Paxton Creek North Subwatershed Restoration Plan

Produced by the Center for Watershed Protection
for the Paxton Creek Watershed and Education
Association

Funded by the National Fish and Wildlife
Foundation and the Canaan Valley Institute

Center for Watershed Protection

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Executive Summary

Paxton Creek is a tributary to the Susquehanna River and is located in Dauphin County on the outskirts of the City of Harrisburg, Pennsylvania. The Paxton Creek Watershed is approximately 27 square miles and the majority of the watershed falls within the jurisdiction of three municipalities: Susquehanna Township, Lower Paxton Township, and the City of Harrisburg. Penbrook Borough has jurisdiction over a very small portion of the watershed. The watershed is bound to the north by the Blue Mountains, to the west by the Susquehanna River, and to the south by the City of Harrisburg (Figure E-1).

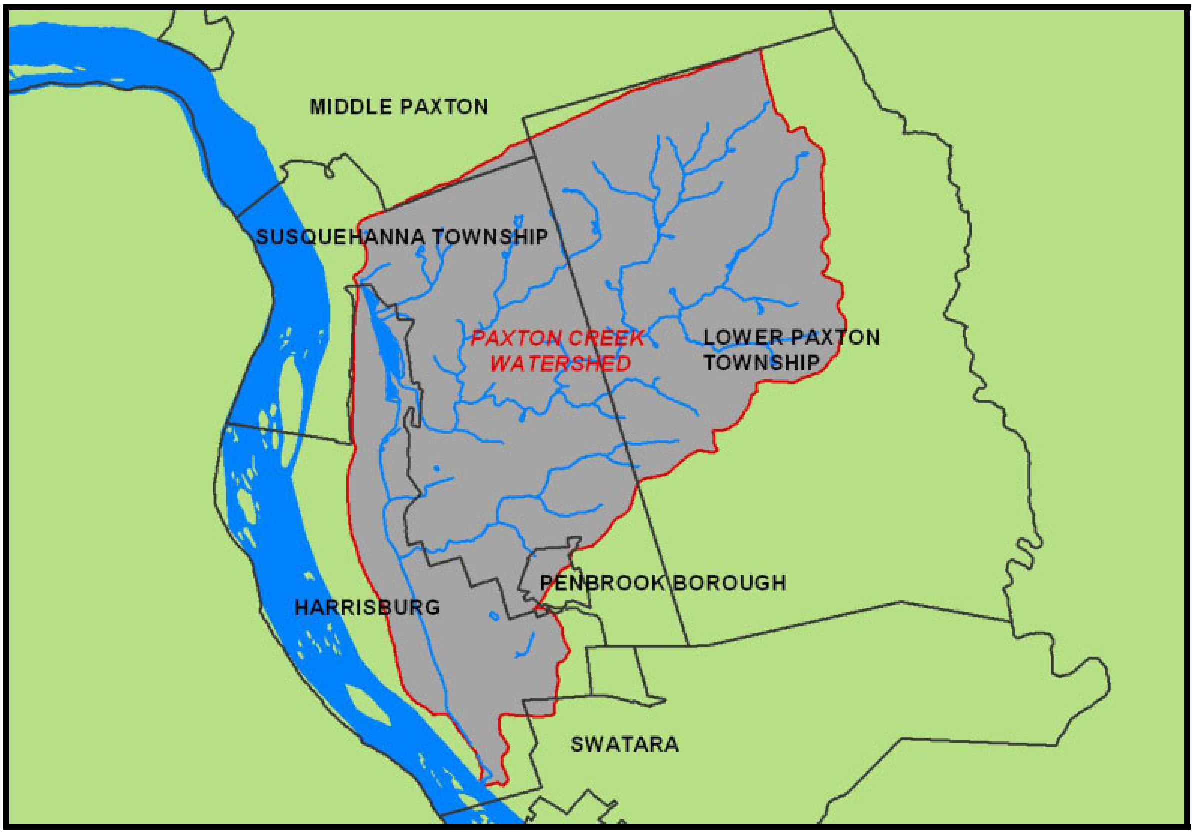


Figure E-1 - Paxton Creek Watershed

One of the recommendations of the 2003 *Paxton Creek Baseline and Stormwater Retrofit Assessment* was to develop a detailed management plan for one subwatershed in the Paxton Creek Watershed (CWP, 2003). The Paxton Creek Watershed and Education Association (PCWEA), the Center for Watershed Protection (CWP) and the Canaan Valley Institute (CVI) jointly selected the Paxton Creek North subwatershed for further detailed assessment because it is one of the least developed subwatersheds in Paxton Creek; therefore, the potential still exists to protect its streams from future degradation (Figure E-2). Studying and assessing at the subwatershed level allows for a more thorough understanding of the entire watershed and enhances the ability to craft restoration strategies based on local stream conditions. This project was conducted with funding from both CVI and the National Fish and Wildlife Foundation (NFWF).

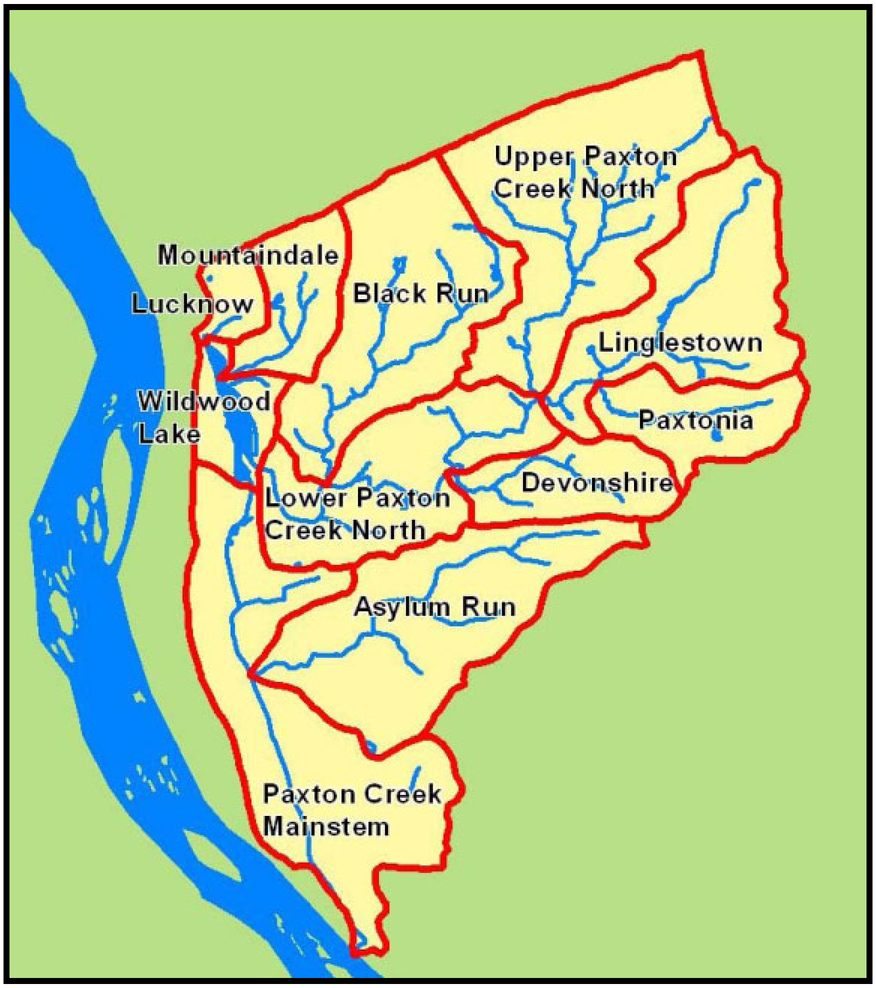


Figure E-2 - Paxton Creek Subwatersheds

The scope of this project included the following tasks:

1. Divide the boundaries for Paxton Creek North into Upper Paxton Creek North and Lower Paxton Creek North
2. Review existing subwatershed monitoring data
3. Conduct stream and upland assessments in Upper Paxton Creek North and Lower Paxton Creek North
4. Create educational materials for PCWEA to use for education and outreach in the watershed
5. Conduct local stakeholder meetings to gain input on subwatershed goals and specific restoration projects and to generate interest in project implementation
6. Develop a subwatershed restoration plan for the Paxton Creek North subwatersheds that outlines recommendations, identifies priority projects, and includes conceptual designs and a subwatershed monitoring plan.

The Paxton Creek North (PCN) subwatershed is comprised of the mainstem of Paxton Creek as it extends from Wildwood Lake up through Susquehanna and Lower Paxton Townships to the headwaters on Blue Mountain. This subwatershed covers approximately 7.4 square miles. Because the upper and lower sections of this subwatershed are fairly distinct, and to simplify assessment procedures, this subwatershed was re-delineated into the Upper PCN and Lower PCN.

The Upper PCN subwatershed covers 4.6 square miles from Blue Mountain down to the confluence of the Paxton Creek mainstem with the Linglestown tributary. The upper reaches of this subwatershed on the mountain are forested with low and medium-density residential development and some industrial and commercial development further down in the subwatershed. Current impervious cover is 14% and future impervious cover is projected to be in the range of 22 to 34%.

The Lower PCN subwatershed is 2.8 square miles in area and continues from the Linglestown tributary confluence all the way down to Wildwood Lake. This subwatershed contains low and medium density residential development as well as commercial and industrial land. Interstate 81 and a portion of State Highway 22 cross through Lower PCN, bringing the current impervious cover up to 25%. Future impervious cover is projected to be in the range of 44 to 54%.

A review of existing monitoring data for PCN included hydrologic, biological, water quality and geomorphologic data. Despite limited data availability, there was a general pattern of decreasing stream quality from upstream to downstream locations in the PCN subwatersheds, indicated by a decline in the macroinvertebrate community and an increase in concentrations of various pollutants.

Desktop methods used for this project included subwatershed delineation and an impervious cover analysis of Paxton Creek North. Methods used to involve stakeholders included the creation and distribution of educational brochures and slideshows as well as conducting two public meetings to gain stakeholder input.

Field methods included spending four days conducting stream and subwatershed assessments of the Upper and Lower PCN subwatersheds. Protocols used included the Unified Stream Assessment (USA), the Unified Subwatershed and Site Reconnaissance (USSR) and a stormwater retrofit inventory. The first tool, the USA, is a comprehensive stream walk protocol for evaluating the physical, riparian and floodplain conditions in small urban watersheds. The second tool, the USSR, is a field survey to evaluate potential subwatershed pollution sources and restoration opportunities in areas outside the stream corridor. Together, the stream and subwatershed methods allowed CWP to identify a number of pollution source control, on-site stormwater retrofits, riparian reforestation, stream restoration, discharge prevention and upland reforestation projects within the subwatersheds.

Common observations in the field included a lack of forested stream buffers, particularly in residential neighborhoods (Figure E-3), significant deposits of sediment in the stream in the lower portion of the subwatershed (Figure E-4), and little management of stormwater runoff from existing developments (Figure E-5).

Figure E-3 - Backyard stream in need of a buffer in Upper PCN

Figure E-4 - Sedimentation in Lower PCN

Figure E-5 - Large expanse of pavement drains untreated to the storm drain in Upper PCN

After compiling the results of the PCN stream and subwatershed surveys, CWP staff were able to identify 51 potential restoration projects within the PCN subwatershed. Due to the limited resources typically available for implementation, restoration projects identified in PCN were evaluated based on a set of criteria to identify priority projects to pursue for implementation. Based on these criteria, CWP selected 14 priority restoration projects depicted in Figure E-6 and described in Table E-1 (large-scale projects) and Table E-2 (small-scale projects).

Figure E-6 - PCN priority restoration projects

Table E-1. Large-Scale Priority Restoration Projects in PCN

Project	Project Type (s)	Area Treated (acres)	Stream Length Restored (ft)	Reason for Prioritizing	Planning -Level Cost Estimate
1. Centennial Acres	Stormwater Retrofit Stream Restoration Riparian Reforestation Better Site Design	5	1000	• Headwater location • Multiple components • Downstream of site slated for development • Identified as priority by Skelly and Loy	$100,000
2. Fairfax Village North	Stormwater Retrofit Riparian Reforestation Stream Restoration Trash Cleanup	1	800	• Headwater location • Multiple components • Meets multiple subwatershed goals	$50,000
3. Honey Bee Golf Center	Stormwater Retrofits Riparian Reforestation	2	600	• Multiple components • Highly visible, high-use location • Headwater location	$50,000
4. Vartan Property	Stormwater Retrofits	2+	N/A	• Treats large area • Runoff is causing erosion downstream • Multiple components	$50,000 - $75,000

Planning-level costs estimates are based on best professional judgment and average costs for local similar types of projects. More specific estimates are not feasible without additional information on precise drainage area and impervious cover, location of utilities and permitting required.

Table E-2. Small-Scale Priority Restoration Projects in PCN					
Project	**Project Type (s)**	**Area Treated (acres)**	**Stream Length Restored (ft)**	**Reason for Prioritizing**	**Planning -Level Cost Estimate**
1. Forest Hills	Riparian Reforestation	1.4 –2	600-1000	• Headwater location • Simple project • Land is likely owned by one entity (HOA)	$3,000
2. Centennial Acres Park	Stormwater Retrofit Upland Reforestation	0.4 -3	N/A	• Headwater location • Public land • Multiple components • Simple projects	$5,000
3. Davis Landscaping	Stormwater Retrofit	TBD	N/A	• Willing landowner • Runoff is causing downstream erosion	$5,000 - $10,000
4. 3B Ice Cream	Stormwater Retrofit	2.25	N/A	• Headwater location • Simple project • Identified as priority in previous retrofit inventory	$5,000
5. State Police Headquarters	Stormwater Retrofit	TBD	N/A	• Public land • Good access	$15,000
6. Salvation Army	Stormwater Retrofit	0.7	N/A	• Good access • Simple project	$15,000
7. Londonderry School	Stormwater Retrofit	0.25	N/A	• Educational value • Simple project • Willing landowner likely	$5,000
8. Doehne Road	Riparian Reforestation	0.7	600	• Simple project • Identified as priority by Skelly and Loy	$5,000
9. Paxton Crossing	Stream Restoration	NA	300-500	• Active erosion of utility • Land is likely owned by one entity (HOA) • Simple project	$10,000
10. Glaser Property	Stream Restoration	NA	300	• Willing landowner • Simple project	$2,000 - $3,000

Planning-level costs estimates for stormwater retrofits are based on best professional judgment and average costs for local similar types of projects. Assumptions for riparian reforestation costs include: trees planted on ten foot spacing using small container stock at $5 per tree (from Octorara Nursery) and planted by volunteers .

Figure E-7 depicts the highest priority large-scale restoration project, located at Centennial Acres. This project entails reforesting the stream buffer and creating a stormwater wetland complex to treat runoff from the nearby development. Figure E-8 depicts the highest priority small-scale restoration project, located at Forest Hills. This is a simple stream buffer planting project and is located in the headwaters of Upper PCN.

Figure E-7. Location for a wetland creation/enhancement project at Centennial Acres

Figure E-8. Buffer planting site at Forest Hills

An important element of watershed planning is to set goals and recommendations for both the overall watershed and the individual subwatersheds evaluated. Subwatershed goals and recommendations were developed for the PCN subwatersheds that built upon previous recommendations made in the 2003 *Paxton Creek Baseline and Stormwater Retrofit Assessment*, input from local stakeholders during public meetings, and observations made during the stream and subwatershed assessments in PCN. The eleven subwatershed goals are listed below.

1. Expand green space/recreational opportunities.

2. Increase understanding and awareness of watershed issues.

3. Improve private stewardship of the land.

4. Maintain good macroinvertebrate habitat.

5. Conserve remaining tracts of contiguous forest.

6. Expand riparian forest cover to form a continuous network of stream buffers.

7. Establish partnerships to actively pursue implementation of restoration projects.

8. Reduce sediment inputs to Paxton Creek North and Wildwood Lake.

9. Minimize impacts of future growth on stream health.

10. Reduce the volume of stormwater runoff from developed land.

11. Reduce pollutant inputs to Paxton Creek North.

Recommendations are a series of concrete actions that can help to achieve the subwatershed goals as well as to identify a timeline and party responsible for implementing these actions. Specific recommendations for PCN are listed in Table E-3 along with a proposed timeline and responsible party.

Table E-3. Paxton Creek North Recommendations			
Recommendations	**Goals Met**	**Timeline**	**Responsible Party/Partners**
1. Adopt an open space or forest conservation ordinance that requires a percentage of green space to be preserved for all new development	1, 5, 9	Short-term	PCWEA, ACB, CBF, Local Municipalities
2. Limit development on steep slopes with the adoption and/or revision of a steep slopes ordinance	1, 5, 8, 9		PCWEA, ACB, CBF, Local Municipalities
3. Develop a public education campaign that improves watershed awareness and targets municipal officials, developers, business owners and residents	2		PCWEA, Local Municipalities
4. Adopt a stream buffer ordinance to protect existing forest buffers for all new development sites	6, 9		PCWEA, ACB, CBF, Local Municipalities
5. Establish a riparian buffer planting program	3, 6		PCWEA, NRCS, CBF, ACB
6. Revise local erosion and sediment control (ESC) ordinances to clearly define acceptable practices and enforcement measures	8, 9		PCWEA, ACB, CBF, Local Municipalities
7. Increase local ESC staff capacity for inspecting and enforcing ESC regulations at construction sites	8, 9		Local Municipalities, DEP, PCWEA, DCCD
8. Implement small-scale priority restoration projects in PCN.	10		PCWEA
9. Directly contact landowners of potential restoration sites to discuss possible project implementation	3	Mid-term	PCWEA
10. Establish a program to conduct regular sampling for macroinvertebrates	4		DCCD, SRBC, PCWEA, DEP
11. Conduct a bi-annual State of the Paxton Creek Watershed meeting for local partners	2, 7		PCWEA
12. Modify relevant local codes and ordinances to allow and encourage use of Better Site Design techniques identified through the Paxton Creek Watershed Site Planning Roundtable	9		Local Municipalities, ACB, DEP, PCWEA
13. Implement large scale priority restoration projects in PCN	10		PCWEA, Local Municipalities, DEP, PENNDOT
14. Establish a program to monitor watershed restoration and protection efforts	4, 8, 9, 10, 11		DCCD, SRBC, PCWEA, DEP, HACC
15. Establish a restoration committee to seek funding for implementation of stormwater retrofits and stream restoration projects	7, 8, 10, 11		DCCD, DEP, SRBC, PCWEA, HACC, CBF, ACB, CVI
16. Adopt a stormwater ordinance that requires new development to provide infiltration and recharge of stormwater runoff	9, 11	Long Term	DEP, PCWEA, Local Municipalities
17. Establish a committee to coordinate illicit discharge detection and elimination (IDDE) efforts among the various jurisdictions	7, 11		DEP, PCWEA, Local Municipalities
18. Purchase undeveloped green space for use as a community park or greenway	1, 5		PCWEA, Local Land Trust

Timeline: short-term = 0-1 years, mid-term = 1-3 years, long-term = > 3 years
ACB = Alliance for the Chesapeake Bay, CBF = Chesapeake Bay Foundation, PENNDOT = Pennsylvania Department of Transportation, HACC = Harrisburg Area Community College, CVI = Canaan Valley Institute, NRCS = Natural Resources Conservation Service.

Recommendations were also made for establishing a long-term monitoring program that has a three-fold purpose:

1. To track the number and location of restoration projects and subwatershed recommendations that have been implemented.
2. To conduct post-construction monitoring of structural restoration practices to ensure that they are functioning properly.
3. To measure the effect of restoration efforts on stream health.

Specific monitoring recommendations are summarized in table E-4.

Table E-4. PCN Monitoring Recommendations

PCN Monitoring	Goal
Track the number and location of restoration projects and subwatershed recommendations that have been implemented.	Provide accounting and tracking for restoration efforts
Conduct post-construction monitoring of structural restoration practices	Ensure that restoration practices are functioning properly
Continue to monitor Macro blitz stations on a annual or bi-annual basis	Track long term health in the watershed, measure effect of restoration practices on bug community and water quality
Conduct water quality monitoring upstream and downstream of newly installed restoration practices	Test innovative restoration practices, measure effect of restoration practices on stream health
Use a paired watershed approach to monitor a reach that is being developed as well as a control reach within PCN	Document the impact of traditional or innovative site development on streams

Finally, the methods used to evaluate Paxton Creek North should be applied in another Paxton Creek subwatershed, namely the Asylum Run subwatershed. Data needs that would facilitate this process in Asylum Run include: stormwater infrastructure, illicit discharge monitoring, stormwater treatment practices, and hydrologic modeling.

Section 1: Introduction

1.1 The Paxton Creek Watershed

Paxton Creek is a tributary to the Susquehanna River and is located in Dauphin County on the outskirts of the City of Harrisburg, PA (Figure 1). The Paxton Creek watershed is approximately 27 square miles and the majority of the watershed falls within the jurisdiction of three municipalities: Susquehanna Township, Lower Paxton Township, and the City of Harrisburg. Penbrook Borough has jurisdiction over a very small portion of the watershed. The watershed is bound to the north by the Blue Mountains, to the west by the Susquehanna River, and to the south by the City of Harrisburg. The watershed is divided into upper and lower halves by I-81. Over 63 miles of stream flow from the forested mountain headwaters through a variety of residential, commercial, and industrial land uses. Land use in the upper watershed includes a mixture of low and medium density residential with some commercial and institutional development. The lower portion of the watershed in Harrisburg contains medium and high density residential as well as dense commercial and industrial development along the Susquehanna River. Future residential growth is projected for the forested headwaters.

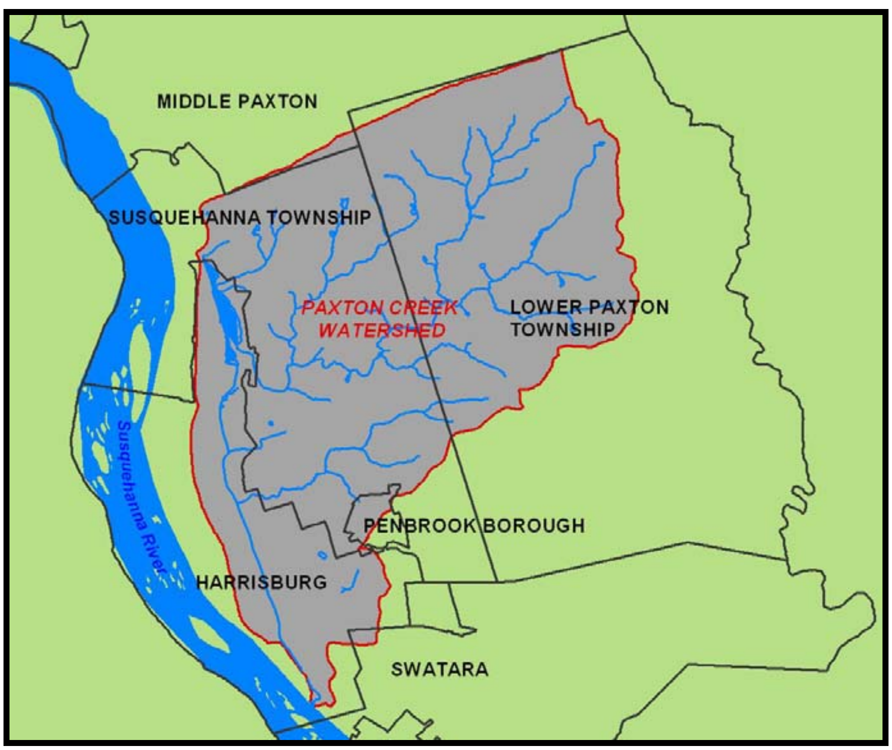


Figure 1. The Paxton Creek Watershed

The Pennsylvania Department of Environmental Protection (DEP) lists 16.5 miles of impaired stream in the Paxton Creek watershed on its 303(d) list. The primary reasons cited for the listing are urban runoff, construction, and storm sewers. The Paxton Creek mainstem is also listed for combined sewer overflows (CSOs) that occur in the City of Harrisburg. Loading rates developed by the SRBC, based on U.S. Geological Survey (USGS) storm event monitoring for portions of the watershed, indicate that Paxton Creek loads are significantly higher for sediment and phosphorus when compared to agricultural and forested watersheds in the basin.

1.2 History of Watershed Work in Paxton Creek

Several efforts have been undertaken over the last five years that begin to address some of the water quality issues in the Paxton Creek watershed. These efforts are described below.

2001 - Formation of the Paxton Creek Watershed and Education Association (PCWEA). The PCWEA was formed in 2001 through funding from a Growing Greener grant to solve watershed problems, protect and enhance watershed resources, and facilitate hands-on environmental education in the Paxton Creek Watershed. PCWEA conducts regular water resource monitoring, organizes rehabilitation projects and other activities, and has conducted stakeholder surveys to identify key watershed issues.

2003 - Paxton Creek Stream Corridor and Watershed Assessment. In 2003, Skelly and Loy conducted an assessment of the Paxton Creek Watershed for the City of Harrisburg to provide baseline information on stream channel conditions in the watershed, to define watershed conditions responsible for channel conditions and to provide preliminary stream corridor conservation or restoration recommendations. Results of this study are summarized in Skelly and Loy (2003).

2003 - Paxton Creek Watershed Local Site Planning Roundtable. Under the Builders for the Bay program (www.buildersforthebay.net) a local site planning roundtable was conducted with Lower Paxton Township and Susquehanna Township, which resulted in a set of 23 principles and recommendations to guide future site development within the watershed. These recommendations are summarized in the Paxton Creek Watershed consensus agreement in Appendix A.

2003 - Paxton Creek Baseline and Stormwater Retrofit Assessment. The Center for Watershed Protection (CWP) partnered with PCWEA to assess and characterize the extent of the urban runoff impacts occurring throughout the watershed by conducting an assessment of baseline conditions and a stormwater retrofit inventory. This study was funded by the Canaan Valley Institute (CVI), and the results are summarized in the *Paxton Creek Baseline and Storm Water Retrofit Assessment* (CWP, 2003).

2003 – Paxton Creek Impervious Cover/Landuse Mapping. CVI developed detailed landuse maps of the Paxton Creek Watershed that included impervious cover estimates. These maps were derived from Ikonos satellite data and were used in both the CWP and Skelly and Loy reports.

2004 - Paxton Creek Watershed "Macroblitz" Sampling. In 2004, an intensive sampling effort was undertaken to study the condition of the instream habitat and water quality within Paxton Creek. The EPA RBP-3 method was used to collect a subsample of 200 macroinvertebrates at 24 sampling sites throughout the Paxton Creek Watershed. This data was collected by Dauphin County Conservation District (DCCD) and other project partners and is discussed in detail in Section 2.

In Progress - Stormwater Management Plan (Act 167) for the Paxton Creek Watershed. Historically, the focus of stormwater management in Pennsylvania has been on flood control; however, new standards require local governments to address other critical issues such as water quality, groundwater recharge, and stream channel protection. To address these new regulations, a new Stormwater Management Plan (Act 167) for the Paxton Creek Watershed is being prepared by Skelly and Loy as an update to the 1991 plan developed by Dauphin County. In addition, an updated flood model for Paxton Creek has been submitted to FEMA. The project is in the initial stages of development and will be completed in 2005.

In Progress – Paxton Creek Rivers Conservation Plan. A draft of the Paxton Creek Rivers Conservation Plan is being prepared by PCWEA and will incorporate suggestions from focus groups and vested interests on stormwater management, education, and recreation/trails. The plan will summarize data for vegetation, impervious surfaces, water chemistry, creek biota, and subwatershed restoration opportunities. A draft of the plan will be available in early 2005.

Other - In addition to the above studies, National Pollutant Discharge Elimination System (NPDES) Phase II assessments are being conducted by the municipalities and coordinated by DCCD. As well, various biological, habitat and water quality assessments have been conducted by the SRBC, USGS, Harrisburg Authority, Pennsylvania Department of Environmental Protection (DEP), Pennsylvania DER and DCCD. This data is discussed in further detail in Section 2.

1.3 Paxton Creek North Subwatershed Restoration Plan

One of the recommendations of the 2003 *Paxton Creek Baseline and Stormwater Retrofit Assessment* was to develop a detailed management plan for one subwatershed in the Paxton Creek Watershed (CWP, 2003). Previous studies (Skelly and Loy, 2003) had delineated the watershed into ten subwatersheds ranging in area from 0.5 to 7.5 square miles (Figure 2). PCWEA, CWP and CVI jointly selected the Paxton Creek North subwatershed for further detailed assessment because it is one of the least developed subwatersheds in Paxton Creek; therefore, the potential still exists to protect its streams from future degradation.

The purpose of this report is to summarize the results of a detailed assessment of the Paxton Creek North Subwatershed, and to present recommendations for its protection and restoration. This project was conducted by CWP with funding from the National Fish and Wildlife Foundation (NFWF) and CVI. For this study, the Paxton Creek North Subwatershed boundary was re-delineated into an upper and lower portion, resulting in 11 subwatersheds in the Paxton Creek Watershed (Figure 3). Conducting the study and assessment at the subwatershed level allows for a more thorough understanding of the entire watershed and enhances the ability to craft restoration strategies based on local stream conditions.

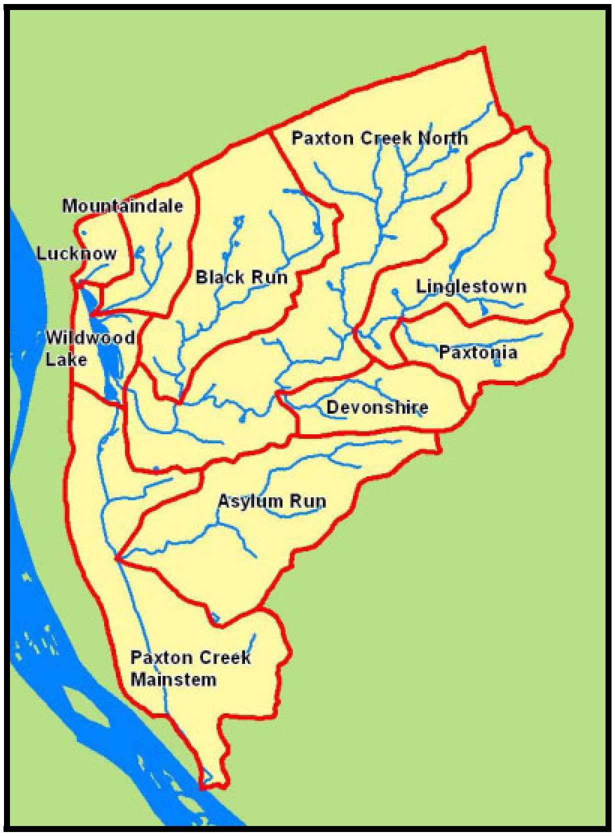


Figure 2. Skelly and Loy's subwatershed delineation for Paxton Creek

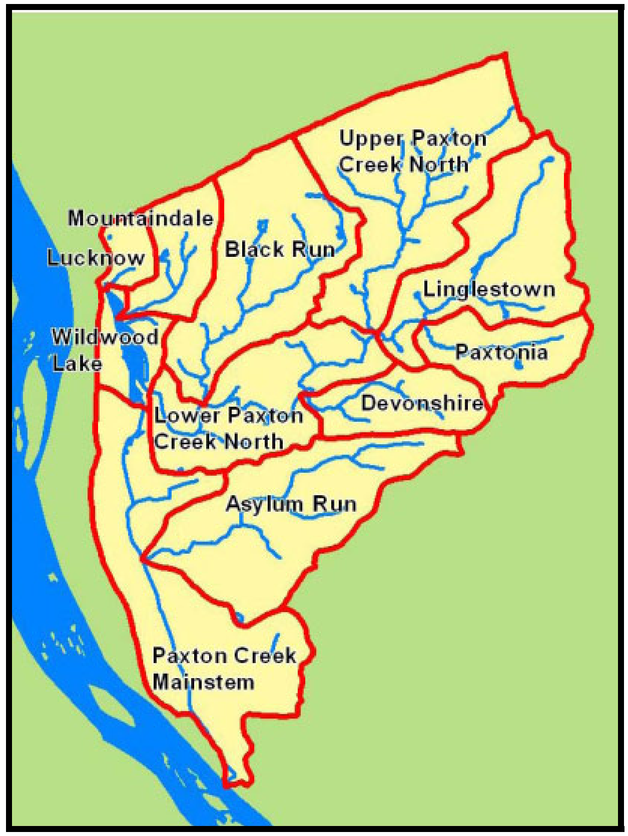


Figure 3. Re-delineation of Paxton Creek subwatersheds

The scope of this project included the following tasks:

1. Divide the boundaries for Paxton Creek North (PCN) into Upper Paxton Creek North and Lower Paxton Creek North
2. Review existing subwatershed monitoring data
3. Conduct stream and upland assessments in Upper PCN and Lower PCN
4. Create educational materials for PCWEA to use for and outreach in the watershed
5. Conduct local stakeholder meetings to gain input on subwatershed goals and specific restoration projects and to generate interest in project implementation
6. Develop a subwatershed restoration plan for the Paxton Creek North subwatersheds that outlines recommendations, identifies priority projects, and includes conceptual designs and a subwatershed monitoring plan.

This report summarizes the results of the above tasks, and is organized into the following sections:

Section 2: Paxton Creek North Subwatershed Characterization
Section 3: Methods
Section 4: Results of Stream and Subwatershed Assessments
Section 5: Recommendations

Section 2: Paxton Creek North Subwatershed Characterization

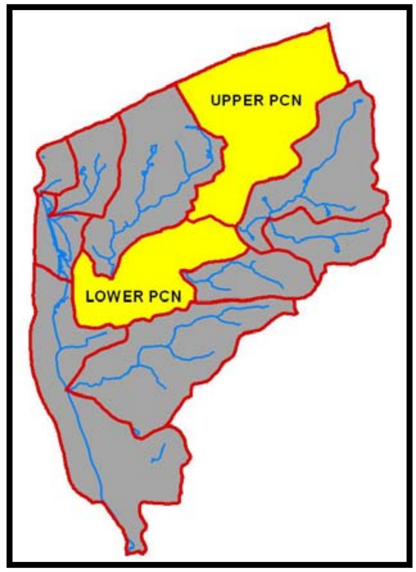


Figure 4. PCN Locator Map

The Paxton Creek North subwatershed is comprised of the mainstem of Paxton Creek as it extends from Wildwood Lake up through Susquehanna and Lower Paxton Townships to the headwaters on Blue Mountain. This subwatershed covers approximately 7.4 square miles. Because the upper and lower sections of this subwatershed are fairly distinct, and to simplify assessment procedures, this subwatershed was re-delineated into the Upper PCN and Lower PCN (Figure 4). Table 1 presents baseline data for the two subwatersheds.

The Upper PCN subwatershed covers 4.6 square miles from Blue Mountain down to the confluence of the Paxton Creek mainstem with the Linglestown tributary. The upper reaches of this subwatershed on the mountain are forested with low and medium-density residential development and some industrial and commercial development further down in the subwatershed. Current impervious cover is 14% and future impervious cover is projected to be in the range of 22 to 34%. Based on the Impervious Cover Model (see text box), this will likely change the management status from Impacted to Non-Supporting given future watershed development.

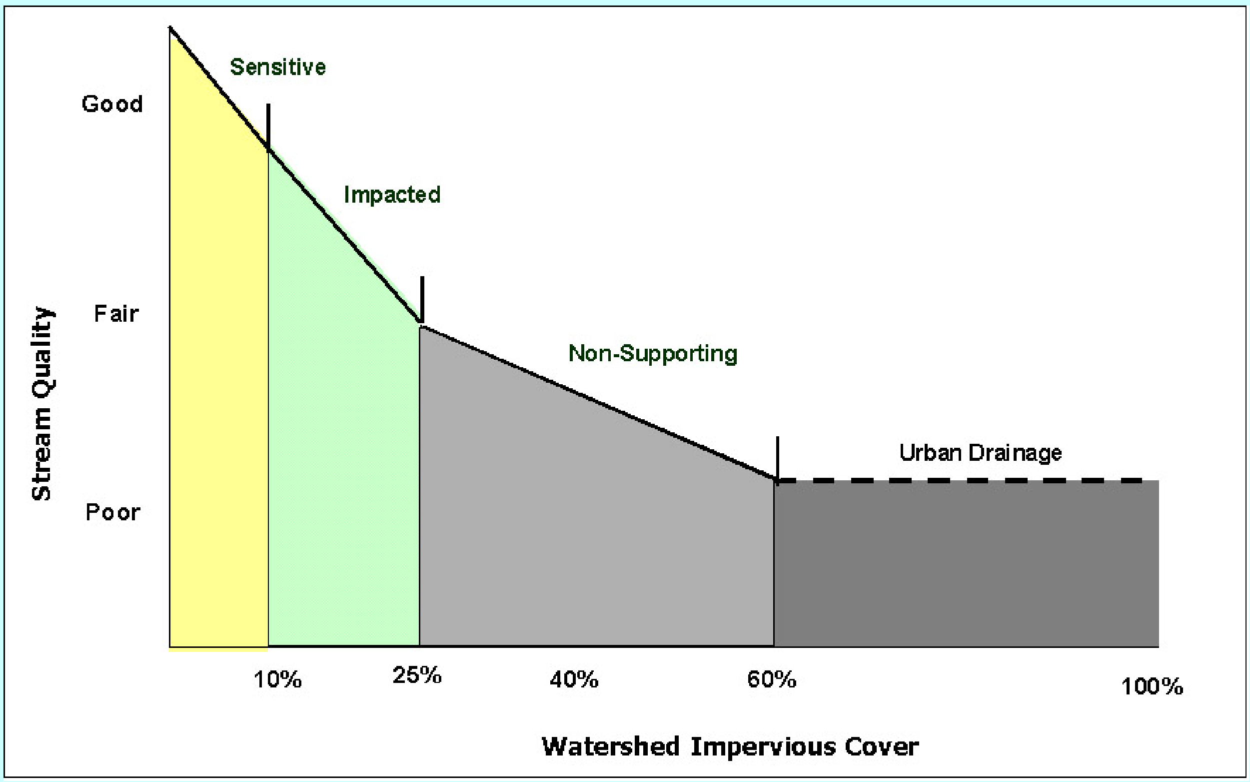
Table 1. Paxton Creek North Subwatershed Data

Subwatershed Metric	Upper Paxton Creek North	Lower Paxton Creek North
Area (square miles)	4.6	2.8
Mapped Stream Miles	11.9	8.2
Miles of Piped Stream	0.4	0.6
% of Streams Piped	3	7
# of Stormwater Treatment Facilities	13	6
# of Stormwater Outfalls	42	31
Density of Stormwater Outfalls (# per stream mile)	3.5	3.8
Current Impervious Cover %	14	25
Current Subwatershed Management Classification	Impacted	Impacted
Future Impervious Cover %	22 to 34	44 to 54
Future Subwatershed Management Classification	Impacted to Non-Supporting	Non-Supporting
Forest Cover %	52	36
Jurisdiction	Mostly within Lower Paxton Twp, small portion in Susquehanna Twp	Mostly in Susquehanna Twp, small portions in Lower Paxton Twp and City of Harrisburg

The Lower PCN subwatershed is 2.8 square miles in area and continues from the Linglestown tributary confluence all the way down to Wildwood Lake. This subwatershed contains low and medium density residential development as well as commercial and industrial land. Interstate 81 and a portion of State Highway 22 cross through Lower PCN, bringing the current impervious cover up to 25%. Future impervious cover is projected to be in the range of 44 to 54%, which will change the management status from Impacted to Non-Supporting with future watershed buildout (see text box).

The Impervious Cover Model

Research has shown that thresholds of impervious cover within a watershed may be used to indicate the degree of water quality impairment. This "impervious cover model" has three categories of impervious cover as it relates to water quality as shown in the figure below. The impervious cover model predicts that most stream quality indicators decline when watershed impervious cover exceeds 10%, with severe degradation expected beyond 25%. Current and future impervious cover for the Paxton Creek North subwatersheds was estimated based on existing land use and impervious cover coefficients (see Appendix B). The ICM is based on several assumptions and caveats and is described in more detail in Appendix B.



2.1 Review of Existing Monitoring Data

Existing monitoring data was reviewed in order to characterize the hydrologic, water quality, biologic and geomorphic conditions in the PCN subwatershed. Table 2 summarizes the data reviewed in this section.

Table 2. PCN Monitoring Data Reviewed	
Type of Data	**Data Source**
Hydrologic	• Peak discharge measurements from 1930-1995 at a USGS gaging station on Paxton Creek near Penbrook. Data obtained from USGS website http://nwis.waterdata.usgs.gov/nwis
Biological	• Macroinvertebrate and habitat data collected in 1997 throughout the Paxton Creek Watershed by the SRBC for the DEP. • Macroinvertebrate and habitat data collected in 2004 by the DCCD and other partners through the Macroblitz sampling study • Macroinvertebrate data collected both recently and historically for State 303(d) listing purposes. Data was collected by the DCCD and Pennsylvania DER, a precursor organization to DEP.
Water Quality	• Surface water samples collected by the SRBC and the USGS for a set of water quality parameters over a two-year period from 1992-1993 (summarized in Takita, 1995). • Water quality grab samples taken by the DCCD and others during the Macroblitz sampling study in 2004 and analyzed for a set of 28 parameters. • Baseflow water quality data collected both recently and historically for PA State 303(d) listing purposes. Data was collected by the DCCD and DER, a precursor organization to DEP.
Geomorphologic	• Data collected in 2003 by Skelly and Loy that ranks stream reaches in the Paxton Creek Watershed in terms of restoration priority based on stream and channel stability, riparian vegetation and habitat (Skelly and Loy, 2003).

The results of this data review are constrained by the limited period of record (e.g. length of time over which data has been collected) for which monitoring data was available, as well as the spatial variability of the data (e.g. only a few sampling sites existed for PCN with the exception of Macroblitz data). Despite these limitations, the data indicates a general pattern of decreasing stream quality as one moves downstream in the PCN subwatershed, indicated by a decline in macroinvertebrate community and increase in concentrations of various pollutants. The following characterization is an initial assessment of the entire PCN subwatershed based on available data, and continued efforts should be made to fill data gaps.

Hydrology

Daily discharge was monitored at the USGS gage (Station 01571000), Paxton Creek near Penbrook beginning March 1, 1930 through September 30, 1995. Monitoring at this gage was not continuous, as there was a break in the period of record from September 30, 1950 through October 1, 1984. Data from this location show that there has been an increase in peak discharge over time at this gage (Figure 5). The higher peak flows from storm events are likely the result of a change from forested and agricultural land uses to urban land uses from 1930 to 1995. As a watershed becomes more urban, the increase in impervious cover results in the generation of more surface runoff and less infiltration of precipitation that produces flashier and higher streamflow compared to pre-development (CWP, 2003). This change in the pattern of streamflow has impacts on stream geomorphology and water quality that include increased streambank and streambed erosion and surface pollutant loadings to the stream (CWP, 2003).

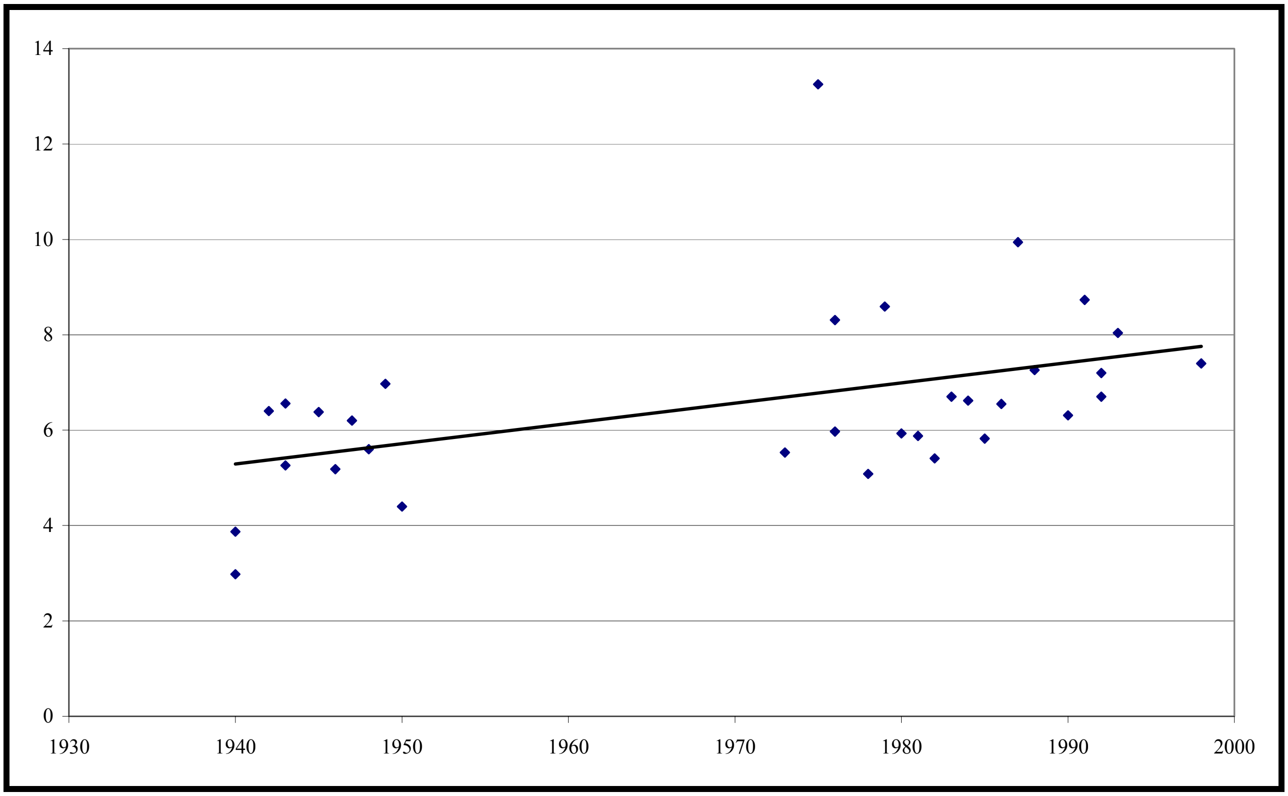


Figure 5. Trend in the peak discharge measurements at the Paxton Creek near Penbrook USGS gage (1930-1995)

Biology

Habitat and macroinvertebrate screenings have been performed both historically and recently throughout most of the Paxton Creek watershed as part of Pennsylvania's 303(d) listing process. Data for Paxton Creek North was collected in 1976 by the Pennsylvania DER (a precursor organization to DEP) and from 1999-2002 by the Dauphin County Conservation District (DCCD). Sampling site locations are shown in Figure 6 and the data is presented in Table 3.

Additional sampling was done in 1997 by the SRBC for DEP using a checklist designed to determine a biologically impaired or non-impaired status. The utility of this method was somewhat limited in that it did not discern between fair, good and excellent communities. CWP worked with a biologist from the DCCD to improve the utility of the 1997 data in order to rate the macroinvertebrate community as poor, fair, or good. Habitat data collected in 1997 was based on a Pennsylvania modified version of EPA's Rapid Bioassessment Protocol (RBP) and did provide a rating of quality based on poor, fair, good and excellent habitat. The data is presented in Table 3.

In March 2004, an intensive sampling effort called "Macroblitz" was undertaken by the DCCD, Harrisburg Area Community College (HACC), PCWEA, DEP, Susquehanna River Basin Commission (SRBC), the Entomological Society of Pennsylvania and The Nature Conservancy (TNC) to study the condition of the in-stream habitat and water quality within the Paxton Creek Watershed. The EPA RBP-3 method was used to collect a subsample of 200 macroinvertebrates at 24 sampling sites, five of which were located in the PCN subwatershed. A total of 16 metrics were compiled to characterize the biological condition of the subwatersheds (including one habitat index). The macroinvertebrate and habitat sampling sites are depicted in Figure 6 and the results are presented in Table 3. More detailed data is provided in Appendix C.

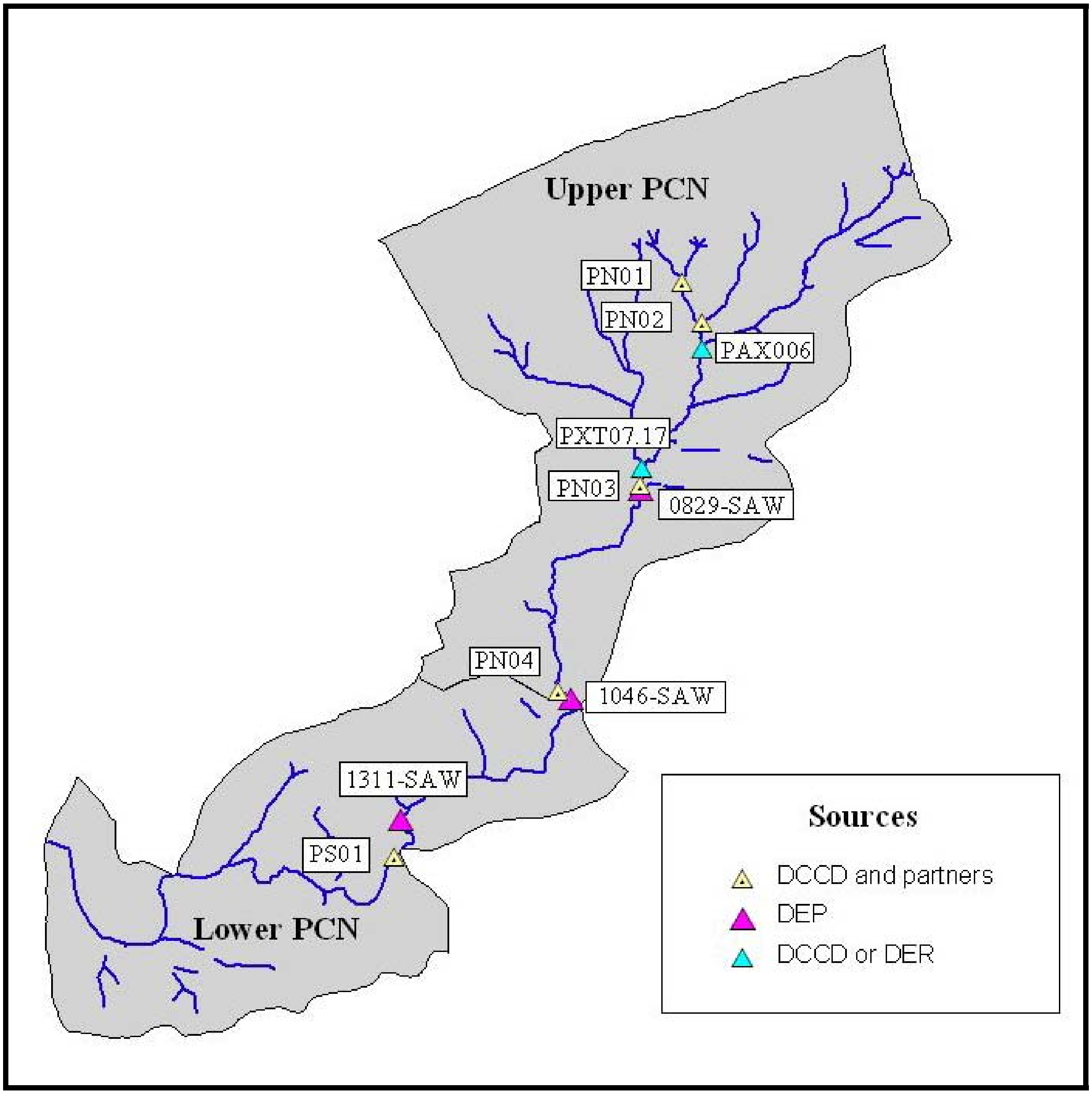


Figure 6. PCN Macroinvertebrate and Habitat Sampling Stations

The macroinvertebrate data reviewed indicate a general decline from upstream to downstream locations within PCN. There was a dramatic decrease in the percent stoneflies (a more sensitive species) from sampling station PN02 (13.6%) to PN03 (0.6%). The decline in the macroinvertebrate community within PCN appears to coincide with an increase in concentrations of water quality parameters such as total dissolved solids (see water quality section), which could be related to changes in landuse or geology. Habitat scores were consistently ranked as 'good' within PCN with little variation among sites, and therefore did not explain the decline in the macroinvertebrate scores. Additional detail on macroinvertebrate sampling data for the 2004 Macroblitz data is provided in Appendix C.

Table 3. PCN Habitat and Macroinvertebrate Data

Station	Location	Dates	Source	Bugs	Habitat
PAX 006	Bridge at Walker Mill- Paxton Church Rd	1976	DER	Not impaired	NA
1311-SAW	South of Doehne Rd. at intersection w/North Progress Ave	1997	SRBC for DEP	Good	Good
1046-SAW*	Trib or Paxton Creek; east of dead end on Paxton Church Rd.			Good	Good
0829-SAW	Paxton Creek south of SR39 at intersection w/ Colonial Rd.			Good	Good
PXTN 07.17	Paxton Creek upstream of Walker Mill	1999-2002	DCCD	Not impaired	Good
PN01	Upstream of culvert at Patton Road and Blue Hen	2004	Macroblitz	Excellent**	Good**
PN02	Upstream of culvert at curve in Patton Road			Excellent**	Good**
PN03	Upstream of culvert near Sheets			Good**	Good**
PN04	End of Paxton Church Road			Fair**	Good**
PS01	North Progress Ave and Interstate Drive upstream from bridge			Fair**	Good**

* based on location data provided, it is unclear if station is in PCN or on Linglestown Tributary
** habitat scores represent preliminary data analysis and are categorized based on McAllister (pers. comm.)

Results of the Macroblitz sampling for the entire Paxton Creek watershed are presented Figure 7 with PCN stations highlighted in yellow (McAllister, pers. comm.). The trend illustrates a decline in the macroinvertebrate community (indicated by taxa richness and percent stoneflies) and the decline in habitat scores from upstream to downstream locations along the Paxton Creek mainstem.

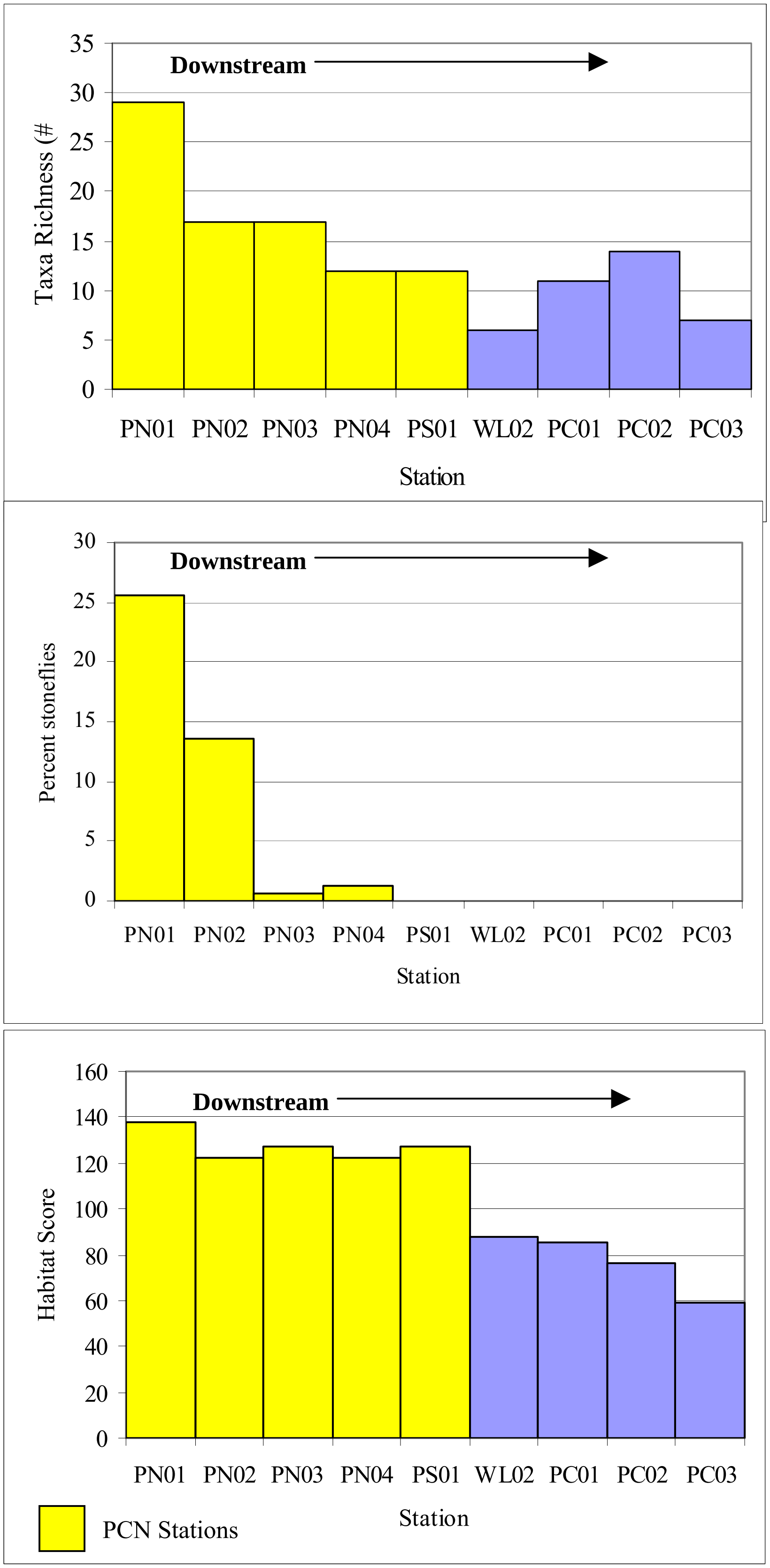


Figure 7. Biological condition of sampling sites along the mainstem Paxton Creek: taxa richness, percent stoneflies and habitat

Water Quality

Three sets of water quality data were available for the PCN subwatershed: baseflow water quality data collected on a one-time basis by DER and DCCD for the state 303 (d) listing; data collected by SRBC and USGS and summarized in Takita (1995); and water quality data collected as part of the Paxton Creek Macroblitz sampling in 2004. Sampling locations for all water quality data are depicted in Figure 8. The baseflow monitoring data collected for the PA State 303(d) listing included two sites in the PCN subwatershed. Results are presented in Table 4.

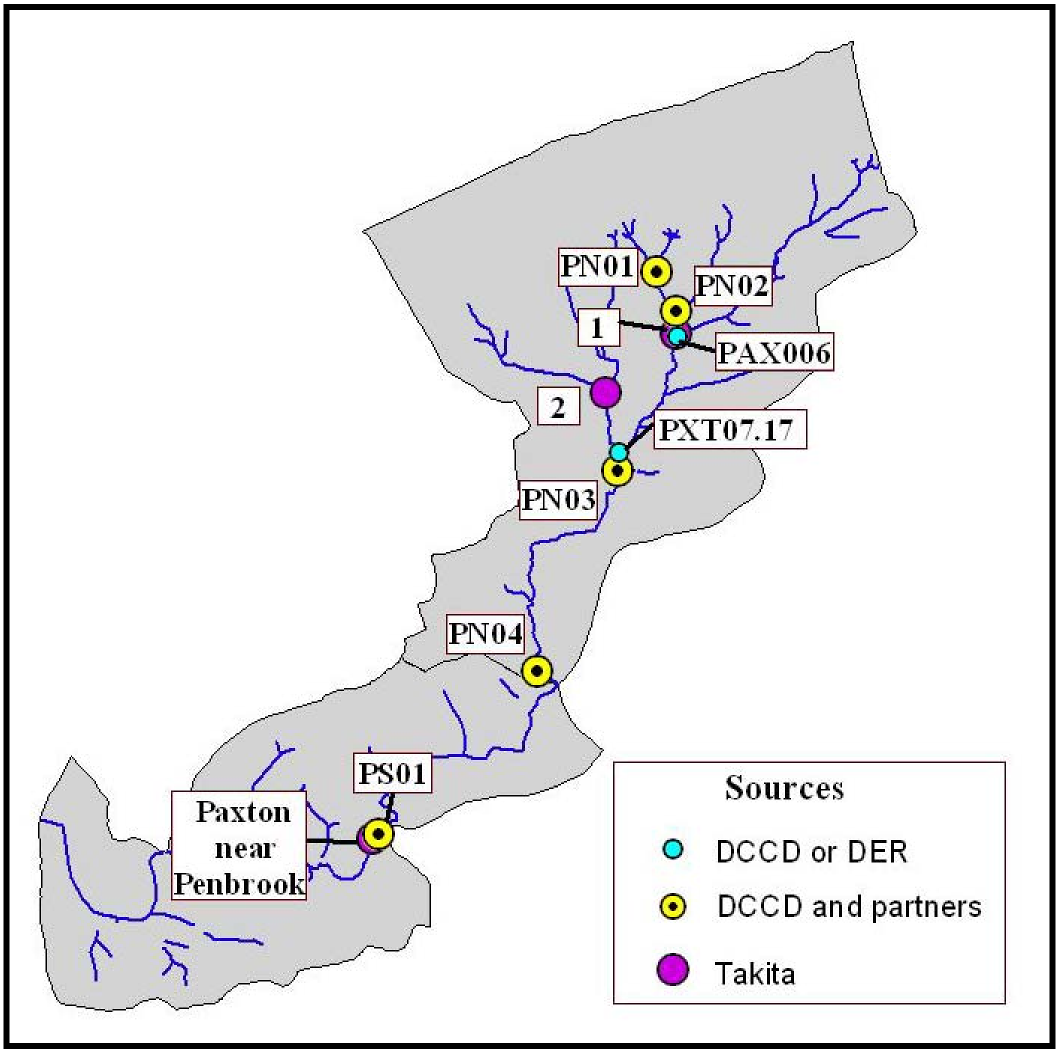


Figure 8. PCN Water Quality Sampling Stations

Baseflow concentration data are useful in identifying areas with potential baseflow contamination but without flow data are limited in their ability to predict loads in urban watersheds. The PCN baseflow data does not indicate the presence of any potential illicit discharges, and too few data are available to identify any spatial variation in pollutant concentrations between the two stations.

Table 4. Baseflow Monitoring Data Collected for 303(d) Listing in the PCN Subwatershed

Station	Location	Date	Source	Parameters in mg/l					Fecal Coliform (col/100 ml)
				NH4	NO3	TP	PO4	TSS	
PAX 006	Bridge at Walker Mill- Paxton Church Rd	1976	DER	0.06	0.88	0.05	NA	8	470
PXTN 07.17	Paxton Creek upstream of Walker Mill	1999-2002	DCCD	NA	<.75	NA	<.07	NA	NA

Parameters: NH4 = ammonia, NO3 = nitrate-nitrogen, TP = total phosphorus, PO4 = phosphate, TSS = total suspended solids

The SRBC/USGS study involved the collection of dry and wet weather surface water samples for a set of water quality parameters over a two-year period from 1992 through 1993. Two of the five sampling sites were located within the PCN subwatershed. Results are presented in Table 5.

No distinct patterns were observed in the data related to differences in land use. This may reflect how the data was analyzed and presented. For example, the SRBC study combined data from dry weather and wet weather samples. A greater distinction between results from various land uses may have been evident if wet weather samples were presented separately. One exception that may be explained by landuse is the significant increase in total zinc (Zn) concentrations from station 1 (undeveloped), to station 2 (residential development).

When comparing the data from Upper PCN sites (1, 2) and the Lower PCN site (Paxton near Penbrook), significant differences exist for concentrations of total suspended solids (TSS), total phosphorus (TP) and total lead (Pb). TSS in Lower PCN was 7.5 times higher than the average concentration at the Upper PCN sites. For both TP and Pb, concentrations in Lower PCN were 3 times higher than the average concentration at the Upper PCN sites.

Table 5. Mean Concentrations for SRBC/USGS Monitoring Data in the PCN Subwatershed

Station	Land Use	Date	Source	Parameters in mg/L				Parameters in μg/L		
				TSS	TN	TP	TOC	Cu	Pb	Zn
1	Undeveloped	1992-1993	Takita (1995)	52	1	0.07	4.46	3.6	2.42	8.3
2	new single family residential			74	1.3	0.09	4.38	2.78	1.53	30.1
Paxton near Penbrook	mixed			473	1.94	0.239	5.11	3.97	6.19	31.5

Parameters: TSS = total suspended solids, TN = total nitrogen, TP = total phosphorus, TOC = total organic carbon, Cu = total copper, Pb = total lead, Zn = total zinc

The impact of urban development within the PCN subwatershed is evident when annual yields of suspended sediments and nutrients are compared to forested and agricultural watersheds within the region. Table 6 compares annual nutrient and sediment yields for PCN stations with results from forested and agricultural basins within the Susquehanna River Basin (PCN data is highlighted in yellow).

Average annual yields of TSS for the PCN sites were almost ten times greater than the average annual yields for the agricultural and forested basins. Similarly, TN and TP were four and almost five times greater, respectively.

Table 6. Average Annual Yields for PCN Compared to Forested and Agricultural Basins

Station	Landuse	Source	Parameters in lbs/acre/year		
			TSS	TN	TP
1	Undeveloped	Takita (1995)	1670	7.48	1.06
2	New single family residential		1,770	10.00	1.30
Paxton Creek near Penbrook	mixed		2,110	51.99	1.29
Young Womans Creek	Mostly forested	Ott et al (1991)	188	3.16	0.06
Stony Creek	Mostly forested		109	3.96	0.23
Susquehanna above Harrisburg	Ag/forest		311	7.39	0.42
Susquehanna above Conowingo	Ag/forest		102	8.47	0.30

Parameters: TSS = total suspended solids, TN = total nitrogen, TP = total phosphorus, Cu = total copper, Pb = total lead, Zn = total zinc

The 2004 Macroblitz sampling was an intensive sampling effort undertaken to study the condition of the in-stream habitat biocommunity and water quality within the Paxton Creek watershed. A grab sample of water quality was taken and analyzed for a set of 28 parameters, including: nutrients, sediment, alkalinity, hardness, temperature, metals, pH, conductivity and bacteria. Five of the sampling sites were located within the PCN subwatershed.

In general, water quality within PCN decreased from upstream to downstream locations (PN01 to PS01) for most parameters (e.g., alkalinity, total nitrogen, nitrate), while no apparent spatial pattern existed for other parameters such as total phosphorus, total suspended solids and total coliform. The increase in concentrations of certain parameters may be related to changes in landuse or geology or potentially to recent applications of road salt (as in the case of increased conductivity). Highly elevated levels of total dissolved solids (TDS) may account for the decline in macroinvertebrate communities within PCN, as concentrations increase from 6 mg/L at PN01 to 590 mg/L at PS01. Concentrations of nitrate-N are well below the EPA standard of 10mg/L, but concentrations at sampling site PN04 exceed Maryland's threshold of 1 mg/L for unnaturally elevated concentrations.

Figure 9 illustrates the general increase in concentrations of total dissolved solids and total nitrate-nitrogen from upstream to downstream locations along the Paxton Creek mainstem within the entire Paxton Creek Watershed (PCN sites are highlighted in yellow). Total coliform concentrations increased greatly from the most upstream location (120MPN/100ml at PN01) to the most downstream location (11,000MPN/100ml at PC03), but did not show any particular pattern within the PCN sites. A subset of the Macroblitz data collected is presented in Table 7 and the full data set is provided in Appendix C.

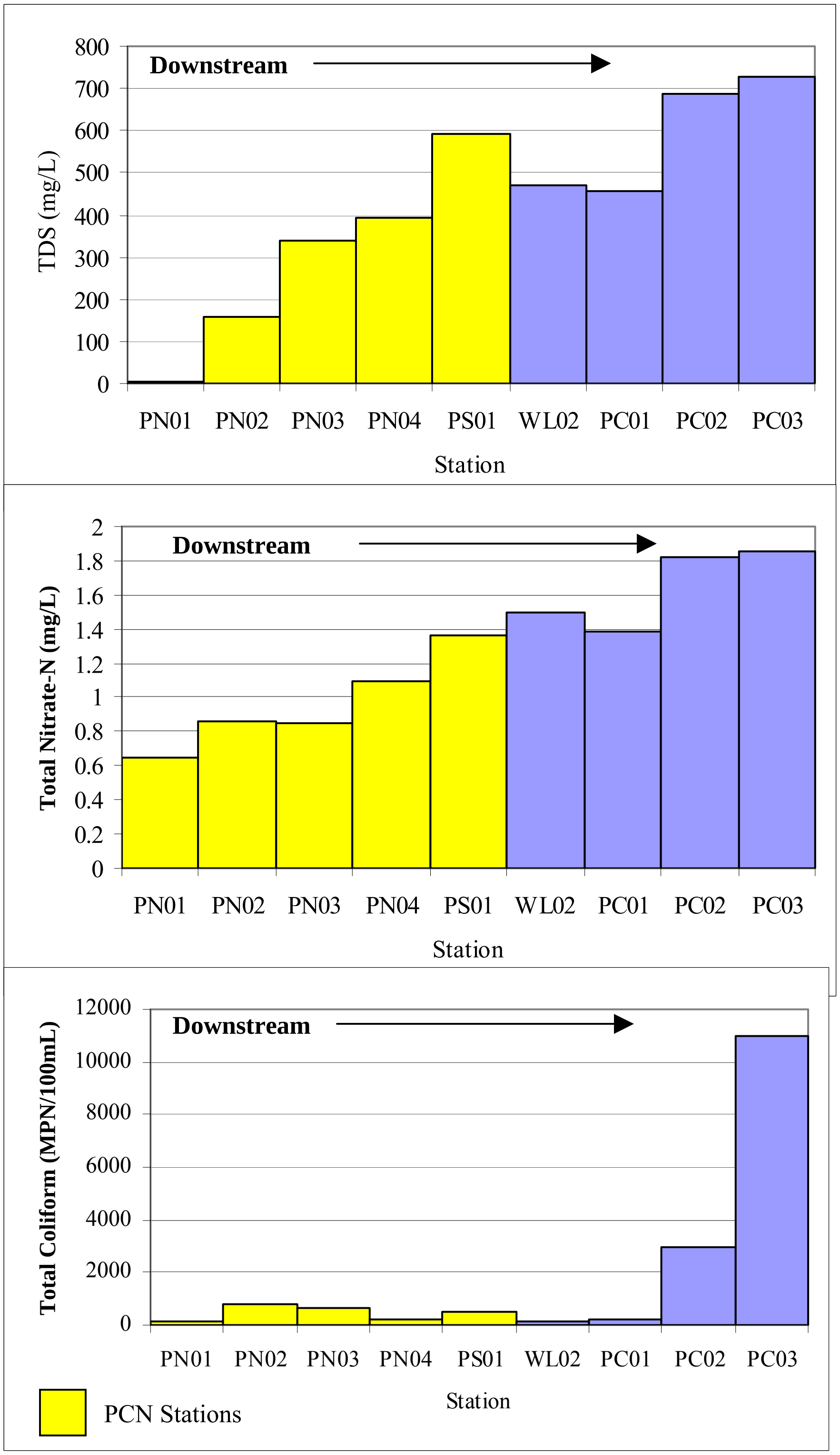


Figure 9. Water Quality concentrations along the mainstem of the Paxton Creek for total dissolved solids (TDS), total nitrate –N and total coliform

Table 7. Macroblitz Monitoring Data for the PCN Subwatershed								
Station	Location	Parameters in mg/L						MPN/100ml
		Alk	TSS	TDS	TN	TP	NO3	Total Coliform
PN01	Upstream of culvert at Patton Road and Blue Hen	26.6	34	6	0.80	0.012	0.65	120
PN02	Upstream of culvert at curve in Patton Road	53.8	14	158	0.82	<0.01	0.86	780
PN03	Upstream of culvert near Sheets	91.8	<5	338	1.04	<0.01	0.85	650
PN04	PCN outlet at end of Paxton Church Road	95.8	6	392	1.34	0.019	1.10	200
PS01	North Progress and Interstate Drive upstream from bridge	95.8	16	590	1.63	0.016	1.36	480

Parameters: Alk = alkalinity, TSS = total suspended solids, TDS = total dissolved solids, TN = total nitrogen, TP = total phosphorus, NO3 = nitrate-nitrogen

Geomorphology

Stream stability in the Paxton Creek Watershed was recently assessed by Skelly and Loy (2003). The data were summarized on a subwatershed basis and were collected using a modified version of the Stream Visual Assessment Protocol (SVAP) developed by Natural Resources Conservation Service (NRCS) and summarized on a subwatershed basis. All reaches were assessed and characterized as Priority I, II, III based on bank stability, channel stability, riparian vegetation and aquatic habitat. Priority I reaches were the most impacted for the aforementioned parameters and thus deemed the highest priority for restoration based on Skelly and Loy's findings (Skelly and Loy, 2003).

The Skelly and Loy study found that sediment is a major water quality problem for Paxton Creek and that sources of sediment include:

- Channel bank and bed erosion
- Stream adjacent gullies to include recesses at stormwater outfalls
- Oversteepened and poorly vegetated road cuts and fill slopes
- Mineral material washed off from road surfaces

In addition, Ott et al. (1991) suggested that the increase in sediment load at Paxton Creek near Penbrook is attributed, in part, to the inadequate or lack of erosion and sediment control practices.

Compared to Paxton Creek in general, the stream reaches within the PCN subwatershed are in better physical condition. For example, only 5.5% (6,015 ft) of the stream reaches within Paxton Creek North were classified as Priority I compared to 14% on average for all of the subwatersheds (Table 8). It should be noted, though, that the values given to the Priority I stream reaches within Paxton Creek North are at the borderline of severely to moderately impaired. However, the majority of the stream reaches have a low priority ranking for restoration (i.e. Priority III).

Table 8. Priority Stream Rankings for PCN Compared to All Paxton Creek Subwatersheds (Skelly and Loy, 2003)		
Priority Designation	**% of PCN Streams**	**% of All Paxton Streams**
Priority I	5.45	14.08
Priority II	42.41	39.16
Priority III	47.26	35.15

There are 29 reaches within PCN in need of riparian reforestation, totalling 28,325 feet, or 40.7% of the total stream length surveyed in Paxton Creek. Of the 29 reaches identified for riparian reforestation, four are classified as Priority I reaches, and 18 as Priority II (Figure 10). The remaining stream reaches were not associated with a priority ranking and/or stream reaches receiving a Priority III ranking were not identified in Skelly and Loy (2003). Additional assessments indicated that stormwater pipe outfalls were the cause of significant erosion at five stream reaches and that gully erosion was noted at two human induced channels.

Skelly and Loy also identified a number of the Priority I reaches for early action because of the degree and potential for additional degradation that these reaches posed. One PCN site in particular was prioritized for early action due to multiple debris jams and potential for flooding. One goal of the PCN stream and subwatershed assessments was to verify conditions at these priority locations. More detail is provided on this verification in Section 4.

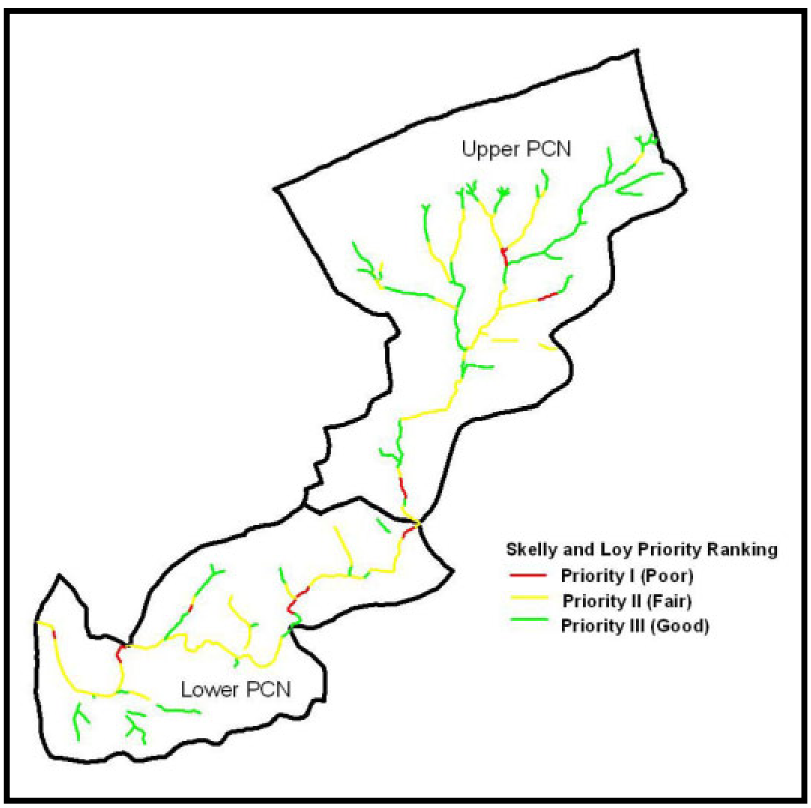


Figure 10. PCN Priority I, I and III Stream Reaches

Section 3: Methods

This section reviews the various methods used to complete the project tasks, including: GIS methods, field methods, project prioritization methods and stakeholder involvement methods.

3.1 GIS Methods

Subwatershed Delineation

Previous studies (Skelly and Loy, 2003) had delineated the Paxton Creek watershed into ten subwatersheds ranging in area from 0.5 square miles to 7.5 square miles. CWP staff performed a re-evaluation of the existing delineations and adjusted them so the original Paxton Creek North subwatershed was split into an Upper and Lower portion. This new delineation was used to re-calculate subwatershed characteristics (i.e., stream miles, land use, impervious cover estimates) and to break up the field assessments into more reasonable time periods. Subwatershed delineation methods used are described in Appendix D.

Impervious Cover Analysis

Impervious cover has been identified as a key indicator to explain and sometimes predict how severely streams change in response to different levels of watershed development (CWP, 2003). CWP staff estimated both existing and future impervious cover percentages for the newly delineated upper and lower PCN subwatersheds. These estimates were based on CVI impervious cover imagery and municipal zoning maps. Impervious cover analysis methods used are described in Appendix B.

3.2 Field Methods

Stream and subwatershed assessments were conducted in PCN using two protocols recently developed by CWP: the Unified Stream Assessment (USA) and the Unified Subwatershed and Site Reconnaissance (USSR). The first tool, the USA, is a comprehensive stream walk protocol for evaluating the physical, riparian and floodplain conditions in small urban watersheds (Kitchell and Schueler, 2004). The second tool, the USSR, is a field survey to evaluate potential subwatershed pollution sources and restoration opportunities in areas outside the stream corridor (Wright, et al, 2004). Together, the stream and subwatershed methods allowed CWP to identify a number of pollution source control measures, on-site stormwater retrofits, riparian reforestation, stream restoration, discharge prevention and upland reforestation projects within the subwatersheds.

The USA and USSR were conducted in the Upper Paxton Creek North subwatershed over a two-day period in mid-April, 2004. These same assessments were conducted in the Lower Paxton Creek North subwatershed over a two-day period in mid-August, 2004. In both instances, field crews consisted of a USA and a USSR team, each with a CWP team leader, one CWP staff person and two or three volunteers from PCWEA or CVI. The USA and USSR are described further below.

Unified Stream Assessment (USA)

The Unified Stream Assessment (USA) is a continuous stream walk method to systematically evaluate conditions and identify restoration opportunities within the stream corridor of small watersheds (Figure 11). The USA is designed to rapidly collect basic information needed to assemble a manageable list of potential restoration projects in the stream corridor. These projects include storm water retrofits, stream restoration, riparian management, and discharge prevention. The USA protocol was adapted to avoid duplication of the Skelly and Loy (2003) physical stream assessment by focusing on verifying restoration priorities, and to identify other problems within the stream corridor such as sewer overflows, trash dumping and stormwater outfalls (Table 9).

Figure 11. Conducting the USA in Paxton Creek North

For detailed information on the USA protocol, see Kitchell and Schueler (2004). Blank field forms are provided in Appendix E.

The PCN field teams conducted the USA for approximately 12 linear stream miles in the PCN subwatershed (Figure 12). Not all streams were walked due to poor access or lack of permission from landowners. Also, in the interest of time, streams that were ranked as Priority I by Skelly and Loy were prioritized. Stream reaches identified as Priority I for rehabilitation by Skelly and Loy (2003) were investigated where possible to verify conditions or gather additional information to expand on their recommended rehabilitation strategies. Outfall sampling was done at locations with suspected illicit discharges, and water quality samples taken were taken to a lab that day for analysis.

Table 9. USA Impact and Reach Assessment Forms and Restoration Practices		
Assessment Form	**What It Assesses**	**Restoration Practice**
Outfalls	All discharge pipes or channels that discharge storm water or wastewater.	Storm water retrofit Stream restoration Discharge prevention
Severe Bank Erosion	Slope failures, bank sloughing, head cuts, and incision or widening in areas noticeably worse than the average erosive condition of the survey reach. Also infrastructure or property threatened by erosion.	Stream restoration
Impacted Buffer	Corridor lengths >100 feet long that lack at least a 25 feet wide, naturally- vegetated riparian buffer on one or both sides of stream.	Riparian management
Utilities in Stream Corridor	Leaking or exposed sewer, water, or other utility lines causing water quality, habitat, or channel stability problems. Includes manhole stacks, pipes along bottom, in the bank, or above the stream susceptible to damage due to lack of maintenance or exposure.	Stream restoration Discharge prevention
Stream Crossing	All engineered or natural structures that cross the stream, such as roadways, bridges, railroad crossings, or dams. Pipe crossings and other overhead utilities are assessed under Utilities in Stream Corridor	Storm water retrofit Stream restoration
Channel Modification	Channelized, concrete-lined, or reinforced sections of stream >50 feet in length, regardless of construction material used. Locations of existing stream restoration or bank stabilization projects included. Enclosed sections are assessed under Stream Crossing or Outfalls	Stream restoration
Trash and Debris	Areas of significant trash and debris accumulation greater than average levels observed across the survey reach. Any areas where potentially hazardous or unknown chemicals have been dumped.	Riparian management Stream restoration
Misc. Impacts	High quality areas or unusual feature or activity impacting the stream corridor that doesn't fit into other seven impact assessments. This may include fish kills, cattle access, near stream construction, flood plain excavation, adjacent wetlands, grade controls, or other notable features.	Depends on feature
Reach Level	Average characteristics for each survey reach. Tracks locations of site-level assessments; used for screening restoration opportunities and for comparing reaches across the subwatershed.	N/A

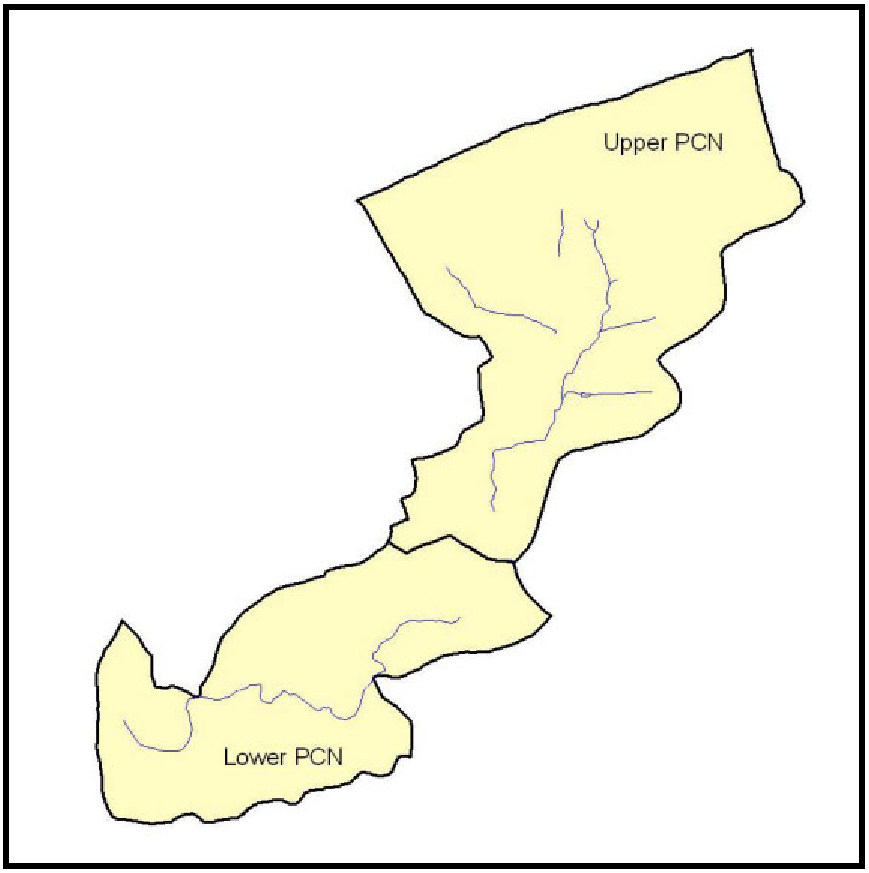


Figure 12. PCN Streams Evaluated Using the USA

Unified Subwatershed and Site Reconnaissance (USSR)

Urban subwatershed restoration has traditionally focused on the stream corridor, with less attention paid to upland areas where neighborhoods and businesses are located. These upland areas, however, are important in subwatershed restoration, since they contribute storm water pollutants to the stream corridor. The USSR is designed to assess these upland areas for behaviors that can potentially influence water quality and to identify promising restoration project opportunities. The concept behind the USSR is to provide a quick but thorough characterization of all upland areas to identify major source areas that are contributing pollutants to the stream, and control them through source controls, pervious area management, and improved municipal maintenance.

The USSR is a rapid field survey to evaluate potential pollution sources and restoration opportunities within urban subwatersheds. It was developed to help watershed groups, municipal staff, and consultants quickly assess subwatershed restoration potential. The USSR can be a powerful tool in shaping your initial subwatershed restoration strategy, and in locating upland restoration projects that deserve further investigation. The USSR is rapid, inexpensive, and applies over a wide range of urban conditions. The USSR consists of the following four major assessment components:

1. *Neighborhood Source Assessment* — a profile of pollution source areas, stewardship behaviors, and restoration opportunities within individual neighborhoods. Looks specifically at yards and lawns, rooftops, driveways and sidewalks, curbs, and common areas.
2. *Hotspot Site Investigation* — a ranking of the potential severity of each commercial, industrial, municipal or transport-related hotspot found within a subwatershed. Looks specifically at vehicle operations, outdoor materials storage, waste management, building conditions, turf and landscaping, and stormwater infrastructure.
3. *Pervious Area Assessment* — an evaluation of the potential to reforest turf areas or restore natural area remnants at all open parcels within a subwatershed. Looks specifically at vegetative cover, potential impacts, and site constraints.
4. *Streets and Storm Drains* – estimates the severity of pollutant accumulation on roads and within storm drain systems.

Detailed information on the USSR protocol is available in Wright, et al (2004). Blank field forms are provided in Appendix E.

USSR field teams identified potential hotspot and neighborhood locations to assess prior to going out in the field. Distinct neighborhood units were delineated using GIS data layers and digital orthophotos (Figure 13). The USSR field teams focused on identifying hotspots, municipal operations, and residential pollution-producing behaviors that contribute to nutrient loading, as well as areas with significant reforestation opportunities. Streets and storm drains were not evaluated during the PCN field assessment.

Figure 13. Example Neighborhood Delineation from Upper PCN

Residential neighborhoods were assessed in terms of age, lot size, tree cover, drainage, lawn size, general upkeep, and resident stewardship. Those with similar characteristics and restoration potential were grouped into a single assessment form. Neighborhoods were assigned a pollution severity of "severe," "high," "moderate," or "low," using a set of benchmarks set forth in Wright et al. (2004). Pollution severity is an index of how much non-point source pollution a neighborhood is likely generating based on easily observable features (lawn care practices, drainage patterns, oil stains, etc). A restoration potential was also determined for each neighborhood type of "high," "moderate," or "low." Restoration potential is a measure of how feasible onsite retrofits or behavior changes would be based on space, number of opportunities, presence of a strong HOA, etc.

Individual hotspot locations were assessed for pollution potential based on observed sources of pollution and the potential of the site to generate pollutants that would likely enter the stormdrain network (Figure 14). The Hotspot Designation Criteria as set forth in Wright et al. (2004) was used to determine whether the site was a "confirmed" or still a "potential" hotspot based on field crew observations.

Figure 14. - USSR teams evaluating a potential retrofit site

The USSR field teams evaluated a total of 24 residential neighborhoods, 43 possible hotspot locations, and five pervious area sites within the PCN subwatersheds. The results of the neighborhood evaluations were used to determine which topics and what areas to focus an educational outreach program developed for PCWEA.

Retrofit Inventory

The previous *Paxton Creek Baseline and Stormwater Retrofit Assessment* included the results of a stormwater retrofit inventory that was performed to identify opportunities for water quality improvement and reduction of stormwater impacts on downstream channels. Retrofits take one of two forms, (1) practices inserted into the landscape where stormwater management does not exist and, (2) improvements to existing facilities. Over 40 retrofit opportunities were identified in the Paxton Creek watershed, which resulted in five conceptual designs for retrofits in the Paxton Creek North subwatersheds. Several of these sites were re-visited during the USA/USSR field work to determine if retrofits were still feasible, and additional locations for stormwater retrofits were identified. Blank retrofit inventory field forms are included in Appendix E.

3.3 Project Prioritization Methods

The goal of identifying potential restoration projects is to ultimately work with local partners and funders to actually implement them. Due to the limited resources typically available for implementation, restoration projects identified in PCN were evaluated based on a set of criteria to identify priority projects to pursue for implementation. The ranking system used was fairly qualitative, but was based on a set of defined criteria. The criteria that were used to rank projects are listed below along with a brief rationale for each.

- **Land ownership.** Public land or sites with willing landowners were prioritized because it is typically easier to implement restoration projects on public land since issues regarding property rights or privacy can be avoided. In some cases, the field crews spoke with landowners who indicated a desire to implement restoration projects.
- **Relative cost.** The cost of stormwater retrofit projects can vary greatly, from several hundred to hundreds of thousands of dollars. Several projects were prioritized because they were simple non-structural projects that could be implemented by PCWEA, or were relatively inexpensive retrofits such as bioretention. The goal was to select projects that could likely be expected to receive funding for implementation.
- **Environmental benefit.** Projects that provide the greatest environmental benefit by treating runoff from a large area, or reforesting or restoring a long stretch of stream were prioritized. Environmental benefit was quantified by making an estimate of the impervious area treated by proposed stormwwater retrofits, and by estimating the length of stream restored or re-planted for stream restoration and riparian reforestation projects. Projects that provide multiple benefits (e.g., water quantity and quality treatment) or provided a connection between existing forested areas were also considered priorities.
- **Location in watershed.** Headwater projects were given higher priority since data indicated that stream habitat and bug diversity were highest in the headwaters and declined further downstream stream. The currently forested headwater areas of Upper PCN are also under the greatest amount of development pressure in the PCN subwatersheds.
- **Number of subwatershed goals met**. Many restoration projects can be designed to meet more than one subwatershed goal. The projects selected met at least two of the goals identified for the Paxton Creek North subwatersheds.

- **Choose a mix of structural and nonstructural projects.** While several projects were prioritized because they were simple non-structural projects with low cost and ease of implementation, it was also important to consider that large structural projects can often treat a much larger area. Additionally, funding sources are sometimes specific to these structural restoration practices. Therefore, an effort was made to include a mix of structural and non-structural restoration projects.
- **Projects with educational value.** Public involvement in restoration is important to the long-term success of any plan and projects that can demonstrate proper behaviors or help plan for runoff reduction on their own property can help emphasize the watershed protection message. Highly visible sites or those with obvious education purposes, such as schools, were prioritized.
- **Projects with multiple components.** The ability to implement multiple projects at a single site or in locations in close proximity to each other helps reduce cost and maximize the use of volunteers. These sites also have the potential to serve as demonstration sites for various types of restoration practices.
- **Access to site.** Easy access to a project site reduces the cost for implementation, lessens safety concerns for volunteers, and means less impact on existing natural resources.

Some projects were not prioritized because it was determined after compiling the field data that not enough information was available at the time to determine if the project would be feasible (e.g., detailed information on location of utilities was not available).

3.4 Stakeholder Involvement Methods

Methods to involve stakeholders included the creation and distribution of educational brochures and slideshows as well as conducting two public meetings to gain stakeholder input. Methods are described below.

Educational Materials

CWP met with PCWEA to determine their needs for educational materials and to identify topics, audience, and desired format. As a result, CWP produced an educational brochure containing information on the Paxton Creek watershed and specific actions that homeowners, business owners, developers and local governments can do to help protect and restore Paxton Creek. Slideshows were also developed that align with the information contained in the brochure, which will be used by PCWEA to educate local stakeholders. Topics included in the brochure were chosen based on PCWEA needs as well as the results of the field assessments. In particular, the USSR results were used to identify education topics specific to residential, municipal, developer and business behaviors commonly observed in the subwatersheds. The brochure topics and slideshows produced are listed below.

Brochure topics:

- Are You Loving Paxton Creek to Death?
- Lawns and Landscaping
- Downspout Disconnection
- Stream Buffer Management
- Outdoor Storage
- Dumpster Management
- Better Site Design
- Erosion and Sediment Control

Educational slideshows:

- Introduction to the Paxton Creek Watershed
- What Homeowners Can Do To Protect and Restore Paxton Creek
- What Business Owners Can Do To Protect and Restore Paxton Creek
- What Developers Can Do To Protect and Restore Paxton Creek
- What Local Governments Can Do To Protect and Restore Paxton Creek

The brochure and slideshows are available online at: http://www.cwp.org/Community_Watersheds/Paxton/paxtoncreek.htm. A copy of the brochure is included as Appendix F.

Public Meetings

Two meetings were held to solicit stakeholder input for this project. The first meeting was designed for residents, business owners and other local stakeholders in the PCN subwatersheds. The goal of this meeting was to inform stakeholders of the work being done in PCN and to get their input on subwatershed goals and specific restoration projects in their neighborhoods. The meeting was held on October 7, 2004 at the East Shore Area Library in Harrisburg and was jointly organized by CWP and PCWEA. In addition to the CWP, PCWEA and CVI staff involved, eight stakeholders were present at the meeting who gave input on specific restoration projects, prioritized subwatershed goals and brainstormed ideas for protecting and restoring Paxton creek. A workshop flyer with agenda and detailed notes from the breakout groups are summarized in Appendix G.

The second meeting was organized by CWP and PCWEA to report on existing conditions in the Paxton Creek watershed and to generate interest from local officials, agencies and other watershed partners for implementing restoration projects. This meeting was held on November 18, 2004 at the Harrisburg Area Community College. A total of forty-three participants attended the workshop representing a wide-range of stakeholders, including:

- Local officials from the City of Harrisburg, Lower Paxton Township and Penbrook Borough.
- Representative from Congressman Holden's office
- Canaan Valley Institute
- Chesapeake Bay Foundation
- Private industry (e.g. consultants)
- Tri-County Regional Planning Commission
- University faculty and students
- Environmental organizations (Pennsylvania Environment Council)
- PA Department of Environmental Protection
- Dauphin County Conservation District
- Susquehanna River Basin Commission

The workshop was organized to present information on the "state of the watershed" and to generate discussion in the form of small breakout groups to define a preliminary implementation strategy for: stream buffers, illicit discharges, stream restoration and stormwater retrofits. A summary of the presentations and breakout group findings are included in Appendix G along with the workshop program.

Section 4: Results of Stream and Subwatershed Assessments

4.1 Preliminary Results

After compiling the results of the PCN stream and subwatershed surveys, CWP staff were able to identify 51 potential restoration projects within the PCN subwatershed. This list of projects included sites previously identified by CWP (2003) and Skelly and Loy (2003), and consisted of six different types of restoration projects: stormwater retrofits, discharge prevention, stream restoration, riparian reforestation, upland reforestation and pollution source control. The locations of the 51 projects identified are shown in Figure 15. A brief description of each type of restoration project identified is presented in Table 10, along with the number of potential projects.

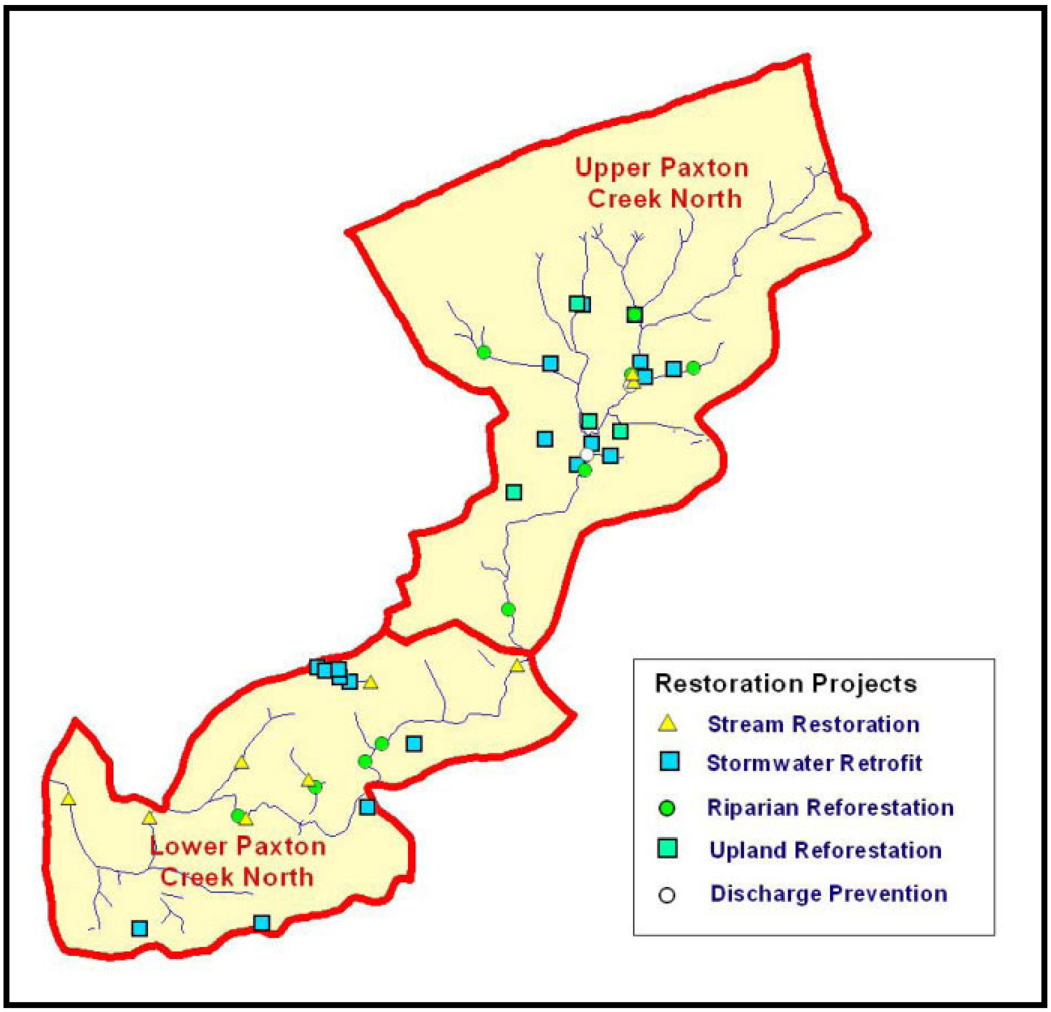


Figure 15. Restoration Projects Identified in PCN

Table 10. Summary of Potential Restoration Projects in PCN		
Project Type	**Description**	**Number of Projects Identified**
Stormwater Retrofit	Retrofits are stormwater management measures inserted in an urban or ultra-urban landscape where little or no prior stormwater controls existed. Typical goals of retrofitting are to: improve water quality, enhance aquatic habitat and minimize channel erosion, reduce flood peaks and volumes, provide groundwater recharge, educate the public, and correct past mistakes. Stormwater retrofit practices capture and treat stormwater runoff before it is delivered to the stream and may involve improving an existing facility.	20
Discharge Prevention	Discharge prevention is used to prevent the entry of sewage and other pollutants into the stream. These discharges may be caused by illicit sewage connections, illicit business connections, failing sewage lines or industrial/transport spills. Discharge prevention entails the use of techniques to find, fix and prevent these illicit discharges, including conducting a survey of all known stormwater outfalls to identify suspicious discharges for further investigation.	2
Stream Restoration	Stream restoration practices enhance the appearance, stability, structure or function of streams. Stream restoration projects address many of the impacts to the stream that are caused by urbanization, including: channel erosion, loss of instream habitat, channel downcutting, loss of bank stability and sediment deposition. Examples of stream restoration projects include: simple stream cleanups, bank stabilization techniques, grade control techniques, enhancement of instream habitat features, removal of fish migration barriers, or comprehensive stream restoration design.	9
Riparian Reforestation	Riparian reforestation projects restore the quality of forests and wetlands within the remaining stream corridor. Trees and shrubs in the riparian zone provide stabilization of stream banks, regulation of stream temperature, habitat for aquatic and terrestrial wildlife, and filtering of pollutants from runoff before entering the stream. Restoring the quality of riparian vegetation may include: techniques to improve the quality of the soil for planting, removal of invasive species, active reforestation and allowing natural regeneration of forests.	10
Upland Reforestation	Upland reforestation projects increase tree cover on open lands in non-riparian areas, such as parks, schools, rights-of-way and vacant lands. Restoring and increasing upland forest cover may include: techniques to improve the quality of the soil for planting, removal of invasive species, active reforestation and allowing natural regeneration of forests (by discontinuing mowing practices). These techniques improve the capacity of the land to absorb rainfall and sustain healthy plant growth and cover.	4
Pollution Source Control	The purpose of pollution source control is to reduce or prevent pollution from residential neighborhoods and stormwater hotspots. A stormwater hotspot is a commercial, industrial, institutional, municipal or transport-related operation that produces high levels of stormwater pollutants, and/or presents a higher potential risk for spills, leaks or illicit discharges. Pollution source control methods include targeting education and/or enforcement efforts that can prevent or reduce polluting behaviors and operations. Examples include: educating business owners about proper techniques for storing materials outdoors, educating homeowners about the benefits of reducing fertilizer and pesticide use, and providing pet waste pickup bags at local parks and beaches.	6

Appendix H contains additional information on each of the 51 potential restoration projects identified in PCN.

The USA streamwalk also resulted in verification of Skelly and Loy Priority I stream reaches. Table 11 lists the Priority I reaches along with the rehabilitation strategy recommended by Skelly and Loy and CWP field observations.

Table 11. Field Observations of Skelly and Loy (2003) Priority I Stream Reaches

Reach ID (Skelly and Loy, 2003)	Potential Rehabilitation Strategy (Skelly and Loy, 2003)	CWP Field Observations
PCN-22	Minimal bank regrading and aggressive bank replanting. Potential for stream corridor reconstruction using FGM techniques	Reach PCN-22 appears to include a stretch of stream where domesticated animals are confined to the stream corridor with fencing. Within the stream corridor and floodplain, bank erosion and closely cropped turf were evidence of overgrazing. Access to this site was poor so additional detail was not collected.
PCN-27	Floodplain/channel recoupling through floodplain excavation and/or channel reconstruction. At a minimum, stabilize channel banks, re-grade and replant.	Site considered as potential flood storage though it is uncertain whether there is a benefit to flood storage in this location. Though recoupling the stream with its floodplain is a good suggestion either way.
PCN-32	Full or partial reconstruction can be done to provide functional floodplain. Simple regrading and replanting may be sufficient.	Identified as priority restoration site (Doehne Road)
PCN-33	Regrade inner bend to recreate floodplain. Replant and stabilize outer bend. Should be done in conjunction with PCN-32.	
PCN-42	Remove debris jams, stabilize streambanks using bioengineering, potential for full-scale channel and floodplain reconstruction.	Unable to access due to deep channel
PCN-48	No recommended action at this time – potential to serve as sediment trap for lake.	Did not visit because no recommended action
PCN-804	Restore riparian vegetation along channel. Some minimal grading might provide flood storage. Pre-emptive structural channel stabilization recommended due to future upstream development.	Identified as priority restoration site (Centennial Acres)
PCN-1103		
PCN-1302	Regrade banks and reforest.	This site has potential for reforestation but may be constrained by residential backyards.
PCN-3003	Bank regrading and planting and installation of grade control structures.	Portions of this reach were unwalkable (too deep) but were observed from the nearby road. It was unclear why Skelly and Loy identified this site as a priority as no significant restoration opportunities were observed.

4.2 Priority Restoration Projects

The goal of identifying potential restoration projects is to ultimately work with local partners and funders to actually implement them. Due to the limited resources typically available for implementing restoration projects, the 51 potential restoration projects initially identified were evaluated based on a set of criteria to identify priority projects to pursue for implementation (see Section 3.3). Based on these criteria, CWP selected 14 priority restoration projects recommended for implementation in PCN. Figure 16 presents the priority projects identified in Upper PCN, while Figure 17 presents priority projects identified in Lower PCN. Conceptual designs are included in Appendix I.

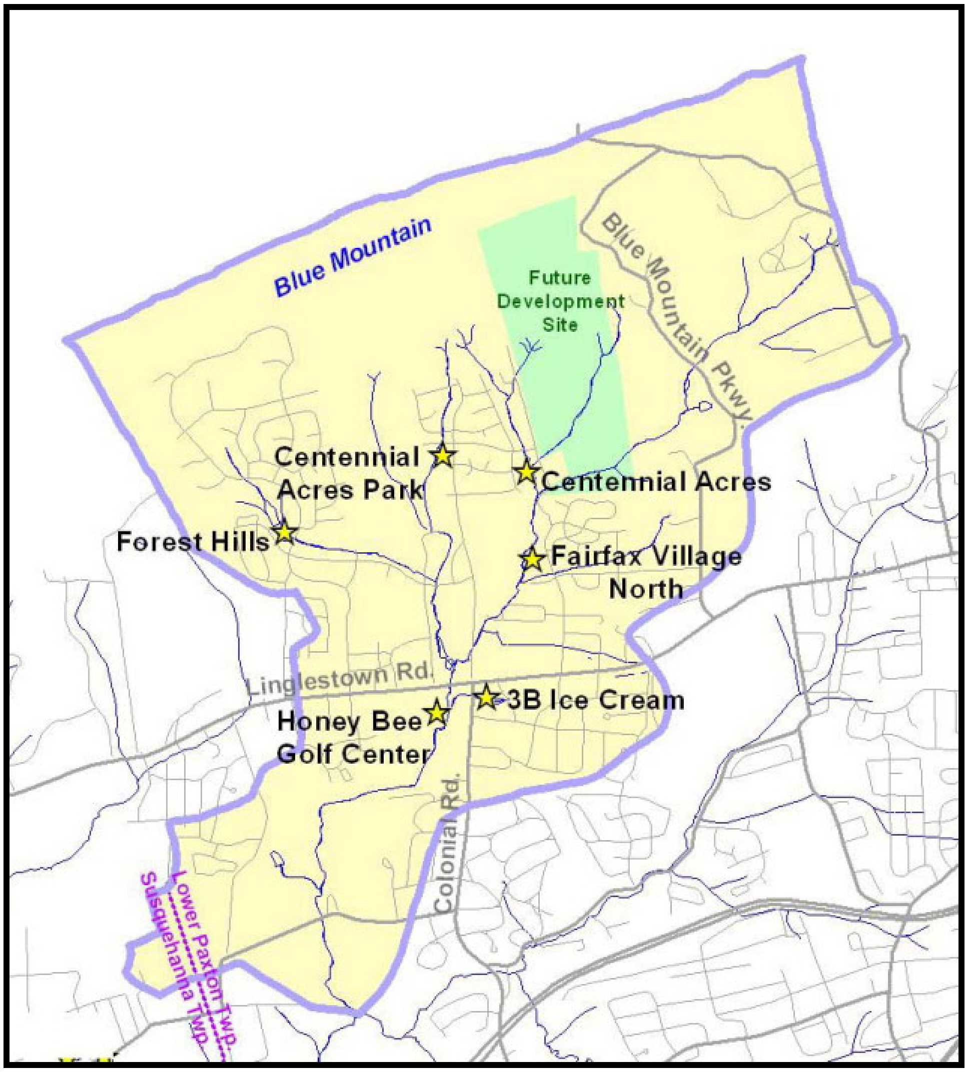


Figure 16. Priority Restoration Projects in Upper PCN

Two types of priority projects were identified: large scale restoration projects (Table 12) and small-scale restoration projects (Table 13). Large-scale restoration projects require a greater degree of design, engineering, capital outlay and construction equipment and may have multiple components. Smaller scale restoration projects are those that can be performed with a low tech engineering approach and utilize volunteers for some percentage of the labor.

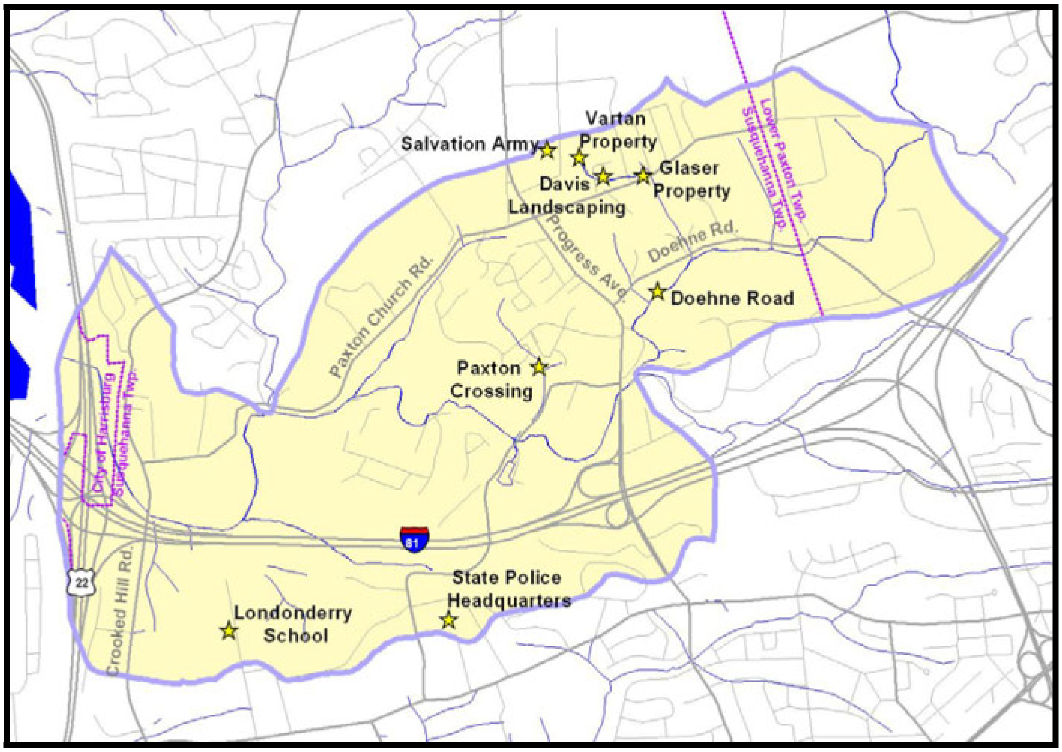


Figure 17. Priority Restoration Projects in Lower PCN

Table 12. Large Scale Priority Restoration Projects in PCN					
Project	**Project Type (s)**	**Area Treated (acres)**	**Stream Length Restored (ft)**	**Reason for Prioritizing**	**Planning -Level Cost Estimate**
1. Centennial Acres	Stormwater Retrofit Stream Restoration Riparian Reforestation Better Site Design	5	1000	• Headwater location • Multiple components • Downstream of site slated for development • Identified as priority by Skelly and Loy	$100,000
2. Fairfax Village North	Stormwater Retrofit Riparian Reforestation Stream Restoration Trash Cleanup	1	800	• Headwater location • Multiple components • Meets multiple subwatershed goals	$50,000
3. Honey Bee Golf Center	Stormwater Retrofits Riparian Reforestation	2	600	• Multiple components • Highly visible location • Headwater location	$50,000
4. Vartan Property	Stormwater Retrofits	2+	N/A	• Treats large area • Runoff is causing erosion downstream • Multiple components	$50,000 - $75,000

Planning-level costs estimates are based on best professional judgment and average costs for local similar types of projects. More specific estimates are not feasible without additional information on precise drainage area and impervious cover, location of utilities and permitting required.

Of the 14 priority projects identified, each project was given a numerical ranking to illustrate its importance in terms of implementation, and the projects are presented in this order in Table 12 and Table 13. In general, projects located in headwater areas were prioritized over projects located further downstream, although other factors were considered, such as landowner willingness and impacts on downstream properties (see Section 3.3). The headwaters represent the most pristine conditions in the entire Paxton Creek watershed and it is vital to protect these headwater areas from any future development impacts. Restoring headwater areas first can also provide an additional measure of protection to downstream locations.

Table 13. Small Scale Priority Restoration Projects in PCN

Project	Project Type (s)	Area Treated (acres)	Stream Length Restored (ft)	Reason for Prioritizing	Planning-Level Cost Estimate
1. Forest Hills	Riparian Reforestation	1.4 –2	600-1000	• Headwater location • Simple project • Land is likely owned by one entity (HOA)	$3,000
2. Centennial Acres Park	Stormwater Retrofit Upland Reforestation	0.4 -3	N/A	• Headwater location • Public land • Multiple components • Simple projects	$5,000
3. Davis Landscaping	Stormwater Retrofit	TBD	N/A	• Willing landowner • Runoff is causing downstream erosion	$5,000 - $10,000
4. 3B Ice Cream	Stormwater Retrofit	2.25	N/A	• Headwater location • Simple project • Identified as priority in previous retrofit inventory	$5,000
5. State Police Headquarters	Stormwater Retrofit	TBD	N/A	• Public land • Good access	$15,000
6. Salvation Army	Stormwater Retrofit	0.7	N/A	• Good access • Simple project	$15,000
7. Londonderry School	Stormwater Retrofit	0.25	N/A	• Educational value • Simple project • Willing landowner likely	$5,000
8. Doehne Road	Riparian Reforestation	0.7	600	• Simple project • Identified as priority by Skelly and Loy	$5,000
9. Paxton Crossing	Stream Restoration	NA	300-500	• Active erosion of utility • Land is likely owned by one entity (HOA) • Simple project	$10,000
10. Glaser Property	Stream Restoration	NA	300	• Willing landowner • Simple project	$2,000 - $3,000

Planning-level costs estimates for stormwater retrofits are based on best professional judgment and average costs for local similar types of projects. Assumptions for riparian reforestation costs include: trees planted on ten foot spacing using small container stock at $5 per tree (from Octorara Nursery) and planted by volunteers .

Detailed descriptions of the large-scale and small-scale priority projects identified in PCN are provided below.

Large-Scale Projects

1. Centennial Acres

The Centennial Acres site (Figure 18) includes a short reach located west of Patton Road and south of Continental Drive in Upper PCN and is just downstream of a parcel slated for development in the near future. This short reach begins at a culvert under Patton Road and continues as an incised channel, which is mainly bordered by mowed lawn. As noted by Skelly and Loy, the pipe outlet and channel banks are stable because of the low stream gradient and the absence of significant development upstream (mainly agricultural land). However, land upstream is currently slated to be developed in the very near future.

Figure 18. Centennial Acres

Restoration efforts should focus on restoring native woody riparian vegetation on both sides of the stream channels and stabilizing and expanding the cross-sectional area of the existing channel to accommodate increased flows from new development. The success of this project will vitally depend on the incorporation of innovative designs in upstream development that reduce impervious cover and preserve natural areas and/or use on-site stormwater treatment practices to reduce downstream impacts. This project should be designed based on the expected post-development discharge to ensure post-development stream stability. Lower Paxton township/PCWEA should work closely with the developer to encourage stormwater reduction and to enforce erosion and sediment control (ESC) practices during construction.

The second component of this project is the conversion of an open grass/wet area located between the stream and the Centennial Acres neighborhood to a wetland complex with a forebay, low marsh, high marsh and permanent pool to treat runoff from the existing development (Figure 19). This area would treat approximately 5 acres (22% impervious cover). Access to the site looks good, but could involve the need to cross the stream. Additional information is needed on the precise drainage area and location of utilities before pursuing this project for implementation. This site provides a good opportunity to monitor the before and after effects of stormwater treatment practices (since the only upstream change will be the one new development). A conceptual design for Centennial Acres can be found in Appendix I.

Figure 19. Location for a wetland creation/enhancement project

2. Fairfax Village North

Fairfax Village North is a townhouse complex located in the Upper PCN headwaters. Multiple projects are proposed at this site. Grass depressions at the north and west ends of the main parking lots could be converted into bioretention areas that would treat approximately 0.2 to 0.4 acres of impervious surface (Figure 20). An existing drop inlet in the parking lot could be converted to a sand filter draining 0.2 acres of impervious cover. Areas of local streambank erosion exist along the stream that runs through the site (Figure 21). These could be stabilized with bioengineering in conjunction with reforestation. Finally, a large pile of yard waste (20 pickup truck loads) that has been dumped next to the stream should be removed.

The field crew spoke with several residents who seemed interested in these potential projects. Since the open areas are maintained by a single entity (the local homeowners association or HOA), this may simplify the process of getting landowner approval for implementation. Skelly and Loy expressed interest in doing stream restoration design for this site, and another local consulting firm, HRG, expressed interest in developing more detailed concepts for the sand filter/bioretention areas. In addition, the HOA has indicated that they have some funds available for project implemetation. The site has good access but site plans would be necessary in order to identify any potential conflicts with sewer or electric utilities. Conceptual designs for Fairfax West are provided in Appendix I.

Figure 20. Proposed location for a bioretention facility at Fairfax Village North

Figure 21. Location for riparian reforestation and stream restoration at Fairfax Village North

3. Honey Bee Golf Center

Figure 22. Potential riparian planting and stormwater wetland retrofit site

The Honey Bee Golf Center is located in Upper PCN in an area of commercial development along Linglestown Road. This site contains a potential reforestation project of approximately 500 feet of stream (right bank) to achieve a 25 to 50-foot wide buffer (Figure 22). This site is in view of Linglestown Rd. and represents a great opportunity for riparian reforestation that would be visible to the public. The site also contains two potential stormwater retrofits, although further investigation is warranted to determine the stormwater conveyance on the site. One retrofit entails conversion of an existing dry pond to a Carroll County sand filter (Figure 23), and the second involves retrofitting of an outfall to create a stormwater wetland by tapping into the existing groundwater table in the floodplain (Figure 22). Opportunities also exist on this site for pollution prevention due to outdoor storage of sand and other materials near a storm drain. Conceptual designs for Honey Bee Golf Center are located in Appendix I.

Figure 23. Existing dry pond at Honey Bee Golf Center

4. Vartan Property
Several parcels along Vartan Way in Lower PCN are owned by a single developer named Vartan, including a bank and several office buildings with almost 100% impervious cover. Several projects are proposed for this property, and because a single landowner is involved, these have been combined into one restoration site referred to as the Vartan Property. The first three components of the project involve installing bioretention facilities at the edge of the bank parking lot (Figure 24), a second facility at the edge of the office building parking lot, and a third facility within an existing swale (Figure 25), accomplished by raising the invert of the existing inlet. Check dams should also be installed in the grass swale to reduce erosion from high flows. Additionally, a dry pond exists on this property next to an apartment complex, and this pond does not appear to be receiving much runoff (Figure 26). This pond could be converted to a pocket wetland and enlarged to provide more treatment (both quality and quantity).

Detailed site plans would be needed for the Vartan Property as it is unclear where the rooftop runoff drains. The existing parking areas do not have curbs and incorporate grass swales along the edges, providing the ideal situation for conversion to bioretention areas. The proposed bioretention facility for the office building parking lot is located immediately adjacent to the Davis property (a small-scale priority site), and some local erosion is occurring where the runoff flows down to the Davis site (Figure 27). Runoff from this site also appears to be affecting the Glaser property (a small-scale priority site) further downstream. Therefore, any restoration done at these downstream sites should be closely coordinated with restoration efforts at the Vartan Property. This site has good access and there will not likely be any conflicts with utilities. Conceptual designs for the Vartan site are provided in Appendix I.

Figure 24. Extensive parking located at the Vartan Property

Figure 25. One of several prime locations for bioretention on the Vartan Property

Figure 26. Potential dry pond retrofit at the Vartan Property

Figure 27. Runoff from Vartan Property office building parking lot causes channel erosion just upstream of Davis Landscaping

Small-Scale Projects

1. Forest Hills

The Forest Hills site is located in Upper PCN behind the homes on the south side of Forest Hills Drive in the Forest Hills development (Figure 28). This simple project would entail reforesting approximately 600-1000ft of stream on the left bank. For this project, it will be important to establish community interest and buy-in. This may entail developing multiple planting plans and concepts that illustrate how attractive the planting projects could be, as well as soliciting community input at neighborhood meetings. The implementation approach taken may also vary depending on whether the land along the stream is owned by a homeowners association, the township or by individual property owners.

Figure 28. Forest Hills reforestation site

2. Centennial Acres Park

Centennial Acres Park is a neighborhood park located near Colonial Road and Continental Drive in the Upper PCN headwaters. This park contains a small parking lot, tennis courts, playground, pavilions and open turf areas. A small stream runs through the property. The proposed stormwater retrofit at this site includes a small turf area below the parking lot that has some minor erosion. The retrofit portion of this project could be used to treat the runoff from the parking lot by converting to a bioretention facility (Figure 29). This area may also capture some runoff from the road but the exact drainage area is unclear. In addition, some under-utilized turf areas in the south end of the park could be reforested (two acres or so) with trails to allow access to the stream. Invasive plants (honeysuckle, multiflora rose) along the stream and forest edge should also be removed. A conceptual design for Centennial Acres Park is provided in Appendix I.

Figure 29. Proposed location for a stormwater retrofit at Centennial Acres Park

3. Davis Landscaping

Davis Landscaping is located north of Paxton Church Road just below the Vartan property (Figure 30). The site does not currently have any stormwater management and is also receiving a lot of runoff from the upstream Vartan property during storms. The property owner is very interested in installing stormwater management practices and, in fact, was going to pursue this on his own anyway. The proposed retrofit includes installation of a new detention pond to treat runoff from the site.

Figure 30. Davis Landscaping site for potential pond creation

4. 3B Ice Cream

3B Ice Cream is located at the corner of Linglestown Road and Colonial Road in Upper PCN. This site was previously identified as a priority retrofit by CWP during the 2003 retrofit inventory. The initial concept for this site was revised during recent field work to expand the area that would be treated by this retrofit. The proposed retrofit would involve conversion of a shallow lined grass depression into a bioretention facility by modifying the existing outlet with a riser/drop inlet structure (Figure 31). Additional runoff can be directed to the bioretention area from an adjacent office building by installing a field connection. Site plans are needed to determine if any conflicts with utilities exist, and the site has good access. Conceptual designs for 3B Ice Cream are provided in Appendix I.

Figure 31. Location that should be drained to previously identified retrofit at 3B Ice Cream

5. State Police Headquarters

The State Police Headquarters is located south of I-81 above Elmerton Avenue in Lower PCN. This site has a large parking lot that drains to multiple storm drain inlets within the lot. The stormwater retrofit proposed here is to redirect the parking lot flow from the stormdrains to an adjacent grassy field that would be converted to bioretention (Figure 32).

Figure 32. Potential bioretention area at State Police Headquarters

6. Salvation Army

The Salvation Army is located on Vartan Way in Lower PCN. This proposed retrofit involves converting a large traffic island in front of the building to a bioretention area that would treat runoff from 0.63 acres of impervious cover (Figure 33). The traffic island currently has areas affected by erosion. The bioretention area could also accept runoff from the building, parking area and driveway. A conceptual design for the Salvation Army is provided in Appendix I.

Figure 33. Island that could be converted to bioretention at the Salvation Army site

7. Londonderry School

The Londonderry School is located on Bamberger Road in Lower PCN south of I-81. The school meets the LEED standards for a green building and currently includes some innovative stormwater management practices (e.g., rooftop runoff is collected and re-used within the building for toilets). This site was prioritized because of its potential educational value and it is likely that the landowners would be amendable to this type of project.

The first recommendation for this site is to install rain gardens using native plantings in existing turf areas along the parking lot to capture and treat runoff (Figure 34). This garden could serve as a demonstration site and would have educational value. An existing stormwater dry pond on site has some minor erosion that may or may not be the product of being recently established (Figure 35). If erosion is not due to recent establishment, a velocity dissipater could be installed in the pond to the control erosion problem, or the pond could be converted to a wet pond to increase water quality treatment. A conceptual design for the Londonderry School is provided in Appendix I.

Figure 34. Space for stormwater treatment practice at the Londonderry School

Figure 35. - Proposed dry pond retrofit at the Londonderry School

8. Doehne Road

The Doehne Road site is located along a stretch of Paxton Creek that runs just south of Doehne Road in Lower PCN. The few residences on the south side of Doehne Road have very deep backyards consisting mainly of mowed grass with scattered trees (Figure 36). These yards descend at a moderate gradient to the edge of the floodplain of Paxton Creek, which is generally well over 150 feet wide in this area. A small, unbuffered intermittent tributary also flows through these yards to where it meets Paxton Creek. A sewer line runs through the floodplain but is located considerably north of the channel margin in most cases. Invasive vines (bittersweet) were noted at this site, as was minor bank erosion.

This site was part of a larger reach previously identified as a priority reach for reforestation and potential floodplain reconnection by Skelly and Loy (1998). The restoration actions recommended as part of this project include reforesting the right bank of the stream and both banks of the intermittent tributary with a 25 to 50 foot buffer of sycamores, green ash and river birch. Red osier dogwood could be used for bank stabilization or aesthetics on the smaller intermittent tributary. This site has multiple private landowners, but since the yards are extraordinarily deep, they may be amenable to yielding some of their lawn area for reforestation.

Figure 36. Photo of riparian reforestation area near Doehne Road

9. Paxton Crossing

Paxton Crossing is a townhouse community located in Lower PCN. The site contains a small first-order tributary that is deeply incised. Erosion is accelerated by the lack of root protection on the left stream bank, which is bordered by turf grass (Figure 37). Underground electric wires have been exposed along the streambank at one portion of the site (Figure 38). The concept for the site is to re-grade the left stream bank to a 2:1 or 3:1 slope and use bioengineering and native plantings to stabilize the stream bank. The site is approximately 200 feet long with an additional 100 to 200 feet downstream that is piped and could be daylighted using a similar bioengineering restoration approach. Permitting and construction for the daylighting portion of the project would likely pose a more difficult and complex task and increase costs considerably.

Figure 37. Undercutting bank and erosion at Paxton Crossing

Figure 38. - Exposed electric wires at a Paxton Crossing stream

10. Glaser Property
The Glaser property is located in Lower PCN near the intersection of Paxton Church Road and Elmwood Drive (Figure 39). The stream runs underground through the side yard of this property and daylights from a 24-inch outfall in the backyard. The stream, which is undercut, flows through the backyard and then into a 36-inch culvert under Paxton Church Road. The property owner reports frequent flooding and erosion problems on her property and adjacent properties, and has indicated that much of the runoff is coming from several properties upstream (Vartan Property, Davis Landscaping). After investigating upstream, it appears that a large dry pond next to the apartment complex may not be functioning properly and does not actually detain much water during storms. Several restoration projects were proposed on these upstream properties to treat stormwater runoff. Any restoration on the Glaser property should be done in conjunction with upstream volume controls to avoid washout of newly installed practices.

On the Glaser property, laying back the stream banks and using bioengineering to stabilize the banks is the proposed approach. A fence in the backyard may have to be relocated to accommodate this change. It should also be noted that the stream channel has a 45-degree bend that likely constricts the flow and may need to be modified.

Figure 39. Small eroding stream located on the Glaser property

Section 5: Recommendations

5.1 Subwatershed Goals

An important element of watershed planning is to set goals for both the overall watershed and the individual subwatersheds evaluated. Subwatershed goals were developed for the PCN subwatersheds that built upon previous recommendations made in the 2003 *Paxton Creek Baseline and Stormwater Retrofit Assessment*, input from local stakeholders during public meetings, and observations made during the stream and subwatershed assessments in PCN. Stakeholder involvement is a key ingredient in a subwatershed plan as stakeholders bring to the table important issues and they are the ones who must live with the ultimate decisions. Eleven subwatershed goals were identified for Paxton Creek North and these are presented below.

1. Expand green space/recreational opportunities. Parkland and other public open space are currently limited in the PCN subwatersheds. Stakeholders identified increasing recreational opportunities (e.g., fishing and hunting) as a priority goal. Opportunities to provide green space and recreational opportunities exist in the forested headwater areas of Upper PCN as well as along the stream corridor throughout the PCN subwatersheds (e.g., greenways).

2. Increase understanding and awareness of watershed issues. Often the most important first step in watershed or subwatershed restoration is the education of local stakeholders, that includes increasing their basic understanding of watersheds, as well as their knowledge of specific problems in their watershed and actions they can take to reduce pollution. This goal is in direct alignment with the mission of PCWEA.

3. Improve private stewardship of the land. Subwatershed assessments revealed that few residents were acting as stewards of the land. Specific areas in need of improvement included protection of stream buffers, appropriate lawn care practices and proper storage of outdoor materials.

4. Maintain good macroinvertebrate habitat. Sampling results for sites in Upper PCN indicated that macroinvertebrate communities were comparable to those of a regional reference site (McAllister, pers. comm..). Because sites upstream of these stations are slated for development, it is vital to take action now to maintain this high quality community.

5. Conserve remaining tracts of contiguous forest. The uppermost reaches of Upper PCN are primarily forested and are comprised of the slopes of the Blue Mountains. This area contains the highest proportion of contiguous forest in PCN but is also under strong development pressure.

6. Expand riparian forest cover to form a continuous network of stream buffers. Riparian buffers are vital to maintain stream health and provide such benefits as shading, bank stabilization, habitat and pollutant removal. Many sites in PCN provide opportunities to improve riparian buffer coverage.

7. Establish partnerships to actively pursue implementation of restoration projects. Implementation of restoration projects is a multi-faceted pursuit that includes: obtaining landowner permission, securing funding and supplies, designing and installing the project and conducting long-term maintenance and monitoring. Partnerships between watershed groups, local governments and private consultants are necessary to ensure coordination of all these elements of implementation.

8. Reduce sediment inputs to Paxton Creek North and Wildwood Lake. A small portion of the Paxton Creek mainstem below Black Run in PCN is listed as impaired for siltation under EPA's 303(d) assessment. Subwatershed assessments in PCN revealed significant sediment deposition in the lower reaches. Wildwood Lake, located just downstream of PCN, is also being clogged with sediment and restoration measures being discussed include dredging. These factors make sediment reduction a goal for PCN.

9. Minimize impacts of future growth on stream health. Paxton Creek North is one of the least developed areas in the Paxton Creek Watershed and is under development pressure. Appropriate regulations and programs must be in place to reduce the impacts of this new development on downstream receiving waters.

10. Reduce the volume of stormwater runoff from developed land. Stormwater management in Pennsylvania has only recently been required as part of development regulations. Therefore, a large proportion of existing development in PCN does not provide any treatment of stormwater runoff. Stormwater retrofits can be installed in the developed landscape to provide treatment of stormwater runoff where none previously existed.

11. Reduce pollutant inputs to Paxton Creek North. Potentially polluting behaviors observed during the subwatershed assessments included: pesticide application, improper draining of pool water, and storage of pollutants next to storm drains. Sediment and phosphorus loads in the Paxton Creek Watershed are significantly higher than loads from agricultural and forested basins in the region. Potential illicit discharges exist further down in the City of Harrisburg. These factors make pollutant reduction a goal for PCN.

Section 5.2 Subwatershed Recommendations

It is important to develop a series of concrete actions that can help to achieve the subwatershed goals as well as to identify a timeline and responsible parties for implementing these actions. Specific recommendations were developed for the PCN subwatersheds that built upon previous recommendations made in the 2003 *Paxton Creek Baseline and Stormwater Retrofit Assessment*, input from local stakeholders during public meetings, and observations made during the stream and subwatershed assessments in PCN. Table 14 presents the 18 recommendations developed for PCN and is followed by a description of each, organized by the proposed timeline. Short-term recommendations should occur with the next year and include those deemed most important or imminent to protecting the health of the subwatershed. Mid-term recommendations should occur within one to three years and long-term recommendations may take longer than three years to implement.

Table 14. Paxton Creek North Recommendations

Recommendations	Goals Met	Timeline	Responsible Party/Partners
1. Adopt an open space or forest conservation ordinance that requires a percentage of green space to be preserved for all new development	1, 5, 9	Short-term	PCWEA, ACB, CBF, Local Municipalities
2. Limit development on steep slopes with the adoption and/or revision of a steep slopes ordinance	1, 5, 8, 9		PCWEA, ACB, CBF, Local Municipalities
3. Develop a public education campaign that improves watershed awareness and targets municipal officials, developers, business owners and residents	2		PCWEA, Local Municipalities
4. Adopt a stream buffer ordinance to protect existing forest buffers for all new development sites	6, 9		PCWEA, ACB, CBF, Local Municipalities
5. Establish a riparian buffer planting program	3, 6		PCWEA, NRCS, CBF, ACB, DEP
6. Revise local erosion and sediment control (ESC) ordinances to clearly define acceptable practices and enforcement measures	8, 9		PCWEA, ACB, CBF, Local Municipalities
7. Increase local ESC staff capacity for inspecting and enforcing ESC regulations at construction sites	8, 9		Local Municipalities, DEP, PCWEA, DCCD
8. Implement small-scale priority restoration projects in PCN.	10		PCWEA
9. Directly contact landowners of potential restoration sites to discuss possible project implementation	3	Mid-term	PCWEA
10. Establish a program to conduct regular sampling for macroinvertebrates	4		DCCD, SRBC, PCWEA, DEP
11. Conduct a bi-annual State of the Paxton Creek Watershed meeting for local partners	2, 7		PCWEA
12. Modify relevant local codes and ordinances to allow and encourage use of Better Site Design techniques identified through the Paxton Creek Watershed Site Planning Roundtable	9		Local Municipalities, ACB, DEP, PCWEA
13. Implement large scale priority restoration projects in PCN	10		PCWEA, Local Municipalities, DEP, PENNDOT
14. Establish a program to monitor watershed restoration and protection efforts	4, 8, 9, 10, 11		DCCD, SRBC, PCWEA, DEP, HACC
15. Establish a restoration committee to seek funding for implementation of stormwater retrofits and stream restoration projects	7, 8, 10, 11		DCCD, DEP, SRBC, PCWEA, HACC, CBF, ACB, CVI
16. Adopt a stormwater ordinance that requires new development to provide infiltration and recharge of stormwater runoff	9, 11	Long Term	DEP, PCWEA, Local Municipalities
17. Establish a committee to coordinate illicit discharge detection and elimination (IDDE) efforts among the various jurisdictions	7, 11		DEP, PCWEA, Local Municipalities
18. Purchase undeveloped green space for use as a community park or greenway	1, 5		PCWEA, Local Land Trust

Timeline: short-term = 0-1 years, mid-term = 1-3 years, long-term = > 3 years
ACB = Alliance for the Chesapeake Bay, CBF = Chesapeake Bay Foundation, PENNDOT = Pennsylvania Department of Transportation, HACC = Harrisburg Area Community College, CVI = Canaan Valley Institute, NRCS = Natural Resources Conservation Service.

Short-Term Recommendations

1. Adopt an open space or forest conservation ordinance that requires a percentage of green space to be preserved for all new development. The purpose of the ordinance is to preserve existing vegetation and avoid mass clearing of development sites. A model open space design ordinance is provided at:
www.stormwatercenter.net/Model%20Ordinances/open_space_model_ordinance.htm

2. Limit development on steep slopes with the adoption and/or revision of a steep slopes ordinance. Protection of steep slopes in Susquehanna Township and Lower Paxton Township will reduce the amount of sediment eroded from steep slopes during the construction process and will help to conserve forests in the headwater area. Susquehanna Township does not currently have a steep slopes ordinance and should adopt one that limits clearing on slopes greater than 15 or 25%. Lower Paxton Township has a Steep Slopes Conservation District, and these regulations should be modified. This regulation currently allows from 10 to 40% of slopes between 15 and 25% to be covered by impervious surfaces. On slopes greater than 25%, clearing and grading is allowed for uses such as driveways, parks and yards. Revision of this ordinance should prohibit clearing and grading on slopes greater than 25% and should severely restrict clearing and grading on slopes between 15 and 25%. Other considerations include providing density credits for zero disturbance and allowing clustering of lots to avoid building on steep slopes.

3. Develop a public education campaign that improves watershed awareness and targets municipal officials, developers, business owners and residents. Specific actions include:

- Develop educational materials such as fact sheets and slideshows for use at public meetings, and distribute at such venues to educate stakeholders on key watershed issues, including: stream buffers, lawn care, Better Site Design (BSD), erosion and sediment control, downspout disconnection, dumpster management and outdoor storage.
- Meet with local media (e.g., newspapers, public television) to identify ways to promote watershed education.
- Conduct meetings with five developers that are active in the watershed to promote BSD. The focus of the meeting should be on the win-win situation of cost savings combined with environmental benefit.
- Organize a tour of developments in the area that use BSD techniques and invite members of the board of supervisors, planning commission, and local developers to attend.
- Publish several articles in local Harrisburg area newspapers that promote BSD and use local developments as case studies. An article could be one method of promoting the BSD tour.
- Educate developers and municipal officials about the importance of good erosion and sediment control (ESC). Encourage local residents to become ESC watchdogs.
- Educate local property owners on the importance of stream buffers and how to install them.
- Implement a targeted education effort that includes going door-to-door in specific neighborhoods that have been identified as needing restoration practices such as stream buffers, or downspout disconnection.
- Identify existing outreach materials that could be routed to local newspapers and other outreach sources or to schools for insertion into the curriculum.

4. Adopt a stream buffer ordinance to protect existing forest buffers for all new development sites. Much of the PCN and its tributaries are currently unbuffered in existing residential developments (Figure 40). Stream buffers can be preserved for all new developments by adopting a stream buffer ordinance. The ordinance language should state that stream buffers are vital to maintain stream health and could also cite the anti-degradation clause of the Clean Water Act as the legal basis. A model stream buffer ordinance is provided at: www.stormwatercenter.net/Model%20Ordinances/buffer_model_ordinance.htm. Municipal stream buffer ordinances should be incorporated into the Dauphin County Greenway plan to ensure overall coordination of protection efforts.

5. Establish a riparian buffer planting program. This program would establish a working relationship between PCWEA and the Chesapeake Bay Foundation (CBF), the Alliance for the Chesapeake Bay (ACB) and the Natural Resources Conservation Service (NRCS) to promote riparian reforestation on private lands. The goals of the program would be to identify potential planting areas, directly contact landowners of these sites to encourage them to participate in the program, and to help interested parties implement planting projects. Methods to solicit participation in this program could include a letter to all riparian property owners announcing the program, followed by a phone call. Another function of this program could be to establish and maintain a nursery or grow-out station to provide a source of trees for the project. Implementation assistance could be given in the form of volunteers, donated trees, and technical assistance in planning and preparation. Other potential partners for this program include the Audubon Society and Ducks Unlimited.

6. Revise local erosion and sediment control (ESC) ordinances to clearly define acceptable practices and enforcement measures. Lower Paxton and Susquehanna Townships should review their existing erosion and sediment control ordinances to ensure that adequate enforcement measures are in place. In addition, the ordinances should reference the latest ESC practices and guidance on design, installation and maintenance of practices.

7. Increase local ESC staff capacity for inspecting and enforcing ESC regulations at construction sites. Even if enforcement measures are in place for ESC at construction sites, enforcement of regulations does not always happen when communities have little staff capacity to do so. Local municipalities should seek funding or allocate a portion of their annual budgets to increase staff capacity for inspecting and enforcing ESC regulations. This should include providing appropriate training for staff who will be conducting the inspections.

8. Implement small-scale priority restoration projects in PCN. Of the ten small-scale priority restoration projects identified in PCN, the short-term goal should be to implement two projects. Small-scale projects can be performed with a low tech engineering approach and utilize volunteer labor for installation of portions of the projects such as plantings. See Section 4.2 for detailed descriptions of the priority projects.

Mid-Term Recommendations

9. Directly contact landowners of potential restoration sites to discuss possible project implementation. PCWEA should work with other local partners to contact landowners of priority restoration projects identified in PCN to solicit their interest in implementation. This will likely involve several phone calls or meetings and may necessitate obtaining additional information about the site (e.g., site plans, utility locations), working with local consulting firms to estimate costs, presenting ideas to local homeowners associations (HOAs), and educating the landowners about watershed issues and the benefits of restoration.

10. Establish a program to conduct regular sampling for macroinvertebrates. Utilize the already established Macroblitz monitoring stations to continue to monitor the long-term health of the bug community on an annual or bi-annual basis. Selecting a few key water quality parameters based on the previous Macroblitz results will provide a multi-faceted approach that will help to identify the sources of any observed patterns of decline. This program will be particularly important to monitor the effects of new development on stream health in PCN. Additional information on long-term monitoring is provided in Section 5.3.

11. Conduct a bi-annual State of the Paxton Creek Watershed meeting for local partners. Invitees would include local governments, developers, businesses and watershed residents. The purpose of the meeting is to interact and talk about the latest work being done in the Paxton Creek watershed and to generate interest in implementing priority projects.

12. Modify relevant local codes and ordinances to allow and encourage use of Better Site Design techniques identified through the Paxton Creek Watershed Site Planning Roundtable. Working with the Alliance for the Chesapeake Bay, Lower Paxton Township and Susquehanna Township should formally adopt the recommendations made in the 2003 site planning roundtable and begin to make changes to their codes and ordinances to reflect these recommendations (Figure 41). A good starting point may be to present the recommendations to local planning commissions or similar entity to get their buy-in and facilitate the process.

13. Implement large-scale priority restoration projects in PCN. Of the four large-scale priority restoration projects identified in PCN, a mid-term goal should be to implement two projects. Large-scale projects require a greater degree of design and engineering, are typically more expensive and may include multiple components such as stormwater retrofits, stream restoration and riparian plantings. See Section 4.2 for detailed descriptions of the priority projects.

14. Establish a program to monitor watershed restoration and protection efforts. It is important to measure and track both the short and long-term health of the streams in Paxton Creek North, and the success of restoration efforts. As restoration projects are implemented in PCN, a monitoring plan should be developed for each project. Specifically, opportunities to measure the effectiveness of innovative restoration projects, such as bioretention or downspout disconnection, should be explored. Additional information on long-term monitoring is provided in Section 5.3.

15. Establish a restoration committee to seek funding for implementation of stormwater retrofits and stream restoration projects. This committee should have a goal of obtaining funding for two large-scale and two small-scale restoration projects in Upper PCN each year (see Section 4.2 for potential projects). Specific tasks include identifying potential funding mechanisms, submitting proposals for funding and/or soliciting potential funders.

Long-Term Recommendations

16. Adopt a stormwater ordinance that requires new development to provide infiltration and recharge of stormwater runoff. The creation of the Pennsylvania Stormwater Best Management Practices Manual is currently underway. This manual will emphasize innovative stormwater treatment practices that encourage on-site stormwater management and increased groundwater infiltration as a means to minimize stormwater discharge and limit the amount of surface pollutants entering Pennsylvania streams. We recommend that Lower Paxton and Susquehanna Townships adopt the PA State regulations (once they are complete) in a stormwater ordinance to encourage the use of practices that provide infiltration and recharge of stormwater. Other useful elements of a stormwater ordinance suggested by stakeholders include: establishing a stormwater utility to fund stormwater projects, and establishing a process to ensure adequate treatment of stormwater given future changes to already developed sites (e.g., future additions and expansions). This recommendation will likely have to be implemented under the long-term timeframe since the state stormwater manual is still in development.

17. Establish a committee to coordinate illicit discharge detection and elimination (IDDE) efforts among the various jurisdictions. Though illicit discharges are not expected to impact PCN to a significant degree, it is important to have a coordinated multi-jurisdictional program in place to prevent illicit discharges and detect future discharges since streams do not observe political boundaries. Guidance for developing an illicit discharge detection and elimination (IDDE) program is provided in Brown, et al (2004).

18. Purchase undeveloped green space for use as a community park or greenway. PCWEA should work with DCCD and local land trusts to identify priority land for conservation and pursue acquisition or conservation easements. In Upper PCN, the forest mountain headwater area should be prioritized as well as the stream corridor. In particular, the Logan Property near the Forest Hills development was identified as a potential acquisition site by stakeholders. In Lower PCN, opportunities exist to develop a greenway along currently forested portions of the mainstem.

Figure 40. Evidence of the need for a stream buffer ordinance in Paxton Creek North

Figure 41. A 100-foot diameter cul-de-sac in Paxton Creek North (a lost opportunity for bioretention) illustrates the need for Better Site Design

5.3 Long-Term Monitoring

Monitoring is an essential component of watershed planning for documenting project success, tracking stream health over time, and testing the effectiveness of innovative restoration practices. Project success is an important buzzword in today's grant-driven funding environment. Three ways to monitor project success include:

1. Track the number and location of restoration projects and subwatershed recommendations that have been implemented.
2. Conduct post-construction monitoring of structural restoration practices to ensure that they are functioning properly.
3. Measure the effect of restoration efforts on stream health.

We recommend establishing a long-term monitoring program that utilizes the above three methods to track project success in Paxton Creek North. The first component, tracking the number and location of restoration projects and recommendations that have been implemented, can be done using a simple spreadsheet, or may be integrated with a Geographic Information System (GIS) to add a spatial element. Basic information about each project should be included in the spreadsheet, and the information should be updated on an annual basis.

The second component, conducting post-construction monitoring of restoration practices to ensure they are functioning properly, should be required with implementation of structural restoration practices such as stormwater treatment practices or stream restoration projects. A maintenance and inspection plan should be developed during the early stages of the project to prevent practice failure and allow a periodic check to ensure the practice is functioning properly. Practices that do not require regular maintenance should at a minimum be inspected on an annual basis. Specific guidance on post-construction maintenance and inspection of stormwater treatment practices is provided at www.stormwatercenter.net.

The third component of a long-term monitoring plan is to measure the effect of restoration practices on stream health. This can be done at both the site and the subwatershed scale; however, detecting change is more easily accomplished at an individual site. For example, it may be difficult at the subwatershed level to distinguish between actual change due to restoration efforts versus changes due to climatic variation and weather patterns. Given these considerations, it is recommended that water quality and biological monitoring in PCN be approached in the following three ways:

1. Track long-term water quality and stream health using macroinvetebrates. Macroinvertebrates are indicators of stream health whose life cycle places them in a stream for a period often of six to twelve months and therefore reflect the conditions in the stream over a longer period of time compared to a water quality sample (NCDENR, 2004). Macroinvertebrate sampling should be conducted on an annual or bi-annual basis in the Paxton Creek Watershed at the already established Macroblitz stations to continue to track long-term health in the watershed. At a minimum, several key water quality parameters should also be selected based on previous Macroblitz results and monitored with the macroinvertebrates to provide clues to the sources of any observed decline in bug communities.

2. Track improvements in water quality from implementation of restoration projects at either the site level or reach level. This monitoring could be useful for testing the pollutant removal effectiveness of innovative practices such as bioretention or sand filters. For example, volunteers could conduct storm event monitoring of inflow water quality versus outflow water quality for a newly installed bioretention facility. Another example is to monitor the effect of downspout disconnection in a single headwater neighborhood (implemented through a targeted door-to-door outreach effort) by monitoring the streamflow at the neighborhood outlet both before and after downspout disconnection occurs.

3. Track the effects of an individual development project at the reach level to determine the impact of either an innovative or traditional development. Ideally, this would include water quality and biological monitoring, although intensive water quality monitoring including storm events may be cost prohibitive. This effort would be best achieved by applying a paired watershed study approach, which would require monitoring a control reach within PCN as well. It is important that the control reach does not have any development within its drainage area. Several potential study reaches exist in Upper PCN where parcels are slated to be developed in the near future.

   A paired watershed study is one of best ways to document change in nonpoint source (NPS) pollution. The following caveats apply to a paired watershed study:

   - Anticipated (or modeled) change should be greater than 20% for the parameter of interest or detecting change over background noise will be very difficult.

- A control watershed (reach) must be used in order to select out background noise due to variations in weather, climate etc.
- Monitoring must occur both pre- and post-restoration efforts

A more detailed discussion of paired watershed design can be found in Clausen and Spooner (1993).

Table 15 summarizes the long-term monitoring recommendations for Paxton Creek North.

Table 15. PCN Monitoring Recommendations

PCN Monitoring	Goal
Track the number and location of restoration projects and subwatershed recommendations that have been implemented.	Provide accounting and tracking for restoration efforts
Conduct post-construction monitoring of structural restoration practices	Ensure that restoration practices are functioning properly
Continue to monitor Macro blitz stations on a annual or bi-annual basis	Track long term health in the watershed, measure effect of restoration practices on bug community and water quality
Conduct water quality monitoring upstream and downstream of newly installed restoration practices	Test innovative restoration practices, measure effect of restoration practices on stream health
Use a paired watershed approach to monitor a reach that is being developed as well as a control reach within PCN	Document the impact of traditional or innovative site development on streams

5.4 Recommendations for Future Subwatershed Assessments

The Paxton Creek North subwatersheds were selected for detailed assessment from the eleven subwatersheds in the Paxton Creek Watershed because the potential exists to protect these streams from further degradation. Conversely, Asylum Run is the most developed subwatershed in the Paxton Creek Watershed after the Paxton Creek mainstem. There is considerable restoration interest in this subwatershed due to the high degree of impervious cover, the large volume of stormwater and the frequent occurrence of downstream flooding. We recommend that PCWEA focus its subwatershed restoration efforts on Asylum Run next by applying the methods used in Paxton Creek North.

Due to the amount and complexity of development in the Asylum Run subwatershed, it is vital to have more technical information on the location of stormwater infrastructure in the subwatershed in order to proceed with the creation of a restoration plan for the area. The components and rationale of such an effort are presented in Table 16.

Table 16. Data Needs for Restoration Planning in Asylum Run		
Data Component	**Rationale**	**Potential Data Source**
1. Generate digital mapping of stormwater infrastructure including pipes, outfalls, drainage area of outfalls and outfall size.	This step is a key component for restoration planning for sizing and siting stormwater retrofits, and for evaluation of hydrology critical for stream restoration and flood management planning. This would facilitate improved planning for restoration efforts.	This is a component of Phase I and II NPDES permits and will likely be performed by the jurisdictions.
2. Conduct the Outfall Reconnaissance Inventory (ORI) to monitor for illicit discharges	Biological data suggests chemical impairment in Asylum Run should be evaluated based on its high number of outfalls and highly developed nature	Dauphin County is currently coordinating the Phase I and II NPDES programs with the townships. Illicit discharge monitoring is a component of Phase I and Phase II and will likely be performed by the jurisdictions.
3. Location, drainage area, and type of each stormwater treatment practice in the subwatershed	Improvement of stormwater retrofitting ability in the subwatershed	Could be conducted by PCWEA using a GPS and input into GIS
4. Hydrologic modeling using improved stormwater infrastructure data	Would allow for the identification of locations creating disproportionately high runoff volumes and locations that may be contributing the greatest volume to downstream flooding conditions. This would aid in the identification and siting of treatment practices that may help to minimize downstream flooding.	Data used for flood modeling done for the Act 167 plan may provide initial starting point

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