Table 7 provides the values for four municipalities in the study area.

Table 7: Municipal Sediment Waste Load Allocations

Sediment TMDL	Sediment Loads (lbs/yr)	Sediment Loads (lbs/yr) in the Study Area
Ambler	42,189.97	38,814.77
Upper Dublin	464,607.60	10,6859.75
Whitpain	291,273.30	783.53
Lower Gwynedd	437,360.30	8,747.21

[25] TMDL for Sediment and Nutrients Wissahickon Creek Watershed

[26] Formuth, R. (ed). (2013). Wissahickon Creek Watershed Act 167 Plan. Temple University Center for Sustainable Communities. http://www.ambler.temple.edu/csc

The stormwater improvements recommended in this report would contribute toward mitigation of the impairments identified in the TMDLs.

Poor Drainage Areas

Many places within the study area have poor drainage. One example of a poor drainage area is the buried stream channel near Orange Avenue and Main Street between Tannery Run and Stuart Farm Creeks. This problem area was cited by Ambler Borough in an interview with the City Manager and Mayor, conducted in 2012. In Figure 33, arrows indicate drainage direction. The red polygon shows the area where ground elevation is 186 feet or lower and where ponding would be expected based on surface topography. This area would expand during large storms.

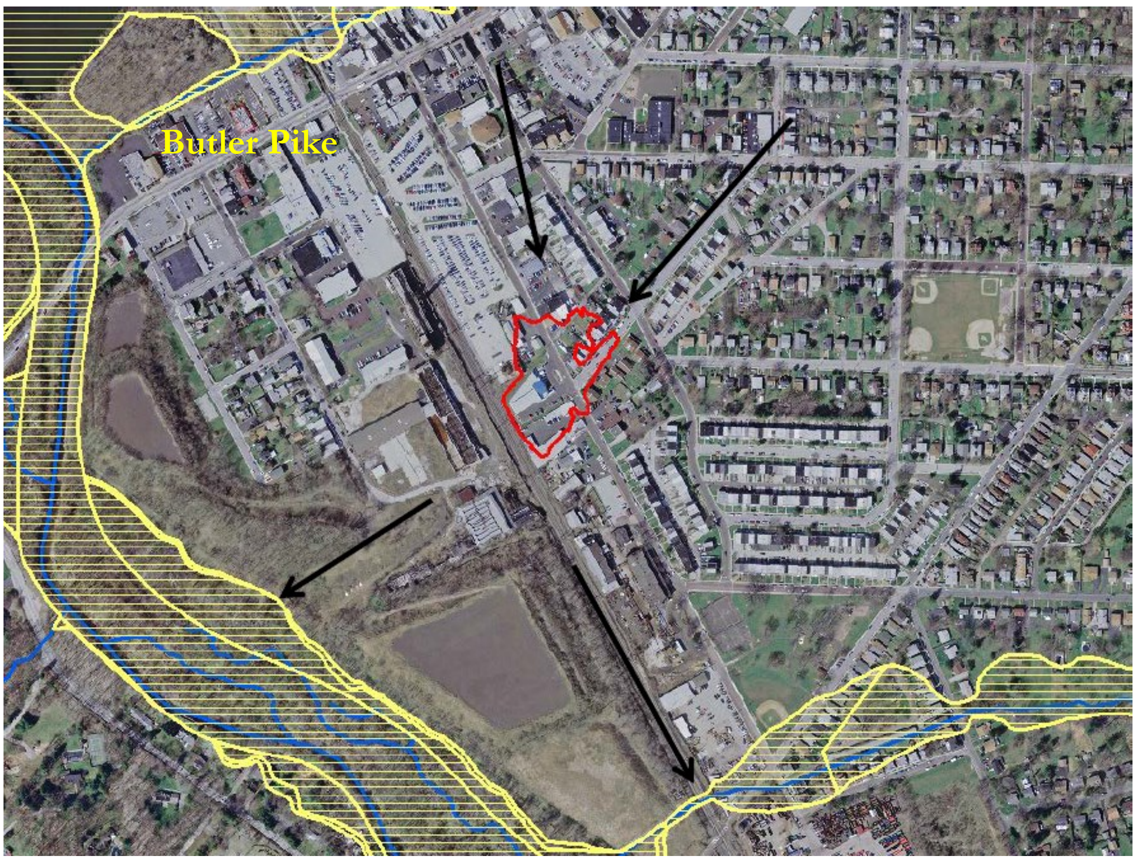

Figure 33: Poor drainage area in Ambler Borough

4. Engineering Models and Results

This section summarizes the hydrologic and hydraulic modeling conducted by the Project Team for Rose Valley Creek, Tannery Run, Honey Run, Stuart Farm Creek and portions of the Wissahickon Creek. This section also describes the hydrologic model used to generate peak stream flows and the hydraulic model used to calculate flood elevations for profiles and mapping. The extent of development of the study area combined with the potential for heavy rainfall has caused repetitive damaging floods, particularly in the downstream sections of Ambler Borough and the West Ambler portion of Whitpain Township. The models were developed to evaluate the extent of flooding for different storm events and to test the effectiveness of potential flood control measures.

The models and mapping completed for this study will be submitted as part of an application to FEMA for a Letter of Map Revision (LOMR). The LOMR will update the official FEMA floodplain maps for Rose Valley Creek, Tannery Run, Honey Run, and Stuart Farm Creek. Although a portion of the Wissahickon Creek was modeled as part of this study, revision of FEMA floodplain maps for the Wissahickon Creek will await re-study of the entire length of the stream. This is necessary to conform to FEMA's requirements for mapping consistency. As a result, the maps presented in this report include the newly generated floodplains for the tributary streams and the existing FEMA floodplain for the Wissahickon Creek. All maps are preliminary pending final approval by FEMA.

As seen in Figure 2, Rose Valley Creek, Tannery Run, and Stuart Farm Creek are each a tributary to the Wissahickon Creek and enter that stream in Ambler Borough. Honey Run is a tributary to Stuart Farm Creek. The four streams have a combined drainage area of 4.1 square miles. The individual drainage areas, measured in square miles, are: Rose Valley Creek (2.05); Tannery Run (0.69); Honey Run (0.56) and Stuart Farm Creek (0.79). A portion of what is shown in Figure 2 as the Stuart Farm Creek watershed actually drains directly to the Wissahickon Creek through culverts along a buried stream channel in the vicinity of Orange Avenue and Main Street. This has been accounted for in the floodplain modeling for Stuart Farm Creek.

The hydrologic and hydraulic models developed for this study were used to evaluate runoff, peak flows, and flood elevations for existing conditions in the watershed, and to determine the effectiveness of potential stormwater and flood control measures. Model applications included the following:

- Determination of runoff volumes and peak flow rates for design storm events including the one-percent chance or 100-Yr storm.
- Calculation of water surface elevation profiles for the 100-Yr storm event.
- Generation of flood maps showing the inundation area for the 100-Yr storm event.
- Calculation of peak flow and water surface elevation reductions from potential stormwater control measures such as extended detention, infiltration and restoration of riparian buffer areas.
- Determination of peak flow reductions in Honey Run assuming continuation of lowered operating water levels in Loch Alsh Reservoir and redesign of Loch Linden Dam as an extended detention facility.
- Evaluation of floodplain impacts of expanding the Rose Valley Creek channel from Ambler Avenue upstream to Rieff's Mill Road.

4.1. The Hydrologic Model

The hydrologic model used for this work was developed by the CSC and calibrated by NTM Engineering. This model, which covers the entire Wissahickon Watershed, was developed for the Act 167 Study completed for the PWD in 2013. A summary of the model development is included in the Act 167 report[27]. A model calibration report was prepared and reviewed by both FEMA and the ACE. The modeling employs the HEC-HMS platform developed by the ACE's Hydrologic Engineering Center and includes 137 subbasins with an average drainage area of 0.46 square miles. Figure 34 shows a schematic diagram of the portion of the model that includes the four study-area tributaries. This portion of the model includes 12 subbasins with an average area of 0.34 square miles.

The model calculates runoff volume based on precipitation, land cover and soils, and then routes runoff and streamflow to determine peak flow rates based on slope, surface roughness and channel geometry. The model consists of watershed units or subbasins, junctions and reaches as designated in Figure 34 by the prefixes W, J, and R, respectively. The suffix DA designates drainage areas associated with detention basins or reservoirs, such as UD_43 DA, which is a detention basin.

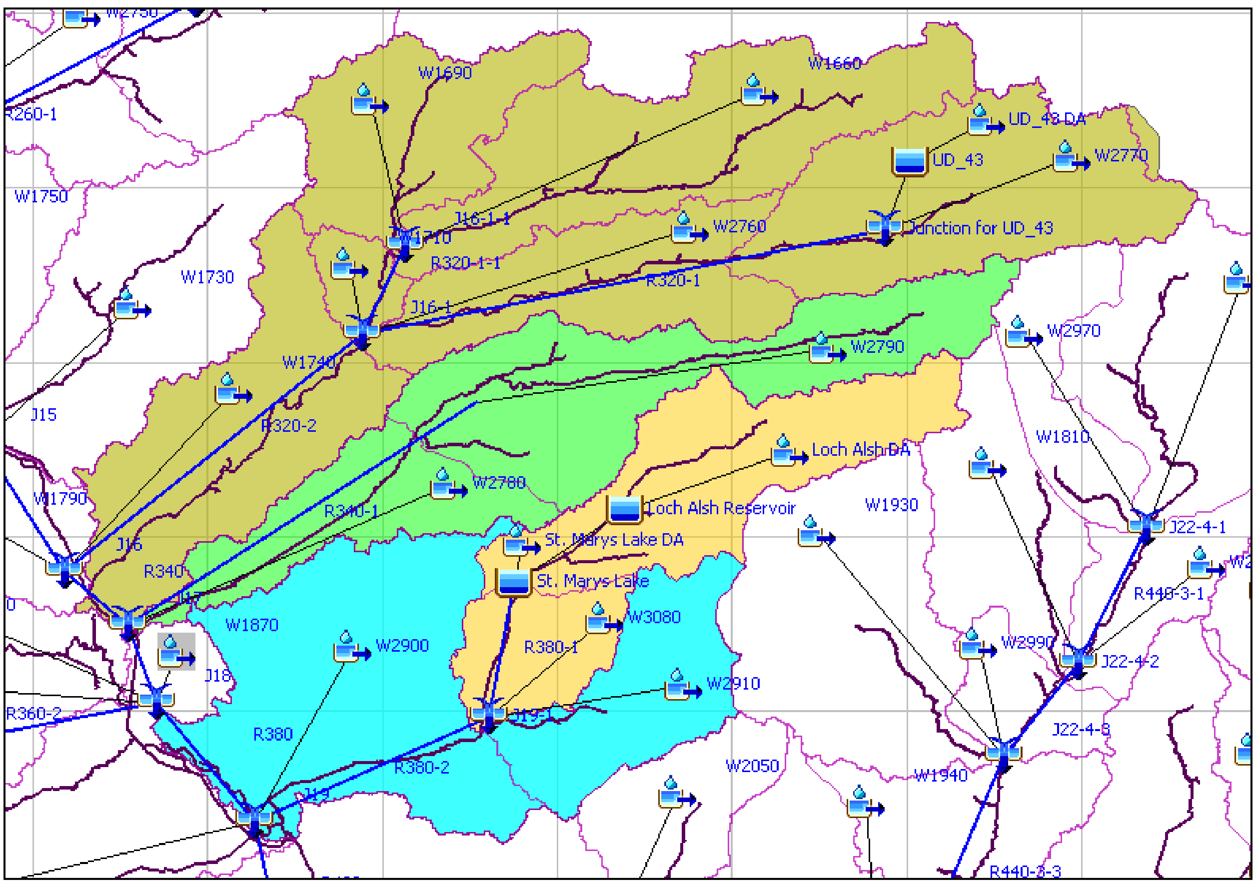

Figure 34: Schematic diagram for HEC-HMS model of study area tributary streams

[27] Center for Sustainable Communities and NTM Engineering, Wissahickon Creek Watershed Act 167 Plan, Draft – December 20113, available at: http://www.temple.edu/ambler/csc/index.htm

Runoff Generation
The Curve Number (CN) method developed by the NRCS, was used to represent the runoff properties of land cover and soils. CN values were calculated using GIS to overlay land use and soils data. The study area is highly urbanized with impervious cover for the Ambler area subbasins ranging from 17 to 50 percent. Impervious cover was included in the calculation of CN values for each subbasin and was not modeled separately. Initial abstraction, which is defined as rainfall that is absorbed by vegetation and the ground surface and does not run off, was initially assumed to equal 20% of total potential storage, but was subsequently adjusted downward during the model calibration process. Initial abstraction varies for each storm; the values used in the modeling are representative of wetter than average conditions.

The modeling used lag time to represent how the shape and slope of a subbasin affects the movement of runoff through it. Lag Time is based on the Time of Concentration, which is defined as the time it takes for runoff to travel from the most hydrologically distant part of the watershed to the outlet of a given subbasin. The Time of Concentration was calculated as the sum of the travel time for sheet flow, shallow concentrated flow and channel flow. Lag Time was initially calculated as 60% of the Time of Concentration and subsequently adjusted during calibration of the model.

Table 8 lists the values for drainage area, CN, initial abstraction, and lag time that were used for the calibrated version of the model to represent subbasin runoff characteristics. Impervious cover was also calculated and is shown for information purposes. However, the runoff effects of impervious cover were included in the Curve Number calculation, and it was not modeled separately.

Table 8: Subbasin characteristics for the hydrologic model in the study area

Subbasin	Area (Mi^2)	Curve Number	Initial Abstraction (inches)	Impervious Cover (%)	Lag Time (Minutes)
Loch Alsh DA	0.29	79.87	0.32	26	58.5
St. Marys Lake DA	0.12	79.87	0.32	26	58.5
UD_43 DA	0.03	78.51	0.34	22	73.5
W1660	0.50	77.68	0.37	17	82.5
W1690	0.28	80.46	0.31	22	49.5
W1710	0.06	83.27	0.26	25	31.5
W1740	0.44	82.96	0.26	41	52.5
W1870	0.06	87.96	0.18	47	19.5
W2760	0.31	77.52	0.37	34	33.0
W2770	0.43	78.91	0.34	22	73.5
W2780	0.22	86.04	0.21	50	37.5
W2790	0.47	79.5	0.33	22	70.5
W2900	0.57	84.67	0.23	38	64.5
W2910	0.22	82.98	0.26	34	46.5
W3080	0.15	79.81	0.32	29	31.5

Note: Impervious cover was not included as a separate model parameter, but was accounted for in the CN calculation.

Channel Routing
Stream flow through channel reaches was modeled using the Muskingum-Cunge method as provided in the HEC-HMS platform. This approach uses representative cross-section geometry,

channel and overbank roughness, reach length and slope to account for energy loss and channel storage in the calculation of peak flow rates. The model parameters for the designated reaches in the study area are provided in Table 9.

Channel lengths and slopes were determined using GIS layers for ortho-photography and LiDAR based 2-ft. elevation contours obtained developed under the PAMAP Program. Manning's roughness values were initially assigned from inspection of ortho-photography based on land cover. Adjustments resulted in increased channel roughness values during the model calibration process. Table 9 shows the final values in the calibrated model. The Muskingum-Cunge routing method represents channel geometry with cross sections consisting of eight elevation points across the section. The cross section elevations were obtained using the LiDAR based 2-ft. elevation contours.

Table 9: Reach properties for hydrologic model in the study area

Reach ID	Length (ft)	Width (ft)	Slope (ft/ft)	Channel Manning's n	Left Overbank Manning's n	Right Overbank Manning's n	Cross Section Table
R320	3732	50	0.0026	0.068	0.090	0.105	WSMS58
R320-1	7079	25	0.0077	0.049	0.120	0.120	WSRV06
R320-1-1	1857	15	0.0137	0.060	0.120	0.120	WSRVA06
R320-2	7260	30	0.0106	0.059	0.120	0.120	WSRV10
R340	1076	55	0.0032	0.051	0.090	0.105	WSMS60
R340-1	6375	20	0.0112	0.051	0.135	0.120	WSTR08
R360	1261	55	0.0031	0.051	0.090	0.105	WSMS60
R380	4079	55	0.0028	0.049	0.090	0.090	WSMS64
R380-1	2572	15	0.0276	0.052	0.105	0.105	WSMSG02
R380-2	4770	20	0.0079	0.052	0.105	0.105	WSMSG02
R400	5238	60	0.0014	0.044	0.090	0.090	WSMS66

Design Storms

As discussed in section 3.1 of this report, precipitation totals for the design storm events were calculated using PennDOT Intensity-Duration-Frequency data for Regions 4 and 5 in Pennsylvania[28]. The PennDOT data is based on the precipitation frequency data presented in NOAA Atlas 14[29] for Pennsylvania. The adopted precipitation totals for various storm frequencies were shown in Table 4 in section 3.1. The hydraulic modeling for the flood study included the 10-, 50-, 100-, and 500-Yr storms. The annual percent probability of these storm events, based on observed precipitation frequency, is 10, 2, 1, and 0.2 percent, respectively. A Type II 24 hour rainfall distribution was used to represent the temporal accumulation of rainfall during each design storm. This distribution was derived by the U.S. Department of Agriculture's (USDA) National Resources

[28] Pennsylvania Department of Transportation, PennDOT Drainage Manual, Publication 584, Chapter 7, Appendix A, "Field Manual for Pennsylvania Design Rainfall Intensity Charts from NOAA Atlas 14 Version 3 Data.

[29] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Bonin, G. M., et. al., NOAA Atlas 14, Precipitation Frequency Atlas of the United States, Volume 2, Version 3, 2004, Revised 2006.

Conservation Service (NRCS) based on National Weather Service duration-frequency data.[30] The distribution represents an event in which the majority of total precipitation falls during a three-hour period in the middle portion of the 24 hour storm event, and the maximum rainfall rate occurs during the twelfth hour. Although all rainfall events are different, this simulation of heavy rainfall midway through a storm, after an initial period of lighter rainfall that saturates the ground, represents an event that could cause severe flooding in the Ambler area.

Model Results

Model results for the design storms were generated after calibration of the hydrologic model. Due to the absence of any stream gages in the study area streams, the calibration was performed based on analysis of peak flow frequency data for two USGS stream gages on the Wissahickon Creek at Fort Washington and Philadelphia. The calibration included a recent gage record to account for the frequent flood events that have occurred in the watershed since the late 1990's.

The hydrologic model output includes peak flows, flow hydrographs and runoff volumes for subbasins, junctions and stream reaches. The peak flows at the model junctions were obtained by summing the peak flows of the contributing reaches and subbasins.

Two versions of the model were used in the study. Model outputs for current conditions were used to generate peak flows for determining flood elevations and flood maps. A second version of the hydrologic model was developed to represent future conditions assuming that upstream stormwater improvements proposed in this study would be put in place. This version of the model represented additional infiltration and riparian buffer areas as increased initial abstraction. Additional stormwater detention volume was counted toward total potential storage in each subbasin, and the runoff curve number for the subbasin was adjusted using the NRCS curve number equation.[31]

4.2. The Hydraulic Model

A HEC-RAS model was developed for each of the study area streams. The approach to the modeling was to allow for a worst case scenario in which flooding would occur in the Wissahickon Creek simultaneously with flooding in the tributaries. In addition, the nearest stream gage available for model calibration is located on the Wissahickon Creek. Accordingly, the modeling included a four-mile reach of the Wissahickon Creek as shown in Figure 35. This reach includes the USGS stream gaging station for the Wissahickon Creek at Fort Washington. This record of elevation and stage for this gage allowed for comparison of modeled vs. observed water surface elevations for given flow rates. The tributaries modeled in the Ambler area included Rose Valley Creek, Tannery Run, Stuart Farm Creek and Honey Run. The total length of these tributary streams was approximately nine miles.

Model Development

Stream alignment was based initially on a GIS shapefile provided by the PWD and derived from 2-ft. elevation contours. The alignment was adjusted using GIS ortho-imagery from multiple sources, including PAMAP imagery for 2003-2005 and 2010, DVRPC imagery for 2005 and 2010, and imagery provided by AERO 2, Inc. in 2012 based on 660 scale aerial photography of the Ambler

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30 U.S. Department of Agriculture, Natural Resources Conservation Service, Technical Release 55, Second Addition, Appendix B, Page B-1

31 U.S. Department of Agriculture, Natural Resources Conservation Service, Technical Release 55, Second Addition, Equation (2.4), Page 2-1

area. In addition, an enhanced Triangulated Irregular Network (TIN) based on 2008 LIDAR terrain data flown under the PAMAP program, and provided by BAE Systems, Inc. was used to determine accurate stream alignment.

Once the stream alignment was established, cross sections for stream channels and locations of obstructions were stationed and cross-section elevations were cut using the HEC-GeoRas GIS application developed by the ACE Hydrologic Engineering Center and the Environmental Systems Research Institute (ESRI). For this work, digital ortho-photographs and terrain data were required. The terrain data consisted of 2-ft. interval LiDAR based contours, a DEM, an enhanced TIN, and break line data provided by BAE Systems, Inc. The reference for all terrain data is NAVD88. These data were a refinement of the 2008 LiDAR for Southeastern Pennsylvania provided under the PAMAP program. The refinements included a denser TIN, and improved contours and break lines for small stream channels. In addition to stream alignment and stationing cross sections and obstructions, these data were used along with photographs of channels near obstructions to determine stream bank locations.

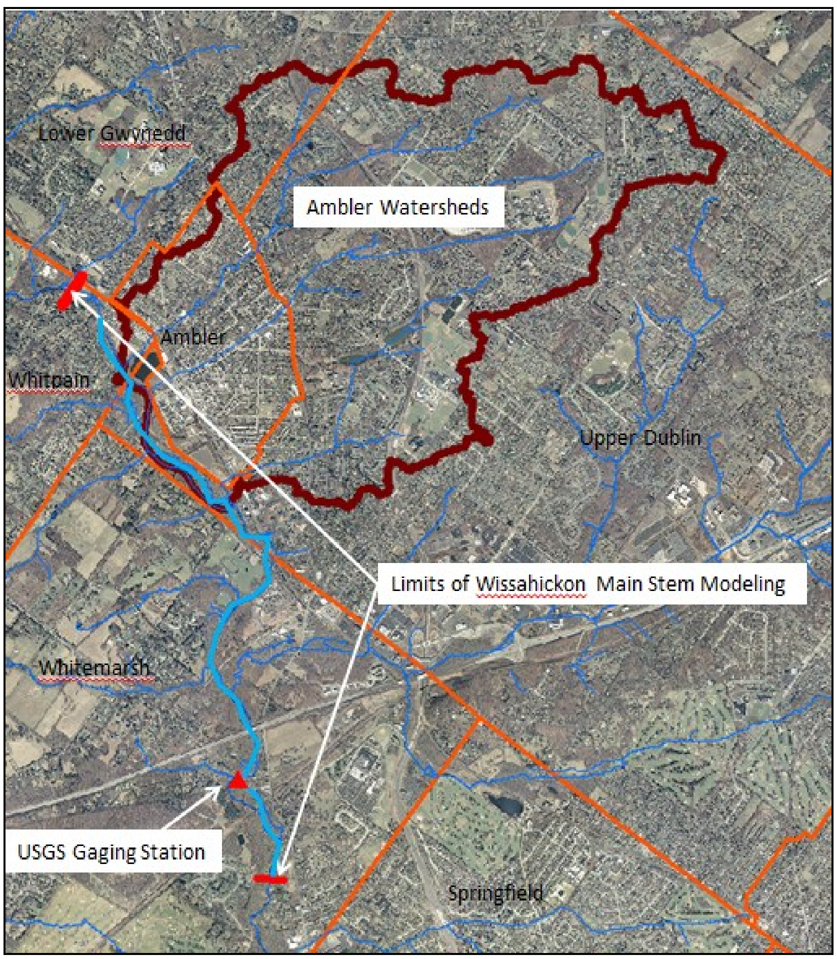

Figure 35: Extent of HEC-RAS modeling

HEC-GeoRas was used to assign Manning's n values to floodplains based on land use using Table 10, which was developed using Federal Highway Administration Publication TS-84-204[32] and Table 3.1 of the HEC-RAS Hydraulic Reference Manual.

The next step in the model development process was to export stream alignment, cross sections, obstruction locations and initial Manning's roughness values from HEC-GeoRas to the HEC-RAS model. Roughness values for floodplains were adjusted by inspection of ortho-photography. Channel roughness values were assigned as 0.040 for the main stem of the Wissahickon Creek and 0.045 for the tributaries, unless the channels were lined with concrete or stone. Inspection of photographs and ortho-imagery, as well as model calibration resulted in adjustments to roughness coefficients from the initial values.

Table 10: Initial Manning's n assignment based on land use

Land Use	Manning's n[1]	Cover Assumption –FHWA Guidance
Multi-Family	0.060	30% paved, 70% grass, with 15-50% obstructions
Row Homes	0.065	50% paved, 50% grass, with 15-50% obstructions
Single Family	0.048	20% paved, 80% grass, with 15% obstructions
Commercial	0.060	Paved with 15-50% obstructions
Parking	0.040	Paved with up to 15% obstructions
Agriculture	0.040	Mature Crops (Table 3.1)
Vacant	0.035	Tall Grass (Table 3.1)
Woods[6]	0.100	Table 3.1, FHWA guidance, no obstructions
Transportation	0.040	Paved with up to 15% obstructions
Water	0.010	Minimum for smooth concrete
Community Services	0.060	Same as multi-family
Manufacturing/Ind.	0.060	Same as Commercial
Mining	0.025	Cement Rubble
Recreation	0.030	Short Grass
Utility	0.060	Same as Commercial

All obstructions that were considered to be a cause for significant flooding due to backwater effects were included in the hydraulic model. Approximately 100 sites were inspected and photographed and a total of 85 were included in the model. For each structure, structure length and opening dimensions were measured, and photographs were taken of the openings using a survey rod with 1-foot color markings to provide a reference scale. Where possible, photographs of upstream and downstream channels were taken. To determine elevation of the openings, the difference in elevation from the road, where a LiDAR based break line elevation was available, to the top of the headwall or opening was measured. Dimension and elevation data for the structures was then input to the HEC-RAS model, with elevation referenced to NAVD 88. In several cases along Tannery Run, long culverts were modeled as lidded channels to represent flow over the ground surface once culvert capacity was exceeded. For Rose Valley Creek, the 7-foot diameter flow diversion pipe just downstream of Tennis Avenue and Reiff's Mill Rd. was modeled as a lateral outlet structure. A

[32] U.S. Department of Transportation, Federal Highway Administration, Guide for Selecting Manning's Roughness Coefficient for Natural Channels and Floodplains, Publication TS-24-204, 1984.

schematic diagram showing the stream alignment and location of all modeled obstructions is shown in Figure 36.

Peak flow rates used for the HEC-RAS model were based on the output from the calibrated HEC-HMS model described in Section 4.1. Flows were assigned directly near HEC-HMS output points or adjusted at intermediate or headwater locations based on the drainage area proportioning. All peak flow rates and calculations were provided to the ACE for review.

Preliminary HEC-RAS model results were compared to observations at the USGS stream gaging station for the Wissahickon Creek at Fort Washington. Based on this comparison, Manning's roughness values were increased for the main channel of the Wissahickon Creek and for wooded floodplains to obtain a better match between modeled and observed results. Figure 37 shows the difference in results between the original and the adjusted model.

The model has been checked and corrected for errors using FEMA's CheckRas program. As a result of FEMA's LOMR review process, additional minor revisions to the model may be required. These revisions will be reflected in the final floodplain maps and elevation profiles when they are adopted by FEMA. The maps presented in this report are preliminary and should not be used for flood insurance determinations.

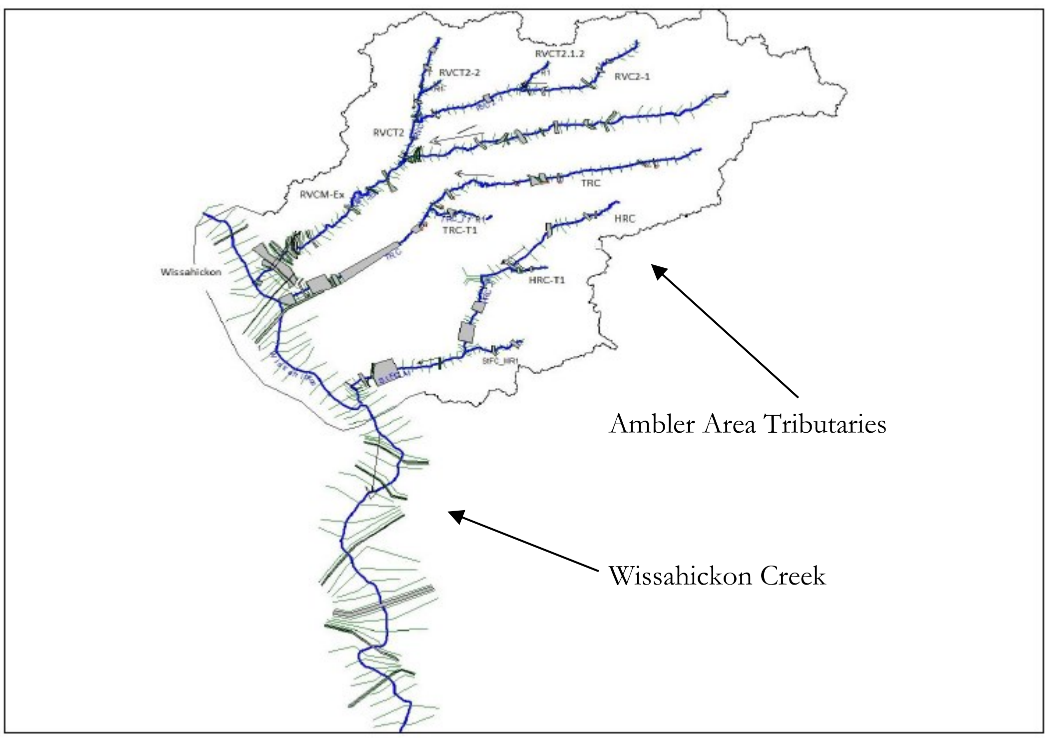

Figure 36: HEC-RAS model schematic showing stream alignment and obstructions

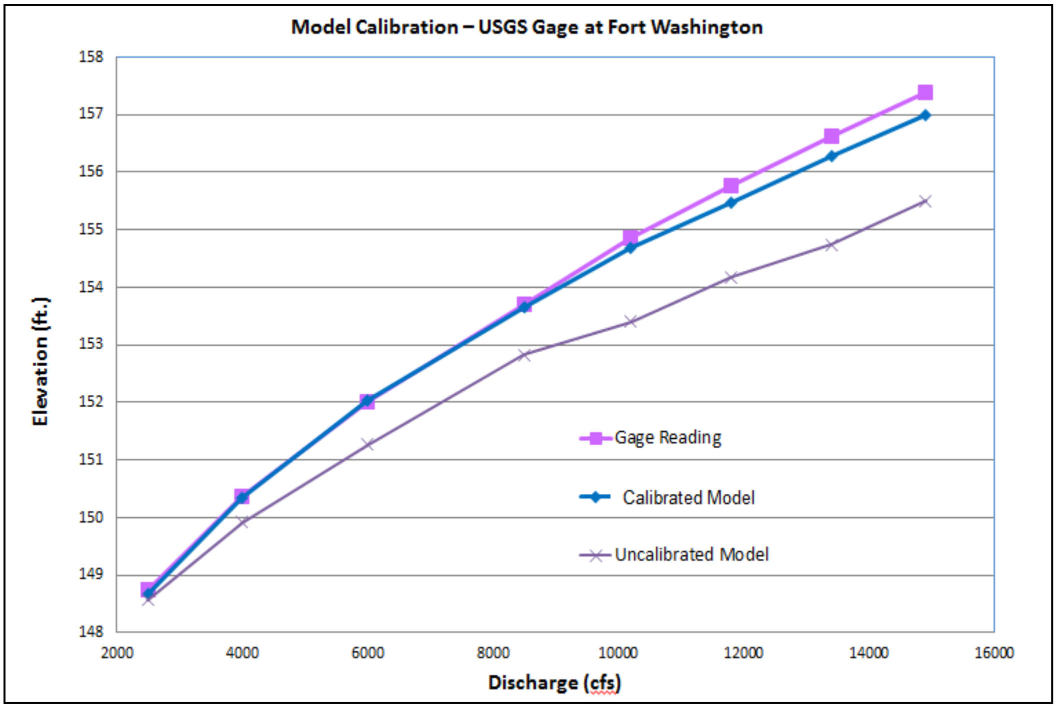

Figure 37: Comparison of modeled vs. observed stage and flow for Hydraulic Model USGS stream gage – Wissahickon Creek at Fort Washington, PA

Model Results

The hydraulic model was used to generate flood elevations and maps for the 100-Yr and 500-Yr floodplain for all study area stream reaches. The peak flows used were based on the hydrologic model discussed in Section 4.1. Figures 38 and 39 show that the modeled flows and elevations for the Wissahickon Creek are significantly higher than in the existing flood insurance study. While Temple's modeling for the four-mile reach of the Wissahickon represents the most recent available information, revisions to the official FEMA flood maps will await restudy of the entire length of the stream. This is necessary to conform to FEMA's requirements for the mapping consistency. As a result, the maps presented in this report include the newly generated floodplains for the tributary streams and the existing FEMA floodplain for the Wissahickon Creek. All maps are preliminary pending final approval by FEMA.

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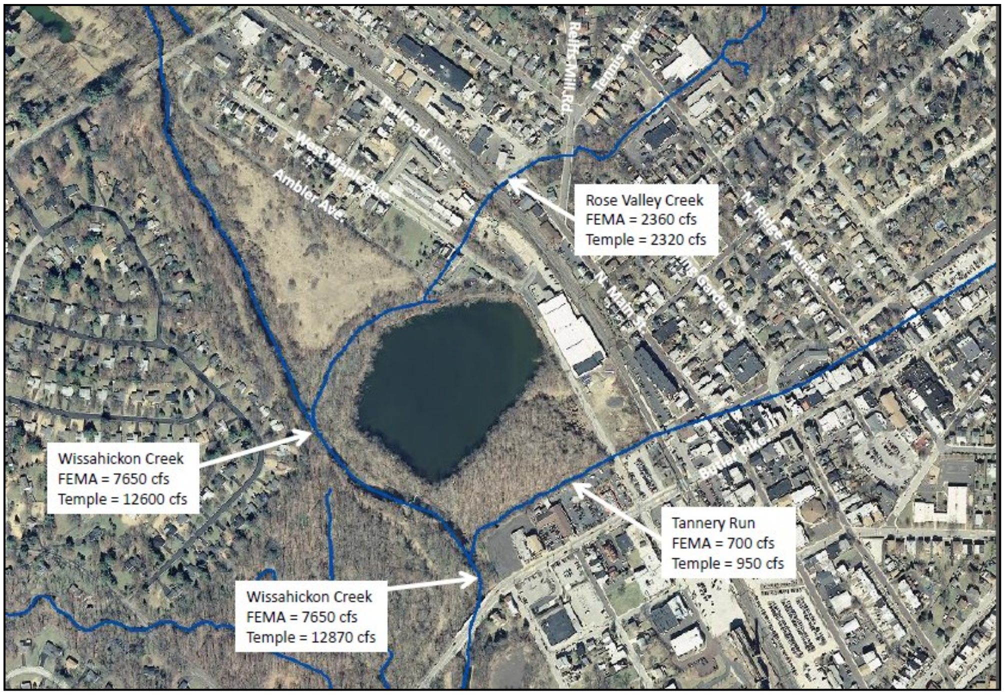

Figure 38: Q100 Peak Discharge Comparison – Temple Values vs. FEMA Values

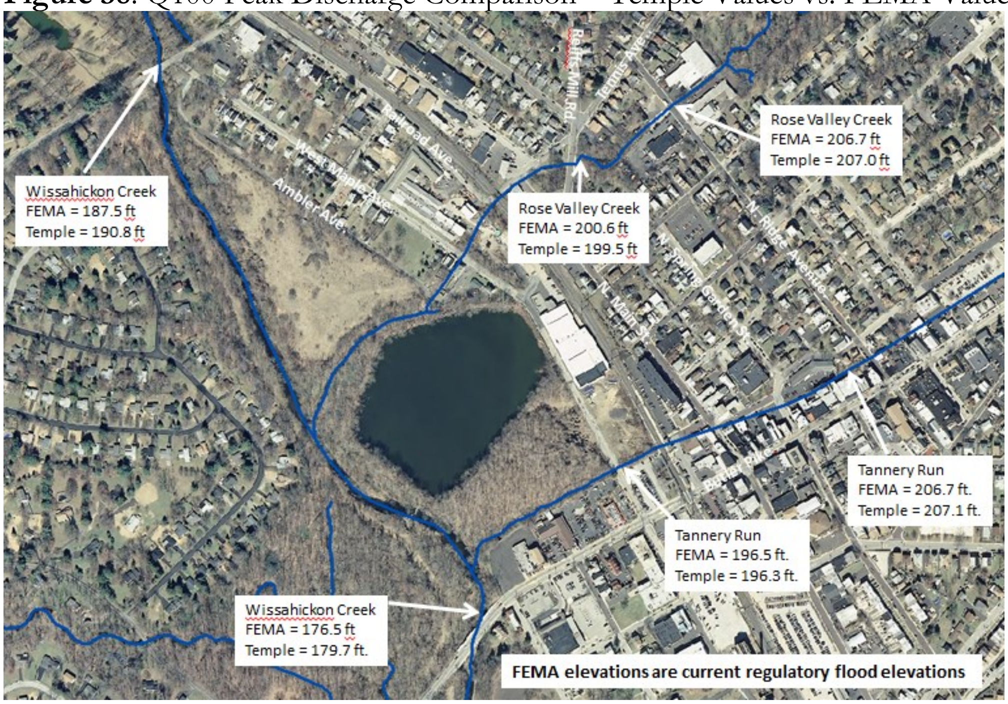

Figure 39: Q100 elevation comparison for Wissahickon Creek, Rose Valley Creek and Tannery Run

4.3. New Preliminary Floodplain Maps

Figure 40 shows a comparison of FEMA and preliminary CSC 100-Yr floodplains for Rose Valley Creek, Tannery Run and Stuart Farm Creek. The floodplain shown for the Wissahickon Creek is the same as currently seen in the map. Floodplains for the Rose Valley Creek in the West Ambler neighborhood of Whitpain Township have been delineated for the new study. The floodplain for this area was not previously mapped and is not included in FEMA's existing flood insurance rate map. Figure 40 also shows that most of the upstream portions of the tributaries were not included in FEMA 100-Yr floodplains, but are now within the new preliminary boundaries. Although hydraulic modeling was developed for the Wissahickon Creek in this study, the floodplain shown for the Wissahickon in Figure 40 and subsequent maps is for the existing FEMA floodplain. This is consistent with LOMR application that will be submitted to FEMA. Temple's hydraulic model and floodplain for the Wissahickon is available for future use if re-mapping of the rest of the Wissahickon is funded.

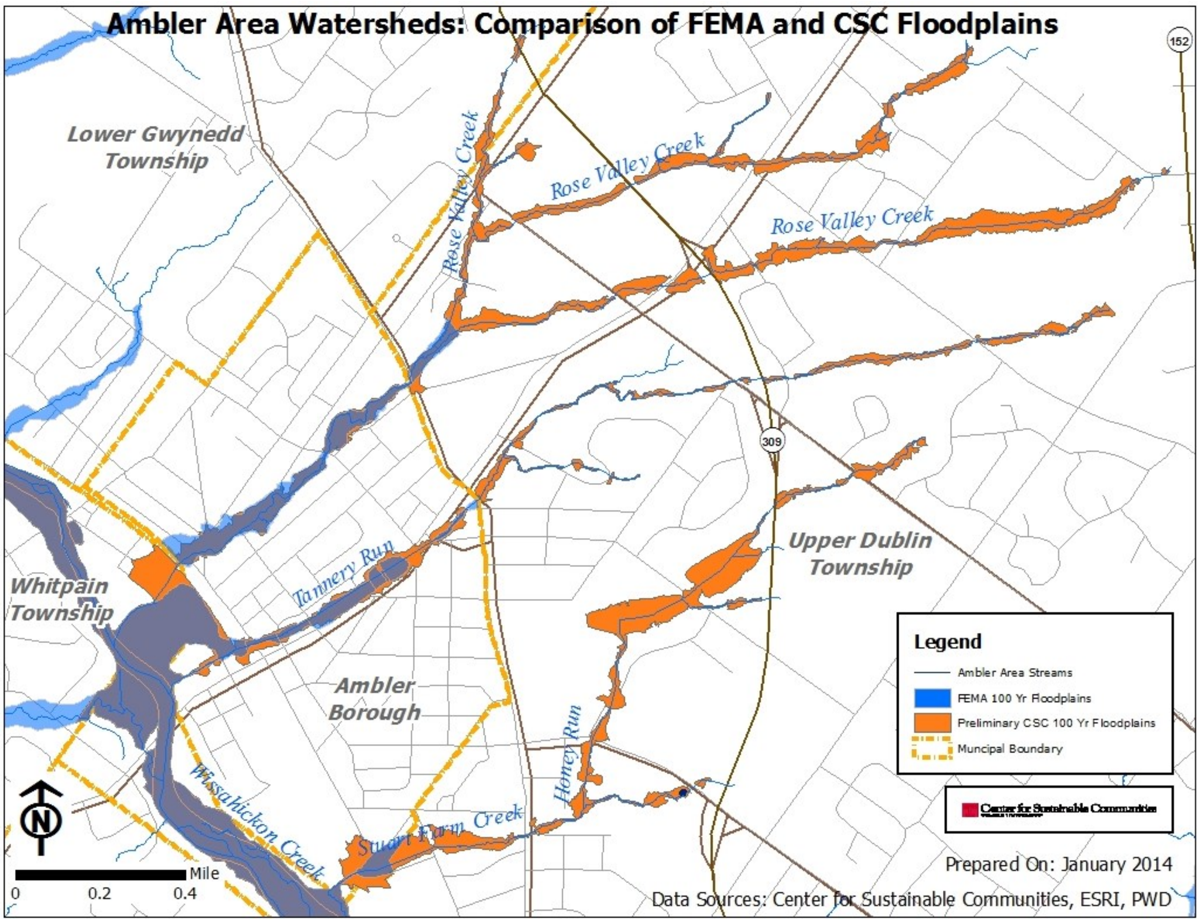

Figure 40: FEMA and preliminary CSC floodplain comparison

Table 11 reports the number of structures or building footprints per municipality that are located inside preliminary CSC floodplains. The building footprint within the new preliminary floodplains increased overall for the four municipalities. While the number of buildings in the preliminary 100-Yr floodplain in Ambler decreased, it was because those structures were contained within the new 500-Yr floodplain. The new preliminary 500-Yr areas are more extensive and therefore encompass a higher number of building footprints. The total building footprint increased overall by 35 for the 100-Yr floodplain and 49 for the 500-Yr. Many areas in Upper Dublin that were not considered before are now within the preliminary floodplain boundaries.

Table 11: Buildings affected by new preliminary 100- and 500-Year Floodplains (CSC)*

Municipality	Building Footprints in Preliminary Floodplains		
	Floodway	100 Year	500 Year**
Ambler	Pending	74	105
Lower Gywnedd	Pending	2	2
Upper Dublin	Pending	47	83
Whitpain	Pending	13	22
Total (in preliminary CSC floodplains)	Pending	**136**	**212**
Total (in FEMA floodplains)***	**1**	**101**	**163**

Source: CSC, Temple University
** Currently under review by US ACE*
*** Includes buildings within 100-Yr floodplain*
**** Details in Table 6*

Figures 41 through 45 show preliminary updated 100- and 500-Yr floodplains created by the CSC Project Team and are currently under review by the US ACE. Floodways are being developed as of February 2014.

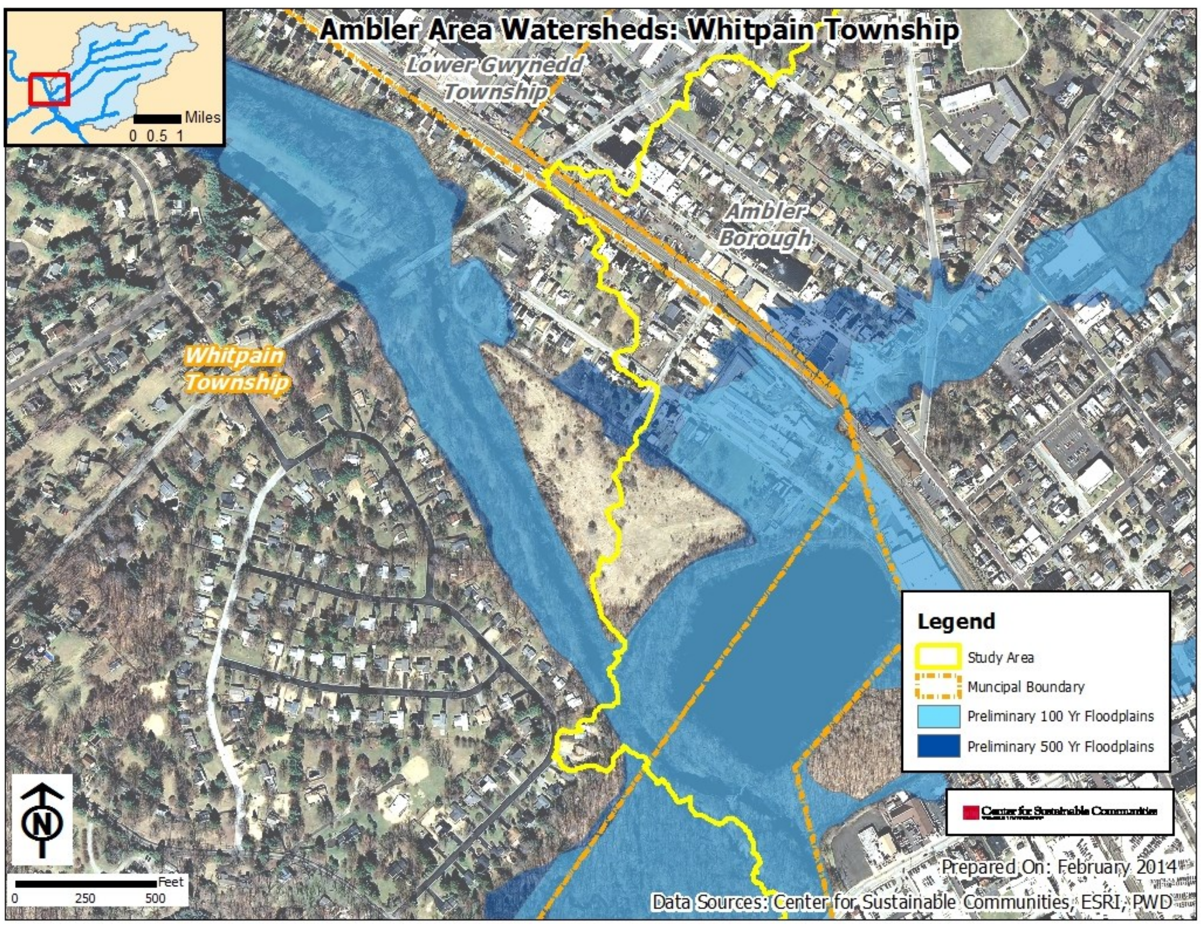

Figure 41: Preliminary CSC floodplains in Whitpain Township portion of the study area

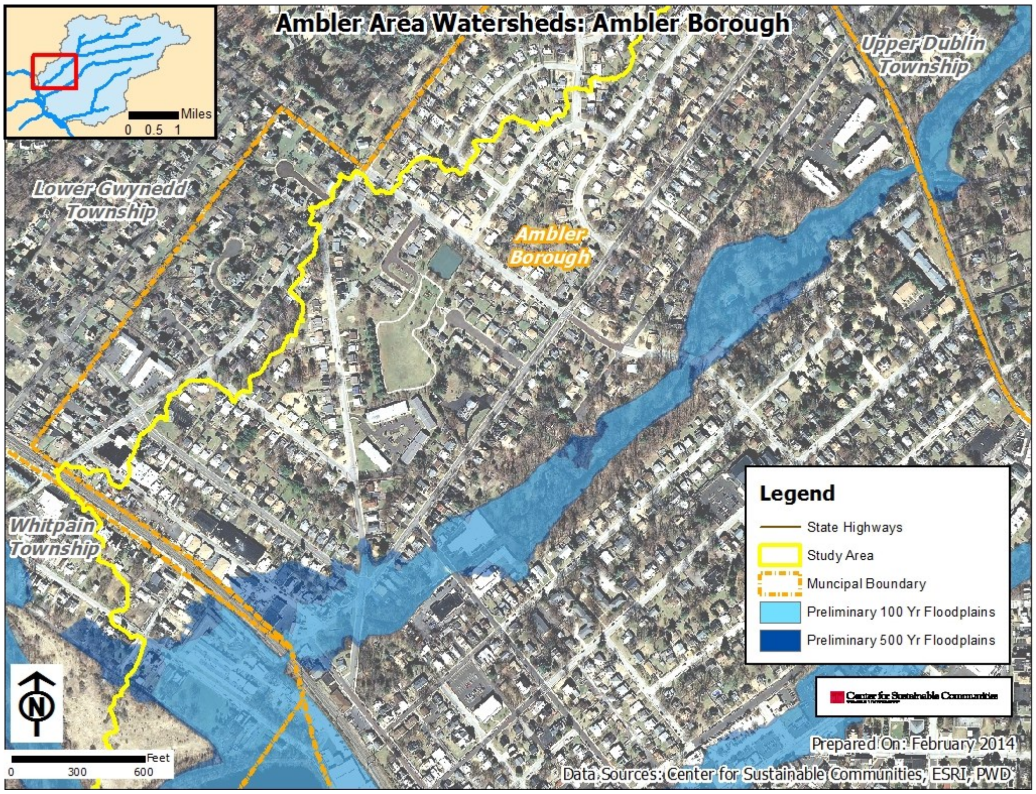

Figure 42: Preliminary CSC floodplains in Ambler Borough (North-West)

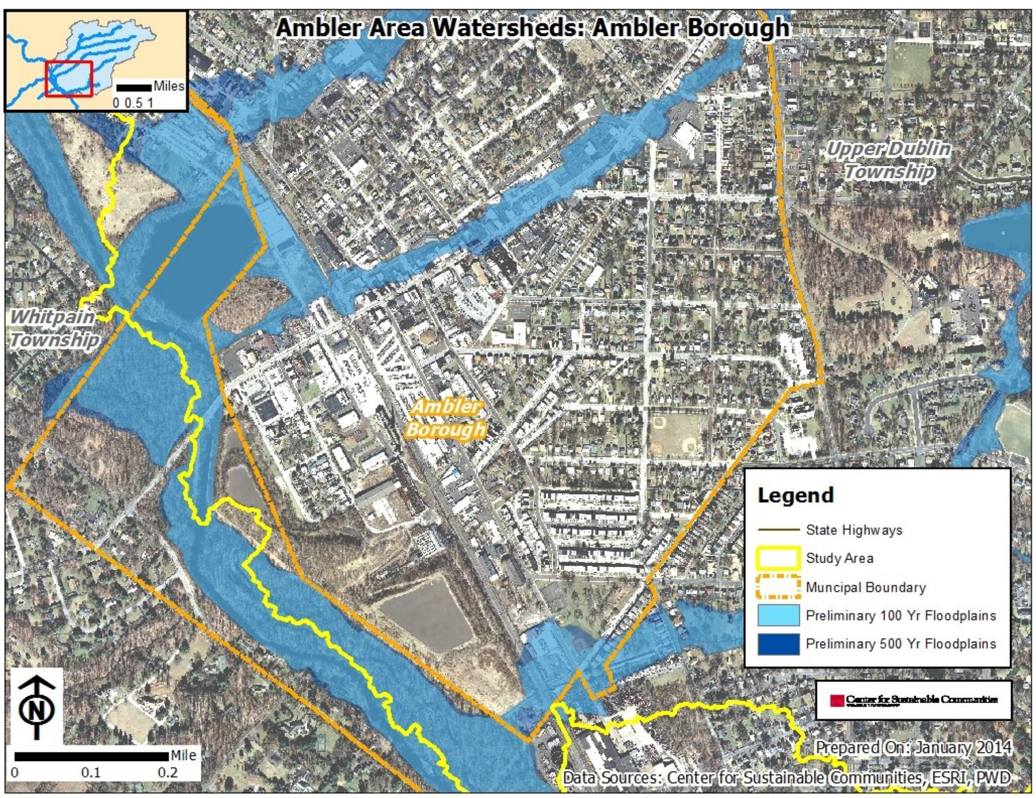

Figure 43: Preliminary CSC floodplains in Ambler Borough (South)

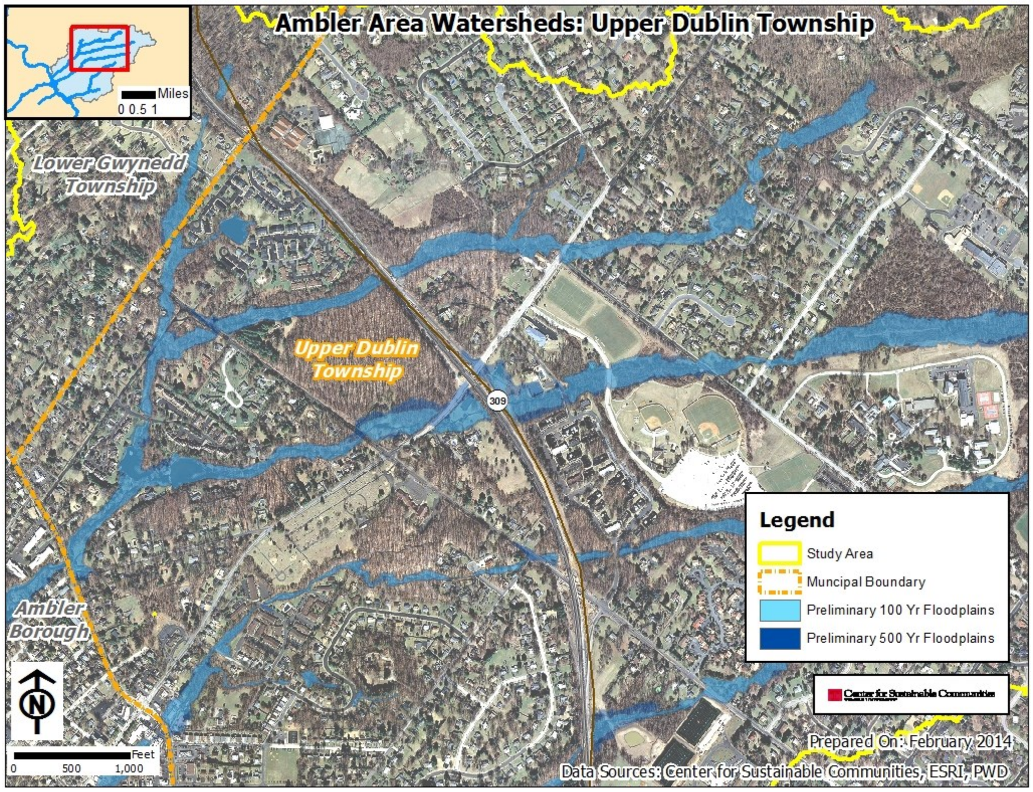

Figure 44: Preliminary CSC floodplains in Upper Dublin (North)

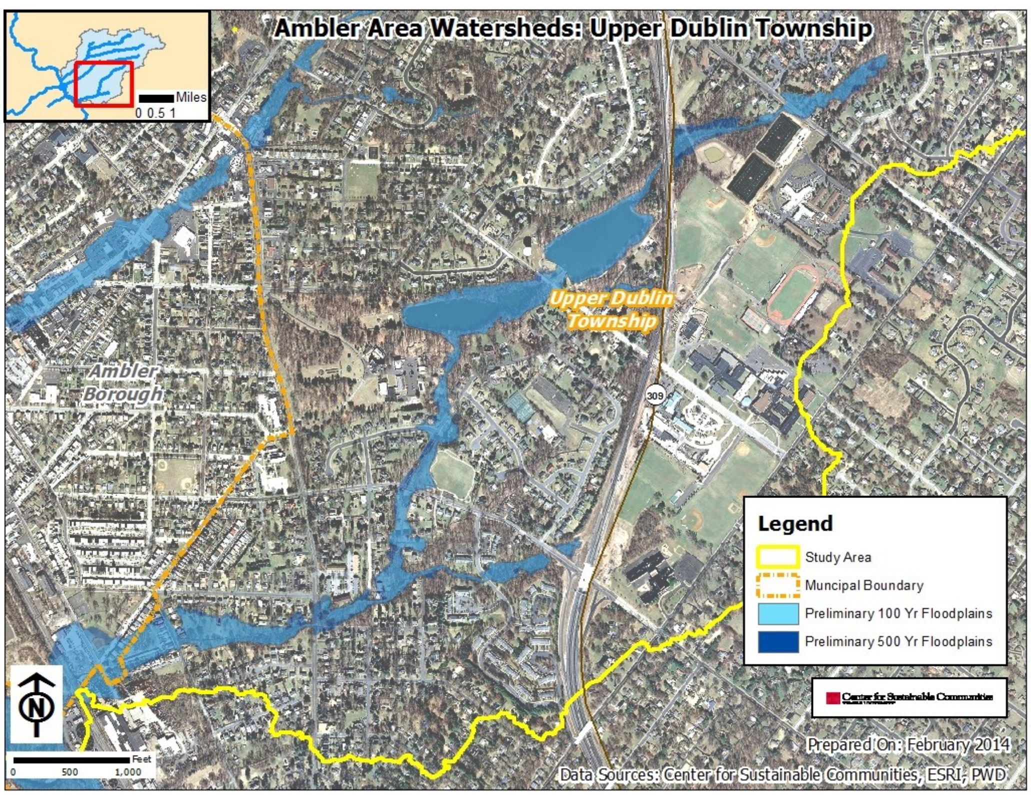

Figure 45: Preliminary CSC floodplains in Upper Dublin (West)

5. Assessment and Recommendations of Stormwater Infrastructure Facilities

Based on field surveys, GIS analysis and hydrologic and hydraulic modeling, the CSC Project Team recommends location-specific stormwater infrastructure (SI) facilities throughout the study area. In order to reduce runoff peaks and volumes, and address the widespread water quality impairments caused by stormwater runoff in the study area, these opportunities for improvements were evaluated. Site locations were based on CSC Team surveys in 2009 and 2012 and input from municipalities and community residents. Riparian buffer restoration suggestions were based on data from the Heritage Conservancy. These recommendations are consistent with community needs, and community projects, initiatives, and plans. The Project Team recommends the following facilities:

- Extended Detention Basins (including retrofitting existing basins to extended detention)
- Infiltration Sites
- Riparian Buffer Restoration
- Site-Specific Recommendations in Ambler, Upper Dublin, and Whitpain
- Low-Impact Green SI Projects

Before recommending and assessing these SI projects, the Project Team calculated the total runoff volume in inches and acre-ft. for all of the three micro-watersheds in the study area. One inch of storage is 53.3 acre-ft. per square mile. Table 12 converts inches of runoff in the study area to acre-ft. volume. Total rainfall for a storm event is more than runoff volume, which is a function of land cover. Most rainfall events produce less than one inch of runoff. However, runoff volume can exceed six inches during major flood events.

Table 12: Runoff volume in the study area

		Runoff Volume (Inches and Acre-Ft)					
Micro-Watershed	**Drainage Area (Acres)**	**1"**	**2"**	**3"**	**4"**	**5"**	**6"**
Rose Valley Creek	1,320	110	220	330	440	550	660
Tannery Run	440	37	73	110	147	183	220
Honey Run/ Stuart Farm	770	64	128	192	257	321	385
Total	2,530	211	421	632	844	1,054	1,265

The Project Team recommends SI projects that will reduce peak flows and volumes in downstream reaches, including downstream culvert and bridge locations. As a general approach, the Team recommends the construction of SI to increase storage and reduce stormwater flows and volumes as the first consideration in addressing drainage problems. For cases where increased culvert capacity is the only viable means for solving a drainage problem, an evaluation of potential increases in downstream flood peaks should be performed to prevent adverse flooding or stream channel impacts. In addition, such actions might require municipalities to modify their FIRMs to outline additional areas subject to inundation during more extreme flood events. The provision of upstream storage through extended detention, infiltration, riparian buffer restoration, or other stormwater control measures can help offset the impacts of increasing the capacities of culverts located downstream.

The main stem of the Wissahickon Creek contains a number of small dams, some of which are deteriorating. Because these dams are overtopped by normal water levels, and were not designed to provide a flood storage pool, they do not reduce flood flows during large storm events. Because deteriorated dams can break apart during severe floods, they represent a flood hazard. It is recommended by the study team that deteriorated dams either be repaired or removed from the stream.

The distribution of the recommended extended detention, infiltration and riparian buffer sites in the three micro-watersheds is shown in Figures 46, 47, and 48. Appendices B, C, and D provides the estimated storage and costs for the improvements at the identified facilities. Table 13 shows a comparison of different types of recommended stormwater infrastructure projects. The following sections summarize the evaluation steps and present additional results of hydrologic modeling of the potential improvements. The facilities were also ranked based on factors including catchment area, cost and watershed location. The ranking method allowed for cross-comparison of all sites. Hydrologic and water quality impact of the proposed improvements are discussed.

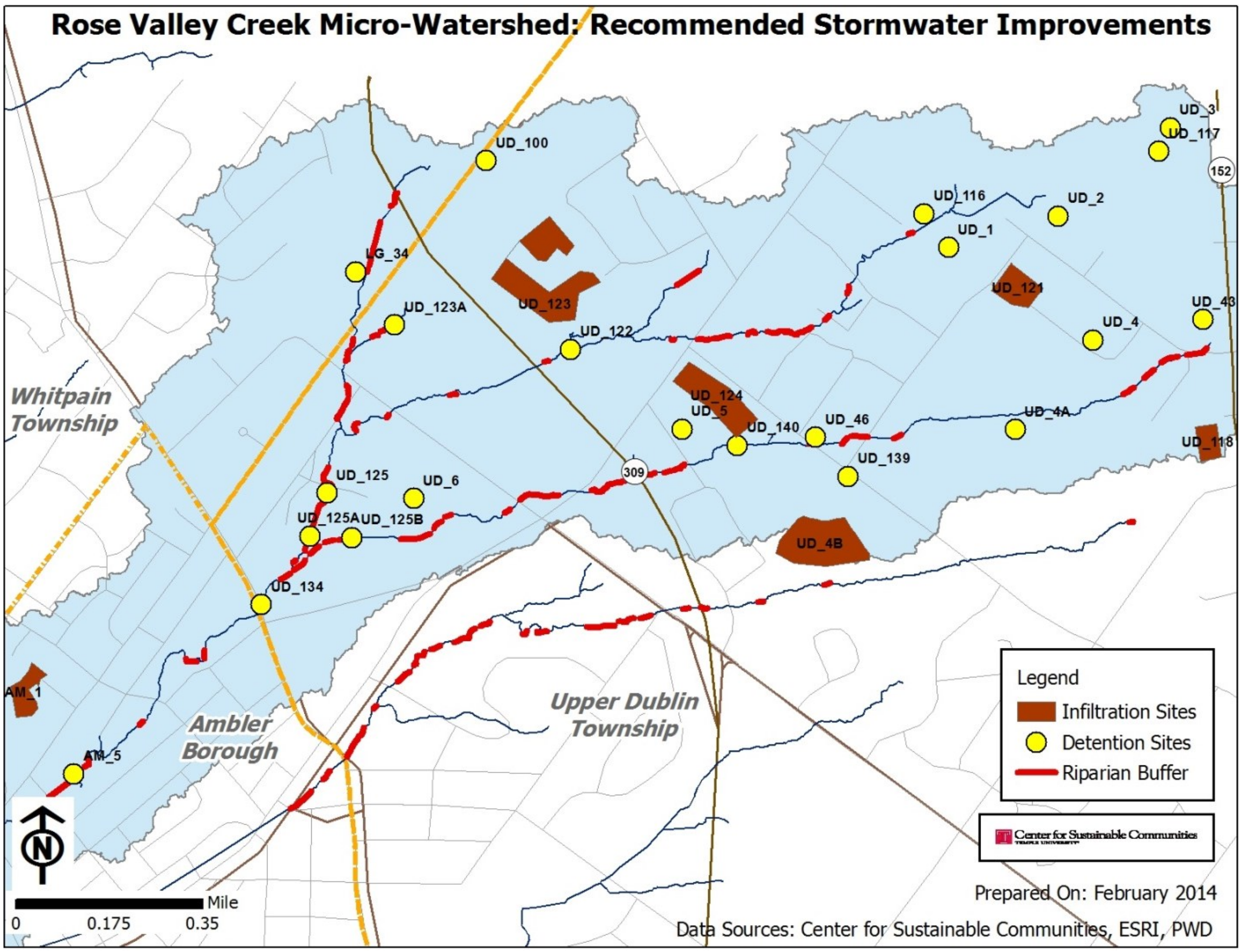

Figure 46: Recommended SI projects in Rose Valley Creek micro-watershed

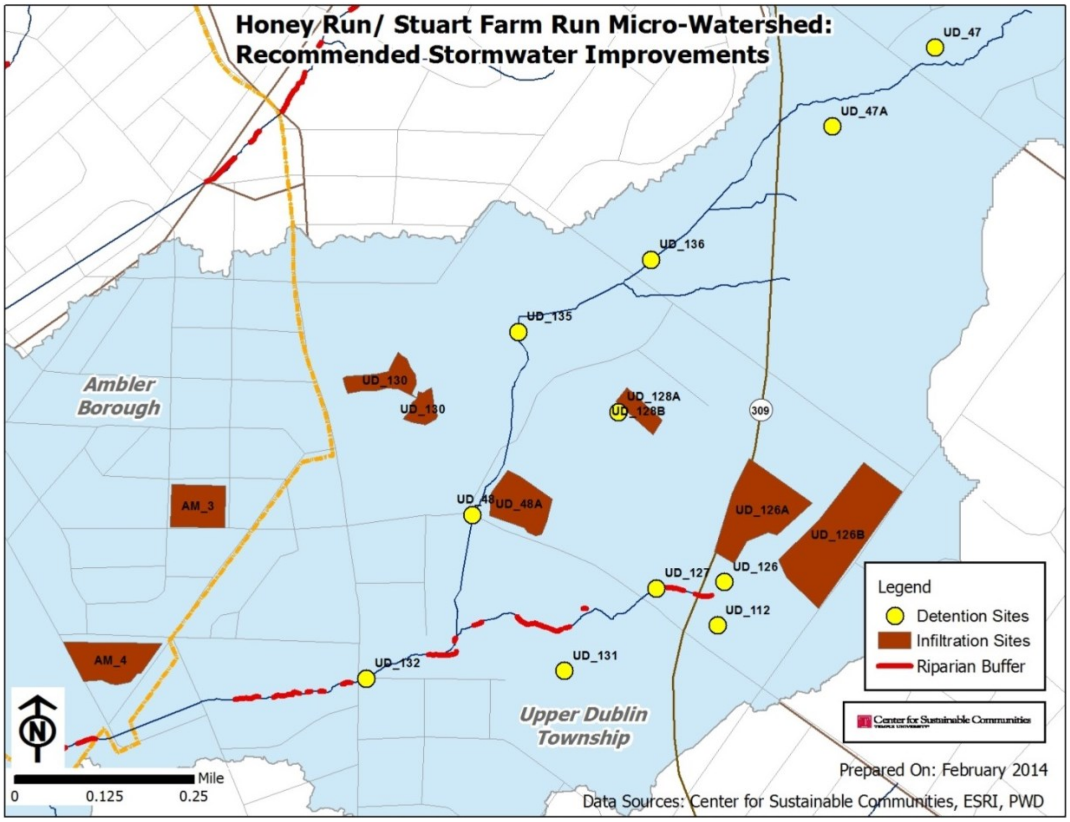

Figure 47: Recommended SI projects in Stuart Farm Run/ Honey Run Micro-Watershed

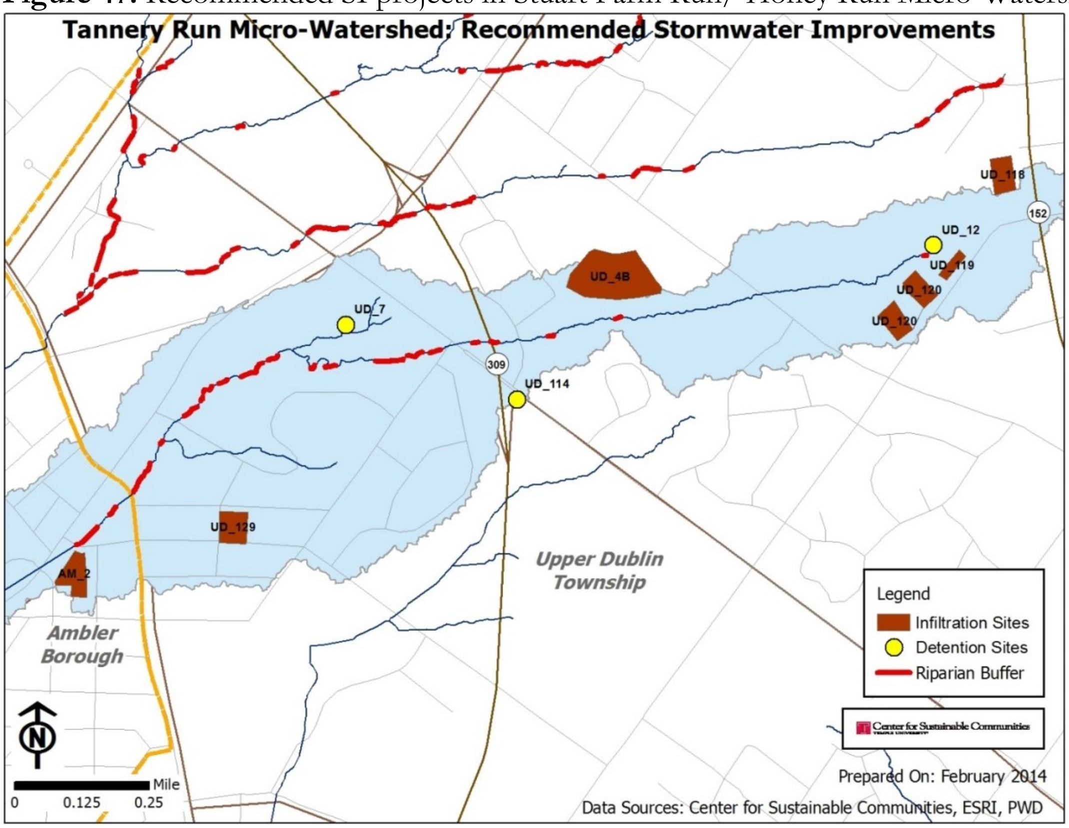

Figure 48: Recommended SI projects in Tannery Run Micro-Watershed

Table 13: Comparison of stormwater infrastructure projects

Type of Intervention	Flood Control – Water Storage Capacity	Water Quality Improvement	Potential Cost (Estimate)	Quality of Life Improvement
Extended detention storage facilities	90.3 Acre-Ft	Reduce scour and erosion potential along stream reaches. Help stream restoration. Provide for settling and storage of sediment in runoff and reduce sediment loading.	$5.82 million	Potential open space, habitat improvement
Potential infiltration sites	5.5 Acre-Ft		$1.06 million	Could be open to public and connected to parks
Riparian buffer restoration	2.8 Acre-Ft		$0.15 million	Could be connected to parks and trails
Day-lighting Stream or Channelization of Rose Valley Creek	Generally increased channel storage	-	$10 million if designed for 500 year storm	Potential community redevelopment opportunities
Channelization of Rose Valley Creek and Tannery Run	Generally increased channel storage	-	$15 million	
Small-scale GSIs (rain gardens, rain barrels, permeable pavement, etc.)	0.46 Acre-Ft (for 100 rain gardens with 200 Cubic Ft each); 1 Acre-Ft (for 5,940 rain barrels)	Rain gardens filter sediments, debris, and many chemicals. Permeable pavement filters out oil and other road and car contaminates.	Rain barrel $70 – $200.	Save water, gardening, physical activity

5.1. Extended Detention Storage Facilities

Thirty-six sites are recommended for new or expanded extended detention storage facilities, including floodplain storage sites. Recommendations are also made to improve outlet structures and re-vegetate basin floors to increase extended detention. The total existing detention basin storage in the study area is 48 acre-ft. This is equal to 0.22 inches of storage averaged over the tributary watershed. Additional potential storage from recommended extended detention basins would be **90.3 acre-ft**. GIS files with the locations, estimated storage, and catchment areas for some of these facilities were provided by the PWD. The remaining sites were added based on field inspections by the Project Team. Existing sites with surface areas greater than a quarter of an acre were field inspected. Factors considered for evaluating potential expansion included:

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

Sites where increased berm height or lowered floors appeared feasible were considered for expansion. For most sites with areas less than a quarter of an acre, a recommendation was made to both increase berm height and lower the basin floor by one foot. In some cases, increased floodplain storage was recommended as a means of providing additional extended detention, rather than construction of a detention facility in the floodplain. Generally, such areas are recommended as constructed wetlands.

The Detention Spreadsheet in Appendix B lists the existing and potential increased storage at each of the detention sites, and provides estimated costs of the improvements. Cost estimates include 35% for design and contingency, and assumed union labor rates. A ranking based on the catchment area (a measure of the potential for extended detention during small storms), cost, and watershed locations is also included to provide a possible means of prioritizing sites. A GIS shape file is available for detailed mapping of the improvement location, such as that shown in Figure 49. Appendix B includes the following fields:

- Facility ID
- Municipality
- Location or nearby intersection
- Current Land Use
- Receiving Watershed
- Existing Depth
- Existing Area
- Existing Volume
- Potential Additional Volume
- Estimated Cost
- Notes regarding the improvement

Figure 49: Sample detention basin site map. Site UD_139 – Potential extended detention/constructed wetland in Upper Dublin Township on Temple University campus between baseball field and Susquehanna Road. Potential new storage = 3.2 acre-ft and estimated cost = $320,000.

5.2. Potential Infiltration Sites

Seventeen sites within the study area are recommended as potential infiltration sites. Opportunities for additional infiltration were based on field inspections of sites where installation of stone-filled trenches or galleries could provide storage for runoff from large rooftops, parking areas, or athletic fields. Cost estimates were based on the design of infiltration trenches to provide storage for one inch of runoff, or four inches in several cases where infiltration galleries were recommended. The average cost for construction of infiltration facilities is over $4 per acre-ft. of storage, making infiltration more costly than detention or riparian buffer restoration. The total combined area of the identified infiltration sites is 65.8 acres, and the estimated infiltration volume is **5.5 acre-ft**. The inventory focused on larger sites rather than individual residential properties where the installation of such measures as pervious paving or rain gardens could also increase infiltration. The Infiltration Spreadsheet in Appendix C lists the infiltration sites and includes the data fields mentioned below. A GIS file for the infiltration sites can be provided upon request. A sample mapping for one of the sites is shown in Figure 50.

- Facility ID
- Municipality
- Location/Intersection
- Current Land Use
- Watershed receiving largest share of site runoff
- Notes
- Infiltration Area
- Potential Infiltration Volume
- Estimated Cost

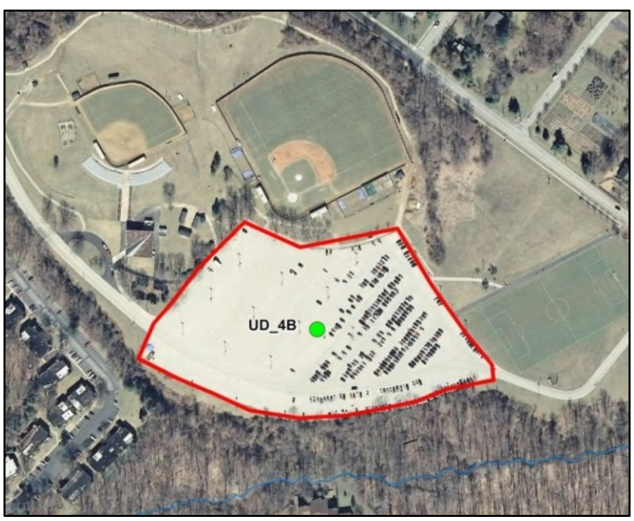

Figure 50: Sample Infiltration Site. Site UD_4B – Potential infiltration site in Upper Dublin Township, student parking lot on Temple University campus. Potential new storage = 0.67 acre-ft, estimated cost = $128,000.

5.3. Riparian Buffer Restoration

A regional inventory conducted by the Heritage Conservancy in 2000 and updated in 2010 identified stream reaches where riparian stream buffers could be restored on either one or both sides of streams. The distribution of these locations is shown in Figure 31 in section 3.1. To estimate the potential additional storage available, the study team assumed an average buffer width of 75 feet for each side of the stream and an average runoff volume reduction of one inch. The estimated acreage and cost of re-establishing the buffers by municipality is presented in Table 14. The total additional storage volume provided to the study area would be **2.84 acre-ft**. Riparian buffer restoration has the lowest average cost of the three improvement categories. It should be noted however, that actual buffer width would vary significantly from site to site, and buffers may no longer be feasible at some locations. The lack of acceptance by property owners can also limit re-establishing buffers. A GIS file for the infiltration sites can be provided upon request. A sample site map is shown in Figure 51. For more detailed information on specific riparian buffer sites, see Appendix D.

Table 14: Potential total riparian buffer restoration areas by municipality

Municipality	*Acreage Requiring Riparian Buffers	**Cost Assuming $4,500 per acre	Rounded-Up Cost	Primary Affected Streams	***Average Volume Reduction per event (Acre-feet)
Ambler	5.96	$26,820	$27,000	Wissahickon Creek, Rose Valley Creek	0.49
Lower Gwynedd	1.79	$8,055	$8,000	Rose Valley Creek	0.15
Upper Dublin	22.83	$102,735	$103,000	Tannery Run, Rose Valley Creek	1.90
Whitpain	3.66	$16,470	$16,500	Wissahickon Creek	0.30

Notes:
**Updated base data on riparian buffer needs were obtained from the Heritage Conservancy. These data indicate stream lengths requiring a riparian buffer, either on one side or both sides of the stream. The CSC assumed an average buffer width of 75 feet, recognizing that 50 feet may be appropriate for some locations and 100 feet for others. Acreage was derived using GIS analysis.*
***Cost assumes 430 three- to four- foot high trees per acre, protective tubes, stakes, and labor, including some replacement in the second year. Calculation includes trees only, does not include potential easement costs.*
**** Average volume reduction is an average value per event and assumed to be an inch of water per acre. The reduction would be the greater in the summer during dry periods, and substantially less in the winter during wet periods.*

Figure 51: Sample riparian buffer restoration site, Tannery Run, Upper Dublin Township

5.4. Hydrologic and Water Quality Impact of the Proposed Improvements

The proposed SI improvements (extended detention, infiltration, and riparian buffer projects) were incorporated into a "Future Conditions" HEC-HMS model run. The modeling approach is summarized in Section 4 of this report. Further details are available from Wissahickon Act 167 Plan report. In some locations downstream from potential improvements, the reduction in peak flow rates is sufficient to reduce water surface elevations for smaller storms. Figure 52 shows a reduction of approximately one foot in the water surface profile for the 2-Yr storm along a section of Rose Valley Creek. The combined potential additional storage provided by the three categories of improvements for the study area watershed is estimated at 98.6 acre-ft, or approximately 33 million gallons. This volume of storage is equivalent to 0.47 inches of runoff from the 4.1 square mile watershed. This is lower than 1” runoff volume.

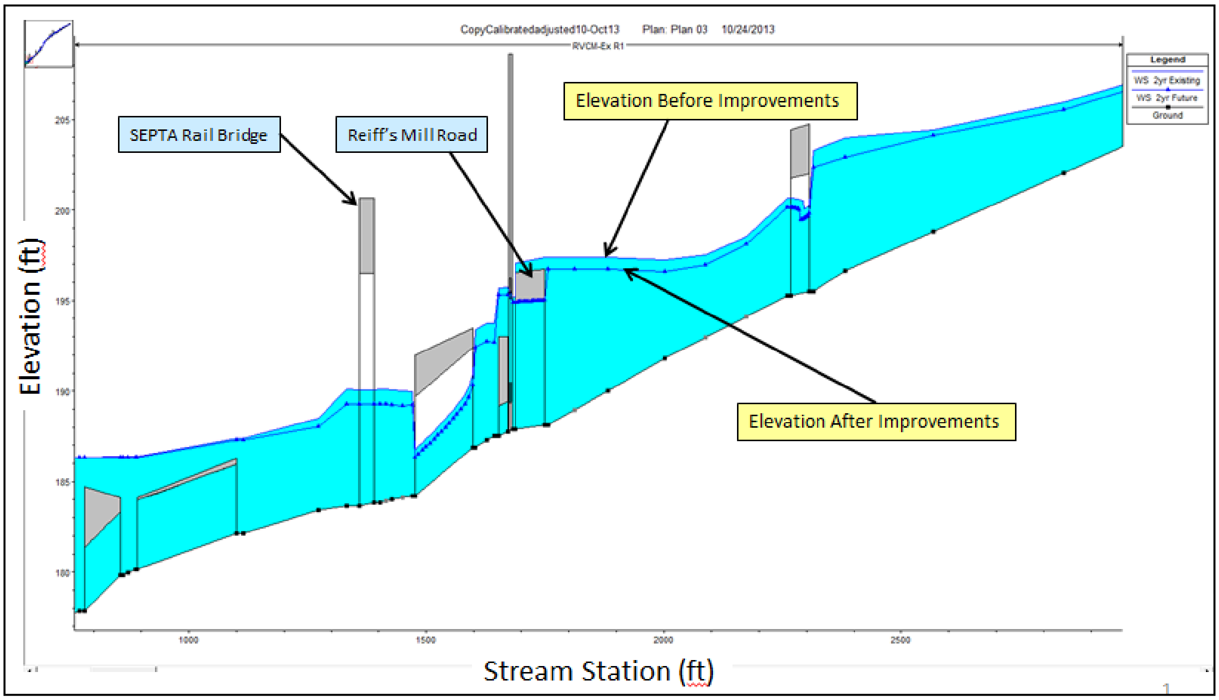

Figure 52: Water surface elevation profiles for 2-yr design storm Rose Valley Creek

Table 15 shows peak flow reductions at the downstream end of each of the tributary watersheds. The peak flow reductions immediately downstream of stormwater control measures and higher than those shown in the table. Infiltration and riparian buffer restoration were modeled as initial abstraction. Detention was modeled by lowering Curve Number (CN) values based on aggregate storage totals for small sites. Larger detention sites were modeled as reservoirs.

Table 15: Peak flow reduction

	% Reduction		
Event	**Rose Valley Creek**	**Tannery Run**	**Stuart Farm/ Honey Run**
Q1 (1-Yr)	18	4	9
Q2 (2-Yr)	15	3	8
Q10 (10-Yr)	13	2	7
Q50 (50-Yr)	9	1	7
Q100 (100-Yr)	8	1	7

The reductions in peak flow and volume would help reduce scour and erosion potential along stream reaches, and would be helpful where stream restoration is planned or has been completed. Examples of similar stormwater control measures have been applied in the neighboring Sandy Run watershed and in other locations throughout the Wissahickon watershed. For example, flood-retarding structures on Pine Run and Rapp Run, constructed wetlands along Rapp Run, and new detention facilities have increased storage upstream of the Fort Washington Office Park in the Sandy Run watershed. In addition, the PWD has been working to return streams to their natural state and create stable, healthy waterways able to sustain native vegetation and aquatic life. The year 2011 saw the restoration of Bells Mill—a 5,100-foot tributary to the Wissahickon with grading and rock structures in place that will help stabilize the stream bank and reduce erosion. Elsewhere in the Wissahickon watershed, stormwater wetlands at Cathedral Run and Wises Mill began functioning in 2013. These wetlands mitigate the impact of stormwater flows, reduce the amount of sediment that ends up in the streams and increase the diversity of aquatic vegetation in those wetland areas. In addition to reducing erosion rates, the facilities recommended by this study would provide for settling and storage of sediment in runoff and reduce sediment loading in the watershed.

5.5. Improvement Site Ranking

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

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

Figure 53 shows the rankings of the extended detention and infiltration sites using the criteria described above. Based on this preliminary screening, sites with the higher score should receive first consideration for further site evaluation and funding. All riparian restoration sites have a ranking score of 1.5 or higher.

< *See Next Page* >

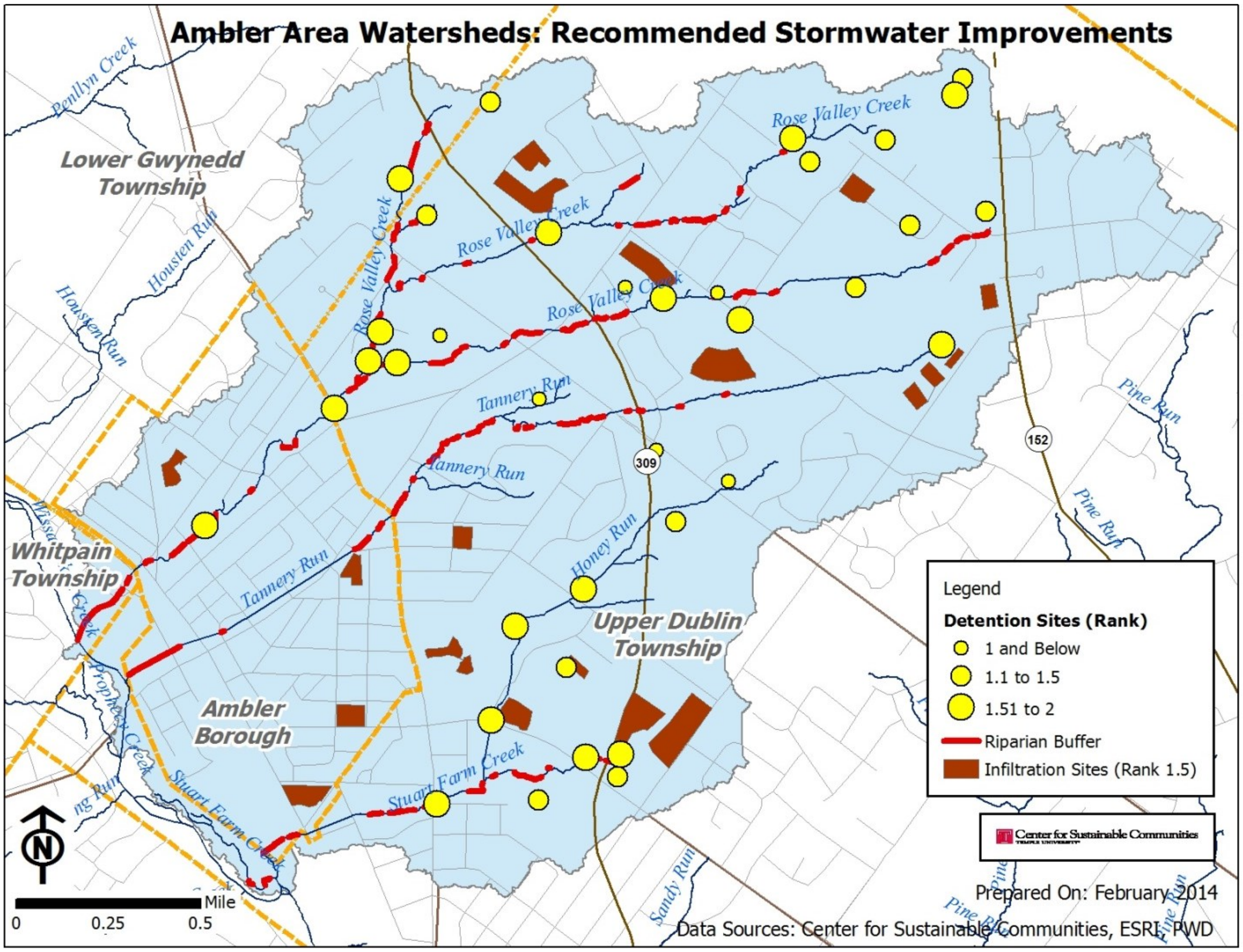

Figure 53: Location and rank of proposed detention and infiltration improvements

5.6. Site Specific Recommendations

Site-specific recommendations for selected six sites are discussed in this section. The sites are (i) Rose Valley Creek channelization in the West Ambler neighborhood, (ii) Loch Alsh Reservoir and Loch Linden Dam (St. Mary's Lake), (iii) Orange Avenue and Main Street, (iv) Ambler Park, (v) the BoRIT Site, and (vi) Church Street and Main Street. The site-specific recommendations include structural measures within existing downstream floodplains. While such measures substantially lower flood risk, flooding will still occur if storms exceed the design of the control measure. For the Rose Valley Creek analysis, the 500-Yr storm was used to determine the size of the enlarged channel. The Project Team recommends the site-specific projects only if the water released would be compensated with upstream storage or infiltration.

Site 1: Rose Valley Creek and West Ambler Neighborhood

In order to address severe flooding issues in the West Ambler neighborhood, the Project Team evaluated an option of daylighting and channelization of Rose Valley Creek. This recommendation is consistent with the *West Ambler Revitalization and Action Plan*. Figure 54 shows a comparison of the new preliminary CSC floodplain and the floodplain after channelization of the Rose Valley Creek.

The Project Team suggests the closing of sections of Tennis Ave and Ambler Ave, the installation of three new culverts/bridges at Reiffs Mill Rd, N. Main St, and West Maple Ave, and reconstruction of the SEPTA Bridge. The existing 7-foot bypass pipe would be reconnected with the new channel. A new roadway would connect Ambler, West Maple, and Railroad Avenues (See Figures 55 and 56). The hydraulic model was used to evaluate the lower section of Rose Valley Creek. This project will generally increase channel storage, but eliminate existing floodplain storage. The project is feasible but could cost $10 million (estimated), if designed for a 500-Yr storm.

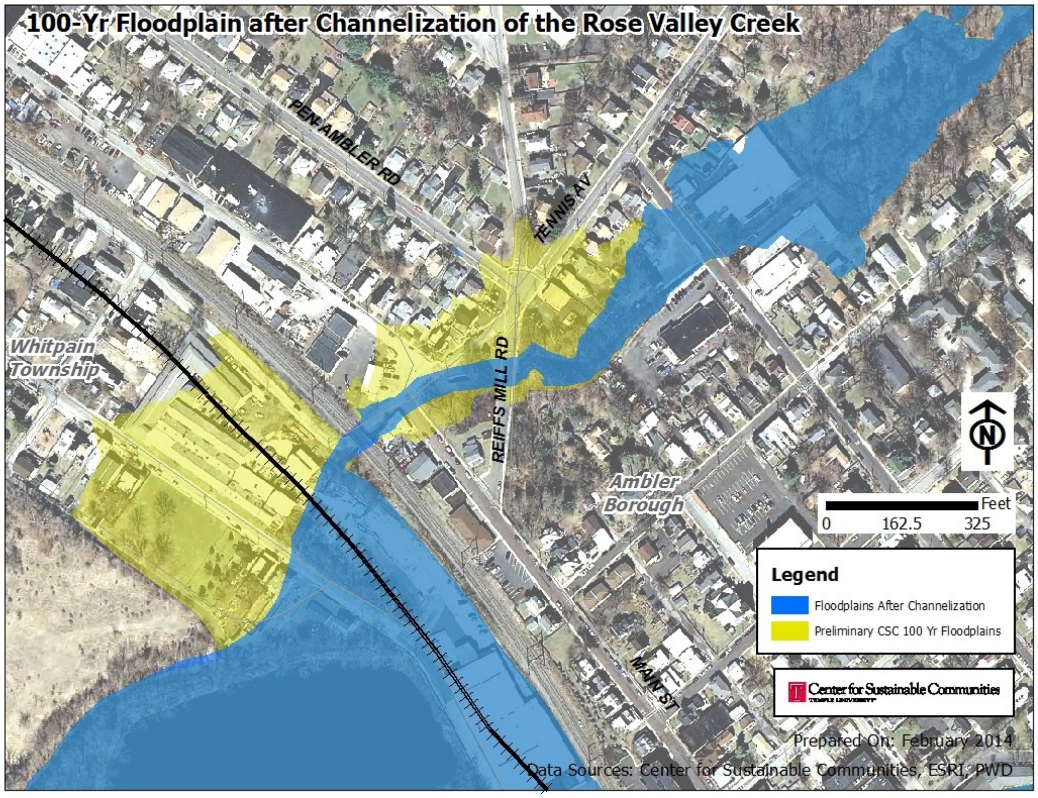

Figure 54: Comparison of the preliminary CSC floodplain (yellow) and the floodplain after channelization (blue). The channel was sized to contain the Q500 of 3690 cfs.

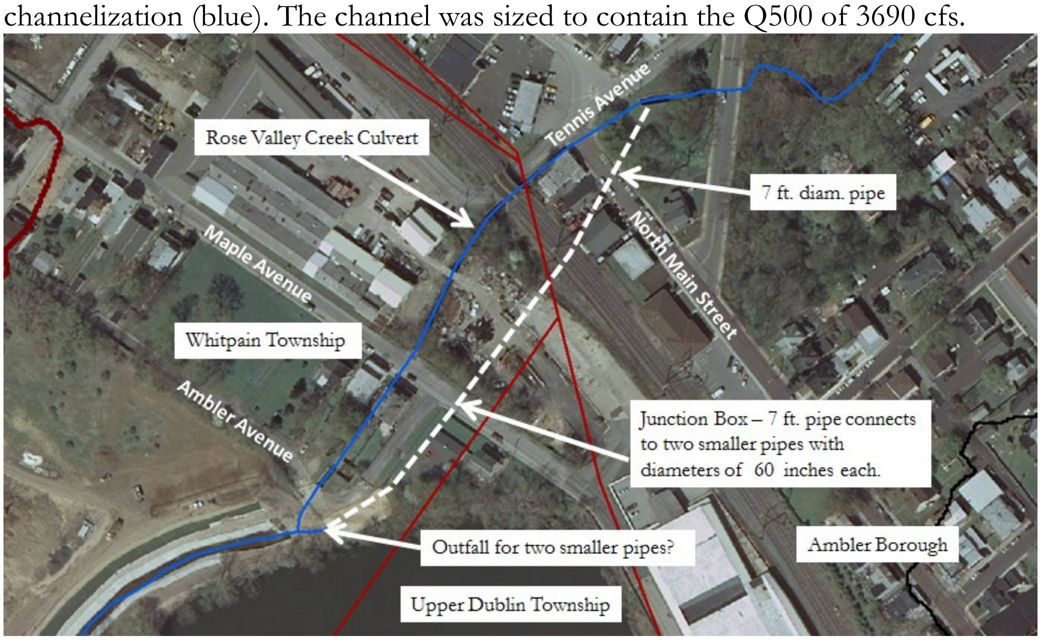

Figure 55: Details of the existing features at the project area along Rose Valley Creek

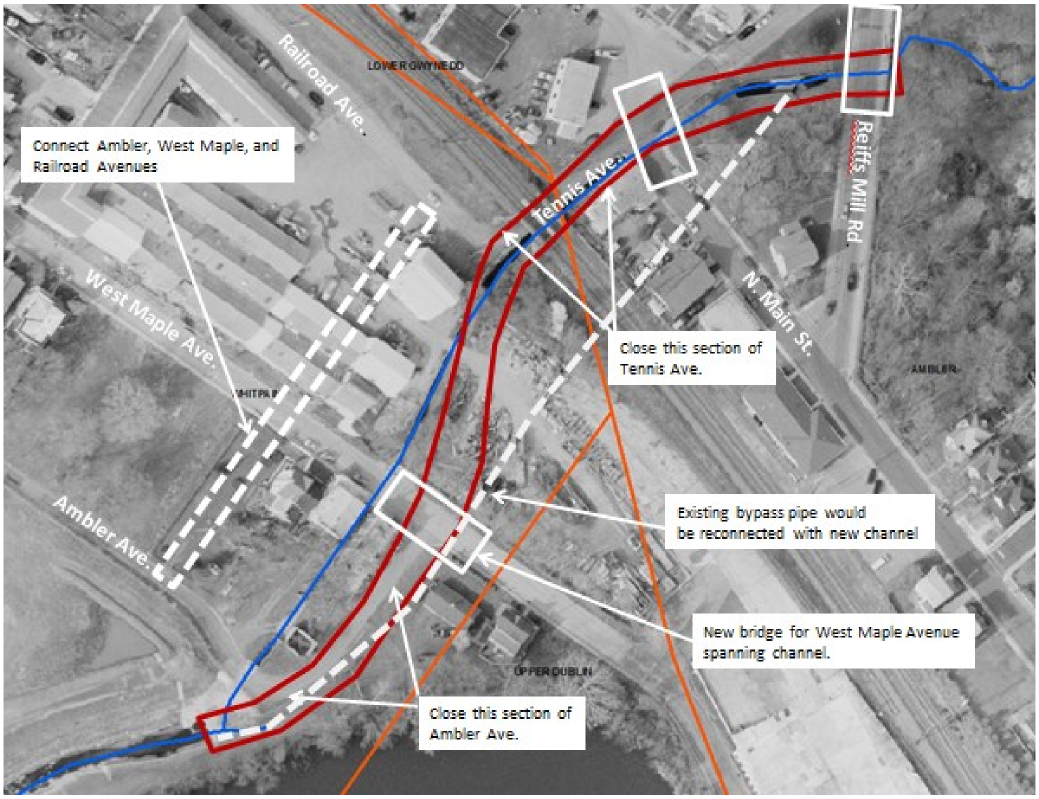

Figure 56: West Ambler Flooding Evaluation – Possible channelization of Rose Valley Creek

The CSC Project Team offers several alternatives to this channelization project, along with estimates cost for each option. Here is a comparison of all of these five options.

- **Option 1:** Rose Valley Creek channel to Reiffs Mill Road – estimated $10 million, including four bridge reconstructions and property acquisition cost (already described above as CSC recommended option)
- **Option 2:** No channel, keep the 7-ft. diameter bypass pipe, and buy out properties – estimated $4 million
- **Option 3:** Rose Valley Creek channel built in Whitpain Township only – estimated $5 million (see a few pictures below)
- **Option 4:** Rose Valley Creek channel extended to the Ambler Park – estimated $15 million (This option would require more property acquisition compared to options 1 and 3, and a fifth bridge reconstruction)
- **Option 5:** This would consist of Option 1 plus channelization of a portion of Tannery Run and replacement of the Maple Avenue and SEPTA bridges across Tannery Run. This option would remove the area west of the SEPTA rail line between Tannery Run and Rose Valley Creek from the 100-Yr and 500-Yr floodplains – estimated $15 million

The yellow areas in Figure 57 (b) display the proposed improvements surrounding the SEPTA line and the revised floodplains after structural improvements to both Tannery Run and Rose Valley Creek. It can be seen that many building owners are impacted in this area. Through daylighting the stream, the area subject to flooding could be greatly reduced to the blue path seen below. While some properties would be impacted by this process, the damage inflicted overall by flooding would be cut back significantly.

Figure 57 (a and b)**:** Enlargement of Tannery Run Channel combined with construction of new bridge spans for Maple Avenue and the SEPTA rail line (left); Area removed from floodplains after Tannery Run and Rose Valley Creek structural improvements are made (right)

For option 3 (if the channel is constructed in Whitpain Township only), it may be feasible to begin the new channel on the downstream side of the SEPTA Bridge. This could lower the cost of this option. Figures 58 (a and b) and 59 (a and b) show some details.

Figure 58 (a and b)**:** Channel could begin on downstream side of the SEPTA Bridge

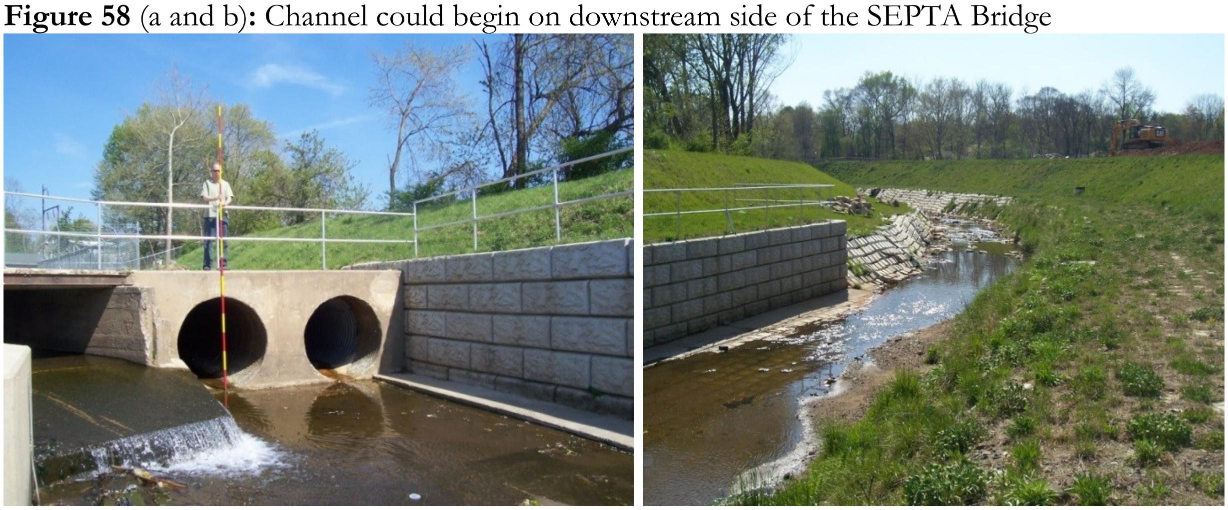

Figure 59 (a and b)**:** Downstream end of bypass and main channel (left); downstream channel (right). Photos were taken in March 2012.

Site 2: Loch Alsh Reservoir and Loch Linden Dam (St. Mary's Lake)
The Project Team performed a hydrologic model analysis to evaluate the effects of the following:

- Maintaining normal operating level at Loch Alsh Reservoir four ft. lower than in the past. This practice has been followed since renovation of the dam.
- Re-construction of both Loch Linden Dam (St. Mary's Lake) and replacement of the lake with a constructed wetland to function as a detention facility

Hydrologic modeling indicates that these two changes would provide a combined total of approximately 35 acre-ft. of additional storage in the Honey Run/Stuart Farm Creek watershed during the 100-Yr storm event. The model run showed that significant reduction in flood flows could be achieved in the reach of Honey Run between Loch Linden Dam and the confluence with Stuart Farm Creek. For the assumptions modeled, the 100-Yr peak outflow from Loch Linden Dam was reduced from 440 to 100 cubic feet per second.

Based on this modeling, the CSC Project Team recommends that Ambler Borough should continue to maintain a water elevation of 4 feet lower to prior to dam renovation. The Team also recommends that Loch Linden Dam be converted to a constructed wetland or extended detention basin. Figure 60 provides more details.

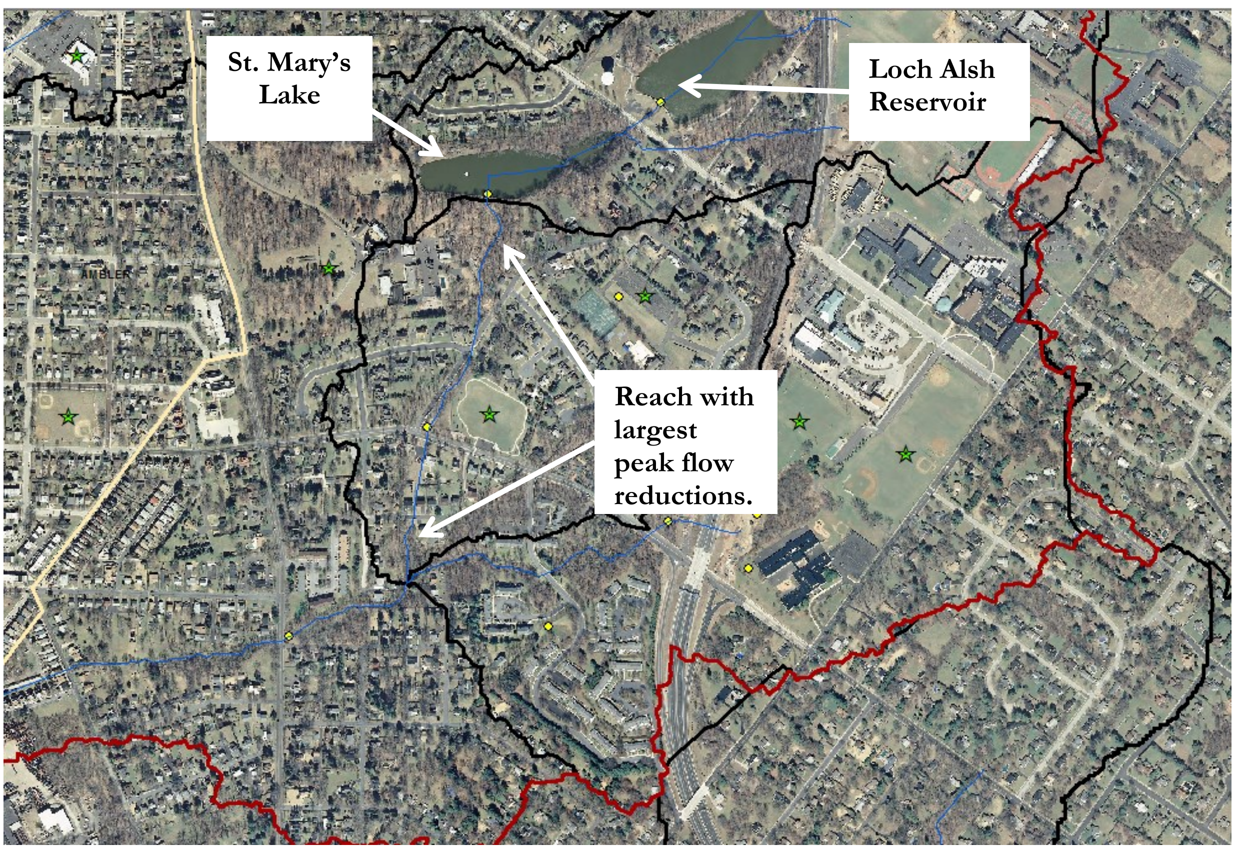

Figure 60: Loch Alsh Reservoir and Loch Linden Dam (St. Mary's Lake)

Site 3: Orange Avenue and Main Street
The Project Team recommends mitigation of flooding near Orange Avenue and Main Street, by installing a 5 Ft x 12 Ft culvert under the SEPTA rail line to increase the capacity to discharge water

from this area to the Wissahickon Creek. Figure 61 shows the possible location of this culvert (in red line). The estimated cost is $1 million.

Figure 61: Culvert near Orange Ave and Main St

Site 4: Ambler Park

For the Ambler Park site, there is a potential for additional storage. Modeling shows that the park currently stores about 12 acre-ft. of floodwater during the 100-Yr storm. Three options for specific projects include:

- Consistent with Appendix B, create two acres of additional wetland area. This would provide an additional four acre-ft. of storage.
- Excavate four acres. This would require additional tree removal and provide up to 12 acre-ft. of additional storage.
- Construct a dam in addition to option mentioned above, to provide up to 30 acre-ft. of additional storage. The dam would have to be coupled with an extended channel for Rose Valley Creek (Option 4 of Site 1) and be similar in design to the Rapp and Pine Run dams in the Sandy Run Watershed.

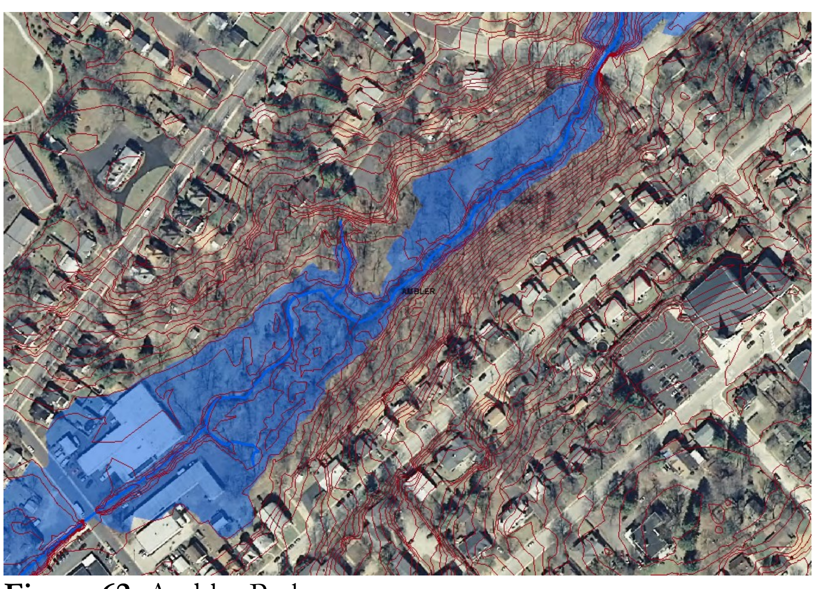
Figure 62: Ambler Park

Site 5: BoRIT Site
For the BoRIT asbestos site, the EPA has ongoing remediation efforts that include: covering all asbestos containing material with clean fill, stream bank stabilization, and removal of reservoir water and its treatment. Testing of water, soil and air quality has been and will continue to be carried out. At the end of the process the reservoir will be restored through relining and refilling. The Project Team recommends that EPA and ACE continue mitigating the BoRIT asbestos site. In addition, these two agencies should consider flooding and stormwater management issues related to lower Tannery Run that directly affects the BoRIT site. With the suggested projects to both Rose Valley Creek and Tannery Run, further improvement can be observed at the BoRIT site (see renderings below in Figure 63). Additionally, the waterfowl preserve can be controlled so that water does not flow into the Wissahickon Creek during a flooding event.

Figure 63: BoRIT site – before and after improvement on Rose Valley and Tannery Run

Site 6: Church Street and Main Street
The Project Team recommends a channel widening and bridge replacement project at Church Street and Main Street. There are approximately 30 homes in the 100-Yr floodplain currently in this area. The approximate cost for this option is $5 million.

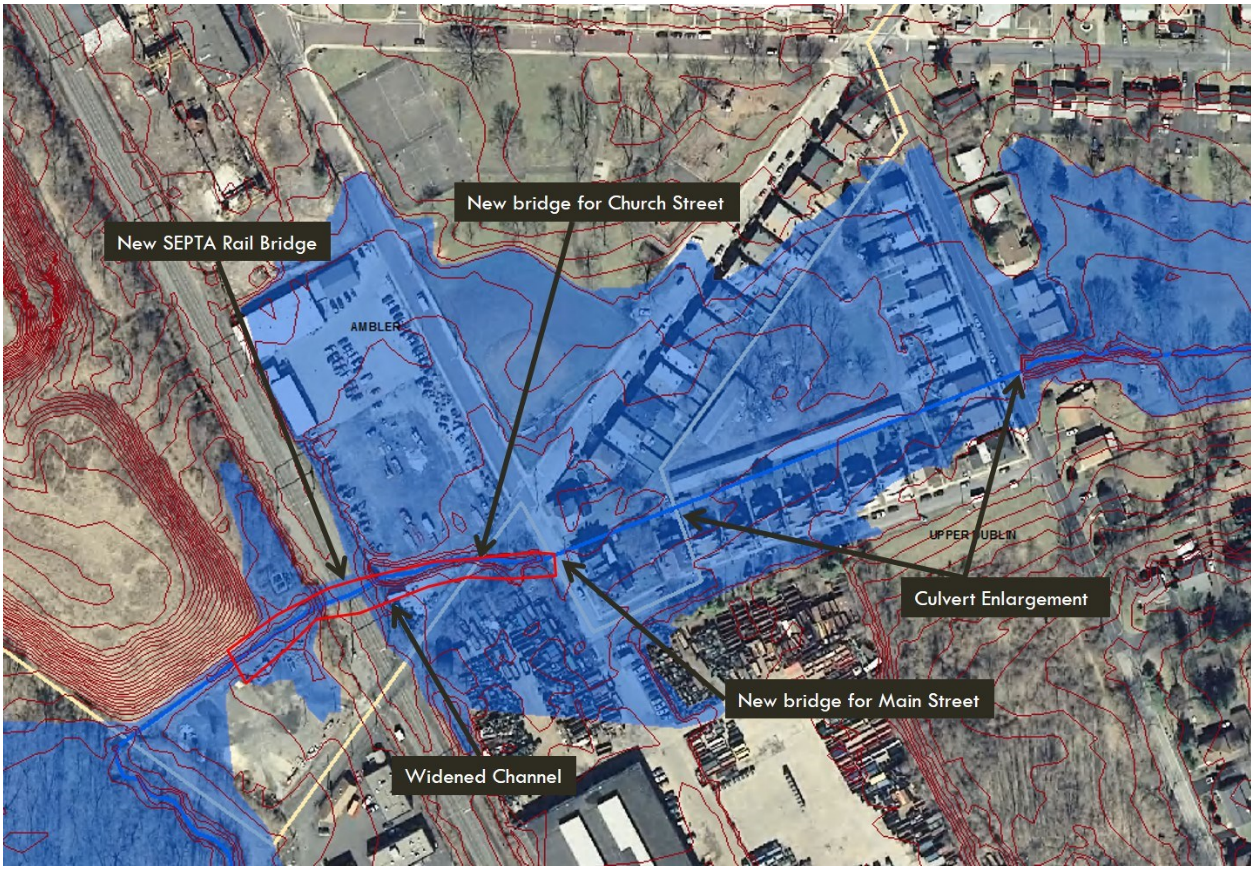

Figure 64: Church and Main Street site

5.7. Low-Impact Green Stormwater Infrastructure (GSI) Projects

There are a number of low-impact GSI projects throughout the study area. These include rain gardens, rain barrels, green roofs and permeable pavement. A few local initiatives were highlighted earlier in this report (See Section 2.3). The placement of 5,940 rain barrels would absorb on average 1 acre-ft of rainwater and 100 rain gardens of 200 cubic feet each would absorb 0.46 acre-ft. The implementation of these GSIs will not likely impact flood control to a greater extent, due to their size, but have been proven to significantly improve water quality on a local scale. Such projects may reduce stormwater marginally, but improve water quality by catching rainwater before it is polluted (rain barrels), by filtering pollutants out, or a combination of both. In the case of rain barrels, the water can be reused for several household purposes. The Project Team recommends continuation of these GSI projects throughout the study area.

6. Implementation Strategies

This stormwater management plan has outlined new computer models and floodplain maps, and recommended site specific stormwater control measures to mitigate flooding and water quality problems. This section offers strategies for the municipalities to implement them.

6.1. Adoption and Enforcement of New Flood Insurance Rate Maps (FIRMs)

In Section 4 the plan presents the results of hydrologic and hydraulic modeling for the study area and identifies proposed new FIRMs for the three watersheds. The municipalities should submit the proposed new FIRMs to FEMA for review and approval. FEMA administers the federal flood insurance program.

The municipalities can independently or jointly submit the proposed new FIRMs to FEMA in the form of a letter of map revision (LOMR). As noted by FEMA: "A LOMR is a letter that officially revises the currently effective FEMA map. It is used to change flood zones, floodplain and floodway delineations, flood elevations, and planimetric features. All requests for LOMRs should be made to FEMA through the chief executive officer of the community, since it is the community that must adopt any changes and revisions to the map." (FEMA F-084/March 2011)

The municipalities are encouraged to adopt the proposed new FIRMs as "best available information" for floodplain management purposes until the new maps are formally approved by FEMA and subsequently by the municipalities.

The federal flood insurance program provides funding for voluntary buyouts of flood-prone properties. This plan has several candidate properties in Section 5. Typically, the federal government through FEMA provides 75% of the funding for property acquisition with the remainder of the funds coming from state and local government. The designation of properties as residing in a flood hazard zone through adoption of FIRMs is a critical step in the buyout process.

6.2. Implementation of Stormwater Improvements and Flood Control Projects

The municipalities are encouraged to construct the stormwater improvements identified in Section 5. This can be done by increasing each municipality's capital improvement program funding. The various improvements are assigned a priority according to their location, cost -effectiveness and capture potential, and municipalities can use this ranking as a basis for funding projects over a long-term period, for example ten years.

Funding the stormwater improvements and flood control projects can be leveraged through a variety of sources. The FEMA Federal Flood Insurance Program can be utilized, as well as Army Corps of Engineers funding – Section 205 (PI 80-858) and Sections 206 and 566 (WRDA). PennVEST funding can be sought to jump start a stormwater improvement program. Other sources include the National Fish and Wildlife Foundation, which recently launched a new program to fund stormwater improvements stemming from the William Penn Foundation's Watershed Protection Initiative. The new program, entitled Delaware River Restoration Fund, will provide approximately $2 million annually for restoration projects. Given that the three watersheds are located within the Wissahickon Creek Watershed, a priority area for funding, this funding source should be given serious consideration by the municipalities.

An alternative approach for funding stormwater improvements projects is to implement them through existing municipal water or wastewater authorities, which can collect parcel-based stormwater fees similar to those collected by the PWD as part of its *Green City, Clean Waters* Program. Recent state legislation enables authorities to impose and collect stormwater fees. A recent national survey conducted by Western Kentucky University (2010) identified 1,112 stormwater utilities located in 38 states and the District of Columbia. The average monthly single family residential fee was $4.12 and the median fee was $3.50. A similar program could be instituted by the municipal authorities in the Ambler area watersheds

Municipalities also can consider a pooled watershed approach for constructing stormwater improvements given that improvements vary according to their effectiveness. The draft Act 167 Plan for the Wissahickon Creek Watershed Appendix C outlined 538 acre-feet of additional stormwater volume reduction potential in the watershed, including the ones noted in this plan. As noted in the Act 167 plan, volume reduction targets can be established for the Wissahickon municipalities and used as credits towards achieving this overall reduction amount. See http://www.temple.edu/ambler/csc/documents/Section7.pdf.

Table 7 (in Section 3.2 of this report) depicts the sediment wasteload (TMDL) allocations for the communities in the Wissahickon Watershed. We also have calculated the amounts within the Ambler area watersheds for these communities. The construction of the SCMs recommended in this plan would contribute to reducing these loads.

Flood control projects are eligible for federal funding. Of the projects identified in Section 5, the daylighting of lower Rose Valley Creek would most likely qualify for federal funding. Section 205 of the Flood Control Act of 1948 (Public Law 80-858), provides authority for the US ACE to plan, design and construct small flood control projects. Each project is limited to a federal cost of no more than $7 million, including all project-related costs for feasibility studies, planning, engineering, design and construction. Also as noted in Subsection 6.1, the federal flood insurance program provides funding for voluntary buyouts of flood prone properties. Several properties were identified in flood hazard zones in the proposed new FIRMs and would be eligible for federal property acquisition funding.

Two other ACE authorities offer potential for funding of projects. Section 206 of the Water Resources Development Act (WRDA) of 1996 provides up to $5 million for aquatic ecosystem restoration projects. Section 566 of WRDA also provides funding for water-related environmental infrastructure and water resource protection and development projects. The cost share for this authority is 75/25 federal/nonfederal. In-kind credits are allowed for the nonfederal share.

6.3. Adoption and Enforcement of Municipal Stormwater Ordinances

The draft Act 167 Stormwater Plan for the Wissahickon Creek Watershed was posted on the CSC website in March 2014. As noted in the draft Act 167 Plan, once it is adopted by the Pennsylvania DEP all municipalities in the watershed including the three Ambler area communities are required to adopt or amend such ordinances and regulations as are necessary to regulate new development and redevelopment within their municipalities consistent with the plan. These ordinances and regulations may include zoning, subdivision and land development (SALDO) building codes, and erosion and sedimentation ordinances.

As noted in the Act 167 model ordinance, regulated activities include the following:

- Land development,
- Subdivisions,
- Alteration of the natural hydrologic regime,
- Construction or reconstruction of or addition of new impervious or semi-pervious surfaces (i.e., driveways, parking lots, roads, etc.),
- Construction of new buildings or additions to existing buildings,
- Redevelopment,
- Diversion piping or encroachments in any natural or man-made channel,
- Stormwater BMPs or appurtenances,
- Earth disturbance activities of equal to or greater than five thousand (5,000) square feet,
- Any of the above regulated activities which were approved more than five (5) years prior to the effective date of this Ordinance and resubmitted for municipal approval.

Among other things, the model ordinance requires infiltration on site and peak rate control for larger projects. With respect to infiltration, the recharge volume shall be equal to one inch of runoff over all proposed impervious surfaces. As per peak rate control, all three communities are located in Peak Rate District B and would be required to meet these standards (see Table 16):

Table 16: Peak rate control standards by stormwater management district in the Wissahickon Watershed

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

Note: See http://www.ambler.temple.edu/csc/documents/AppendixA.pdf for additional information on the ordinance provisions.

6.4. Participation in FEMA's Community Rating System

The National Flood Insurance Program's (NFIP) Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. As a result, flood insurance premium rates are discounted to reflect the reduced flood risk resulting from the community actions. The three communities are encouraged to participate in the program.

The CRS uses a class-rating system that is similar to fire insurance rating to determine flood insurance premium reductions for residents. CRS classes are rated from 10 to 1. A community that does not apply for the CRS or that does not maintain the minimum number of credit points would be considered a Class 10 community. Today, most communities enter the program at a Class 9 rating, which entitles residents in Special Flood Hazard Areas (SFHAs) to a five-percent discount on their flood insurance premiums. As a community engages in additional mitigation activities, its residents become eligible for increased NFIP policy premium discounts. Each CRS Class improvement produces a five-percent greater discount on flood insurance premiums for properties in the SFHA, with a Class 1 community receiving the maximum 45 percent premium reduction.

6.5. Flood Warning in the Ambler Area Watersheds

Flood warning provides lead time for emergency responses such as evacuations, road closures, and clearing flood prone parking or storage areas. A flood warning system for small watersheds requires forecasting, rainfall and water level monitoring, and response when flood rainfall rates or levels are triggered. The modeling conducted for this study indicates that the time between heavy rainfall and flooding for the storm events modeled is two to three hours. This time increment can be even less depending on the intensity of actual storms and location in the watershed. This allows little time for emergency response. Despite this short lead time, having a flood warning and response system is a recommended and relatively low cost measure to improve community safety.

With improvements in remote monitoring and telemetry equipment, and the flood modeling products generated in this study, there are opportunities to improve flood warning for the Rose Valley Creek, Tannery Run, and Honey Run/Stuart Farm Creek watersheds. The following components are recommended:

- Three automated rain gages located in the lower, middle, and headwater portions of each tributary.
- At least two automated water level gages equipped with trigger alarms in the middle and headwater portions of each watershed. Flood profiles from this study can be used to select the most flood-prone stream crossings for placement of these gages.
- Dedication of funds to monitor, report, and maintain the automated gages.
- Assignment of responsibility to monitor, report, and respond to flood warning triggers.
- Community education about flood warning and response.
- In developing a response system for flood warnings, a key component is the extensive local knowledge of experienced emergency responders concerning flood prone areas.

Experience with flood conditions in small watersheds shows that they occur at any hour, and that 2 to 3 inches rainfall in a short period of time can cause flash flood conditions. This means that knowledge of the forecasting products available from the National Weather Service or private weather services are an important part of a flood warning system. Radar and flash flood guidance products can be very useful in flood preparedness. The National Weather Service Office in Mount Holly covers the study area and offers community education and assistance directed at flood warning. The project team recommends that the Office be contacted as an initial step in further developing a flood warning program.

Appendix A: Ambler Area Watersheds, Stakeholder Floodplain Problems:

ID Code	Residency Status	Municipality	Worst Storm Event	Nature of flood damage	Past 10-year floods	Flood Insurance?	Filed claim?	Paid?	Do/Know of any Upgrades?
A2	Owner	Ambler	2010	Basement; lost appliance	3	Y	Y	Y	Y; self
A3	Owner	Ambler	TS Lee	Lost appliances, equipment	1	N	Y	N	N
A4.1	Business	Ambler							
A4.2	Business	Ambler	TS Lee	Lost inventory, appliances, equipment	4-5; 2011, 2004,	Y	N	-8	Y; self
A5	Owner, Business	Ambler	Irene; TS Lee	Lost inventory, appliances, equipment, cars (~$200,000)	2; Aug 2011 & Sept 2011	N	Y	P	N
A6	Owner	Ambler	Irene & Lee	None	-8	Y	N	-8	N
A7	Owner	Ambler	TS Lee	Basement and yard; lost appliances, fence	6; Aug 2011 & Sept 2011, 2009 (2x)	Y	Y	Y	Y; self, *maybe* municipality
A8	Owner	Ambler	TS Lee	Basement and yard; lost appliances, cars, structural	4; 2009 (2x)	Y	Y	Y	N
A9	Owner	Ambler	TS Lee	Basement, structural; lost car, plumbing	8; 2011, 2010, 2001	Y	Y	P	Y; *maybe* municipality, don't know results
A10	Owner	Ambler	TS Lee	Basement, structural; lost appliances, 2 cars, PP	5	Y	Y	Y	N
A11	Owner	Ambler	TS Lee	Basement; lost appliances, PP, living space	2; 1999, 2011	Y	Y	Y	Y; municipality
A12	Owner	Ambler	TS Lee	Basement; lost appliances, 2 cars	5; 2011 (2x), 2009	Y	Y	Y	Y; self, municipality
A13	Owner	Ambler	TS Lee	Yard; no major damage	6	N	N	N	N
A14.1	Owner	Ambler	TS Lee	Yard; lost landscaping, berms	8-10	Y	Y	P	Y; self
A14.2	Owner	Ambler							
A14.3	Owner	Ambler							
A14.4	Owner	Ambler							

Appendix A: Ambler Area Watersheds, Stakeholder Floodplain Problems:

ID Code	Residency Status	Municipality	Worst Storm Event	Nature of flood damage	Past 10-year floods	Flood Insurance?	Filed claim?	Paid?	Do/Know of any Upgrades?
A15	Business	Ambler	TS Lee	Basement; lost appliances, drywall/carpeting, PP	2; 2001, 2011	Y	N	-8	N
A16	Owner	Ambler	TS Lee	Basement; lost drywall/carpeting	1	N	N	N	Y
A17	Owner	Ambler	(Floods on regular basis)	(Depends)	7	N	N	N	Y; self
A18	Owner	Ambler	TS Lee	Basement and yard; lost appliances, car and PP	3; Jul 2009, Aug 2011, Sept 2011	Y	Y	Y	Y; self
A19	Owner	Ambler	TS Lee	Basement; lost some PP	2; Aug 2011 & Sept 2011	N	N	-8	N
A20	Owner	Ambler	TS Lee	Basement; lost appliances	4-5	N	N	N	N
A21	Owner	Ambler	TS Lee	Basement and yard; lost appliances, car and PP	5; 2004, 2009 (2x), 2011 (2x)	Y	Y	Y	N
W1	Owner	Ambler	TS Lee	Basement; lost appliances, vehicle damage, PP	twice a year	N	N	-8	Y
W2	Owner	Ambler	TS Lee	Basement; lost appliances	-8	N	N	-8	Y; self
W3	Owner	Ambler	TS Lee	Basement; lost appliances, electronics, PP	2; 2001 (2x)	N	N	-8	N
U1	Owner	Ambler	TS Lee/Irene	Basement; lost appliances, furniture,	2; 2011 (2x)	N	Y	N	Y; self, not municipality
U2	Tenant	Ambler	TS Lee	Driveway; washed out driveway	3	N	N	N	Y; self
U3	Owner	Ambler	TS Lee	Basement and road; Lost appliances, landscaping, car	6	N	N	-8	-8
U4	Owner	Ambler	TS Lee	Driveway and yard; muddy yard, wear on driveway bridge	2	N	N	-8	N; but PennDOT did
U5	Owner	Ambler	TS Lee	Basement; lost appliances, damage to sidewalk	6	N	N	N	Y; municipality

Appendix A: Ambler Area Watersheds, Stakeholder Floodplain Problems:

ID Code	Residency Status	Municipality	Worst Storm Event	Nature of flood damage	Past 10-year floods	Flood Insurance?	Filed claim?	Paid?	Do/Know of any Upgrades?
U6	Owner	Ambler	TS Lee/Irene	Basement & yard; erosion, lost trees and bushes	twice a year	N	-8	-8	N
U7	Owner	Maple Glen	-8	Detention basin floods basement	6	N	-8	-8	Y; self
U8	Owner	Ambler	TS Lee	Basement; lost appliances	5	N	N	P	Y; municipality

Appendix B: Ambler Area Detention Sites:

Facility ID	Municipality	Location or Intersection	Current Land Use	Receiving Waters	Type of Measure	Existing Basin Area (Ft^2)	Existing Basin Depth (Ft.)	Existing Volume (Acre-Ft)	Type of Measure	Potential Additional Extended Detention (Acre-Ft)	Final Estimated Cost ($)	Notes
AM_5	Ambler Borough	Ambler Borough Park between Hendricks St. and Ridge Ave.	Wooded	Rose Valley Creek	Increase floodplain storage	0	0.0	0.0	Increase floodplain storage	4.0	312,000	Wooded park in floodplain. Excavate approximately 2 acres of area an average of 3 ft. to increase floodplain storage, but maintain park function.
LG_34	Lower Gwynedd	Gwyn Oaks	Residential	Rose Valley Creek Tributary	Detention Retrofit	7,223	5.0	0.5	Detention Retrofit	0.3	30,000	Site inspected in 2012. Excavate 2 ft. and modify outlet for extended detention.
UD_1	Upper Dublin	Bell Lane	Residential	Rose Valley Creek Tributary	Detention Retrofit	8,045	N/A	0.4	Detention Retrofit	0.2	30,000	Small detention basin. Not surveyed. Assume potential additional storage of 0.20 acre-ft. and cost of $30,000.
UD_100	Upper Dublin	Tennis Avenue and Cheston Lane	Residential	Rose Valley Creek	Detention Retrofit	4,000	2.0	0.1	Detention Retrofit	0.1	30,000	Small basin at private residence. Deepen 2 ft. and modify outlet piping.
UD_112	Upper Dublin	Highland Ave. and Rt. 309 (NB) by Ft. Wash Elementary	Institutional	Stuart Farm Creek	Detention Retrofit	5,400	4.0	0.3	Detention Retrofit	0.2	30,000	Small detention basin. Assumed 0.2 acre ft. increase in storage.

Appendix B: Ambler Area Detention Sites:

Facility ID	Municipality	Location or Intersection	Current Land Use	Receiving Waters	Type of Measure	Existing Basin Area (Ft²)	Existing Basin Depth (Ft.)	Existing Volume (Acre-Ft)	Type of Measure	Potential Additional Extended Detention (Acre-Ft)	Final Estimated Cost ($)	Notes
UD_114	Upper Dublin	Susquehanna Ave. by Lincoln Dr. W. and Rt. 309 (NB)	Residential	Between Tannery Run and Honey Run	Detention Retrofit	10,300	4.0	0.6	Detention Retrofit	0.0		Small detention basin with limited opportunity for expansion. This is now a rock-filled infiltration area - no additional work recommended.
UD_116	Upper Dublin	Northeast of Hutchins Drive	Open Space	North Branch Rose Valley Creek	New Detention	0	0.0	0.0	New Detention	2.8	200,000	Upper Dublin Township has designed and is seeking permits for new detention basin. Upper Dublin cost estimate.
UD_117	Upper Dublin	West of Limekiln and Wright Drive	Open Space	North Branch Rose Valley Creek	New Detention	0	0.0	0.0	New Detention	3.4	340,000	Existing depression could be expanded 2 ft. to provide additional storage.
UD_122	Upper Dublin	Upstream of Rte. 309 culvert in Robbins Park	Open Space	North Branch Rose Valley Creek	Two, 2 ft. high check dams	0	0.0	0.0	Two, 2 ft. high check dams	0.5	50,000	Locations are at the site of existing foot bridges, 110 and 290 ft. upstream from culvert. Upper dam would have greatest potential storage.

Appendix B: Ambler Area Detention Sites:

Facility ID	Municipality	Location or Intersection	Current Land Use	Receiving Waters	Type of Measure	Existing Basin Area (Ft²)	Existing Basin Depth (Ft.)	Existing Volume (Acre-Ft)	Type of Measure	Potential Additional Extended Detention (Acre-Ft)	Final Estimated Cost ($)	Notes
UD_123A	Upper Dublin	Southwest of Iroquois Way	Pond	Rose Valley Creek	Constructed Wetland	45,620	3.0	2.0	Constructed Wetland	3.0	300,000	Pond with 3 ft. of freeboard. Difficult to raise berm do to proximity of nearby dwellings. Consider conversion of constructed wetland detention.
UD_125	Upper Dublin	Bridge on Rose Valley Way off Tennis Avenue	Residential	Rose Valley Creek	Add floodplain storage	0	0.0	0.0	Add floodplain storage	0.3	30,000	Excavate 3 ft. upstream and downstream of right bridge arch to create additional floodplain storage.
UD_125A	Upper Dublin	Pond in Walmere on Rose Valley Creek Tributary	Residential	Rose Valley Creek	Create constructed wetland	36,600	1.5	0.8	Create constructed wetland	3.1	310,000	Dredge pond area to 5 ft. depth. Add 2 ft. to berm height. Modify outlet to create a constructed wetland to provide habitat and flood storage.
UD_125B	Upper Dublin	Pond on main stem of Rose Valley Creek east of site125A	Residential	Rose Valley Creek	Create constructed wetland	56,000	1.0	1.3	Create constructed wetland	3.0	234,000	Dredge pond to 5 ft. depth. Modify outlet to create a constructed wetland area.

Appendix B: Ambler Area Detention Sites:

Facility ID	Municipality	Location or Intersection	Current Land Use	Receiving Waters	Type of Measure	Existing Basin Area (Ft^2)	Existing Basin Depth (Ft.)	Existing Volume (Acre-Ft)	Type of Measure	Potential Additional Extended Detention (Acre-Ft)	Final Estimated Cost ($)	Notes
UD_126	Upper Dublin	NE of Highland Ave. and Rte. 309 intersection	Institutional	Stuart Farm Creek	Create constructed wetland	16,000	10.0	2.5	Create constructed wetland	0.2	20,000	Excavate 1 ft. Vegetate and remove rip-rap low flow channel, modify outlet to provide extended detention.
UD_127	Upper Dublin	NW of Highland Ave. and Rte. 309 intersection	Wooded Wetland	Stuart Farm Creek	New Detention	0	0.0	0.0	New Detention	1.4	50,000	Upper Dublin Township proposed detention basin. Upper Dublin cost estimate.
UD_128A	Upper Dublin	1000 ft. West of Rte. 309 Overpass of Loch Alsh Ave.	Recreation	Honey Run	Detention Retrofit	18,000	5.0	1.4	Detention Retrofit	0.6	60,000	Excavate 2 ft. and modify outlet and piping for extended detention
UD_131	Upper Dublin	Creek Road SW of Highland Avenue	Residential	Stuart Farm Creek	Detention Retrofit	22,500	5.0	1.8	Detention Retrofit	1.4	140,000	Excavate 4 ft. Modify outlet and piping.
UD_132	Upper Dublin	Upstream side of Bethlehem Pike NE of Randolf Ave	Wooded	Stuart Farm Creek	Check Dam	0	0.0	0.0	Check Dam	0.2	25,000	Install 3 ft. check dam 30 ft. upstream of Highland Avenue. Repair wing culvert wing wall on north upstream side.
UD_134	Upper Dublin	Upstream side of Bethlehem Pike at Rose Valley Creek	Wooded	Rose Valley Creek	Add floodplain storage	0	0.0	0.0	Add floodplain storage	3.8	380,000	Excavate area of 0.75 acres an average of 5 ft. to create additional floodplain storage

Appendix B: Ambler Area Detention Sites:

Facility ID	Municipality	Location or Intersection	Current Land Use	Receiving Waters	Type of Measure	Existing Basin Area (Ft^2)	Existing Basin Depth (Ft.)	Existing Volume (Acre-Ft)	Type of Measure	Potential Additional Extended Detention (Acre-Ft)	Final Estimated Cost ($)	Notes
UD_135	Upper Dublin	St. Mary's Lake south of Lake Avenue	Lake	Honey Run	Dam Renovation for detention	211,000	1.0	4.8	Dam Renovation for detention	14.0	1,400,000	Excavate 2 ft. and renovate dam. Convert to extended detention
UD_136	Upper Dublin	Loch Alsh Reservoir	Water Supply Res	Honey Run	Water Level Management	311,000	2.0	14.0	Water Level Management	28.0	0	Lower operating level by 4 ft. to create additional flood storage
UD_139	Upper Dublin	Temple Ambler Campus west of baseball field	Wooded	Rose Valley Creek	Constructed Wetland	0	0.0	0.0	Constructed Wetland	3.2	320,000	Excavate 1.6 acre area an average of 3 ft. to create constructed wetland area for parking lot drainage
UD_140	Upper Dublin	Temple Ambler Campus north of baseball field	Wooded	Rose Valley Creek	Constructed Wetland	0	0.0	0.0	Constructed Wetland	5.2	520,000	Excavate 2.6 acre area an average of 3 ft. to create constructed wetland and expand flood storage on Rose Valley Creek
UD_2	Upper Dublin	Belle Aire	Residential	Rose Valley Creek Tributary	Detention Retrofit	23,352	4.0	1.4	Detention Retrofit	5.0	500,000	Excavate 2 Ft. Expand excavated area to 1.6 acres

Appendix B: Ambler Area Detention Sites:

Facility ID	Municipality	Location or Intersection	Current Land Use	Receiving Waters	Type of Measure	Existing Basin Area (Ft^2)	Existing Basin Depth (Ft.)	Existing Volume (Acre-Ft)	Type of Measure	Potential Additional Extended Detention (Acre-Ft)	Final Estimated Cost ($)	Notes
UD_3	Upper Dublin	Belle Aire	Residential	Rose Valley Creek Tributary	Detention Retrofit	92,73	N/A	0.4	Detention Retrofit	0.0	12,000	High water table. Cannot be deepened or expanded based on field inspection during 2012. Retrofit outlet. Vegetate floor.
UD_4	Upper Dublin	Saint Alphonsus School	Institutional	Rose Valley Creek	Detention Retrofit	15,018	6.0	1.4	Detention Retrofit	0.5	88,560	Excavate 2 Ft. Existing Depth based on field inspection.
UD_43	Upper Dublin	Belle Aire	Residential	Rose Valley Creek	Detention Retrofit	65,828	5.0	5.0	Detention Retrofit	1.5	50,000	Upper Dublin Twp. is constructing expanded detention. Upper Dublin cost estimate.
UD_46	Upper Dublin	Meetinghouse at Friends Lane	Residential	Rose Valley Creek	Detention Retrofit	416	N/A	0.4	Detention Retrofit	0.2	30,000	Small detention basin. Not surveyed. Assume potential additional storage of 0.20 acre-ft. and cost of $30,000.
UD_47	Upper Dublin	Tannerie Wood	Residential	Honey Run	Detention Retrofit	59,945	2.0	1.8	Detention Retrofit	0.0	12,000	Elevation of excavation not recommended. Modify outlet structure and piping.

Appendix B: Ambler Area Detention Sites:

Facility ID	Municipality	Location or Intersection	Current Land Use	Receiving Waters	Type of Measure	Existing Basin Area (Ft^2)	Existing Basin Depth (Ft.)	Existing Volume (Acre-Ft)	Type of Measure	Potential Additional Extended Detention (Acre-Ft)	Final Estimated Cost ($)	Notes
UD_47A	Upper Dublin	Sports Park South of Joel and Susquehanna	Recreation	Honey Run	Detention Retrofit	56,700	4.0	3.5	Detention Retrofit	2.6	92,880	New constructed wetland for sports park, spillway 4 Ft above permanent pool, could elevate berm by 2 ft. Modify outlet structure and piping
UD_48	Upper Dublin	Farm Lane & Highland Road	Recreation	Stuart Farm Creek	Detention Retrofit	0	0.0	0.0	Detention Retrofit	0.5	50,000	Install two check dams at distances of 30 ft. and 200 ft. from upstream culvert opening under Highland Rd.
UD_4A	Upper Dublin	Temple Ambler	Campus	Tannery Run	Detention Retrofit	13,500	2.0	0.4	Detention Retrofit	0.4	82,080	Excavate 2 ft. Modify outlet structure and piping.
UD_5	Upper Dublin	Community Ambulance Association	Institutional	Rose Valley Creek	Detention Retrofit	7,604	N/A	0.4	Detention Retrofit	0.2	30,000	Small detention basin. Not surveyed. Assume potential additional storage of 0.20 acre-ft. and cost of $30,000.

Appendix B: Ambler Area Detention Sites:

Facility ID	Municipality	Location or Intersection	Current Land Use	Receiving Waters	Type of Measure	Existing Basin Area (Ft^2)	Existing Basin Depth (Ft.)	Existing Volume (Acre-Ft)	Type of Measure	Potential Additional Extended Detention (Acre-Ft)	Final Estimated Cost ($)	Notes
UD_6	Upper Dublin	Gentry Lane	Residential	Rose Valley Creek	Detention Retrofit	5,362	N/A	0.4	Detention Retrofit	0.2	30,000	Small detention basin. Not surveyed. Assume potential additional storage of 0.20 acre-ft. and cost of $30,000.
UD_7	Upper Dublin	Upper Dublin Lutheran Church	Institutional	Tannery Run	Detention Retrofit	2,919	N/A	0.4	Detention Retrofit	0.2	30,000	Small detention basin. Not surveyed. Assume potential additional storage of 0.20 acre-ft. and cost of $30,000.
UG_12	Upper Gwynedd	414 Forest Lane	Residential	Haines-Dittingers Run	Detention Retrofit	20,023	6.0	1.8	Detention Retrofit	0.0		No additional measures recommended. Part of Basin is Residential lawn. Poor Access. Some Large Trees in Basin.

Appendix C: Ambler Area Infiltration Sites:

Facility ID	Municipality	Location or Intersection	Current Land Use	Receiving Waters	Type of Measure	Infiltration Area (Acres)	Infiltration Volume (Acre-Ft)	Estimated Cost ($)	Notes
AM_1	Ambler	Ricciardi Park SE of Hendricks and Walker	Recreation	Rose Valley Creek	Infiltration	2.2	0.18	35,200	Infiltration trench and rain garden opportunities throughout park. Design for 1 inch of infiltration.
AM_2	Ambler	Butler Pike and Park Ave.	Community	Rose Valley Creek	Infiltration	2.0	0.17	32,000	Infiltration opportunity for replacement of old pavement. Design for 1 inch of infiltration
AM_3	Ambler	Between Park Ave and North St. and Trinity and Highland	Recreation	Rose Valley Creek	Infiltration	2.8	0.23	44,800	Infiltration trenches, rain gardens, bioswales opportunity. Design for 1 inch of infiltration.
AM_4	Ambler	Knight Park - Bannockburn and Church Avenues	Recreation	Rose Valley Creek	Infiltration	3.6	0.30	57,600	Infiltration trench opportunities throughout park. Design for 1 inch of infiltration.
UD_4B	Upper Dublin	Temple Ambler	School	Tannery Run	Infiltration	8.0	0.67	128,000	Infiltration opportunity. Design for 1 inch of infiltration.
UD_48A	Upper Dublin	Park at intersection of Highland and Farm Roads	Recreation	Stuart Farm Creek	Infiltration	3.1	0.26	49,600	Infiltration opportunity. Galleries under fields or trenches along west and south perimeters. Design for 1 inch infiltration
UD_118	Upper Dublin	West of Limekiln Pike between Ft. Washington and Bell Ln	Recreation	Rose Valley Creek	Infiltration	1.7	0.15	28,800	Infiltration opportunity for soccer field. Design for 1 inch infiltration.

Appendix C: Ambler Area Infiltration Sites:

Facility ID	Municipality	Location or Intersection	Current Land Use	Receiving Waters	Type of Measure	Infiltration Area (Acres)	Infiltration Volume (Acre-Ft)	Estimated Cost ($)	Notes
UD_119	Upper Dublin	Across Ft. Washington Ave. from Fort Washington Elem. School	Parking Lot	Tannery Run	Infiltration	0.7	0.06	11,520	Opportunity for infiltration trenches. Design for 1 inch infiltration.
UD_120	Upper Dublin	Soccer fields across from Ft. Washington Elem. School	Recreation	Tannery Run	Infiltration	3.0	0.25	48,000	Opportunity for infiltration at soccer fields. Design for 1 inch infiltration.
UD_121	Upper Dublin	Playing fields at Saint Alphonsus School off Temple Drive	Recreation	Rose Valley Creek	Infiltration	2.9	0.24	46,080	Opportunity for infiltration at playing fields. Design for 1 inch infiltration
UD_123	Upper Dublin	Open fields NE of Rte. 309 and SW of E. Fielder Rd.	Pasture	Rose Valley Creek	Infiltration	9.6	0.80	153,600	Infiltration trenches and bio-swales along down-slope edges of "Succession" fields. Design for 1 inch infiltration.
UD_124	Upper Dublin	Soccer fields NE of Butler Pike and Meetinghouse Rd.	Recreation	Rose Valley Creek	Infiltration	5.4	0.45	86,400	Infiltration trench opportunity. Design for 1 inch infiltration.
UD_126A	Upper Dublin	Playing field at Upper Dublin High School	Recreation	Stuart Farm Creek	Infiltration	5.8	0.48	92,160	Infiltration opportunity for playing fields. Design for 1 inch infiltration.
UD_126B	Upper Dublin	Playing field at Upper Dublin High School	Recreation	Stuart Farm Creek	Infiltration	9.1	0.76	145,920	Infiltration opportunity for playing fields. Design for 1 inch infiltration.

Appendix C: Ambler Area Infiltration Sites:

Facility ID	Municipality	Location or Intersection	Current Land Use	Receiving Waters	Type of Measure	Infiltration Area (Acres)	Infiltration Volume (Acre-Ft)	Estimated Cost ($)	Notes
UD_128B	Upper Dublin	Parking lot at Ft Washington Swim and Tennis Club	Recreation	Honey Run	Infiltration	1.1	0.10	19,200	Infiltration trenches for parking lot. Design for 1 inch infiltration.
UD_129	Upper Dublin	Sheeleigh Park, Approx. 750' E of Bethlehem Pike	Recreation	Tannery Run	Infiltration	2.0	0.16	30,720	Infiltration trenches along north and west perimeter
UD_130	Upper Dublin	East side of Bethlehem Pike opposite Matson Ave.	Institutional	Honey Run	Infiltration	2.9	0.24	46,080	Infiltration trenches along down slope perimeter of lawns. Design for 1 inch infiltration.

Appendix D: Ambler Area Riparian Repair Sites:

Riparian ID	Stream Type	Coverage	County	Municipality	New_Len_Ft	New Riparian ID	Zone	Area (Acres)	Cost ($)	Rank Score
0	0	No tree cover on either side	Montgomery	Ambler Borough	138.12	AM_R1	C	0.48	2,140	2.00
474	1	Tree cover on 1 side	Montgomery	Ambler Borough	57.07	AM_R10	C	0.10	442	2.00
475	1	Tree cover on 1 side	Montgomery	Ambler Borough	130.64	AM_R11	C	0.22	1,012	2.00
476	1	Tree cover on 1 side	Montgomery	Ambler Borough	79.70	AM_R12	C	0.14	618	2.00
558	0	No tree cover on either side	Montgomery	Ambler Borough	123.24	AM_R13	C	0.42	1,910	2.00
559	1	Tree cover on 1 side	Montgomery	Ambler Borough	24.96	AM_R14	C	0.04	193	2.00
560	1	Tree cover on 1 side	Montgomery	Ambler Borough	24.65	AM_R15	C	0.04	191	2.00
561	1	Tree cover on 1 side	Montgomery	Ambler Borough	223.71	AM_R16	C	0.39	1,733	2.00
562	1	Tree cover on 1 side	Montgomery	Ambler Borough	61.79	AM_R17	C	0.11	479	2.00
563	0	No tree cover on either side	Montgomery	Ambler Borough	48.62	AM_R18	C	0.17	753	2.00
564	0	No tree cover on either side	Montgomery	Ambler Borough	80.46	AM_R19	C	0.28	1,247	2.00
65	1	Tree cover on 1 side	Montgomery	Ambler Borough	466.64	AM_R2	C	0.80	3,616	2.00
663	0	No tree cover on either side	Montgomery	Ambler Borough	141.51	AM_R20	C	0.49	2,193	2.00
67	0	No tree cover on either side	Montgomery	Ambler Borough	43.96	AM_R3	C	0.15	681	2.00
468	0	No tree cover on either side	Montgomery	Ambler Borough	49.99	AM_R4	C	0.17	775	2.00
469	0	No tree cover on either side	Montgomery	Ambler Borough	49.90	AM_R5	C	0.17	773	2.00
470	1	Tree cover on 1 side	Montgomery	Ambler Borough	90.89	AM_R6	C	0.16	704	2.00

Appendix D: Ambler Area Riparian Repair Sites:

Riparian ID	Stream Type	Coverage	County	Municipality	New_Len_Ft	New Riparian ID	Zone	Area (Acres)	Cost ($)	Rank Score
471	0	No tree cover on either side	Montgomery	Ambler Borough	156.36	AM_R7	C	0.54	2,423	2.00
472	0	No tree cover on either side	Montgomery	Ambler Borough	258.91	AM_R8	C	0.89	4,012	2.00
473	1	Tree cover on 1 side	Montgomery	Ambler Borough	120.66	AM_R9	C	0.21	935	2.00
508	1	Tree cover on 1 side	Montgomery	Lower Gwynedd Township	25.61	LG_R212	C	0.04	198	2.00
509	0	No tree cover on either side	Montgomery	Lower Gwynedd Township	35.65	LG_R213	C	0.12	552	2.00
510	1	Tree cover on 1 side	Montgomery	Lower Gwynedd Township	96.59	LG_R214	C	0.17	748	2.00
511	0	No tree cover on either side	Montgomery	Lower Gwynedd Township	270.54	LG_R215	C	0.93	4,192	2.00
512	1	Tree cover on 1 side	Montgomery	Lower Gwynedd Township	44.49	LG_R216	C	0.08	345	2.00
514	0	No tree cover on either side	Montgomery	Lower Gwynedd Township	16.99	LG_R217	C	0.06	263	2.00
515	0	No tree cover on either side	Montgomery	Lower Gwynedd Township	112.38	LG_R218	C	0.39	1,741	2.00
1	0	No tree cover on either side	Montgomery	Upper Dublin Township	208.95	UD_R1	C	0.72	3,238	2.00
658	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	60.89	UD_R102	C	0.10	472	2.00
659	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	36.94	UD_R103	C	0.06	286	2.00
660	0	No tree cover on either side	Montgomery	Upper Dublin Township	34.38	UD_R104	C	0.12	533	2.00
661	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	39.10	UD_R105	C	0.07	303	2.00
662	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	87.35	UD_R106	C	0.15	677	2.00
664	0	No tree cover on either side	Montgomery	Upper Dublin Township	56.58	UD_R107	C	0.19	877	2.00

Appendix D: Ambler Area Riparian Repair Sites:

Riparian ID	Stream Type	Coverage	County	Municipality	New_Len_Ft	New Riparian ID	Zone	Area (Acres)	Cost ($)	Rank Score
665	0	No tree cover on either side	Montgomery	Upper Dublin Township	31.85	UD_R108	C	0.11	494	2.00
666	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	56.50	UD_R109	C	0.10	438	2.00
667	0	No tree cover on either side	Montgomery	Upper Dublin Township	95.08	UD_R110	C	0.33	1,473	2.00
668	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	90.95	UD_R111	C	0.16	705	2.00
669	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	97.97	UD_R112	C	0.17	759	2.00
670	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	27.65	UD_R113	C	0.05	214	2.00
671	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	33.70	UD_R114	C	0.06	261	2.00
672	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	64.09	UD_R115	C	0.11	497	2.00
673	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	44.03	UD_R116	C	0.08	341	2.00
674	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	133.98	UD_R117	C	0.23	1,038	2.00
675	0	No tree cover on either side	Montgomery	Upper Dublin Township	85.63	UD_R118	C	0.29	1,327	2.00
676	0	No tree cover on either side	Montgomery	Upper Dublin Township	29.96	UD_R119	C	0.10	464	2.00
677	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	63.90	UD_R120	C	0.11	495	2.00
678	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	157.91	UD_R121	C	0.27	1,223	2.00
679	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	177.39	UD_R122	C	0.31	1,374	2.00
680	0	No tree cover on either side	Montgomery	Upper Dublin Township	29.60	UD_R123	C	0.10	459	2.00
681	0	No tree cover on either side	Montgomery	Upper Dublin Township	35.34	UD_R124	C	0.12	548	2.00

Appendix D: Ambler Area Riparian Repair Sites:

Riparian ID	Stream Type	Coverage	County	Municipality	New_Len_Ft	New Riparian ID	Zone	Area (Acres)	Cost ($)	Rank Score
682	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	27.92	UD_R125	C	0.05	216	2.00
683	0	No tree cover on either side	Montgomery	Upper Dublin Township	135.27	UD_R126	C	0.47	2,096	2.00
684	0	No tree cover on either side	Montgomery	Upper Dublin Township	68.32	UD_R127	C	0.24	1,059	2.00
66	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	182.61	UD_R15	C	0.31	1,415	2.00
72	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	94.35	UD_R18	C	0.16	731	2.00
73	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	92.73	UD_R19	C	0.16	718	2.00
477	0	No tree cover on either side	Montgomery	Upper Dublin Township	115.41	UD_R20	C	0.40	1,788	2.00
493	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	35.42	UD_R21	C	0.06	274	2.00
494	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	270.36	UD_R22	C	0.47	2,095	2.00
495	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	259.06	UD_R23	C	0.45	2,007	2.00
496	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	99.81	UD_R24	C	0.17	773	2.00
497	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	40.46	UD_R25	C	0.07	313	2.00
498	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	39.51	UD_R26	C	0.07	306	2.00
499	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	86.96	UD_R27	C	0.15	674	2.00
500	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	94.73	UD_R28	C	0.16	734	2.00
501	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	107.39	UD_R29	C	0.18	832	2.00
504	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	62.58	UD_R30	C	0.11	485	2.00

Appendix D: Ambler Area Riparian Repair Sites:

Riparian ID	Stream Type	Coverage	County	Municipality	New_Len_Ft	New Riparian ID	Zone	Area (Acres)	Cost ($)	Rank Score
505	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	49.33	UD_R31	C	0.08	382	2.00
513	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	69.08	UD_R32	C	0.12	535	2.00
516	0	No tree cover on either side	Montgomery	Upper Dublin Township	45.44	UD_R33	C	0.16	704	2.00
517	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	270.22	UD_R34	C	0.47	2,094	2.00
518	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	45.35	UD_R35	C	0.08	351	2.00
1676	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	112.78	UD_R354	C	0.19	874	2.00
1677	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	239.23	UD_R355	C	0.41	1,854	2.00
502	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	54.52	UD_R359	C	0.09	422	2.00
519	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	118.53	UD_R36	C	0.20	918	2.00
503	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	5.83	UD_R360	C	0.01	45	2.00
506	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	71.78	UD_R361	C	0.12	556	2.00
507	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	71.48	UD_R362	C	0.12	554	2.00
520	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	56.86	UD_R37	C	0.10	441	2.00
521	0	No tree cover on either side	Montgomery	Upper Dublin Township	115.33	UD_R38	C	0.40	1,787	2.00
522	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	101.41	UD_R39	C	0.17	786	2.00
523	0	No tree cover on either side	Montgomery	Upper Dublin Township	127.29	UD_R40	C	0.44	1,972	2.00
524	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	185.39	UD_R41	C	0.32	1,436	2.00

Appendix D: Ambler Area Riparian Repair Sites:

Riparian ID	Stream Type	Coverage	County	Municipality	New_Len_Ft	New Riparian ID	Zone	Area (Acres)	Cost ($)	Rank Score
525	0	No tree cover on either side	Montgomery	Upper Dublin Township	79.35	UD_R42	C	0.27	1,230	2.00
526	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	58.03	UD_R43	C	0.10	450	2.00
527	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	69.02	UD_R44	C	0.12	535	2.00
528	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	77.74	UD_R45	C	0.13	602	2.00
529	0	No tree cover on either side	Montgomery	Upper Dublin Township	48.15	UD_R46	C	0.17	746	2.00
530	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	149.22	UD_R47	C	0.26	1,156	2.00
531	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	114.88	UD_R48	C	0.20	890	2.00
532	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	118.15	UD_R49	C	0.20	915	2.00
533	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	183.49	UD_R50	C	0.32	1,422	2.00
534	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	21.93	UD_R51	C	0.04	170	2.00
535	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	59.19	UD_R52	C	0.10	459	2.00
536	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	68.30	UD_R53	C	0.12	529	2.00
537	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	67.66	UD_R54	C	0.12	524	2.00
538	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	72.61	UD_R55	C	0.13	563	2.00
539	0	No tree cover on either side	Montgomery	Upper Dublin Township	118.32	UD_R56	C	0.41	1,834	2.00
540	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	77.40	UD_R57	C	0.13	600	2.00
541	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	75.62	UD_R58	C	0.13	586	2.00

Appendix D: Ambler Area Riparian Repair Sites:

Riparian ID	Stream Type	Coverage	County	Municipality	New_Len_Ft	New Riparian ID	Zone	Area (Acres)	Cost ($)	Rank Score
542	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	65.05	UD_R59	C	0.11	504	2.00
543	0	No tree cover on either side	Montgomery	Upper Dublin Township	334.07	UD_R60	C	1.15	5,177	2.00
544	0	No tree cover on either side	Montgomery	Upper Dublin Township	49.83	UD_R61	C	0.17	772	2.00
545	0	No tree cover on either side	Montgomery	Upper Dublin Township	88.95	UD_R62	C	0.31	1,378	2.00
546	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	99.51	UD_R63	C	0.17	771	2.00
547	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	69.88	UD_R64	C	0.12	541	2.00
548	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	133.23	UD_R65	C	0.23	1,032	2.00
549	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	33.17	UD_R66	C	0.06	257	2.00
550	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	78.80	UD_R67	C	0.14	611	2.00
551	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	173.26	UD_R68	C	0.30	1,342	2.00
552	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	86.96	UD_R69	C	0.15	674	2.00
553	0	No tree cover on either side	Montgomery	Upper Dublin Township	221.15	UD_R70	C	0.76	3,427	2.00
554	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	127.82	UD_R71	C	0.22	990	2.00
555	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	137.49	UD_R72	C	0.24	1,065	2.00
556	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	108.22	UD_R73	C	0.19	838	2.00
557	0	No tree cover on either side	Montgomery	Upper Dublin Township	78.52	UD_R74	C	0.27	1,217	2.00
565	0	No tree cover on either side	Montgomery	Upper Dublin Township	195.76	UD_R75	C	0.67	3,033	2.00

Appendix D: Ambler Area Riparian Repair Sites:

Riparian ID	Stream Type	Coverage	County	Municipality	New_Len_Ft	New Riparian ID	Zone	Area (Acres)	Cost ($)	Rank Score
566	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	66.86	UD_R76	C	0.12	518	2.00
567	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	42.40	UD_R77	C	0.07	329	2.00
568	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	162.75	UD_R78	C	0.28	1,261	2.00
569	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	43.89	UD_R79	C	0.08	340	2.00
570	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	32.25	UD_R80	C	0.06	250	2.00
571	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	46.93	UD_R81	C	0.08	364	2.00
572	0	No tree cover on either side	Montgomery	Upper Dublin Township	100.57	UD_R82	C	0.35	1,558	2.00
573	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	277.84	UD_R83	C	0.48	2,153	2.00
574	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	117.45	UD_R84	C	0.20	910	2.00
575	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	68.90	UD_R85	C	0.12	534	2.00
576	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	40.24	UD_R86	C	0.07	312	2.00
577	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	75.64	UD_R87	C	0.13	586	2.00
578	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	87.59	UD_R88	C	0.15	679	2.00
579	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	191.22	UD_R89	C	0.33	1,482	2.00
580	0	No tree cover on either side	Montgomery	Upper Dublin Township	170.33	UD_R90	C	0.59	2,639	2.00
581	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	79.71	UD_R91	C	0.14	618	2.00
582	0	No tree cover on either side	Montgomery	Upper Dublin Township	28.35	UD_R92	C	0.10	439	2.00

Appendix D: Ambler Area Riparian Repair Sites:

Riparian ID	Stream Type	Coverage	County	Municipality	New_Len_Ft	New Riparian ID	Zone	Area (Acres)	Cost ($)	Rank Score
583	0	No tree cover on either side	Montgomery	Upper Dublin Township	59.05	UD_R93	C	0.20	915	2.00
584	0	No tree cover on either side	Montgomery	Upper Dublin Township	81.26	UD_R94	C	0.28	1,259	2.00
585	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	60.98	UD_R95	C	0.10	472	2.00
586	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	63.52	UD_R96	C	0.11	492	2.00
587	1	Tree cover on 1 side	Montgomery	Upper Dublin Township	37.30	UD_R97	C	0.06	289	2.00
74	0	No tree cover on either side	Montgomery	Whitpain Township	801.23	WP_R10	C	2.76	12,416	2.00
75	0	No tree cover on either side	Montgomery	Whitpain Township	54.05	WP_R11	C	0.19	838	2.00
76	0	No tree cover on either side	Montgomery	Whitpain Township	101.02	WP_R12	C	0.35	1,565	2.00
465	0	No tree cover on either side	Montgomery	Whitpain Township	27.97	WP_R16	C	0.10	433	2.00
466	0	No tree cover on either side	Montgomery	Whitpain Township	49.95	WP_R17	C	0.17	774	2.00
467	1	Tree cover on 1 side	Montgomery	Whitpain Township	56.90	WP_R18	C	0.10	441	2.00

Appendix E: Ambler Area Watersheds Report Comments and Questions

The Project Team notified the community residents, business owners, and other stakeholders on October 16, 2014 about a public presentation of study results scheduled for November 12, 2014 from 7 to 9 pm at the First Presbyterian Church of Ambler. Flyers were distributed to local municipalities and posted on the project's web page (amblerwatersheds.wordpress.com). The draft final report was posted to the web page on October 27, 2014 and was distributed to Ambler Borough, Upper Dublin Township, and Whitpain Township. The comment period was open until November 24, 2014.

Comments, questions and concerns received about the study are presented below. These represent both comments raised at the public presentation and those sent via email following the meeting. The Project Team received two general types of comments: 1) informational and 2) concerns and suggestions.

1) Informational:
The informational comments were both general and study-specific. The general comments included questions regarding terminology (i.e., daylighting, floodplains), funding/implementation/timing, stormwater ordinances, and proposed developments in the area.

The study-specific comments mentioned were questions about details of the stormwater management projects and explanations of the floodplain changes.

At the public meeting, a resident questioned why most of the properties being removed from the floodplains after the stormwater measures were commercial and not residential.

Several residents posed questions about plans for the development of a four-house subdivision in the Rose Valley Creek watershed and whether the study considered these plans.

2) Concerns and Suggestions:
The concerns and suggestions received can be broken into three primary categories: a) floodplains, b) stormwater management projects, and c) miscellaneous.

a) Floodplains:
Comments about the floodplains were primarily concerns and/or opposition about individual properties being included in the preliminary floodplains. One resident wrote:

> *"My property is in Upper Dublin Township, and having lived in the house during Irene 2011 and Lee 2011, I feel I understand the impact of large rain events. From memory, Hurricane Irene didn't cause flooding for my creek even though this was considered a 100-yr. storm. Tropical Storm Lee packed a bigger punch because of the saturated soil and fallen branches from Hurricane Irene. At one point Tropical Storm Lee dropped almost 8 [inches] of rain in an hour followed by up to an inch an hour for the next several hours. This overloaded all the nearby basins, culverts and bridges. Even then, I remember that the flooding lasted only 6 hours. During the worst of the storm the creek was actually flowing over Susquehanna Rd and Willow Ave -- I couldn't sleep. However,*

throughout the entire storm my house and garage were not underwater; my biggest concern was losing power and the basement sump pump stopping. Your Study Map shows my garage as being a flood risk and that is not the case. The inclusion of my garage as being in a 100 yr flood plain is inaccurate and damaging to my property value and my interests for improving my property and neighborhood. I am concerned about the implication that any part of my house is in the Zone A flood plain... I believe the current Zone X designation is more accurate. I would be glad to discuss this further and understand how to have the maps edited to more accurately show the risk level for my property.

In addition, I would also like to get more information about some of the proposed improvements that directly impact my property. The proposed riparian buffer improvements Upper Dublin IDs 500 and 501 are in front of my house. The basins LG_34 and UD_123A are just upstream from my house and both discharge into my creek. Lastly, I would like to understand how to submit additional ideas/proposals for improvements for my yard and creek"

Another wrote:

"I have read your comprehensive proposal on floodplain areas in the Ambler area and am very concerned that you have included my entire house and the house next door uphill in this report as categorized as floodplain. I have been very involved with Upper Dublin Township in recent years over concerns with overtopping of the Loch Alsh dam which runs too much water downhill past my property. A few years ago I gave them about 20 feet of front of my property to build a culvert underground to carry the water downhill past my property. No water ever flooded my property and remained there in a flat floodplain. Most seems to be resolved with this culvert being built however my concern is that you have included my house in Upper Dublin Township and the house next door and further uphill in your report as a flood plain. My house cannot be considered a floodplain by definition, nor can my uphill neighbors. We are on the downslope and our topography is not flat, nor is it formed of depositional material derived from sediments being transported downstream. The water flows under Farm Lane and a few feet under the front of my property when loch Alsh dam floods, but all water flows downhill past my property towards and under Highland Avenue. The sloping from uphill continues rather steeply past and below my property. I hope we can discuss this as I do not want my house listed in a floodplain. It's simply not correct. Perhaps a small sliver at the bottom of my property downhill could be considered where I have given easement to the township for the culvert. My home has never been flooded. My basement only once in all of these storms the past ten years has gotten six inches of water."

<u>b) Stormwater Management Projects:</u>
The second type of concerns and suggestions the Project Team received were in regards to the specific stormwater management projects proposed in the study. Residents questioned why certain areas and projects were or were not included and offered ideas for other projects to be considered.

Several residents questioned why some project sites were chosen over others, particularly in regards to the SEPTA bridge:

Rather than enlarge the culvert at Orange Street, why wasn't the culvert at the SEPTA bridge included (the one near Church and Main Streets)? There are major problems with flooding here. Is there funding available for this?

"Slide #57 [of the final presentation] indicates the total cost of all the channel widenings and bridge replacements to be about $5 million. But what about starting with just replacing the culvert under the SEPTA tracks with a bigger culvert or turning it into a deck bridge? I know from watching several of our major floods that that SEPTA culvert is the single biggest bottleneck for the creek during these high-flow events. Allowing a greater volume of water to get under the SEPTA tracks is the single biggest thing that would help alleviate our flooding problems. The creek will probably still overflow the culvert that runs under the alley behind our homes between Ambler Rd. and Main St., but at least it would stay in the alley and would only end up on the road briefly where it crosses Main St. and Church St., rather than piling up 2-3 feet of water in all of our yards (and thence into our basements!). It's the bottleneck at the SEPTA tracks that causes the water to start backing up into our yards.

Slide #38 [of the final presentation] recommends enlarging the culvert under the SEPTA tracks near the intersection of Main St. and Orange Ave. and estimates the cost at $1 million. Couldn't we also replace the culvert at Main St. and Church St. for another $1 million, and see if that solves the problem, rather than assuming that all $5 million worth of the studied improvements would be necessary? In fact, it looks from your slides that the culvert under the tracks near Church St. wouldn't need to be as long as the one near Orange Ave., so maybe it wouldn't even be as expensive? Isn't this option worth considering?"

Multiple residents proposed the possibilities of projects in Ambler Borough Park:

Would dredging some of the ponds help with flooding issues in Ambler? Particularly in the Rose Valley Creek watershed?

Would a detention basin in Ambler Park help with flooding issues in Ambler? [A suggestion to expand the existing detention basins.]

"Should the park be returned to a mowed grassy area leaving the thriving trees in place?
Should the Borough add funds into the 2015 budget for the Lawn Rangers to follow the Borough Park Maintenance Plan so that the riparian buffer can be left as natural as possible?
Should the park be converted into a retention basin to hold back flood waters from downstream properties and the Wissahickon Creek?"

One resident asked several specific questions about the Loch Linden dam:

"You may have heard that the St. Mary's Villa site in UDT [Upper Dublin Township] is going to be developed with Senior Independent Housing Apartments, Condos, twins and townhomes. Additionally, you may learned that DEP wants the Class II Loch Linden dam upgraded or removed due to its condition. It has been proposed that the lake be taken off-line and the original stream bed re-established. The portion of the lake to remain would function as a detention basin. I see your draft report recommends converting the lake to a wetland detention area. Not certain how this would fly politically, but the old dam remains a concern under this scenario. That said, I'm concerned about the loss attenuation if the lake is taken off-line. Also, not your standard analysis with the upstream Loch Alsh dam.
Any thoughts or ideas that you may have?

Is the reservoir sediment clean? Is there a way to design it such that it wouldn't be a class II dam?

Do you know the drainage area to Loch Linden? Do any of your design storms actually top the Loch Linden berm?

I couldn't attend last Wednesday's Ambler meeting, but did take a quick look at the report today. The proposal for Loch Linden and potential storage was significant as based on the dredging/wetland concept. However; elimination of any permanent water body might be a problem with the neighbors and a Class C2 dam would still be required, albeit at a new and better location. However; given the potential for floodwater storage, I'm not suggesting the idea be removed from the report as it has real merit. Additionally, based on Rick Fromuth's response that the current Loch Linden Lake/Dam retains floodwaters from a 100 year event without overtopping the berm, the existing dam/lake are a critical component of the area's current storm water management system. A lot of hydraulic/hydrologic analyses will be required before anyone can ascertain what is actually feasible. As we all know, UDT, DEP and the developer cannot increase the downstream flooding situation. This is well beyond your study and will be a requirement for the Developer. The 260 acre drainage area to Loch Linden is very significant and any loss of existing attenuation will not be readily made up elsewhere."

Another resident posed a question regarding upstream improvements:

"It would be very helpful to emphasize the balance between doing upstream improvements for more detention/retention/infiltration before or as the engineering solutions are implemented. We all know there is not money to do all and certainly not at once. Your comment about the small amount achievable upstream makes me think they will never be balanced, and out of balance there could be an increase into the Creek.
Are there other options upstream to accomplish more? When we worked on the Open Space Plan I recall a few large properties just downstream of Rt. 309 and north of the Butler/Susquehanna intersection where additional detention was possible if some of that land was developed or acquired for detention and open space. Was that one of the sites considered (or could it be) understanding it is now private land. I have attached the map showing the properties #39 and 40."

At the public meeting, a resident questioned whether certain projects upstream would slow the water coming into Ambler (i.e. dredging three ponds in Rose Valley Creek, a detention basin in Ambler Borough Park).

c) Miscellaneous:
The last type of concerns and suggestions the Project Team received was of miscellaneous topics including flood insurance/FEMA and asbestos site questions.

There were several questions related to FEMA flood insurance and whether the preliminary floodplains needed to be adopted before the projects are implemented:

I have had experience with FEMA flood insurance and have some tips and realities regarding the process and insurance. Firstly, they do not work and are not appropriate for this area (as opposed to coastal areas, for example). Now I am required by FEMA to purchase insurance, but a lot of things are not covered. This also restricts what I can do with my property, and zoning ordinances are now required for very minor adjustments on my property. Would it possible to do the remapping of the floodplains after the implementation of the recommendations?

Can the projects be constructed before the floodplain revisions are accepted?

Once their properties are included in the revised floodplains, are they able to afford the cost of the flood insurance or flood damage?

If they live in a high-risk flood area, and are now required to get insurance, they will actually be able to get the flood insurance (because they are having problems getting the insurance currently, per the respondent), so this is a win-win situation.

With FEMA flood insurance, is the basement covered? And items/appliances in the basement?

If we take measures to waterproof the basement, do flood insurance premiums get reduced? How will this affect the rating of the property?

One resident posed several concerns and alternatives involving the BoRit and Ambler asbestos sites:

"West Ambler is mentioned several times regarding the flooding, asbestos, air quality issues, etc. These conditions also exist for South Ambler regarding the Ambler Asbestos Piles and should be mentioned. Ambler Asbestos Piles are not mentioned and are in the study area.

The study states that Orange Ave and Main St flooding is suspected to increase. Does the Ambler Asbestos Piles Superfund site impact the drainage at this location?

For [recommended] Site 1 - acquisition of property is a huge concern. For [recommended] Site 3- the recommendation of a larger storm water pipe has the pipe going into the Ambler Asbestos Superfund site, looks like the old filter bed lagoon. Who would be responsible for placing and maintaining it if we were to implement this option? And could any alteration of the Superfund actual cause or increase instability of the remedy and containment of the toxic waste? For site 4- Is the Ambler Asbestos Piles Superfund just as impacted by the Wissahickon creek and Stuart Farm creeks as BoRit and why is this not mentioned?

Finally the Ambler Asbestos Piles Superfund site is in the study area but unfortunately has not been included. They are contributing to the flooding of this area as much as the BoRit Asbestos Superfund site. The Ambler Asbestos Piles and the BoRit Asbestos Superfund site are disposed of factory waste in what used to be the original flood plain and watershed of the Wissahickon creek. The piles take up 78 acres of much needed natural creek spill ways and marshlands that once served well in keeping flooding problems at bay in the Ambler Study Area. Trying to maintain these toxic waste dumps in the Wissahickon creek's natural flood plain has been a lesson in futility since both asbestos superfund sites are greatly impacted by the flooding of the Rose Valley, Tannery Run, Stuart Farm and the Wissahickon creeks, according to the USEPA's documents of the sites.

Removing the asbestos piles from the Wissahickon Creek flood plain will widen the water channels and allow the flood waters to spill into lands that nature intended and man has wrongfully impeded. This will relieve the pressure from high water flooding which prevents the smaller streams from emptying naturally into the larger Wissahickon during heavy storms. Simply unclogging the clogged up water ways caused by the narrowing of the channels that the asbestos piles caused will relieve an *enormous amount of flooding problems. This will also relieve the pollution problem as well, solving 2 economic drains with one solution!!! Removing the asbestos dumps will free up over 70 acre feet of much needed lands for flood waters, re-establish the natural banks of the Wissahickon, Tannery Run, Rose Valley and Stuart Farm Creeks, re-establish natural flora and fauna, re-establish more well needed open space for recreation and solve a 100 year old pollution problem."*

Response:
All of the original comments, concerns, and questions received were compiled into a single document, and delivered to the municipal officials. The following message was sent out to everyone who commented on the study report.

> *Thank you for your comments regarding the Ambler Area Watersheds study – we greatly appreciate your feedback. Following your suggestions, we will make minor changes and fix any typos in the final version of the report. All responses we received will be included in the study's appendix. Additionally, all comments and concerns will be forwarded to the respective township officials.*
>
> *We have reviewed all the recommendations we received, and want to thank you for your suggestions. There are far more sites appropriate for reducing flooding than were included in our report, but we will be sending your suggestions to the respective township officials.*
>
> *The scope of the study does not allow the Temple research team to address individual property concerns. Please be advised that these floodplains are preliminary, and there is a set of processes in place that will allow for public input before they are accepted by FEMA (anticipated 2016).*
>
> *Thank you again for your feedback on the study.*

The Project Team made the following changes to the Draft Report:

- Addition of Option 5 under the Rose Valley channelization project
- Addition of two site-specific recommendations, based on suggestions received from residents
- Two new 3-D renderings
- The following clarification: "The Project Team recommends the site-specific projects only if the water released would be compensated with upstream storage or infiltration."