WISSAHICKON CREEK STREAM ASSESSMENT STUDY
LOWER WISSAHICKON WATERSHED

Philadelphia Water Department Office of Watersheds 2010

Wissahickon Creek Watershed Stream Assessment Report
Lower Wissahickon Watershed

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1 INTRODUCTION

1.1 PROJECT PURPOSE

The purpose of the Wissahickon Creek Watershed Stream Assessment Report was to provide the Philadelphia Water Department (PWD), local watershed partnership groups, and other interested parties with an analysis and summary of the existing physical conditions within the watersheds of Wissahickon Creek Watershed inclusive of both stream networks and riparian corridors. Specifically, the goals of this assessment were to provide:

+ a characterization and documentation of existing conditions
+ a reference point for evaluating changes over time
+ a tool for prioritizing stream and habitat restoration sites
+ insight into appropriate restoration strategies
+ a land use planning and redevelopment tool
+ an aid in determining the effects of urbanization

With the insight gained from this assessment, it will be possible to strategically plan and coordinate restoration activities throughout the watershed as well as within individual watersheds. The ultimate goals of these restoration efforts will include: improving water quality, managing or replanting riparian vegetation, enhancing in-stream habitat, providing increased fish passage and finally, facilitating stream bank stabilization.

1.1.1 REPORT STRUCTURE

Each watershed section has been written to be a stand alone document. The methodologies described in the beginning of the report apply to all the data collection and processing techniques mentioned in each of the watershed assessments.

1.2 PROJECT DESCRIPTION

The Wissahickon Creek Watershed Stream Assessment consisted of an evaluation of approximately 115 miles of stream channel within the 64 square mile watershed by members of the Philadelphia Water Department's Office of Watersheds (PWDOOW) in 2005. The assessment involved walking the entire length of main stem Wissahickon Creek and 26 of its tributaries (Figure 1-1), to record specific information about the channel, surrounding habitat, and infrastructure located in or near the creeks. The Lower Wissahickon Creek Watershed from henceforth is defined as the portion of the watershed south of Northwestern Avenue, which forms the border between Mountgomery and Philadelphia counties.

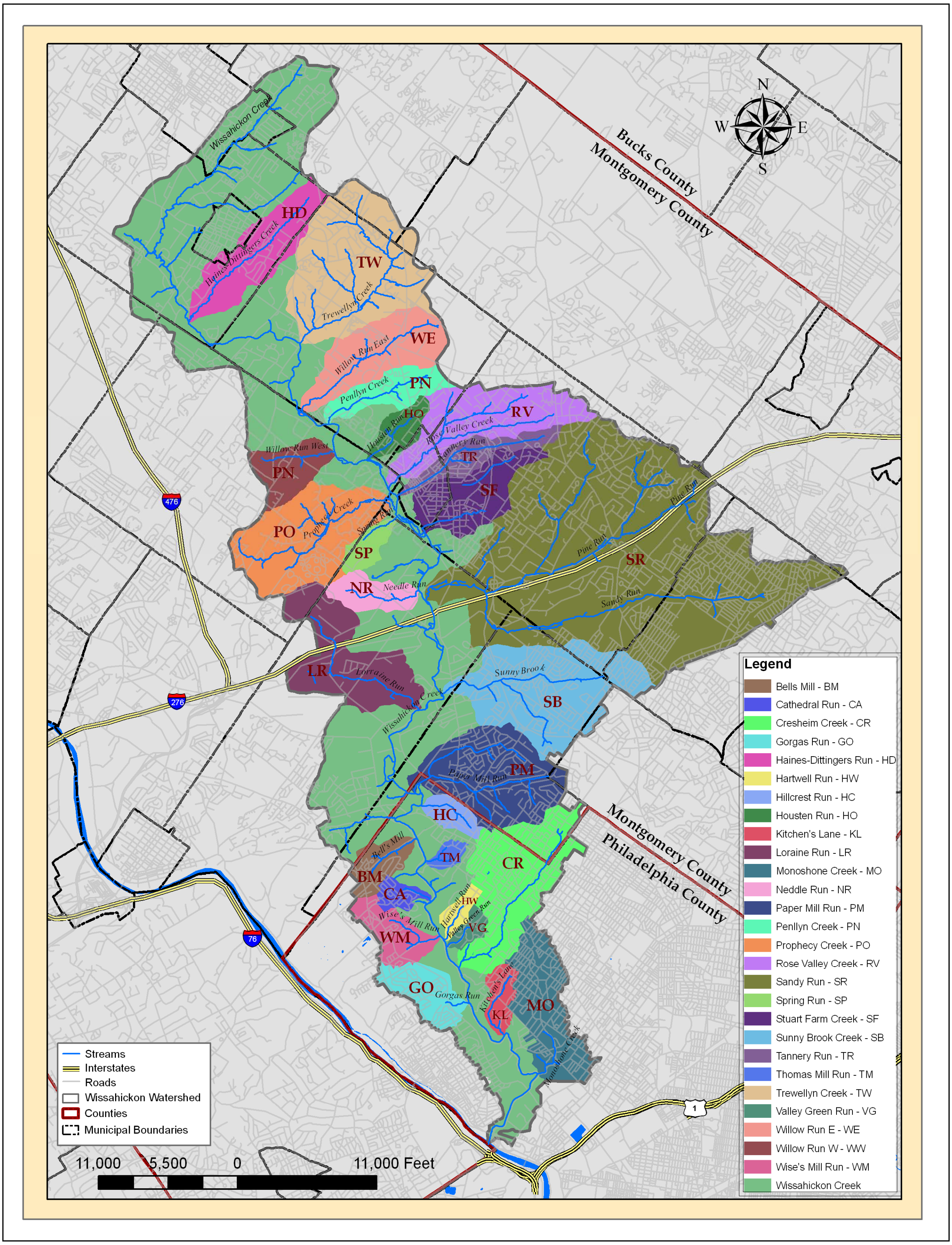


Figure 1-1: Wissahickon Creek Watershed

PWD completed a suite of field surveys and desktop analyses to summarize existing stream and riparian conditions in the Wissahickon Creek Watershed. Field surveys were focused on the characterization of channel morphology and in-stream hydraulics through the use of surveyed cross-section data and substrate particle size distribution. The physical processes that determine channel morphology, instream hydraulics, channel slope and sediment load are dependant on the physical conditions within the respective sub-catchments that drain into the Wissahickon Creek stream network. Factors that influence these conditions include valley slope, land-use and local geology as well as the potential impacts of infrastructure. Thus, to thoroughly characterize instream conditions, it was necessary to examine the physical conditions within respective watershed stream corridors as well (Figure 1-2).

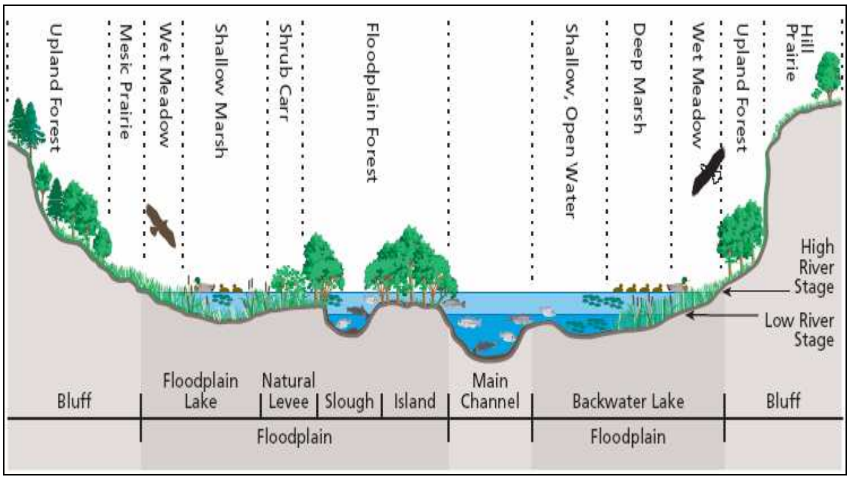


Figure 1-2: Generalized Cross Section of a Stream Corridor

*adapted from Bioscience, vol. 45, p. 170, March 1995.

Conceptually, stream corridors are extended watershed cross-sections consisting of three main components, which are the stream channel, flood plain and an upland transitional zone or terrace. The stream channel lies at the lowest elevation of this system and conveys water at least part of the year. The floodplain exists on one or both sides of the channel and is inundated by floodwaters at an interval determined by the regional hydrologic regime. The transitional upland portion of the river corridor exists on one or both sides of the floodplain and serves as the transition between the floodplain and the surrounding landscape (FISRWG 1998).

These three components are dynamically linked through the transport and storage of water, nutrients and sediment, such that alterations to one component will over time influence another component. An example of this process is evident in the change in hydraulic, hydrologic and sediment regimes of watersheds that undergo urbanization or have changes in land use.

Land cover is intrinsically linked to a watershed's hydrologic regime through the conversion of precipitation and throughfall to runoff. As a watershed is converted from a natural, forested land cover to a more impervious and urbanized land cover, runoff increases and concomitantly increases the volume of water transported or stored by the stream channel and floodplain (Figure 1-3).

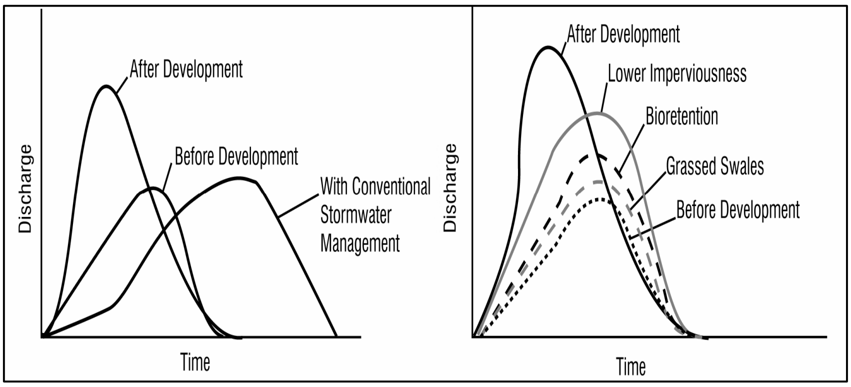


Figure 1-3: Comparison of Volume and Duration of Stormwater Runoff Before and After Land Development, and Reductions in Runoff from BMPs.

*Source: Prince George's County Department of Environmental Resources et. al. (undated)

1.3 WATERSHED DESCRIPTION

Wissahickon Creek is located in southeastern Pennsylvania, flowing from the suburbs of Montgomery County through the northwestern portion of the City of Philadelphia. The headwaters of the Wissahickon Creek originate in a parking lot at the Montgomeryville Mall complex in Montgomery Township and the main stem of the creek continues for approximately 27 miles through nine municipalities before reaching its confluence with the Schuylkill River. Wissahickon Creek Watershed has a total drainage area of approximately 64 square miles and drains portions of fifteen municipalities as well as the City of Philadelphia (Table 1-1). Numerous tributaries converge into main stem Wissahickon Creek as the total number of stream miles contributing to the Wissahickon Creek stream network is roughly 115 miles (Table 1-2).

Table 1-1: Municipalities with Contributing Drainage Area to the Wissahickon Creek Watershed

Municipality	% of Wissahickon Drainage in each Municipality
Upper Dublin Township	18.9%
City of Philadelphia	16.8%
Lower Gwynedd Township	13.0%
Whitemarsh Township	12.9%
Springfield Township	10.1%
Whitpain Township	8.3%
Upper Gwynedd Township	7.9%
Abington Township	5.6%
Montgomery Township	2.4%
Ambler Borough	1.3%
Lansdale Borough	1.1%
North Wales Borough	0.9%
Cheltenham Township	0.4%
Horsham Township	0.2%
Worcester Township	0.1%
Upper Moreland Township	0.1%

Table 1-2: Stream Lengths for Wissahickon Creek Main stem and Tributaries

Hydrologic Feature	Length (mi)
Bell's Mill	1.2
Cathedral Run	0.1
Cresheim Creek	3.1
Gorgas Run	0.3
Haines-Dittingers	3.3
Hartwell Run	0.7
Hillcrest Run	0.8
Honey Run	1.0
Housten Run	1.3
Kitchen's Lane	1.5
Lorraine Run	3.2
Monoshone Creek	1.3
Paper Mill Run	5.8
Pennlyn Creek	2.3
Pine Run	8.5
Prophecy Creek	5.0
Rose Valley Creek	5.7
Sandy Run	8.1
Spring Run	0.7
Stuart Farm Creek	1.2
Sunny Brook Run	3.8
Tannery Run	2.6
Thomas Run	0.8
Trewellyn Creek	7.3
Valley Green Run	0.5
Willow Run East	3.9
Wise's Mill	1.3
* Wissahickon Creek Main Stem	39.4
Total	**115**

* Wissahickon Creek stream length additionally includes small unnamed tributaries with direct drainage to the main stem.

1.4 LAND USE

Land use information for the Wissahickon Creek Watershed (Figure 1-4) was obtained from the Delaware Valley Regional Planning Commission (DVRPC). Over time, the Wissahickon Creek watershed has experienced continual and extensive urban and suburban development. The drainage area is characterized by a mixture of various land uses, but single family detached homes cover more than half of the watershed. During the initial stages of development within the Wissahickon Valley, agricultural and industrial (e.g. grist mills) land-use dominated the rugged landscape; however, the dominant land-use in the watershed is now residential at approximately 52 percent (Table 1-3).

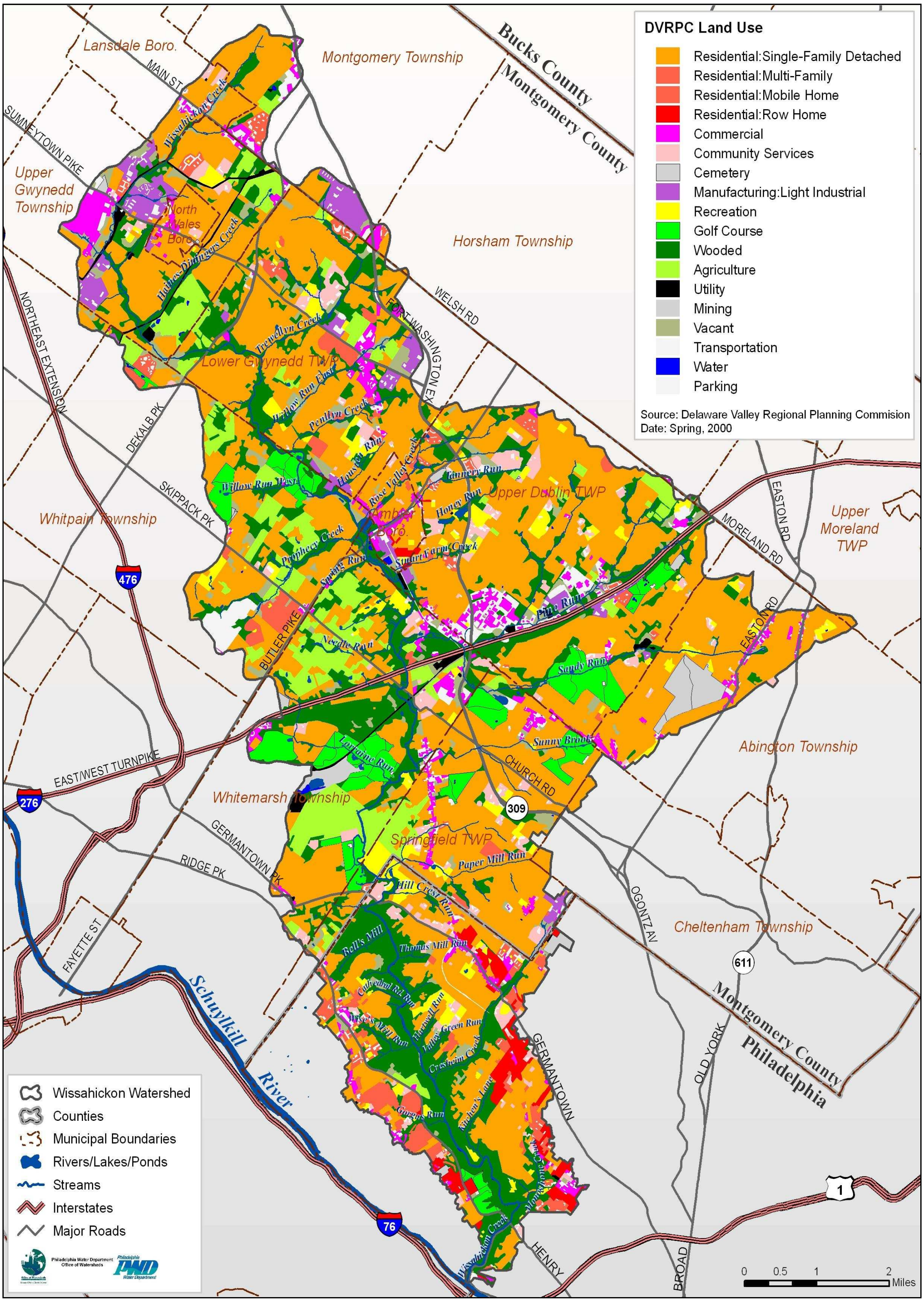


Figure 1-4: Wissahickon Creek Watershed Land Use

Source: DVRPC 2000 Land Use Data

Table 1-3: Land Use within the Wissahickon Watershed

Land Use Category	Percentage
Agriculture	6.2%
Cemetery	0.9%
Commercial	3.3%
Community Services	2.9%
Golf Course	4.0%
Manufacturing: Light Industrial	2.0%
Mining	0.2%
Parking	2.7%
Recreation	2.9%
Residential: Mobile Home	0.0%
Residential: Multi-Family	3.6%
Residential: Row Home	1.2%
Residential: Single-Family Detached	47.2%
Transportation	1.3%
Utility	0.7%
Vacant	3.3%
Water	0.8%
Wooded	16.8%

Source: DVRPC 2000 Land Use Data

1.5 GEOLOGY AND SOILS

1.5.1 WISSAHICKON CREEK GEOLOGY

Geology and soils play a significant role in the hydrology, water quality, and ecology of a watershed. The northern portion of the Wissahickon Creek Watershed is located within the Gettysburg-Newark Lowlands and Piedmont Lowlands (Figure 1-5), underlain by various clastic sedimentary rocks. The southern portion of the watershed is within the Piedmont Upland physiographic region, which is underlain by a variety of sedimentary, metamorphic and igneous rocks (Fairmount Park Commission, Montgomery County Planning Commission and Pennsylvania Department of Conservation and Natural Resources, 2000). As one moves from the northern most point in the watershed through each of the physiographic regions, the topography changes to reflect the differences in the underlying geology. Most notable are the steep slopes and large rock formations along the Wissahickon main stem as observed along Forbidden Drive in the Philadelphia portion of the watershed. A description of the geologic formations present throughout the Wissahickon Creek Watershed is presented in Table 1-4.

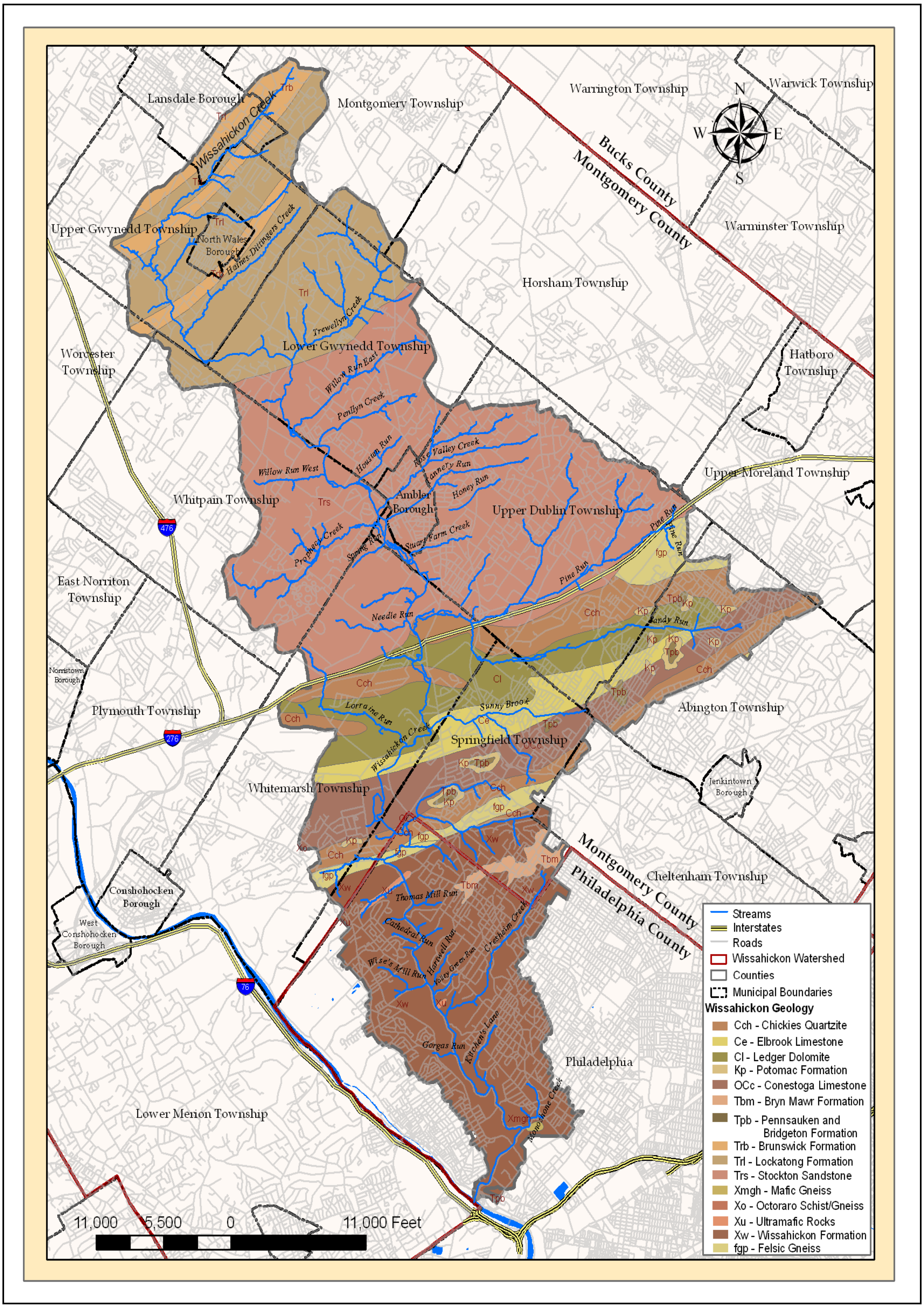


Figure 1-5: Wissahickon Creek Watershed Geology

Table 1-4: Generalized Descriptions of Geologic Formations within the Wissahickon Creek Watershed

Source: U.S. Department of Agriculture, Natural Resource Conservation Service, 2005, Montgomery County Open Space Plan, 2005, and Wissahickon Creek River Conservation Plan, 2001

Formation	Description
Brunswick Formation	This formation underlies much of the northwestern half of Montgomery County and is characterized by reddish brown shale, mudstone, and siltstone. The topography of the formation is characterized by rolling hills.
Bryn Mawr Formation	This formation consists of white, yellow, and brown gravel and sand. This is a deeply weathered formation.
Chickies Formation	This formation is created when sandstone is exposed to extreme heat and pressure. Composed of quartzite and quartz schist. This hard, dense rock weathers slowly. This formation has good surface drainage. A narrow band of quartzite extends westward across Bucks County from Morrisville.
Conestoga Formation	Conestoga Limestone is a blue-gray, thin-bedded, argillaceous limestone with intervals of a purer, granular limestone. Some of the basal beds are a coarse limestone conglomerate containing large pebbles and irregular masses of coarse white marble in a gray limestone This formation consists of Ordovician micaceous, medium-gray, impure, shaly limestone, which extends in the relatively wide belt across the county.
Elbrook Formation	The formation consists of blue dolomite and dolomitic limestone, some siliceous and shaly beds that weather to a well drained yellowish-red loam. This formation is moderately resistant to weathering. Solution channels provide a secondary porosity of moderate magnitude; moderate to high permeability. Solution openings which may be found in the substrata create certain structural problems for heavy buildings.
Felsic Gneiss, Pyroxene Bearing	This formation consists of metamorphic rock units that yield small quantities of water due to the smallness of the cracks, joints, and other openings within the rock. This fine - grained granitic gneiss is resistant to weathering but shows good surface drainage.

Ledger Dolomite	Ledger Dolomite is a white to light gray, massive to thick-bedded, granular, rather pure dolomite with high magnesium content. The dolomite is interbedded with some siliceous beds and laminated limestone. The Ledger contains a few beds of marble with high calcium content. Limestone and dolomite formations yield good trap rock and calcium rich rock which has been quarried for various industrial and construction uses. (Coorson's Quarry is found in this formation.)
Lockatong Formation	This formation is composed of dark gray to black argillite with occasional zones of limestone and black shale. This formation is part of a larger band, several miles wide, which runs from the Mont Clare area to the Montgomery/Horsham Township border. Resistant to weathering, these rocks form the prominent ridge that runs through central Montgomery County.
Mafic Gneiss	This formation consists of medium to fine grained, dark colored calcic plagioclase, hyperthene, augite, and quartz. It is highly resistant to weathering, but shows good surface drainage.
Pennsauken Formation	This formation consists of sand and gravel yellow to dark reddish brown, mostly comprised of quartz, quartzite, and chert. It is a deeply weathered floodplain formation.
Serpentine	This formation forms barren, rocky outcrops on low hills and ridges. Only small quantities of water are contained in the fractures. The water is hard and mineralized (magnesium bicarbonate).
Stockton Formation	This formation consists of interbedded arkose, arkosic conglomerate, feldspathic sandstone, and red shale and siltstone. It is a primarily coarse sandstone formation, which tends to form ridges resistant to weathering. This rock is a good source of brick, floor tile, and sintered aggregate material.
Wissahickon Schist	This formation is composed of mica schist, gneiss and quartzite. The schists are softer rock and are highly weathered near the surface. This formation consists mostly of metamorphosed sedimentary rocks, but also includes rocks of igneous origin.

1.5.2 WISSAHICKON CREEK WATERSHED SOILS

Soils in the United States have been assigned to Hydrologic Soil Groups (HSG). The assigned groups are listed in Natural Resources Conservation Service (NRCS) Field Office Technical Guides, published soil surveys, and local, state, and national soil databases. The Hydrologic Soil Groups, as defined by NRCS engineers, are A, B, C, D, and dual groups A/D, B/D, and C/D. The HSG rating can be useful in assessing the ability of the soils in an area to recharge stormwater or to accept recharge of treated wastewater or to allow for effective use of septic systems. Figure 1-6 shows the hydrologic soil groups in the study area. The map indicates that most of the study area contains soil in the hydrologic category B, with some areas at the upstream shown as category C. This has implications for the design of stormwater infiltration systems, and also affects the amount of water that needs to be infiltrated in newly developed areas to maintain predevelopment or natural infiltration rates.

Table 1-5: NRCS Soil Group Characteristics

Source: United States Department of Agriculture, Natural Resources Conservation Service. 2006. Field Indicators of Hydric Soils in the United States, Version 6.0

Hydrologic Soil Group	Average Infiltration Rates (in/hr)
A	1.00 - 8.3
B	0.50 -1.00
C	0.17 - 0.27
D	0.02 - 0.10

Soils in hydrologic group A have low runoff potential. These soils have a high rate of infiltration (Table 1-5) when saturated. The depth to any restrictive layer is greater than 100 cm (40 inches) and to a permanent water table is deeper than 150 cm (5 feet).

Soils that have a moderate rate of infiltration (Table 1-5) when saturated are in hydrologic group B. Water movement through these soils is moderately rapid. The depth to any restrictive layer is greater than 50 cm (20 inches) and to a permanent water table is deeper than 60 cm (2 feet).

Hydrologic group C soils have a slow rate of infiltration (Table 1-5) when saturated. Water movement through these soils is moderate or moderately slow; they generally have a restrictive layer that impedes the downward movement of water. The depth to the restrictive layer is greater than 50 cm (20 inches) and to a permanent water table is deeper than 60 cm (2 feet).

Soils in hydrologic group D have a high runoff potential. These soils have a very slow infiltration rate (Table 1-5) when saturated. Water movement through the soil is slow or very slow. A restrictive layer of nearly impervious material may be within 50 cm (20 inches) of the soil surface and the depth to the permanent water table is shallower than 60 cm (2 feet). Dual Hydrologic Soil Groups (A/D, B/D, and C/D) are given for certain wet soils that could be adequately drained. The first letter applies to the drained and the second to the saturated condition. Soils are assigned to dual groups if the depth to a permanent water table is the sole criteria for assigning a soil to hydrologic group D.

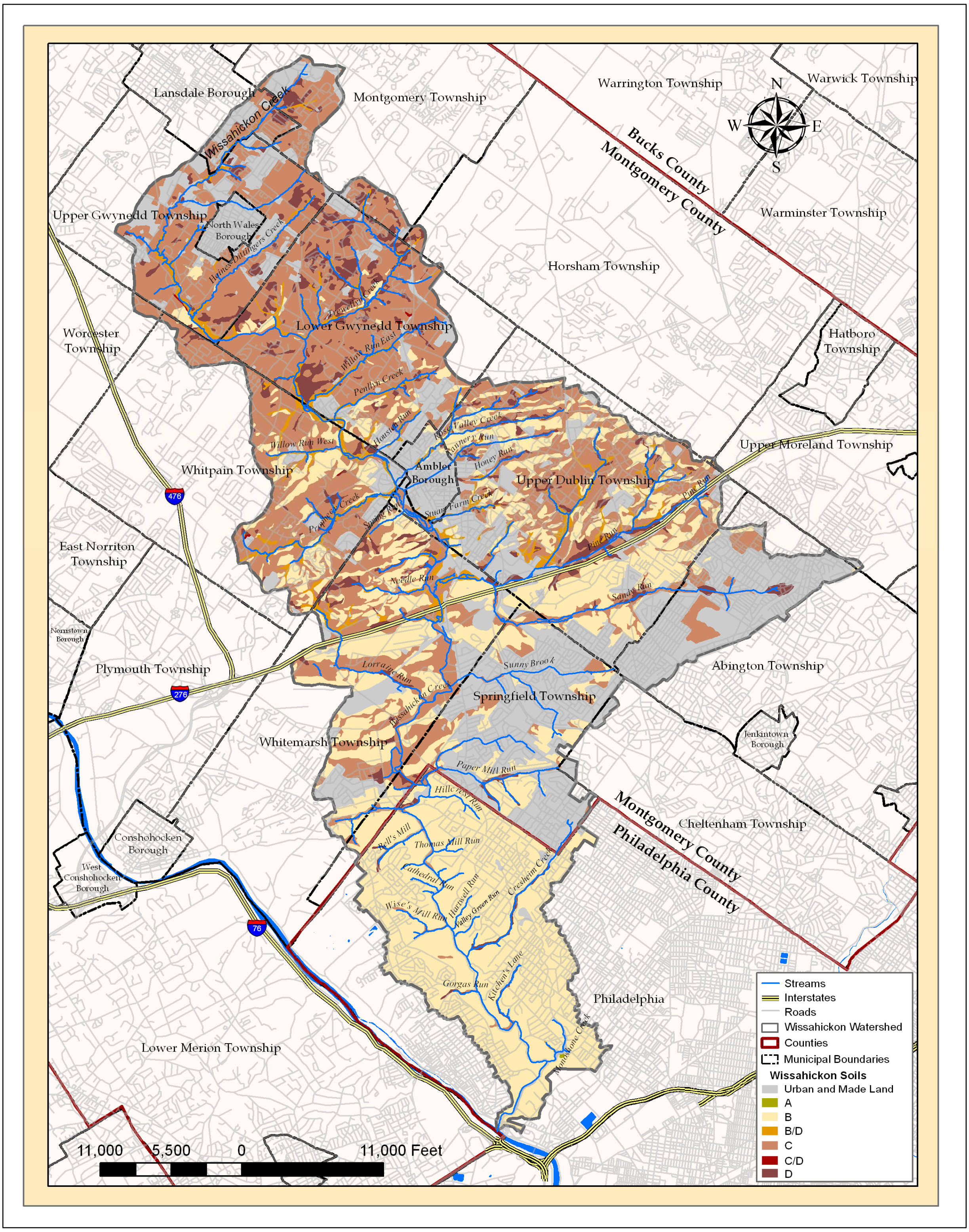


Figure 1-6: Wissahickon Creek Watershed (NRCS) Soil Types

2 METHODS

2.1 METHODS OVERVIEW

The individual stream networks assessed in this study were divided into one or several representative reaches, depending on the size and complexity of the stream network. One representative stream channel cross section, including local slope, was measured per reach. Measured field data was compiled to determine stream channel types for each reach and to help evaluate channel stability. Qualitative habitat data was compiled and used to determine habitat types adjacent to the stream channel. In addition, a full infrastructure assessment was conducted to survey all manholes, pipes, outfalls, culverts, channels, and bridges that were within the stream corridor. Both quantatative and qualitative datasets were evaluated for correlations between the natural and urbanized watersheds.

All of this data aided in the calculation of a reach-scale ranking metric which allowed for comparison between reaches and watersheds. Besides being used to make comparisons between reaches, the ranking scheme could also be used to prioritize restoration efforts and provide recommendations for each watershed.

2.2 CROSS SECTION LOCATION

Cross section locations were chosen according to multiple channel stability and geometry parameters that were representative of the entire reach. The appropriate location of a cross section in a channel exhibiting riffle/pool sequences is at the cross over reach (Rosgen, 1996). A cross over reach is a straight riffle section of channel between two meander bends. This riffle is used since it is a hydraulic control. Cross sections were placed in this location when the following criteria were satisfied:

+ Presence of bankfull indicators, or active floodplain
+ Representative of reach
+ No debris or obstructions such as rock, logs, outfalls, or in-stream structures

Debris or obstructions such as rocks, logs, outfalls, or in-stream structures were avoided because they would influence bankfull indicators and yield a false bankfull width. In some cases, reaches were so strongly influenced, degraded and/or altered such that there were no crossover reaches or riffle sections. Criteria used to determine the cross section location in these situations consisted of:

+ Representative of reach
+ Presence of best bankfull indicators
+ Least amount of debris, obstructions, and alterations
+ Safe wading water levels

Cross section locations were demarcated on the downstream right and downstream left banks with 2’ long, 1/2”-5/8” diameter rebar that was installed flush with the ground, when possible. At some sites where substrate consisted of large rocks, or tree roots or at sites where concrete debris was encountered, rebar could not be installed flush with the ground. After ensuring that the rebar could not be pulled out of the ground, the length of exposed rebar was noted on the data sheet. One inch yellow survey caps imprinted with the letters "PWD" were placed on each rebar as well as orange and black flagging. Flagging was also placed on the tree branch closest to the rebar to ensure that the rebar could be easily located upon subsequent field visits. The location (Northing, Easting, Elevation) of each rebar was then survey using a Total Station (Topcon GT235) in Pennsylvania South State Plane Coordinates and City of Philadelphia Datum.

2.3 REACH SELECTION

The reaches within each watershed were defined after all of the cross sections had been completed. The distance between two cross sections was then split in half and the distance upstream and downstream of a single cross section was combined to form one single reach (Figure 2-1). There was minimal geomorphic significance for the reach delineation. Reach lengths averaged 2500 feet with average cross section spacing of 1400 feet. Collecting channel cross section data at this increment ensured that all possible Rosgen channel types would be measured and that hydraulic and hydrologic models would be more reliable. The longest reach assessed was 7,695 feet (WSMS136) and the shortest was 361 feet (WSMSH04).

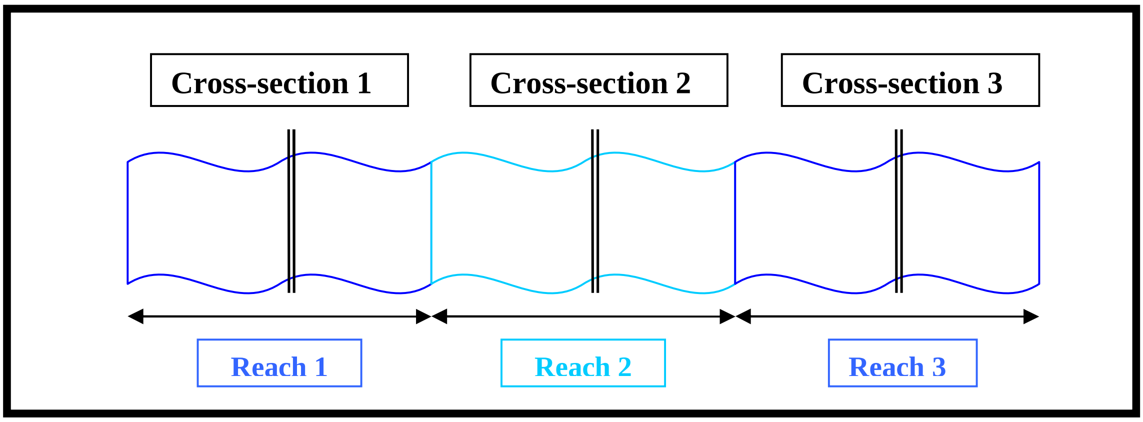


Figure 2-1: Diagram of Reach Delineation Procedure

2.4 STREAM SURVEY

The stream assessment consisted of PWD field crews performing a field reconnaissance of the Wissahickon Creek Watershed under protocols established by the Unified Stream Assessment Method (USAM) (Center for Watershed Protection, 2004). The Unified Stream Assessment is a tool used to quickly and systematically evaluate the physical conditions within stream corridors in urbanized streams and watersheds. These conditions include habitat quality, riparian condition, floodplain function as well as the potential for man-made structures and other anthropogenic factors to adversely impact stream corridor quality. Reach assessments were performed to get an overall picture of stream corridor conditions over defined reaches and to compare reach quality across the watershed. The Overall Stream Condition (Figure 2-2) form was used to characterize the average conditions present within a reach, such as bank stability and vegetative protection, instream and riparian habitat availability, and flood plain connectivity. Using this form, sites were given a standardized metric score (0-160) which allowed for comparison of total scores and individual component scores between assessed reaches.

Approximately 115 miles of stream channel were assessed on the main stem of Wissahickon Creek, and the majority of its contributing tributaries. The field reconnaissance included walking the entire length of stream, choosing and marking cross section locations, while also making general observations of the surrounding watershed. All initial field observations and cross section locations were noted on datasheets and large scale field maps respectively. Field data was later transferred to Mecklenburg sheets in order to calculate stream channel morphology and hydraulic parameters. The field reconnaissance was completed throughout the year of 2005.

2.5 MEASURED STREAM SURVEY AND CROSS SECTION PARAMETERS

Based on results of the stream assessment/field reconnaissance and following additional planning and base map preparation, the measured reach portion of the stream survey was completed. Measured reach stream surveys consisted of collecting data for channel morphology, disturbance, stability, and habitat parameters. Data for this analysis was based on results of stream surveys and field reconnaissance which were used to prepared watershed-scale base maps. Specific channel and habitat parameters included:

Channel Habitat
+ Riparian Width
+ Riparian Composition
+ Canopy Cover
+ Bed Materials
+ Sediment Supply
+ Sinuosity
+ Woody Debris
+ Substrate Attachment Sites

Channel Morphology
+ Stream Bed Materials
+ Sinuosity
+ Water Surface Slope
+ Bankfull Width
+ Floodprone Area Width
+ Entrenchment Ratio
+ Bankfull Cross-sectional Area
+ Rosgen Stream Classification Type

Channel Disturbance
+ Anthropogenic Channels
+ Culverts
+ Utilities (Manholes and Sewers)
+ Fish Blockages
+ Road, Railroad, Mass Transit Crossings

The measured reach stream survey also consisted of surveying channel cross sections at each location previously chosen during the field reconnaissance. Appendix A contains a summary of the results of the surveyed cross sections and local longitudinal profiles. Digital photographs were taken at every cross section location as a means of verification for field identified parameters. The photos consisted of an upstream view, a downstream view, and a view from left bank to right bank and/or right bank to left bank (Appendix A). Cross section locations are shown in Figure 2-3.

OVERALL STREAM CONDITION				
	Optimal	**Suboptimal**	**Marginal**	**Poor**
IN-STREAM HABITAT *(May modify criteria based on appropriate habitat regime)*	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
VEGETATIVE PROTECTION *(score each bank, determine sides by facing downstream)*	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
	Left Bank 10 9	8 7 6	5 4 3	2 1 0
	Right Bank 10 9	8 7 6	5 4 3	2 1 0
BANK EROSION (facing downstream)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Grade and width stable; isolated areas of bank failure/erosion; likely caused by a pipe outfall, local scour, impaired riparian vegetation or adjacent use.	Past downcutting evident, active stream widening, banks actively eroding at a moderate rate; no threat to property or infrastructure	Active downcutting; tall banks on both sides of the stream eroding at a fast rate; erosion contributing significant amount of sediment to stream; obvious threat to property or infrastructure.
	Left Bank 10 9	8 7 6	5 4 3	2 1 0
	Right Bank 10 9	8 7 6	5 4 3	2 1 0
FLOODPLAIN CONNECTION	High flows (greater than bankfull) able to enter floodplain. Stream not deeply entrenched.	High flows (greater than bankfull) able to enter floodplain. Stream not deeply entrenched.	High flows (greater than bankfull) **not** able to enter floodplain. Stream deeply entrenched.	High flows (greater than bankfull) **not** able to enter floodplain. Stream deeply entrenched.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
OVERALL BUFFER AND FLOODPLAIN CONDITION				
	Optimal	**Suboptimal**	**Marginal**	**Poor**
VEGETATED BUFFER WIDTH	Width of buffer zone >50 feet; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, crops) have not impacted zone.	Width of buffer zone 25-50 feet; human activities have impacted zone only minimally.	Width of buffer zone 10-25 feet; human activities have impacted zone a great deal.	Width of buffer zone <10 feet: little or no riparian vegetation due to human activities.
	Left Bank 10 9	8 7 6	5 4 3	2 1 0
	Right Bank 10 9	8 7 6	5 4 3	2 1 0
FLOODPLAIN VEGETATION	Predominant floodplain vegetation type is mature forest	Predominant floodplain vegetation type is young forest	Predominant floodplain vegetation type is shrub or old field	Predominant floodplain vegetation type is turf or crop land
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
FLOODPLAIN HABITAT	Even mix of wetland and non-wetland habitats, evidence of standing/ponded water	Even mix of wetland and non-wetland habitats, no evidence of standing/ponded water	Either all wetland or all non-wetland habitat, evidence of standing/ponded water	Either all wetland or all non-wetland habitat, no evidence of standing/ponded water
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
FLOODPLAIN ENCROACH-MENT	No evidence of floodplain encroachment in the form of fill material, land development, or manmade structures	Minor floodplain encroachment in the form of fill material, land development, or manmade structures, but not effecting floodplain function	Moderate floodplain encroachment in the form of filling, land development, or manmade structures, some effect on floodplain function	Significant floodplain encroachment (i.e. fill material, land development, or man-made structures). Significant effect on floodplain function
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Sub Total In-stream: _____ **/80** + Buffer/Floodplain: _____ **/80** = **Total** Survey Reach _____ **/160**

Figure 2-2: Overall Stream Condition Field Sheet

Source: Center for Watershed Protection, 2004

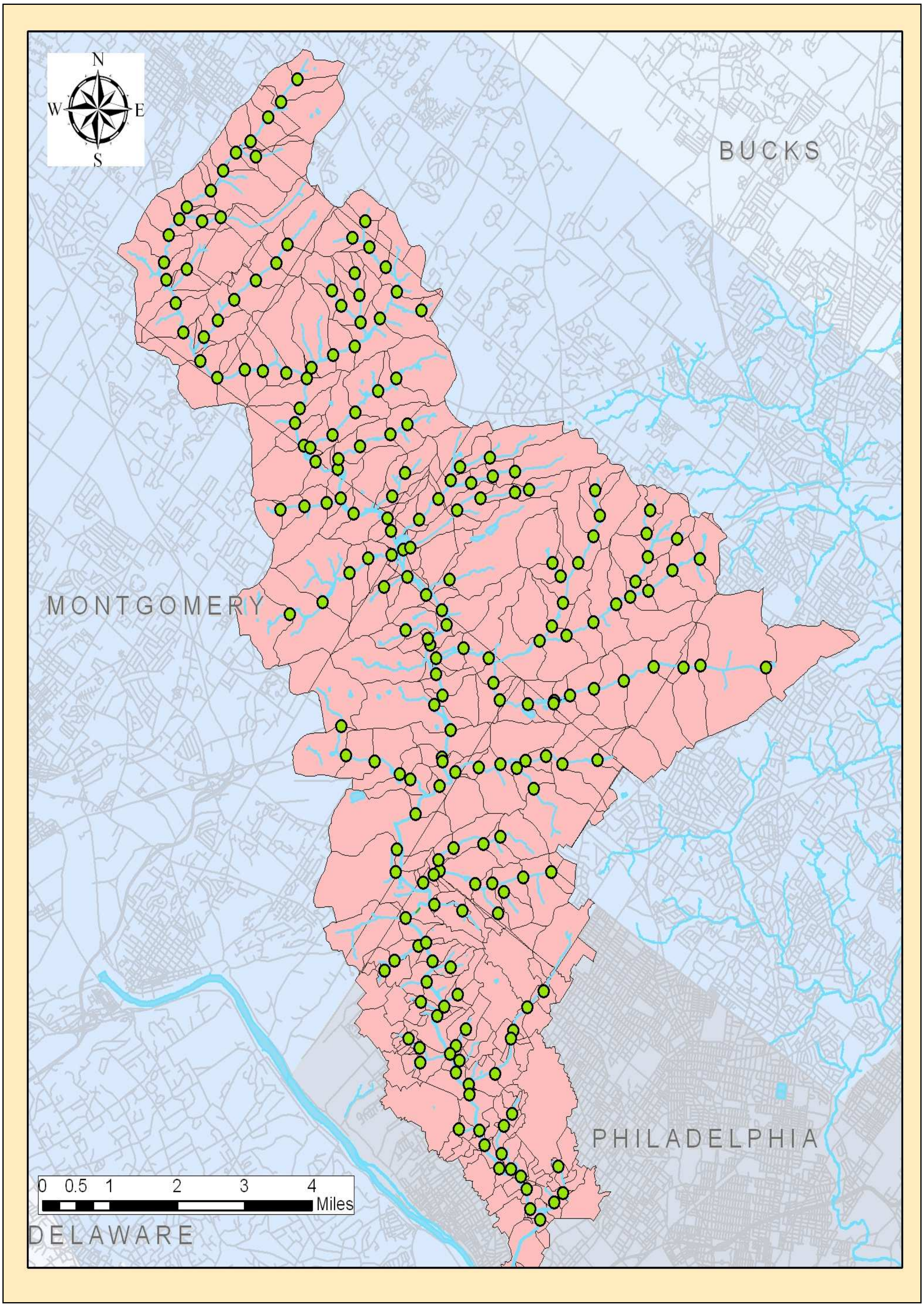


Figure 2-3: Wissahickon Creek Watershed Cross Section Locations

Figure 2-4: Lower Wissahickon Reach Breaks (Small Tributary reach breaks at confluences)

2.6 CROSS SECTION SURVEY PROTOCOL

Each stream cross section was measured by extending a 100 foot measuring tape across the channel. Where possible, a measuring tape was extended a minimum of twice the bankfull width for each cross section and a maximum of the entire valley width according to the estimated flood prone width. A transit level was used to record survey rod readings from the downstream left bank across the channel to the end of the measuring tape on the downstream right bank. Rod readings were taken at all significant channel features, or changes in channel features, such as the thalweg, bed materials, vegetation, slope, and flow lines including field identified bankfull. From the survey data, field data, and topographic base map, the following items were calculated:

+ Bankfull Area
+ Width to Depth Ratio
+ Entrenchment ratio
+ Shear Stress
+ Velocity
+ Water Surface/Channel slope
+ Sinuosity
+ Median particle size (D_{50})
+ Bankfull Discharge

2.6.1 EXTENDED CROSS SECTION PROCEDURE

PWD-surveyed cross sections were positioned at the center of the stream corridor and cross sections were then extended by hand beyond the flood prone width to the valley wall, where the flood prone width was defined as the width flooded at a stage equal to twice the maximum channel depth. Extended cross sections allowed for the estimation of entrenchment ratio (Equation 1). Lines were drawn from the last surveyed point on each side of the cross section perpendicular to 2-foot topographic contour line coverage (City of Philadelphia, Mayor's Office of Information Services, 2004). The extended cross sections were then plotted in excel and corrected if any obvious elevation discontinuities existed between the two data sets (Figure 2-5). Upstream cross sections are assumed to be representative of the stream channel geometry until the next downstream surveyed cross section.

$$\text{Entrenchment Ratio} = \frac{\text{Flood Prone Width}}{\text{Bankfull Width}} \qquad \text{(Equation1)}$$

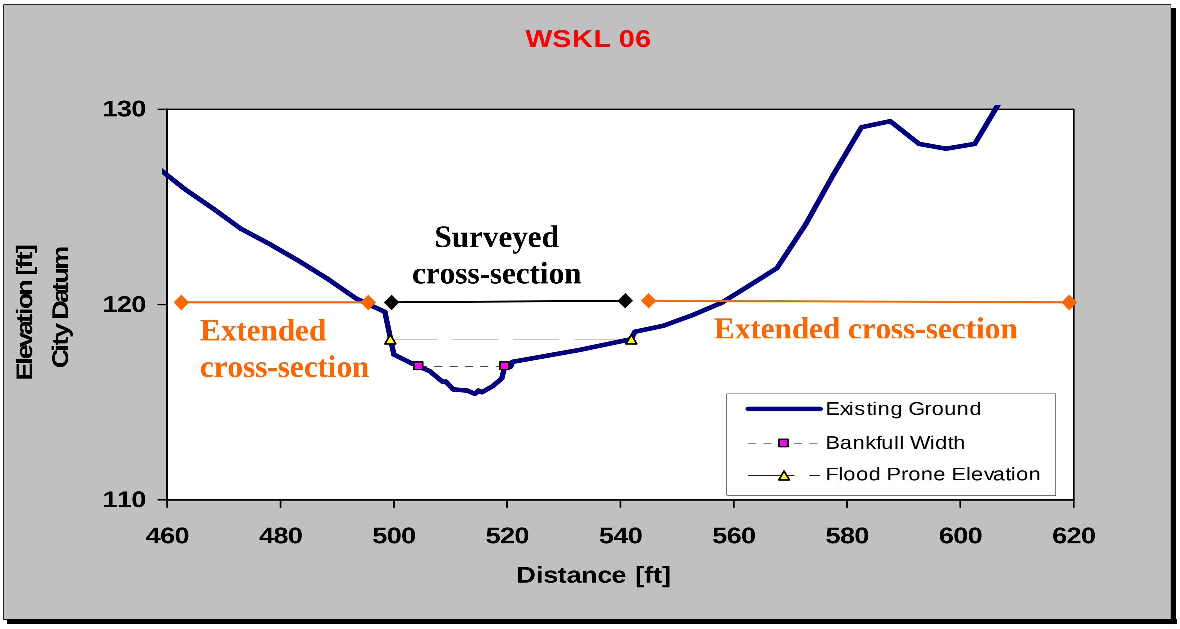


Figure 2-5: Sample Extended Cross Section surveyed on Kitchen's Lane Creek

2.7 LONGITUDINAL PROFILE SURVEY PROCEDURE

To estimate the local water surface slope at each cross section, the difference between the water surface elevation at the thalweg at the cross section immediately upstream and the water surface elevation at the thalweg at the cross section immediately downstream was divided by the stream distance measured between those two points as shown in Equation 2.

$Slope_{MS16}$ = (Water Surface Elevation at $Thalweg_{MS18}$ – Water Surface Elevation at $Thalweg_{MS14}$)/Creek $Distance_{MS14\text{->}MS18}$ (Equation 2)

In instances where there was no cross section present either upstream or downstream from the reach of interest, Equation 3 was utilized.

$Slope_{B10}$ = (Water Surface Elevation at $Thalweg_{B10}$ – Water Surface Elevation at $Thalweg_{B8}$)/Creek $Distance_{B10\text{->}B8}$ (Equation 3)

In instances where there was no cross section present both upstream and downstream from the reach of interest, an alternate procedure was implemented. A short channel profile was completed at these cross section locations, extending through the reach from the nearest upstream and downstream rifle. A 300 foot measuring tape was extended, upstream to downstream, in the channel thalweg. When there were no channel or line-of-sight obstructions, the profile was extended the full length of the measuring tape to 300 feet, or to the next riffle. Rod readings were taken at the top of riffles within the thalweg, except at degraded reaches where no riffles were present. These profile measurements were used as an estimate of bankfull slope and also for the calculation of a local slope for each cross section (Appendix A).

2.8 BANKFULL ELEVATION AND DISCHARGE CALIBRATION

In an ideal channel, bankfull elevation is at the top of the bank and is the point where the stream begins to overflow onto the floodplain. The bankfull discharge, defined by Manning's Equation (Equation 4), has the ability to transport sediment, alter a channel's morphology and eventually change the planform of the channel. The bankfull stage has been defined in many ways, but the commonly accepted definition provided here (Dunne and Leopold, 1978) was used for this study:

"The bankfull stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels."

$$Q = \frac{1.49}{n} * R_h^{2/3} * S^{1/2} * A \qquad \text{(Equation 4)}$$

where:
R_h = hydraulic radius (cross sectional area (A)/ wetted perimeter)
S= slope
n= Manning's Roughness coefficient

2.8.1 QUALITY OF BANKFULL INDICATORS

Bankfull indicators are often more difficult to identify, or not present at all, in impacted or disturbed urban streams such as the Wissahickon Creek Watershed, but are still essential to determining a bankfull elevation and discharge. Bankfull elevations at individual cross-sections were derived from all available indicators including depositional features such as the tops of point bars, scour and storm debris lines or changes in bank slope, vegetation or the grain size of bank material. During stream surveys, the quality of assessed bankfull indicators was determined based on the criterion set for five indicator quality classes: excellent, good, moderate, fair and poor. Analysis of the bankfull indicator quality was important because it provided a reference from which to determine the legitimacy of bankfull flow estimates as well as an explanation for some estimates that deviated substantially from anticipated flows.

- Excellent - characterized by a large, flat terrace with significant sandy deposition on the streambank's natural levee and no evidence of active adjustment of the channel.
- Good - characterized by isolated depositional features that were similar to features observed in upstream and downstream reaches. Such an observation would be indicative of minimal rates of active channel adjustment.
- Moderate - characterized by a change in bank slope adjacent to a terrace, but with little to no deposition. Within this category some signs of active channel adjustment were observed.

- Fair - characterized by consistent change in bank slope or vegetation with evidence of past incision. In these channels evidence reflecting some level of active adjustment was present.
- Poor - characterized by no observable bankfull indicators due to channel incision and/or vertical banks, which is indicative of active channel adjustment.

2.8.2 CALIBRATION OF BANKFULL DISCHARGE

Most regional curve studies to date have been conducted on streams in non-urban environments where bankfull indicators, such as the existence of terraces, fine sediment deposition, bank slope, and vegetation, are fairly easy to determine. The recurrence interval of a bankfull event is between every 1 to 2 years; however, these events occur more frequently in urbanized streams due to altered (i.e. impervious) land cover patterns. As such, these non-urban regional curves may not be directly applicable to urban systems. Several studies have been successful in creating regional curves that are fairly applicable to this region (e.g. Chaplin, 2005), although the predominance of impervious surfaces often precludes the use of regional curves in watersheds with grater than 20% imperviousness. As such, alternate methods must be used in urban, ungaged streams.

The bankfull discharge was calibrated using multiple methods: field cross section calculations, gauge station data, regional drainage area to peak discharge curves, and bankfull regression equations. Regression equations were fit to drainage area versus peak discharge curves and those equations with the highest coefficients of determination (i.e. R^2) were generally considered the most reliable bankfull calibration estimate. All preliminary bankfull discharge values for respective calibration methods were compared and evaluated based on factors such as the reliability of bankfull indicators and strength of coefficients of determination in order to determine the most appropriate discharge.

PWD personnel identified bankfull elevations in the field at varied locations as part of the Wissahickon Creek Watershed FGM study. As a result of channel disequilibrium, bankfull indicators were not easily identified. Depositional features were the primary indicator used in the final determination of bankfull elevation. Bankfull discharge was estimated by solving Manning's equation for discharge given the estimated bankfull elevation and measurements of the local channel geometry, slope, and roughness. Channel roughness, represented by Manning's "n," was approximated using the results of the Limerinos equation (Equation 5)

$$n = \frac{1.49 * R_h^{2/3} * (S/100)^{1/2}}{F * u_*} \qquad \text{(Equation 5)}$$

where:
F^1= Friction factor
u_*= shear velocity

[1]where:
$F = 2.83 + 5.7*\log(d/D_{84})$ (Equation 6)
d= mean depth
D_{84} = measured particle size where 84% of the particles are this size or smaller

2.9 PEBBLE COUNT PROCEDURE

Pebble counts were conducted at every other cross section within a reach using the Wolman Pebble Count procedure (Wolman, 1954). Intermediate axis lengths were then entered into Mecklenburg sheets to plot particle size frequency distributions used to extract D_{50} and D_{84} parameters for use in channel hydraulic calculations. For cross sections without pebble counts, the pebble count was interpolated based on pebble counts actually performed upstream, downstream, or both.

2.10 BANK PROFILE MEASUREMENTS

PWD employed the Bank Assessment for Non-point source Consequences of Sediment (BANCS) Model as defined by Rosgen (1996) to predict erosion rates and classify the erosion potential of the tributaries. The BANCS method utilizes two bank erosion estimation tools: the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS). The BEHI is an assessment tool that allows the erosion potential of a stream bank to be quantified. The NBS method evaluates the amount of shear stress along the stream bank. BEHI and NBS methods were used to assess 368 stream segments in 12 tributaries to the Wissahickon Creek. The twelve tributaries were: Monoshone, Kitchen’s Lane, Gorgas Lane, Cresheim, Valley Green, Hartwell, Wise’s Mill, Cathedral Run, Rex Avenue, Thomas Mill, Bell’s Mill, and Hillcrest Creeks.

To field verify predictions made by the BANCS model, bank pins (18” lengths of ½” or 5/8” iron rebar) were driven horizontally into the stream bank normal to the curve of the bank at the location where radius of curvature was minimized (most severe bend). At least one bank pin was installed below field-estimated bankfull elevation. Depending on bank height, one or two additional pins were installed, spaced no closer than 1 foot apart, such that the total number of bank pins at a site ranged from one to three (Figure 2-6). In order to enable measurement of lateral erosion, toe pins (12” lengths of 5/8” rebar) were also installed at each site. Toe pins were driven vertically into the stream bed at the toe of slope inline with the bank pins along a line normal to the curve in the bank. Toe pin locations were captured using GPS (Xplore technologies model iX140C2 tablet PC with GPS module) and yellow plastic survey caps were installed. To further assist field teams in re-locating bank pin sites, orange spray paint was applied to bank pins and survey flagging was hung from nearby vegetation.

A total of 81 bank pin sites were chosen to reflect varying BEHI and NBS scores in order to validate and calibrate an erosion rate prediction model. 21 bank pin sites were installed during the fall of 2005, and 60 bank pin sites were installed during the summer of 2006 (Figure 2-7).

Figure 2-6: Example of Toe Pin (left) and Bank Pin (right) Setup along stream bank

Measurements were made using a survey rod (CRAIN, SFR Series Leveling Rod), a flexible "pocket rod" (Keson, Inc.) and two small cylindrical spirit levels (Figure 2-8). The survey rod was placed on the edge of the toe pin and held vertical using a level. The pocket rod was placed over the bank pin up against the bank and leveled with the second level. The distance from the bank to the edge of the survey rod closest to the bank was recorded on the field data sheet. Lateral erosion or aggradation of the stream bank was determined by measuring changes in bank pin distance from a line extending vertically from the toe pin. In order to obtain a better measurement of bank profile, a series of vertical reference points were measured in addition to the bank pins for several of the bank pin sites. These vertical reference points were measured at predetermined vertical points on the survey rod.

The measurement frequency for the bank pins varied throughout the duration of the study. Originally, the bank pins were measured quarterly to capture any seasonal effects. The frequency of measurements was then reduced to twice a year.

The most recent round of bank measurements occurred during the week of August 10th, 2009. During this week, PWD revisited the 81 bank pin monitoring locations installed during 2005 and 2006 in the Monoshone, Kitchen's Lane, Gorgas Lane, Cresheim, Valley Green, Hartwell, Wise's Mill, Cathedral Run, Rex Ave, Thomas Mill, Bell's Mill, and Hillcrest tributaries. A total of 30 monitoring locations were unable to be re-measured during the August 2009 monitoring event.

The average monitoring period for a bank pin location was 31 months. The minimum monitoring period was 12 months and the maximum monitoring period was 45 months. For the 30 monitoring locations where re-measurement was not possible, the lateral erosion rate for the longest observation period at that location was used for further calculation.

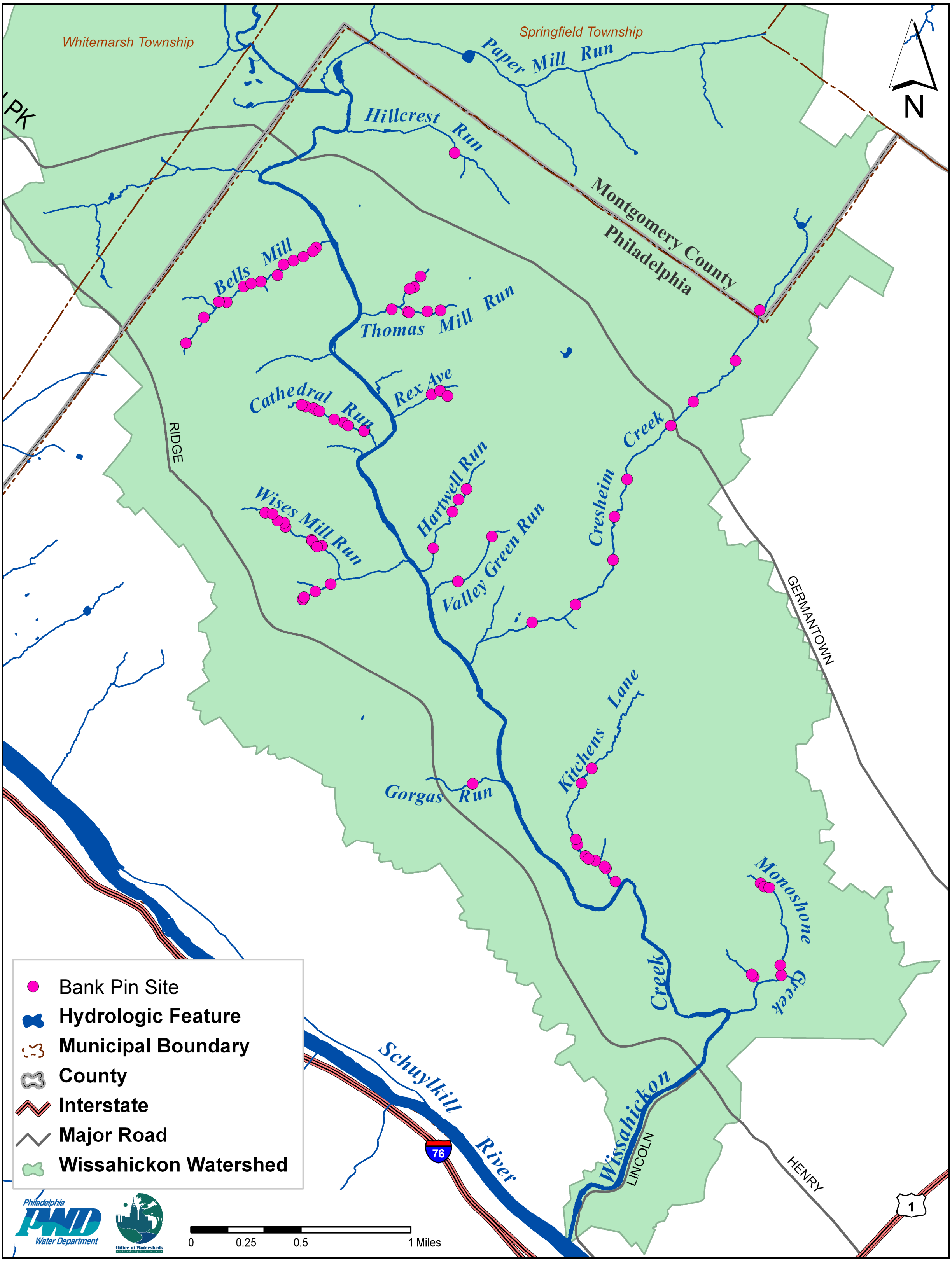


Figure 2-7: Wissahickon Creek Watershed Bank Pin Locations

Figure 2-8: Example of bank pin installation (left) and bank pin measurement (right) by PWD staff

2.11 INFRASTRUCTURE TRACKDOWN

The infrastructure trackdown was conducted by walking the entire length of the stream and taking note of the infrastructure encountered along the way. Data was collected on outfalls, bridges, manholes, culverts, pipes, dams, and channels. The amount and type of information collected for each point of infrastructure varied depending on type. Basic information included the date in which the data was collected, the names of crew members, and the weather conditions.

For each infrastructure point identified and mapped, photos were taken and documented, along with important notes which included the GPS point number, approximate dimensions, location, and any other miscellaneous characteristics. Photographs of each infrastructure point can be found in Appendix B. Maps with the location of Lower Wissahickon Creek Watershed infrastructure locations can be found in Appendix C. The naming convention used to describe infrastructure elements used the following format: WS to denote “Wissahickon”; a three letter descriptor indicting the type of infrastructure element being described (i.e. “out” for outfall, “bri” for bridge’ or “cha” for a channelized segment); and a unique numerical identifier. For example, outfall 507 (Thomas Mill Run) would be called “WSout507.”

2.11.1 OUTFALLS

An outfall was defined as the end of a pipe which releases either stormwater, combined sewage, or an encapsulated creek into the waterway (Figure 2-9). Data was collected on outfalls larger than 12 inches. The data collected for each outfall included the pipe diameter, height and width of the outfall including the presence of an apron, the construction material (i.e. metal, concrete, terra cotta, etc.), structural condition (i.e. good, fair, or poor), presence of, and quality of dry weather flow, bank location (right or left), and submergence depth.

Figure 2-9: Example of an outfall point assessed in infrastructure trackdown

2.11.2 BRIDGES

A bridge was defined as a structure that spanned a stream over which a road or walkway passes (Figure 2-10). Bridges mapped in this report are shown as one point at the center of the bridge along the creek. The data collected for each bridge included the approximate height, width and depth of the bridge opening, the construction material (i.e. metal, concrete, wood, stone, etc.), and structural condition (i.e. good, fair, or poor).

Figure 2-10: Examples of bridges assessed in infrastructure trackdown

2.11.3 MANHOLES

A manhole was defined as the covered opening that allows access to an existing utility (Figure 2-11). Data was collected for manholes either located within the creek or in close proximity to the stream banks. The data collected for each manhole included the approximate diameter of the manhole, the construction material (i.e. concrete or terra cotta), the height of the portion of manhole exposed above the ground or water surface, structural condition (good, fair, or poor), bank location (left or right) and the presence and description of any odor.

Figure 2-11: Examples of manholes assessed in infrastructure trackdown.

2.11.4 CULVERTS

A culvert was defined as a conduit which carried the stream under a roadway, sidewalk, building, or miscellaneous structure (Figure 2-12). Culverts were mapped by taking GPS coordinates at the start and end of the culvert with photos taken at each point. The data collected for each culvert included the approximate dimensions, construction material (e.g. stone, concrete, brick, etc.), structural condition (i.e. good, fair, or poor), presence and quality of dry weather flow, and bank location (left or right).

Figure 2-12: Examples of culverts assessed in infrastructure trackdown.

2.11.5 DAMS

A dam was defined as an obstruction that impounded stream flow (Figure 2-13). Data was only collected for manmade dams and did not include natural debris jams caused by coarse woody debris (CWD). The data collected for each dam included the approximate dimensions, construction material, structural condition (good, fair, or poor) and bank location (left, right, or across the creek).


Figure 2-13: Examples of dams assessed in infrastructure trackdown.

2.11.6 CHANNELS

A channel was defined as a straightening and reinforcement of stream bed and/or banks with manmade materials such as concrete (Figure 2-14). Channels were located on one or both banks, as well as on the bottom of the stream bed. Each channel was mapped by taking GPS coordinates at the start and end of the channel with photos taken at each point. The data collected for each channel included approximate dimensions, structural condition (good, fair, or poor), the portion of stream that was channelized (i.e. left bank, right bank or bottom), and construction material (stone or concrete).


Figure 2-14: Examples of channels assessed in infrastructure trackdown.

2.11.7 CONFLUENCES

A confluence was defined as the junction where two streams meet (Figure 2-15). The data collected for each confluence included the GPS coordinates of the larger stem bank location looking downstream (left or right) and width of the stream entering the larger stem.

Figure 2-15: Examples of confluences assessed in infrastructure trackdown.

2.11.8 PIPES

A pipe was defined as a conduit for carrying a utility across the stream (Figure 2-16). The data collected for each pipe included the approximate diameter, construction material (i.e. concrete, metal, terra cotta, etc.), the length and height above the water or ground surface of the exposed portion, structural condition (i.e. good, fair, or poor), presence and quality of dry weather flow, bank location (i.e. left, right or across the creek), and submergence depth.

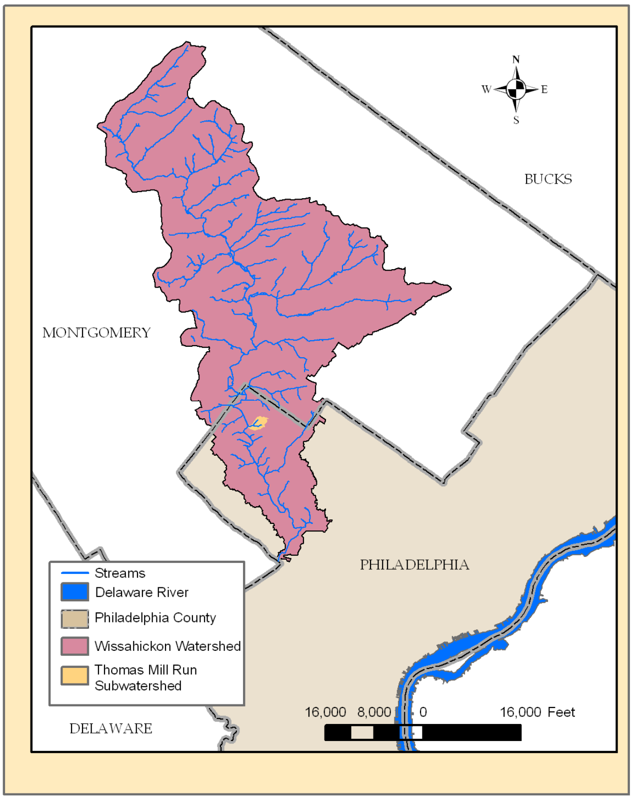
Figure 2-16: Example of a pipe assessed in infrastructure trackdown.

3 WATERSHED ASSESSMENTS

3.1 SMALL TRIBUTARY WATERSHED AND REACH CHARACTERISTICS

The Small Tributaries to the Wissahickon Creek were defined as those having only one cross section and representative reach. In the subsequent sections, "Small Tributary Average" refers to the average USAM score of the respective metric.

3.1.1 THOMAS MILL RUN WATERSHED AND REACH CHARACTERISTICS



Thomas Mill Run is a tributary to the main stem of the Wissahickon Creek. Thomas Mill Run originates from a privately-owned stormwater outfall. Thomas Mill Run is a first-order tributary for approximately 0.3 miles until a smaller 0.25 mile tributary enters Thomas Mill Run approximately 0.2 miles from the confluence with the Wissahickon main stem. The dominant substrate varies from course gravel to medium cobble material. Both the valley floor and channel have been substantially impacted by past and current land use.

The entire Thomas Mill Run watershed is 104 acres. Major land use types within the watershed include: wooded (59%) and residential – single family detached (32%). Thomas Mill Run is surrounded by Fairmount Park on both sides for the entire length. The Park buffer ranges from about 20 feet to about 2,000 feet.

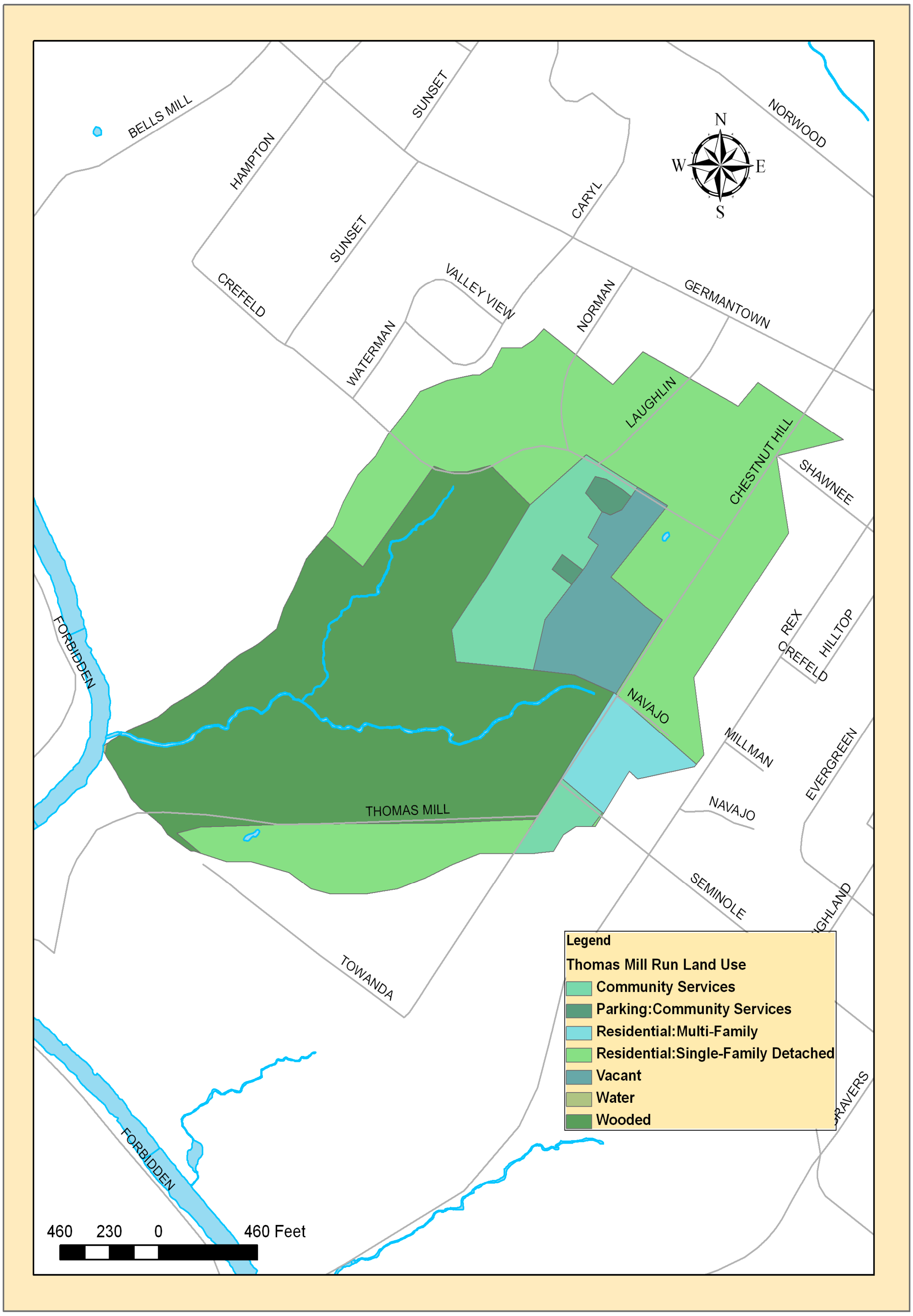


Figure 3-1: Thomas Mill Run Watershed Land Use

3.1.1.1 GEOLOGY

The majority of the Thomas Mill Run watershed is underlain by the Wissahickon Formation. The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

There is one small section within the Thomas Mill Run watershed that is underlain by the Bryn Mawr Formation. The Bryn Mawr Formation consists of white, yellow and brown gravel and sand. The Bryn Mawr Formation is considered a deeply weathered formation.

3.1.1.2 SOILS

According to the National Resource and Conservation Service Soil Survey, the soils for the entire Thomas Mill Run watershed are classified as hydrologic group B. These soils have a moderate rate of infiltration when the soils are wet (0.50-1.00 in/hr). Water movement through these soils is considered moderately rapid.

Table 3-1: Distribution of NRCS Soil Types in Thomas Mill Run Watershed

Group	Area (ft^2)	Percent of Total Area
B	4,530,240	100%
Total Area	**4,530,240**	**100%**

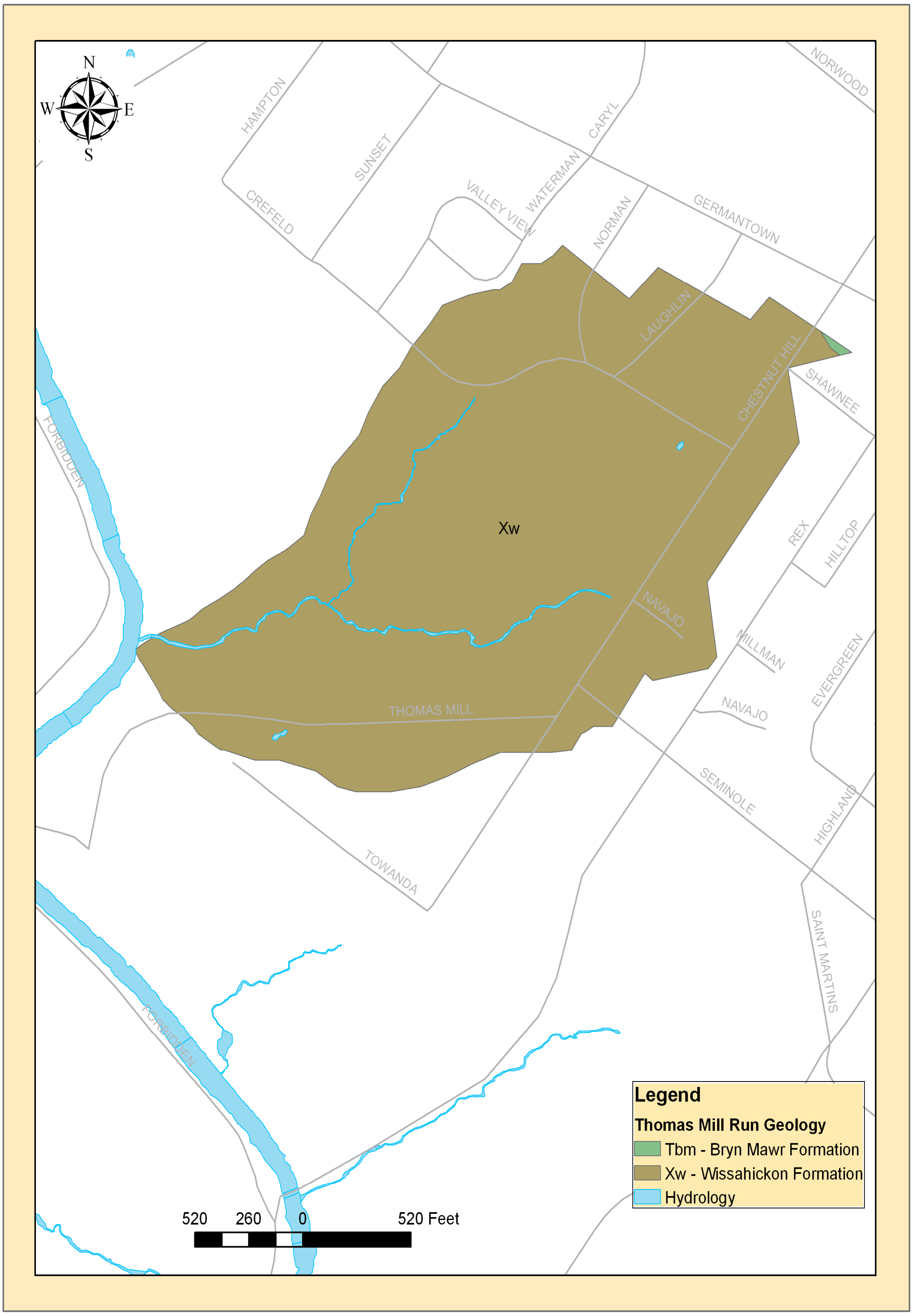


Figure 3-2: Geology of Thomas Mill Run Watershed

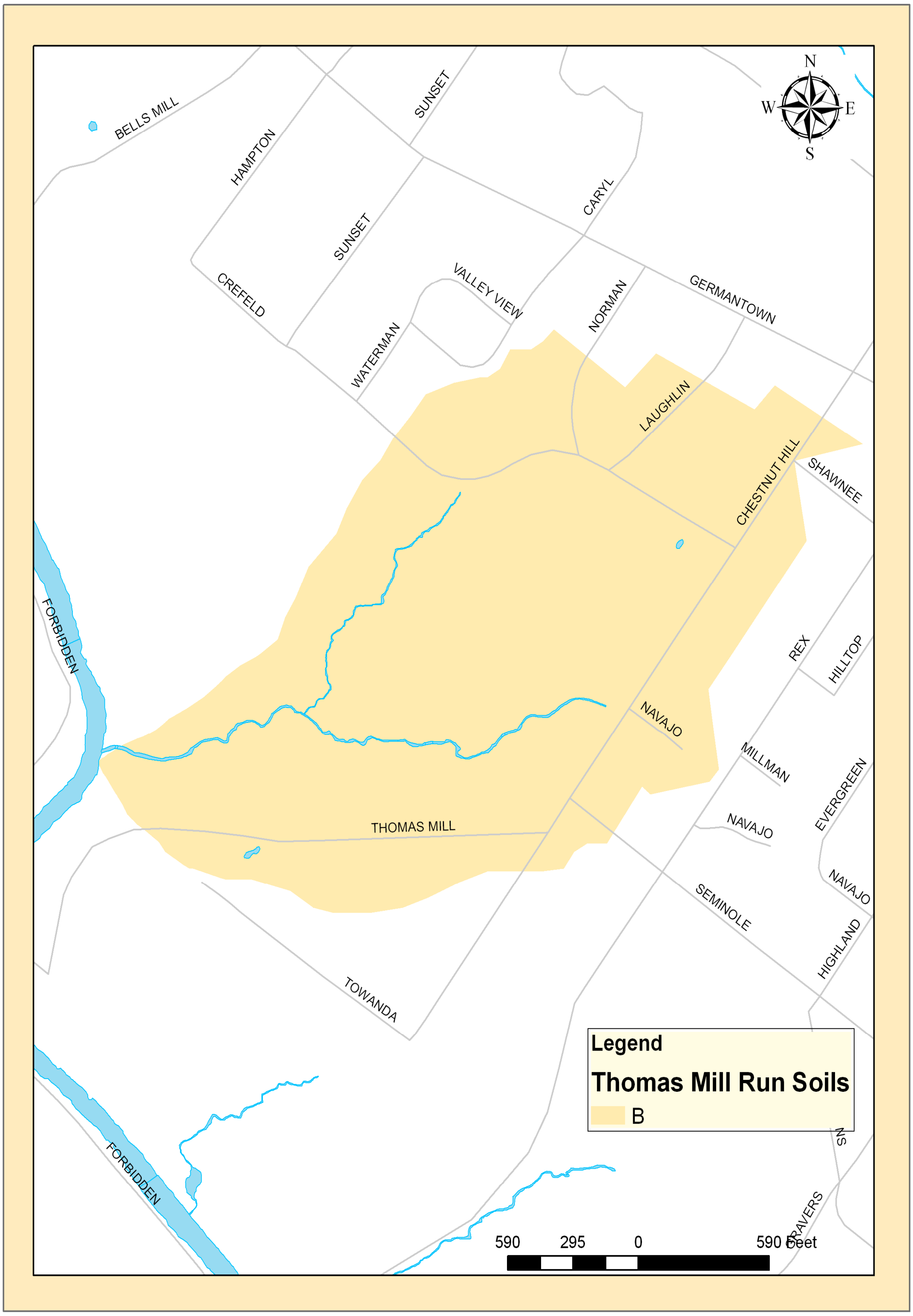


Figure 3-3: Distribution of NRCS Soil Types in Thomas Mill Watershed

3.1.1.3 BANK EROSION

There were nine bank pin locations along Thomas Mill Run (Figure 3-4). The calculated erosion rates are included in Table 3-2. The spatial distribution of BEHI assessment results were represented graphically (Figure 3-4) for each of the segments assessed on Thomas Mill Run. Each bank within a respective segment was assessed and rated separately; however, channelized and culverted segments were not assessed as they confer a high degree of protection from bank erosion.

Table 3-2: Thomas Mill Run Bank Pin Locations

	BEHI	NBS	Baseline Reading	Most Recent Reading	Erosion Rate (ft)	Erosion Rate (ft/yr)	Eroding (-) or Aggrading (+)
Thomas Mill							
TM18	Moderate	Low	8/16/2007	8/15/2008	-0.14	-0.14	E
TM21	Very High	Low	6/29/2006	8/9/2007	-0.26	-0.23	E
TM23	Moderate	Low	8/9/2007	8/10/2009	0.040	0.020	A
TM28	Moderate	Low	4/11/2007	8/15/2008	-0.28	-0.21	E
TM512	Low	Very Low	6/29/2006	8/10/2009	0.12	0.038	A
TM518	Low	Low	8/21/2006	8/10/2009	0.26	0.087	A
TM9	Moderate	Low	6/29/2006	8/10/2009	-0.025	-0.008	E
TM8	Moderate	Low	11/15/2006	8/10/2009	-0.20	-0.074	E

Total erosion rates were also calculated for the entire length of each tributary within the lower Wissahickon (Table 3-3). To assess the normalized erosion potential of each tributary, the erosion rate per acre of drainage area per year and the erosion rate per foot of stream length per year were calculated. This allowed direct comparison between each of the tributaries with respect to both watershed size and the length of the tributary. Thomas Mill Run was ranked second out of the twelve tributaries within the lower Wissahickon for erosion rate per foot of stream length. The rankings were based on a scale of one being the highest erosion rate and twelve being the lowest erosion rate.

Table 3-3: Erosion Rates for Lower Wissahickon Tributaries

Tributary	Drainage Area (Acres)	Stream Length (feet)	*2009*		
			Erosion Rate (lb/yr)	*Erosion Rate Per Acre*	*Erosion Rate Per Foot of Stream*
Bell's Mill	323	6,722	420,000	1,307	63
Cathedral Run	160	2,790	150,000	913	52
Cresheim Creek	1,218	16,431	840,000	690	51
Gorgas Run	499	2,170	170,000	345	79
Hartwell Run	217	3,530	200,000	918	56
Hillcrest	144	5,272	90,000	597	16
Kitchen's Lane	234	7,753	200,000	850	26
Monoshone Creek	1,056	6,926	160,000	156	24
Rex Ave	137	1,903	150,000	1,131	81
Thomas Mill Run	104	4,008	320,000	3,058	79
Valley Green Run	128	2,874	140,000	1,086	48
Wise's Mill Run	446	7,056	490,000	1,090	69
Total/*Average*	**4,666**	**67,435**	**3,300,000**	***1,012***	***54***

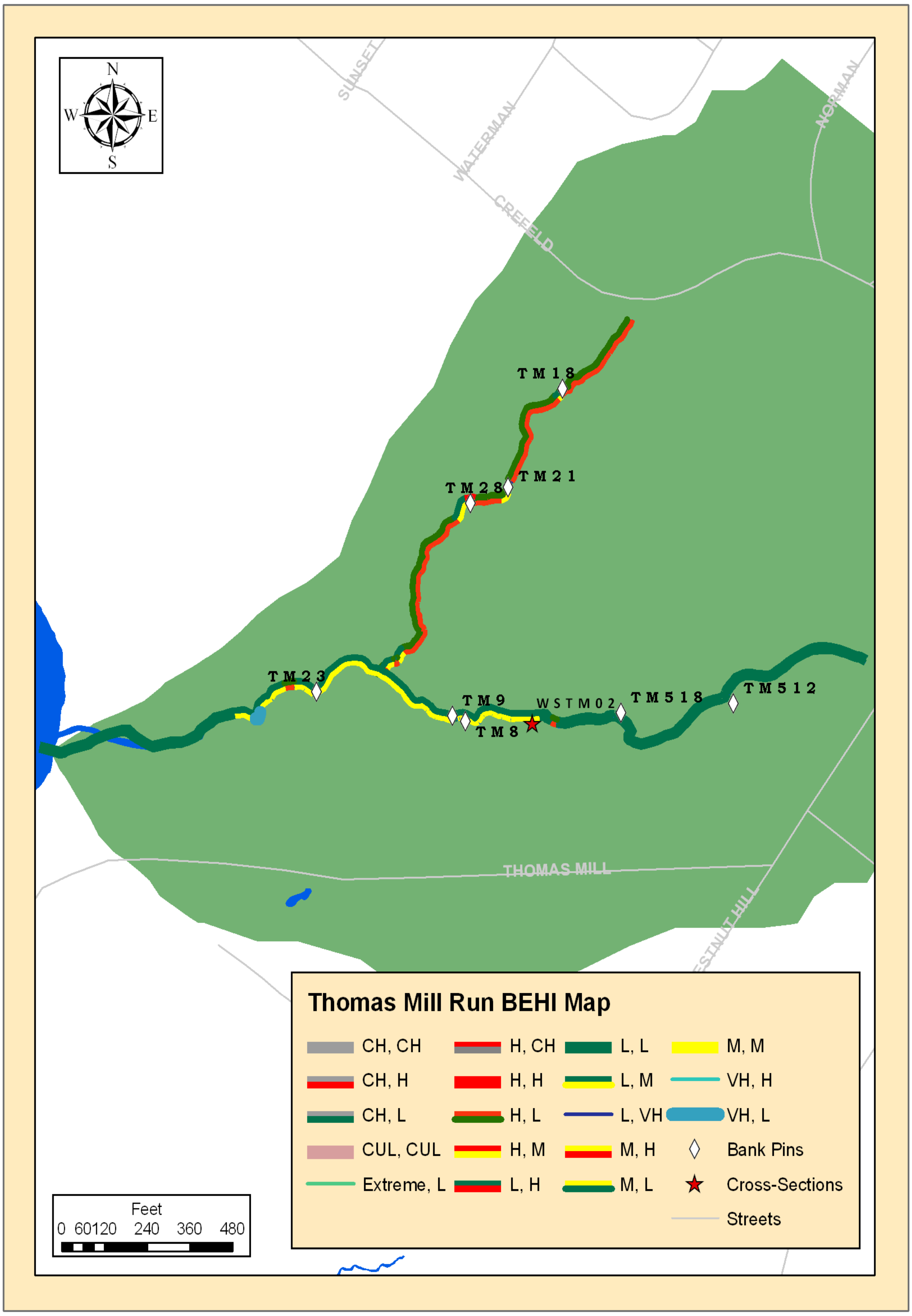


Figure 3-4: Thomas Mill Run Watershed BEHI Ratings and Bank Pin Locations

3.1.1.4 INFRASTRUCTURE TRACKDOWN SUMMARY

Thomas Mill Run is a small tributary to the Wissahickon Creek that flows almost entirely within Fairmount Park. This stream has only a few infrastructure elements which is a direct result of the tributary's location within the Park. Despite the benefit of its location, Thomas Mill Run exhibits some of the impairments associated with urban streams given its proximity to development in the form of residential neighborhoods that surround the stream channel. The most predominant infrastructure elements in the watershed were stormwater outfalls. The number of headwater outfalls (Table 3-4) on this stream indicates that it is heavily influenced by stormwater discharges in the upstream-most segments of WSTM02 (Figure 3-5).

WSout505 had an area of five square feet and conveyed no dry weather flow. This outfall was the headwaters for a tributary (unnamed tributary A) to the main stem of Thomas Mill Run. The tributary channel was observed to be intermittently dry, as there was only flow in the channel during wet weather events. These unfavorable flow conditions can cause channel instability and degrade instream habitat from frequent erosion and sedimentation. The channel did however convey the stormwater flows away from Crefeld Avenue effectively.

Similarly, the main stem of Thomas Mill Run is impacted by stormwater runoff discharged from outfalls (WSout506, WSout507 and WSout508). There was a small amount of steady dry weather flow observed at the headwaters of the main stem. The headwaters emanated from WSout508, a four foot diameter outfall, which conveyed drainage from Chestnut Hill Avenue. The size of this outfall indicates that during wet weather events the discharge from this outfall has the potential to be substantially larger. The other two outfalls, WSout507 and WSout506, had no dry weather flow but were in degraded condition. WSout506 was partially blocked by a build-up of sediment and debris. The three bridges on Thomas Mill Run (WSbri221, WSbri222 and WSbri223) were small although they constricted flow within the channel. The bridges were built along the stream to connect the Fairmount Park trails parallel to the channel. WSout507 was the only piece of infrastructure identified as being in poor condition. The bank that once supported the pipe eroded which exposed the pipe leading to the outfall; subsequently, the pipe collapsed due to the lack of proper support.

Table 3-4: Summary of Thomas Mill Run Infrastructure Points

Section ID	Bridge Count	Outfall Count	Confluence Count	Infra Point Count	Combined Outfall Area (ft^2)
WSTM02	3	4	1	7	22.33

Table 3-5: Summary Thomas Mill Run Infrastructure Linear Features

Section ID	Segment Length (ft)	Culvert Length (ft)	Percent Culverted	Channel Length (ft)	Percent Channelized
WSTM02	3648	0	0	0	0

Figure 3-5: Thomas Mill Run Infrastructure Locations

Figure 3-6: Thomas Mill Run Infrastructure in Poor Condition

3.1.1.5 UNIFIED STREAM ASSESSMENT RESULTS FOR THE THOMAS MILL RUN WATERSHED

In total, there were approximately 3,648 feet of stream channel within the Thomas Mill Run watershed. There was one associated tributary, unnamed tributary A, which began as flow from WSout505 which drains the neighborhood delimited by Germantown Avenue to the north and Crefeld Avenue to the south. The Center for Watershed Protection's (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and watersheds within the Lower Wissahickon Basin.

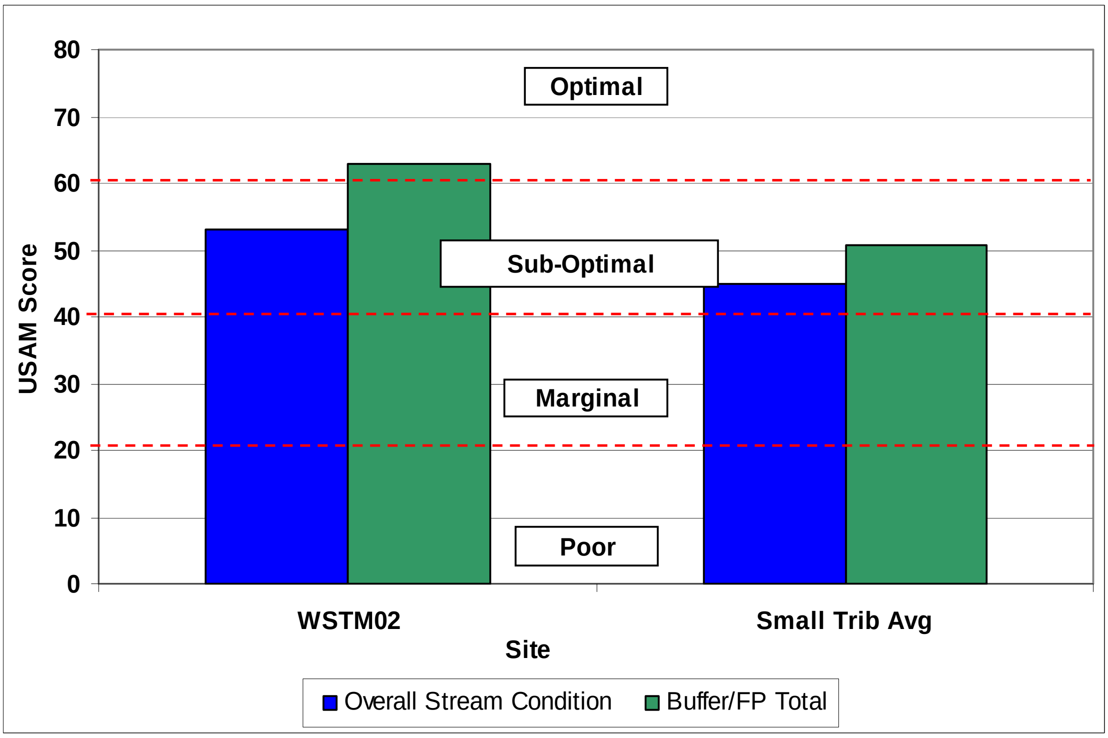


Figure 3-7: Results for Thomas Mill Run USAM Components

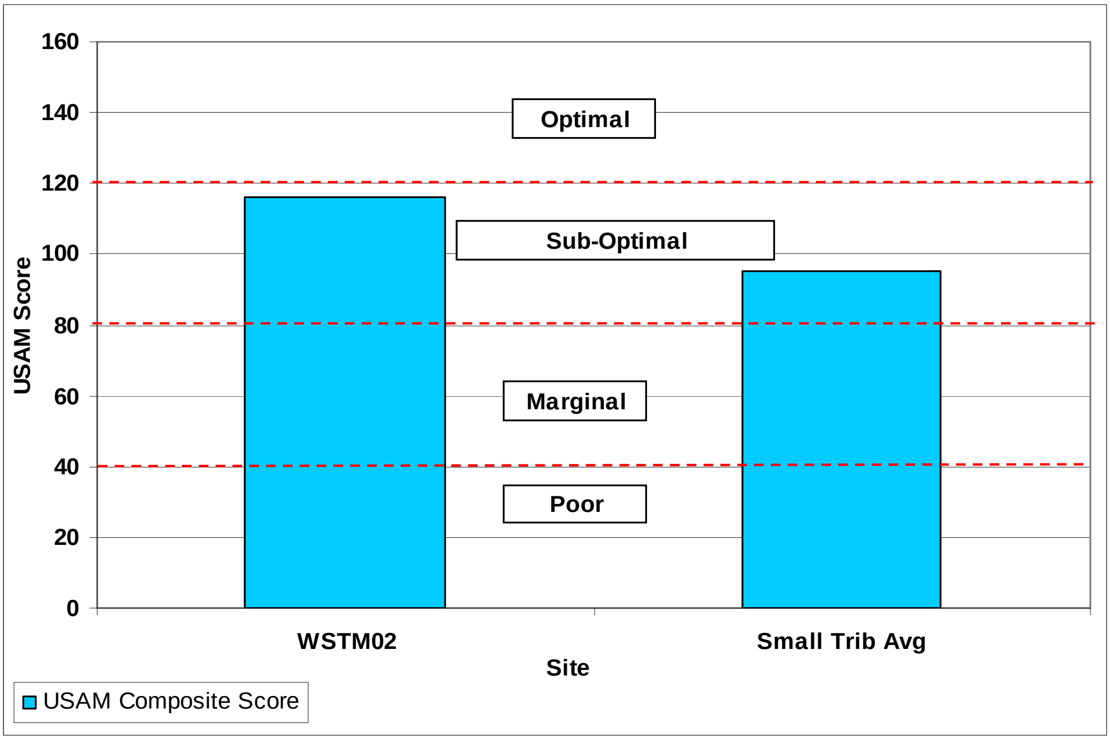


Figure 3-8: Thomas Mill Run USAM Results

3.1.1.5.1 WSTM02

Reach WSTM02 was characterized by a second order main stem channel (approximately 2,653 feet) with headwaters beginning at WSout508, which is due west of Chestnut Hill Road. The stream channel substrate distribution was dominated by gravel (2-64 mm) which comprised 53% of the substrate however there were boulder and cobble deposits as well as isolated areas in the watershed that were bedrock controlled. With a low width to depth ratio and relatively steep slope, the reach was classified as an A4 channel.

Most of reach WSTM02 is located entirely within Fairmount Park. About 485 feet of the main stem channel, upstream of outfall WSout506 and up to the headwaters, was outside of Fairmount Park. The watershed was completely forested; however, the surrounding land use was residential. As such, Thomas Mill Run receives large volumes of runoff from its very small drainage area (0.07 mi^2), which is notable given the relatively small bankfull channel in WSTM02 (10.4 ft^2). The WSTM02 reach received a USAM composite score of 116/160 (Figure 3-8).

3.1.1.6 Summary of Unified Stream Assessment Results

The mean scores for both the *Overall Stream Condition* USAM component as well as the *Overall* USAM score were all classified as “suboptimal” (Table 3-6). Conditions within the Thomas Mill Run watershed’s buffers and floodplains were considerably better than conditions observed within the stream channels as the *Overall Buffer and Floodplain Condition* was rated as “optimal”. The watershed scores for the both USAM components as well as the composite USAM score compared well against the respective Small

Tributary averages, especially the *Overall Buffer and Floodplain* score, which was considerably higher then the Small Tributary average.

Table 3-6: USAM Results for Thomas Mill Run Watershed

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP Condition	USAM Score
WSTM02	Thomas Mill	53	63	116
Small Tributary Average	**----**	**44.8**	**50.6**	**95.4**

3.1.1.6.1 SUMMARY OF OVERALL STREAM CONDITION SCORES IN THE THOMAS MILL RUN WATERSHED

The *Overall Stream Condition* score in the Thomas Mill Run watershed (53/80) was rated as "suboptimal" and was considerably higher than the Small Tributary average (44.8/80). Thomas Mill Run was observed to be among the best small tributaries in the Lower Wissahickon, as only Valley Green Run had a higher *Overall Stream Condition* Score (66/80). The habitat features that contributed most to the "suboptimal" rating were the abundance of CWD, stable bed substrate and channel morphology conducive to floodplain inundation. High rates of bank erosion observed on the unnamed tributary to Thomas Mill Run contribute an excessive amount of sediment to the main channel and ultimately Wissahickon Creek; however, most of Thomas Mill Run was observed to have relatively stable banks.

Table 3-7: USAM Overall Stream Condition Scoring for Thomas Mill Run Watershed

OVERALL STREAM CONDITION								
Reach ID	Sub-watershed	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	Overall Stream Condition
			Left	Right	Left	Right		
WSTM02	Thomas Mill	16	6	5	6	5	15	53
Small Tributary Average	**----**	**15.8**	**4.4**	**4.2**	**5.6**	**5.8**	**9**	**44.8**

3.1.1.6.1.1 INSTREAM HABITAT

The *Instream Habitat* parameter in Thomas Mill Run was rated as "optimal" with a score of 16/20. The habitat template in the creek was characterized by stable bed substrate, undercut banks and an abundance of coarse woody debris (CWD). The dominant substrate particle class was gravel (53%) although the majority of these particles were coarse (16-32 mm) or very coarse (32-64 mm) gravel which offers a much higher degree of stability than small gravel particles. Cobble (23%) and boulder (1%) particles were also present throughout riffle segments. The abundance of CWD throughout the reach was also an advantageous habitat feature as the small debris jams they caused throughout the reach serve as optimal habitat for macroinvertebrates and fish and are excellent at retaining organic matter (e.g. leaf packs).

3.1.1.6.1.2 VEGETATIVE PROTECTION

Scores for the *Vegetative Protection* parameter were rated as "marginal" for both the left (6/10) and right (5/10) banks. The scores for both banks of the Thomas Mill Run watershed were higher than the Small Tributary averages of 4.4/10 and 4.2/10 for the left and right banks respectively. The reduced scores were attributed to the observation of bare patches of soil throughout the watershed as shrubs and ground cover vegetation were sparsely distributed.

3.1.1.6.1.3 BANK EROSION

Bank erosion was observed to be most prevalent in the small tributary to Thomas Mill Run on which the entire DSL bank had high rates of erosion (Figure 3-4) - the main channel however, was observed to have limited erosion. The scores for both the left and the right banks were rated as "marginal" although both banks compared favorably to the Small Tributary averages which were also rated as "marginal." The erosion observed on the unnamed tributary to Thomas Mill Run was significant in that Thomas Mill Run was ranked among the most-erosion prone tributaries in the Lower Wissahickon. The erosion rate (normalized to stream length) was the second highest in the Lower Wissahickon at (79 lb/ft) after Gorgas Run where an erosion rate of (81 lb/ft) was estimated.

3.1.1.6.1.4 FLOODPLAIN CONNECTION

The score for the *Floodplain Connection* parameter (15/20) was rated as "suboptimal" and was the second highest score observed among the small Lower Wissahickon tributaries after Valley Green Run, which scored 17/20. The high entrenchment ratio (2.5) of the Thomas Mill Run main channel permits most flows in excess of bankfull discharge (estimated at 96.2 cfs) to enter the floodplain, which is a characteristic absent from many of the other small Lower Wissahickon tributaries.

3.1.1.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE THOMAS MILL RUN WATERSHED

The *Overall Buffer and Floodplain* score (63/80) for the Thomas Mill Run watershed was rated as "optimal" and was considerably higher than the Small Tributary average score (50.6/80) which was rated as "suboptimal". The vegetated buffers and riparian areas within the watershed were relatively undisturbed and as such were characterized by a well structured canopy and understory hierarchy. The steep valley walls precluded the formation of floodplain habitat features such as backwaters, vernal pools and wetlands; however the abundance of mature trees throughout the watershed offered additional bank stability and supplied adequate amounts of CWD (and "root wad" habitat) to the main channel.

Table 3-8: USAM Buffer and Floodplain Condition Scoring for Thomas Mill Run Watershed

OVERALL BUFFER AND FLOODPLAIN CONDITION							
Reach ID	Sub-watershed	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	Overall Buffer/FP Condition
		Left	Right				
WSTM02	Thomas Mill	10	10	18	7	18	63
Small Tributary Average	**----**	**9**	**8.8**	**16.2**	**5.6**	**11**	**50.6**

3.1.1.6.2.1 VEGETATED BUFFER WIDTH

The vegetated buffers throughout Thomas Mill Run were extensive and relatively uninterrupted on both sides of the corridor. The scores for both banks were rated as "optimal" and were higher then the Small Tributary averages for both the left (9/10) and right (8.8/10) banks which were rated as "suboptimal" (Table 3-8).

3.1.1.6.2.2 FLOODPLAIN VEGETATION

The score for the *Floodplain Vegetation* parameter (18/20) was the highest recorded amongst the small tributaries and was the second highest score observed throughout the Lower Wissahickon (following WSMO02 and WSBM02 which both had scores of 19/20). The dominant floodplain vegetation type was mature forest, although there was a well established understory throughout the watershed. Large, mature trees often abutted the stream which provided increased bank stability and a source of CWD.

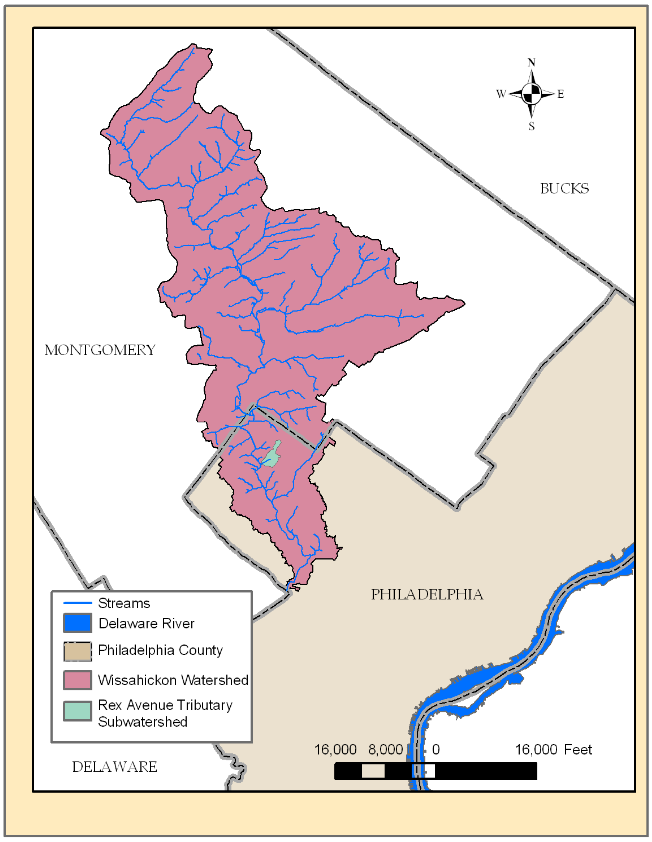
3.1.1.6.2.3 FLOODPLAIN HABITAT

Floodplain habitat was limited throughout the reach even though the main channel had a relatively high entrenchment ratio. The dominant floodplain habitat features were fallen logs and snags. The steep valley walls of the watershed and the lack of floodplain "benches" precluded the formation of many valuable habitat features that require periodically saturated conditions. The score for this parameter (7/20) was rated as "marginal", which was considerably higher than the Small Tributary average of 5.6/20.

3.1.1.6.2.4 FLOODPLAIN ENCROACHMENT

There were very few instances of floodplain encroachment observed throughout the watershed, most of which were attributed to infrastructure. The score of 18/20 was rated as "optimal" and was the highest score recorded throughout the Lower Wissahickon.

3.1.2 Main stem Tributary I (Rex Avenue Run) Watershed



WSMSI – Tributary 1, also know as Rex Avenue, is a tributary to the main stem of the Wissahickon Creek. The tributary originates from a privately owned outfall located in a residential neighborhood. WSMSI – Tributary 1 is a first-order tributary that travels for approximately 1,900 feet before entering the Wissahickon Creek. The dominant substrate varies from medium gravel to medium cobble at different sections along the tributary. Both the valley floor and channel have been substantially impacted by past and current land use.

The entire WSMSI – Tributary 1 watershed is 137 acres. Major land use types within the watershed include: wooded (52%), residential – single family detached (36%), and recreation (3%). Approximately 375 feet of the northern portion of the tributary are located on private property. The rest of the tributary is surrounded by Fairmount Park on both sides. The Park buffer ranges from about 30 feet to about 2,000 feet.

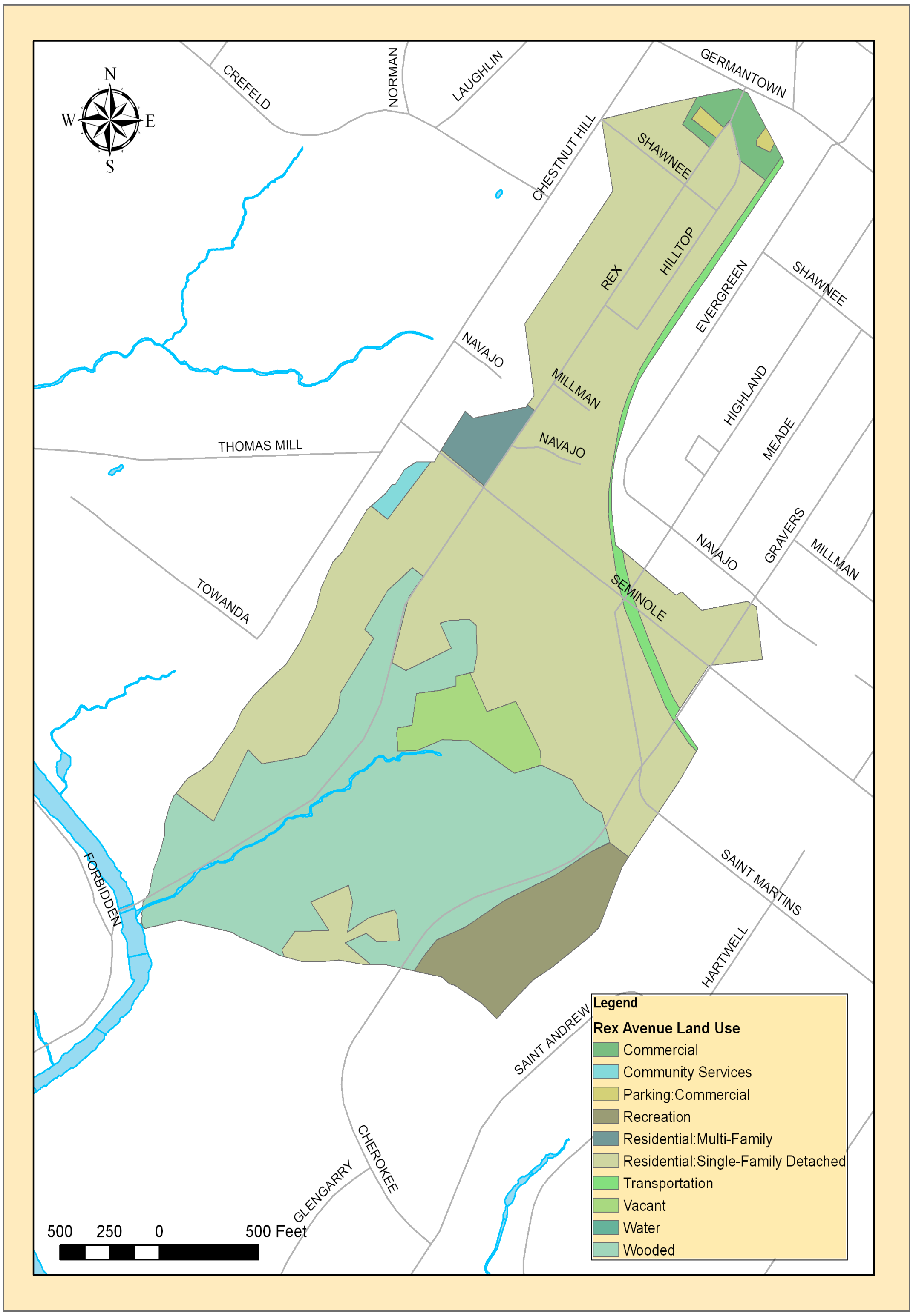


Figure 3-9: Tributary I - Rex Avenue Watershed Land Use

3.1.2.1 GEOLOGY

The majority of the Rex Avenue watershed is underlain by the Wissahickon Formation. The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

The northern portion of the Rex Avenue watershed is underlain by the Bryn Mawr Formation. The Bryn Mawr Formation consists of white, yellow and brown gravel and sand. The Bryn Mawr Formation is considered a deeply weathered formation.

3.1.2.2 SOILS

According to the National Resource and Conservation Service Soil Survey, the soils for the entire Rex Avenue watershed are classified as hydrologic group B. These soils have a moderate rate of infiltration when the soils are wet (0.50-1.00 in/hr). Water movement through these soils is considered moderately rapid.

Table 3-9: Distribution of NRCS Soil Types in Tributary I - Rex Avenue Watershed

Group	Area (ft^2)	Percent of Total Area
B	5,967,720	100%
Total Area	**5,967,720**	**100%**

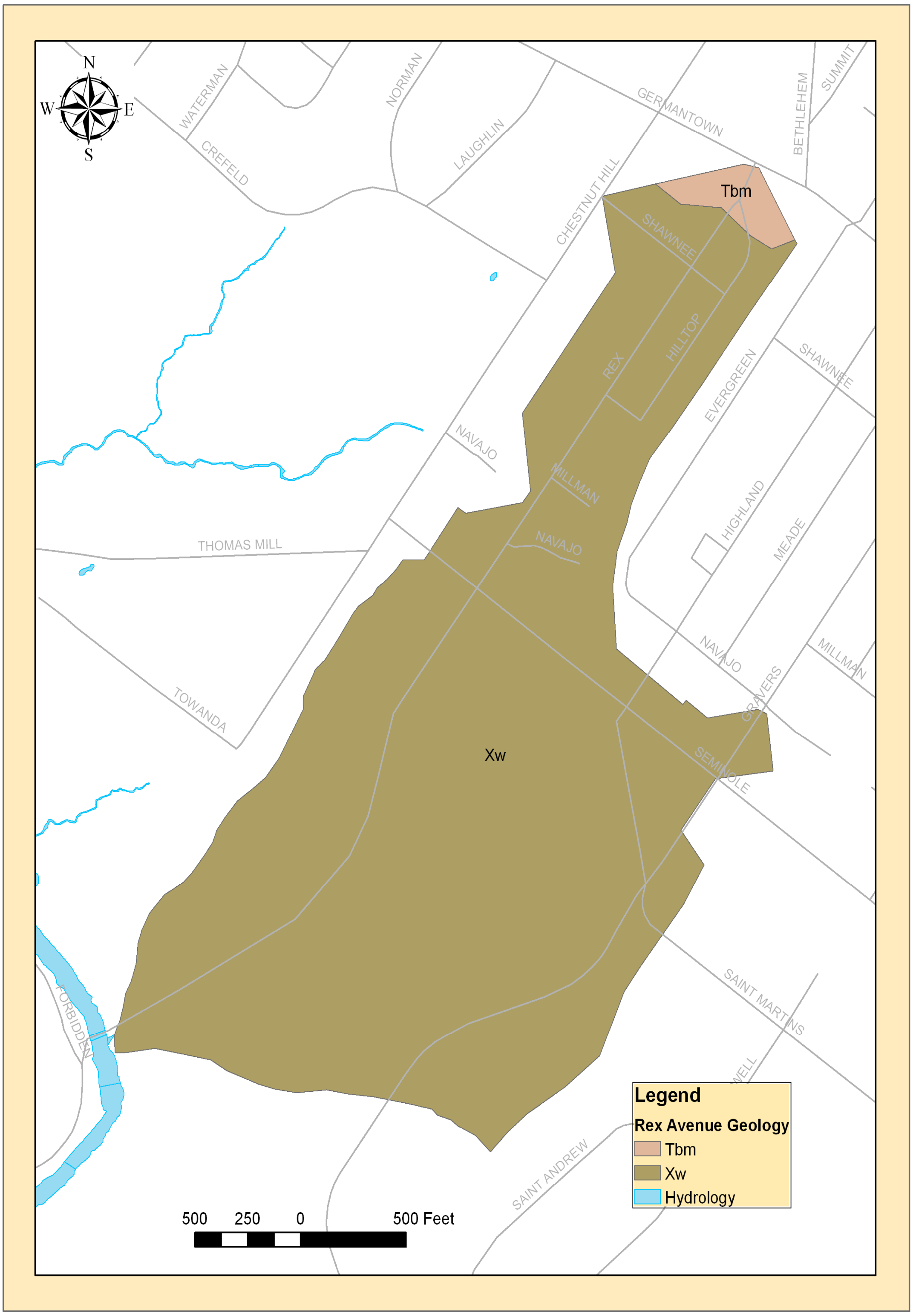


Figure 3-10: Geology of Tributary I - Rex Avenue Watershed

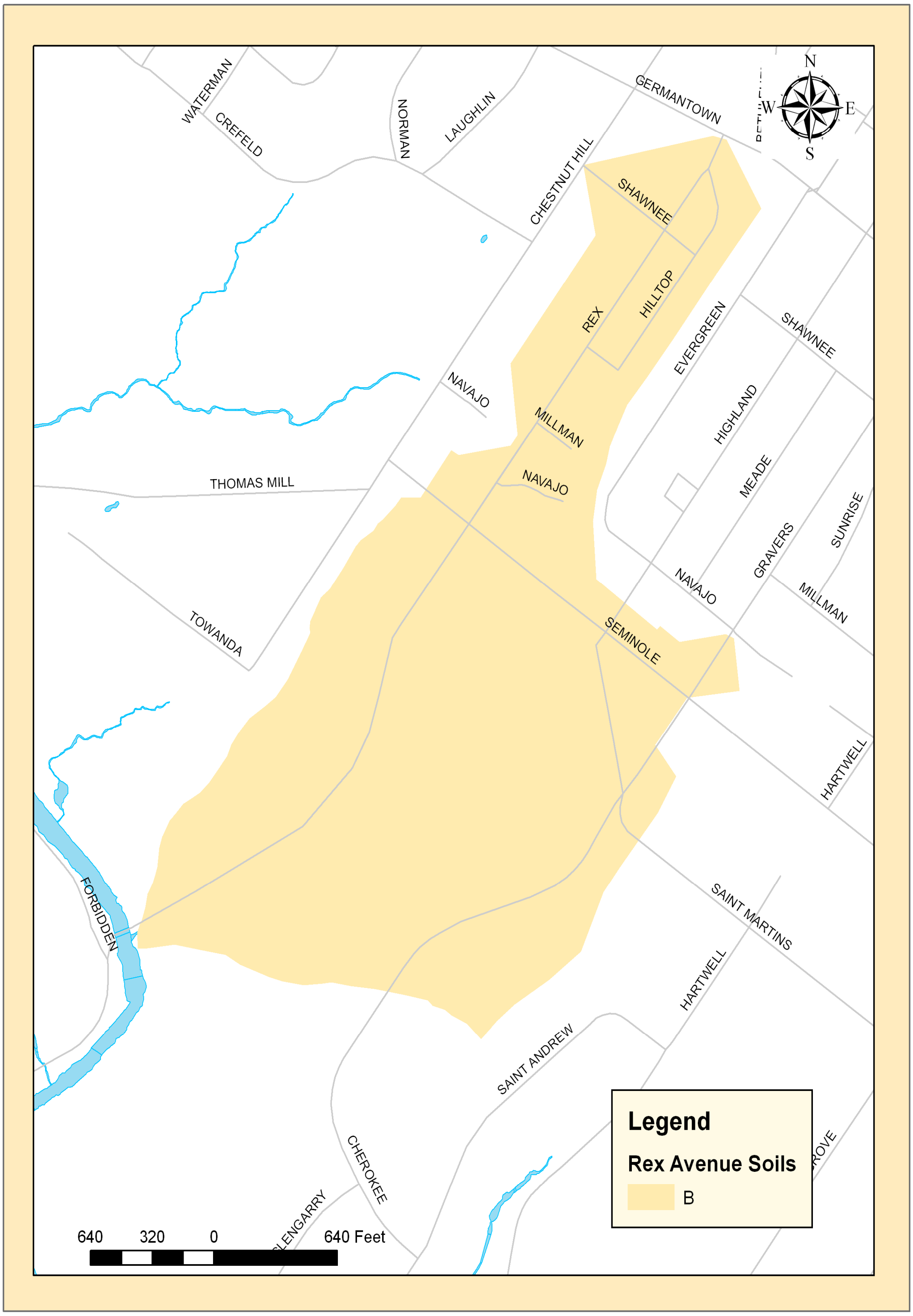


Figure 3-11: Distribution of NRCS Soil Types in Tributary I - Rex Avenue Watershed

3.1.2.3 BANK EROSION

There were three bank pin locations along WSMSI – Tributary 1 (Figure 3-12). The calculated erosion rates are included in Table 3-10. The spatial distribution of BEHI assessment results were represented graphically (Figure 3-12) for each of the segments assessed on WSMSI – Tributary I. Each bank within a respective segment was assessed and rated separately; however, channelized and culverted segments were not assessed as they confer a high degree of protection from bank erosion.

Table 3-10: Rex Avenue Bank Pin Locations

	BEHI	NBS	Baseline Reading	Most Recent Reading	Erosion Rate (ft)	Erosion Rate (ft/yr)	Eroding (-) or Aggrading (+)
Rex Avenue Tributary							
TO202	Moderate	Low	8/24/2006	8/10/2009	-0.48	-0.16	E
TO203	Low	Low	8/24/2006	8/10/2009	-0.19	-0.064	E
TO9	High	Low	8/24/2006	8/10/2009	-0.088	-0.030	E

Total erosion rates were also calculated for the entire length of each tributary within the lower Wissahickon (Table 3-11). To assess the normalized erosion potential of each tributary, the erosion rate per acre of drainage area per year and the erosion rate per foot of stream length per year were calculated. This allowed direct comparison between each of the tributaries with respect to both watershed size and the length of the tributary. WSMSI - Tributary 1 was ranked first out of the twelve tributaries within the lower Wissahickon for erosion rate per foot of stream length. The rankings were based on a scale of one being the highest erosion rate and twelve being the lowest erosion rate.

Table 3-11: Erosion Rates for Lower Wissahickon Tributaries

Tributary	Drainage Area (Acres)	Stream Length (feet)	*2009*		
			Erosion Rate (lb/yr)	*Erosion Rate Per Acre*	*Erosion Rate Per Foot of Stream*
Bell's Mill	323	6,722	420,000	1,307	63
Cathedral Run	160	2,790	150,000	913	52
Cresheim Creek	1,218	16,431	840,000	690	51
Gorgas Run	499	2,170	170,000	345	79
Hartwell Run	217	3,530	200,000	918	56
Hillcrest	144	5,272	90,000	597	16
Kitchen's Lane	234	7,753	200,000	850	26
Monoshone Creek	1,056	6,926	160,000	156	24
Rex Ave	137	1,903	150,000	1,131	81
Thomas Mill Run	104	4,008	320,000	3,058	79
Valley Green Run	128	2,874	140,000	1,086	48
Wise's Mill Run	446	7,056	490,000	1,090	69
Total/*Average*	**4,666**	**67,435**	**3,300,000**	***1,012***	***54***

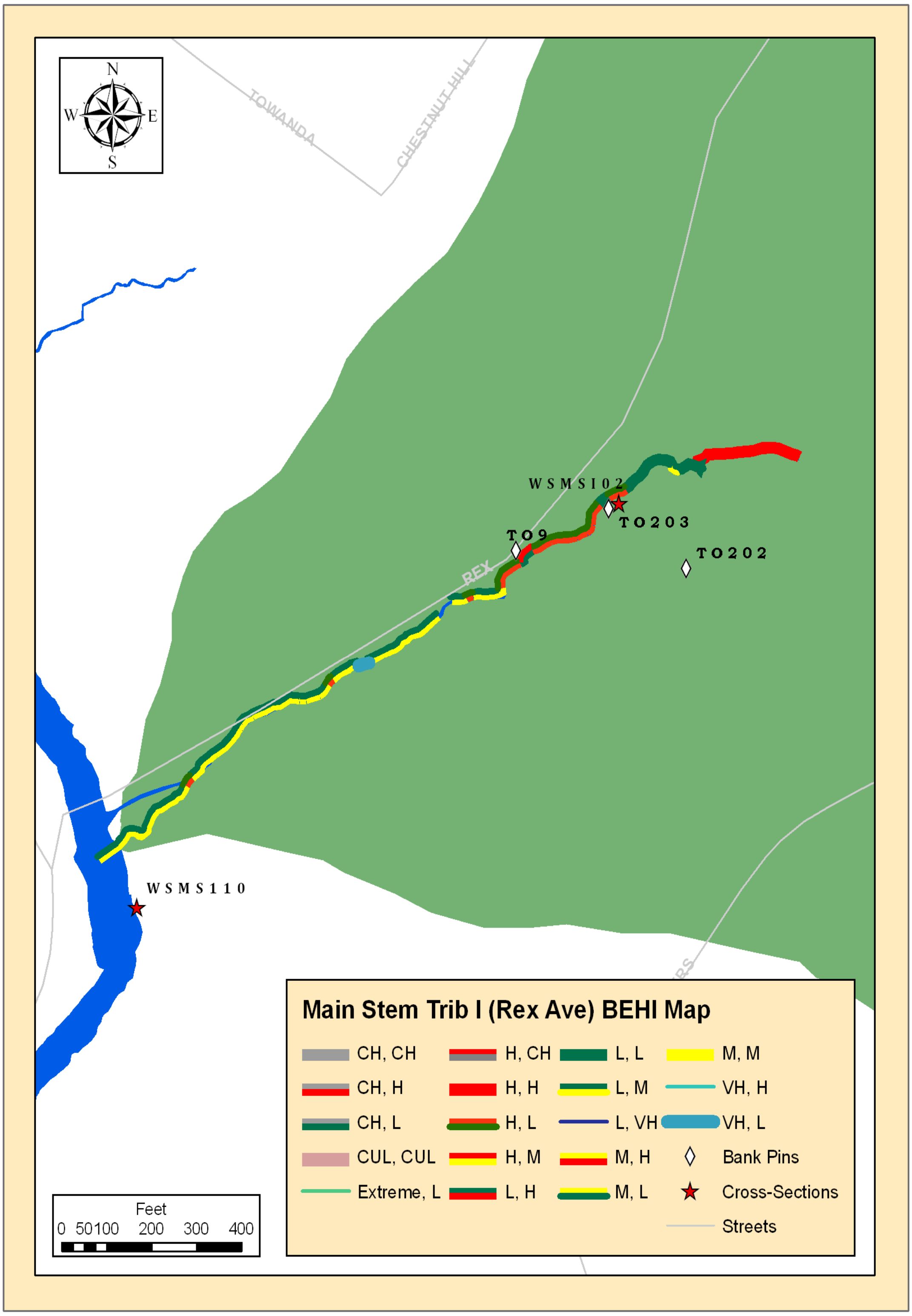


Figure 3-12: Tributary I - Rex Avenue Watershed BEHI Ratings and Bank Pin Locations

3.1.2.4 INFRASTRUCTURE TRACKDOWN SUMMARY

Wissahickon Tributary I is located within Fairmount Park adjacent to Rex Avenue and north of Gravers Lane. The most prominent piece of infrastructure on this stream is WSout509 (W-085-02), which is the largest outfall (4.5 foot diameter) on the tributary. It conveys stormwater drainage from Germantown Avenue and the nearby streets through a 54-inch diameter pipe directly to Tributary I. This outfall was observed to have a dry weather baseflow, which was a major contributing factor to the impairment of this tributary.

The high flows from WSout509 and to lesser extent outfalls WSout725 and WSout510 have impacted many aspects of the stream's physical and biological health. The eroding banks and "flashy" flow regime have spawned emergency repair and bank restoration projects to improve the condition of the stream. WScha115 was most likely a temporary structure constructed to provide immediate protection to the eroding bank in the vicinity of the channel; to prevent Rex Avenue from collapsing into the stream, and possibly to keep the stream from exposing the water main sewer and sanitary interceptor that run parallel to Rex Avenue. Just downstream of this channelized portion, the 15-inch Wissahickon High Level Interceptor crosses underneath the stream. There were no infrastructure elements found to be in poor condition. WScha115 was in fairly poor condition; however, it appeared to be a temporary structure.

Table 3-12: Summary of Main stem Tributary I Infrastructure Points

Section ID	Bridge Count	Outfall Count	Channel Count	Infra Point Count	Combined Outfall Area (ft^2)
WSMSI02	2	3	1	5	17.48

Table 3-13: Summary Main stem Tributary I Infrastructure Linear Features

Section ID	Segment Length (ft)	Culvert Length (ft)	Percent Culverted	Channel Length (ft)	Percent Channelized
WSMSI02	1865	0	0	45	0.8

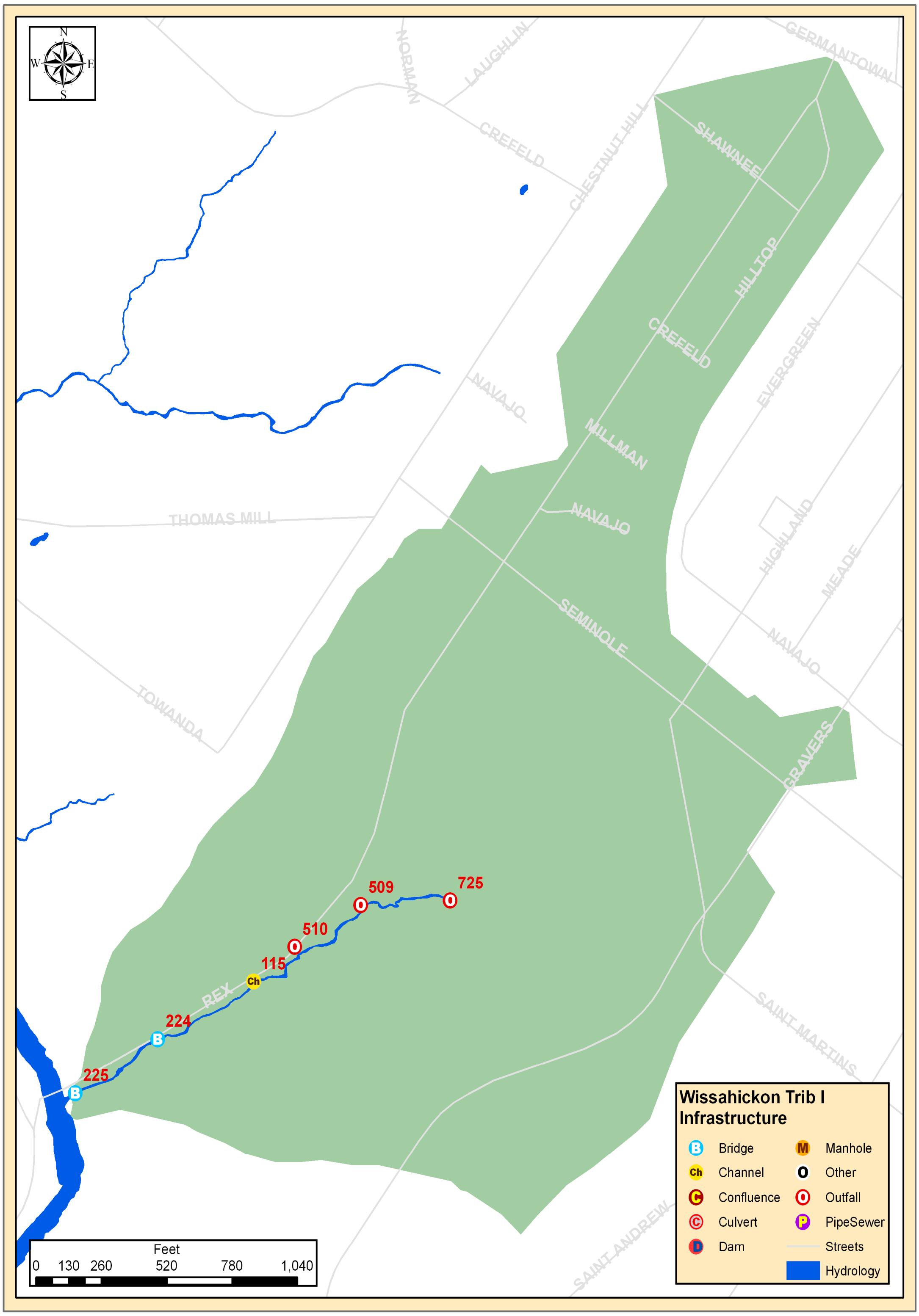


Figure 3-13: Tributary I Infrastructure

3.1.2.5 UNIFIED STREAM ASSESSMENT RESULTS FOR THE MAIN STEM TRIBUTARY I WATERSHED

The Main Stem Tributary I watershed had a single channel (approximately 1,865 feet) with no tributaries. Main Stem Tributary I was the only tributary of the Wissahickon Creek direct drainage that was entirely within the Lower Wissahickon Basin. The majority of the channel was located within Fairmount Park although the channel migrated outside of Park boundaries in several locations. The Center for Watershed Protection's (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and watersheds within the Lower Wissahickon Basin.

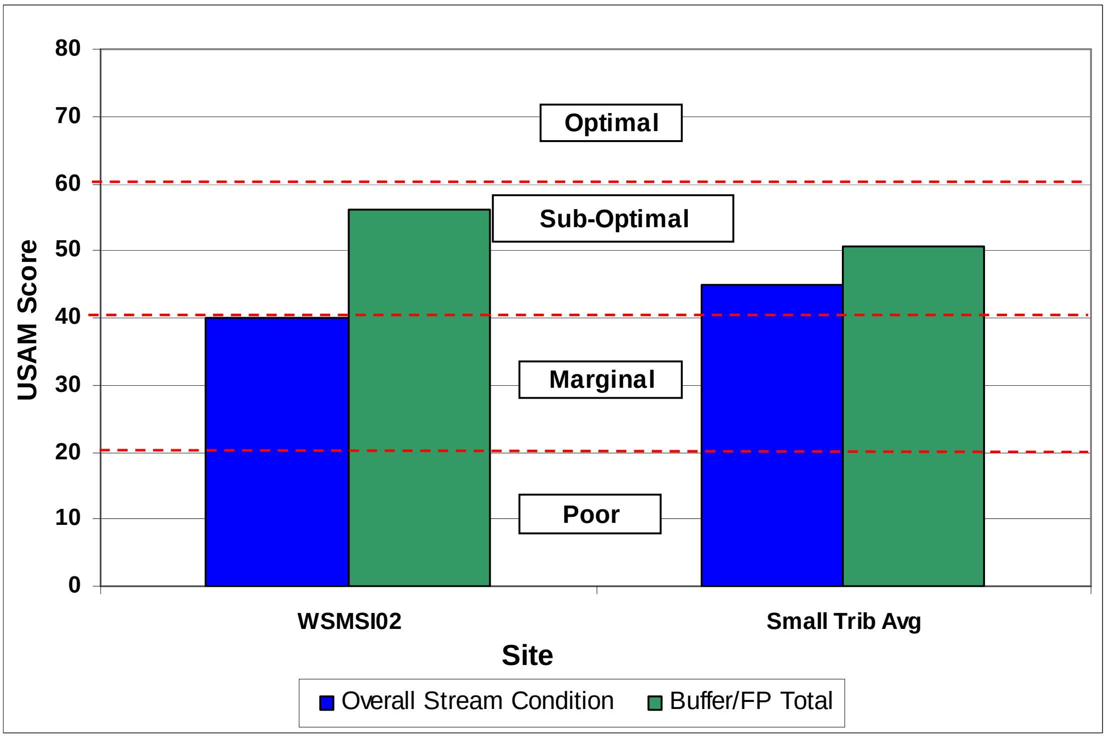


Figure 3-14: Results for Main Stem Tributary I – Rex Avenue USAM Components

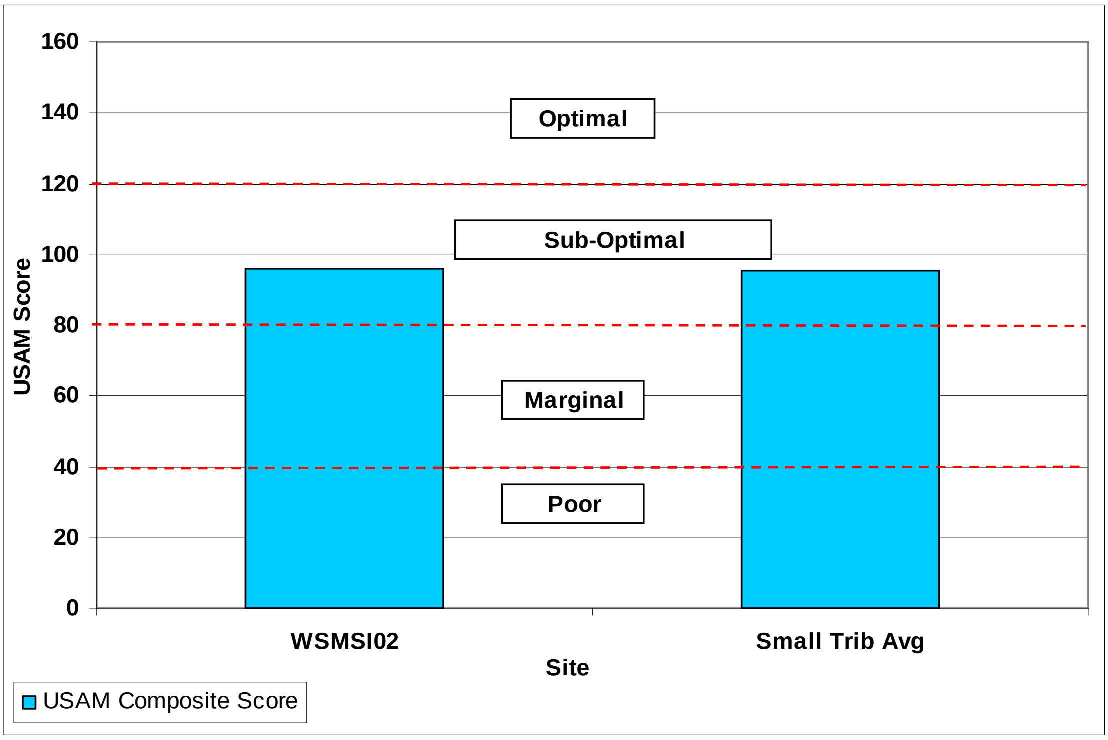


Figure 3-15: Tributary I - Rex Avenue USAM Results

3.1.2.5.1 WSMSI02

The headwaters of reach WSMSI02 began as flow from a privately owned outfall, WSout725, which was located within Fairmount Park. The channel was relatively small with a bankfull cross-sectional area of only 11.4 ft^2. The substrate distribution was dominated by gravel (61%) although cobble and a limited amount of boulders were also observed. The channel was characterized by a moderate width to depth ratio (13.8) and moderate degree of entrenchment (ER=1.4). As such, reach WSMSI02 was classified as a B4 type channel. The USAM composite score for the reach was 96/180 (Figure 3-15).

3.1.2.6 Summary of Unified Stream Assessment Results

The mean scores for both the *Overall Buffer and Floodplain Condition* USAM component as well as the overall USAM score were all classified as “suboptimal” (Table 3-14). Conditions within the Tributary I watershed’s buffers and floodplains were considerably greater than conditions observed within the stream channels. The watershed score for the *Overall Stream Condition* component did not compare well against the respective Small Tributary averages, though the *Overall Buffer and Floodplain* score was considerably higher than the Small Tributary average.

Table 3-14: USAM Results for Tributary I - Rex Avenue Watershed

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP Condition	USAM Score
WSMSI02	Main Stem Tributary I	40	56	96
Small Tributary Average	**----**	**44.8**	**50.6**	**95.4**

3.1.2.6.1 SUMMARY OF OVERALL STREAM CONDITION SCORES IN THE MAIN STEM TRIBUTARY I WATERSHED

In general, the *Overall Stream Condition* score for WSMSI02 was not very high (40/80) and was rated as "marginal." The score at WSMSI02 was observed to be the median condition among the small Lower Wissahickon tributaries. Valley Green Run and Thomas Mill Run were considerably better than Rex Avenue Run and the other two tributaries, Cathedral Run and Gorgas Run, were considerably worse. The individual scores for each of the *Overall Stream Condition* parameters were low to moderate for all parameters except for the *Instream Habitat* parameter, which had the highest score among the small Lower Wissahickon tributaries.

Table 3-15: Overall Stream Condition USAM Results for Tributary I - Rex Avenue Watershed

OVERALL STREAM CONDITION								
Reach ID	Sub-watershed	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	Overall Stream Condition
			Left	Right	Left	Right		
WSMSI02	Main Stem Tributary I	19	3	3	5	6	4	40
Small Tributary Average	**----**	**15.8**	**4.4**	**4.2**	**5.6**	**5.8**	**9**	**44.8**

3.1.2.6.1.1 INSTREAM HABITAT

Instream Habitat was rated as "optimal" in reach WSMSI02 with a score of 19/20, which was considerably higher than the Small Tributary average score of 15.8/20 which was rated as "suboptimal." The dominant substrate class was gravel as medium to coarse gravel (8-64 mm) comprised 52% of the bed substrate. There was also an abundance of cobble (64-256 mm) substrate of various size classes. Boulders were present throughout the reach, however, a large proportion of the boulders present throughout the reach were positioned along the margins of the stream. The combination of stable substrate and CWD positioned WSMSI02 as the highest scoring small tributary for this parameter.

3.1.2.6.1.2 VEGETATIVE PROTECTION

Scores for the left and right banks of reach WSMSI02 were very low and ranked among the worst scores recorded among the small Lower Wissahickon tributaries. Both the left and right banks of the reach had scores of 3/10 and were rated as "poor." In comparison, the Small Tributary averages for the left (4.4/10) and right (4.2/10) banks were rated as "marginal."

3.1.2.6.1.3 BANK EROSION

There was a moderate amount of bank erosion observed in WSMSI02, mostly in the upper half of the reach. The most severe erosion occurred at the top of the reach and was attributed to the impacts of WSout725 which functioned as the headwaters of the reach. Scores for both the left (5/10) and the right (6/10) banks of WSMSI02 were considerably lower than the Small Tributary average scores of 5.6/10 and 5.8/10 for the left and right banks respectively.

3.1.2.6.1.4 FLOODPLAIN CONNECTION

The *Floodplain Connection* parameter is a measure of the degree channel entrenchment observed throughout a reach. WSMSI02 had a score of 4/20 and was rated as "poor" compared to the Small Tributary average which was rated as "marginal" with a score of 9/20. The only small tributary with a similar degree of floodplain disconnection was WSGO02 which had a score of 2/20.

3.1.2.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE MAIN STEM TRIBUTARY I WATERSHED

The conditions within the floodplains and vegetated buffer zones of Main Stem Tributary I were among the best observed among the small Lower Wissahickon tributaries. The WSMSI02 score was higher than the Small Tributary average for each parameter except for the *Floodplain Habitat* parameter; however, low scores were recorded for this parameter throughout the Lower Wissahickon. The *Overall Buffer and Floodplain* score for WSMSI02 (56/80) was rated as "suboptimal" and greatly exceeded the Small Tributary average score (50.6/80). The only watershed to have a higher score was Thomas Mill Run (63/80) which was rated as "optimal".

Table 3-16: USAM Buffer and Floodplain Condition Scoring for Tributary I - Rex Avenue Watershed

OVERALL BUFFER AND FLOODPLAIN CONDITION							
Reach ID	Sub-watershed	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	Overall Buffer/FP Condition
		Left	Right				
WSMSI02	Main Stem Tributary I	10	10	17	5	14	56
Small Tributary Average	----	**9**	**8.8**	**16.2**	**5.6**	**11**	**50.6**

3.1.2.6.2.1 VEGETATED BUFFER WIDTH

Scores for the right and left vegetated buffer zones were rated as "optimal" as both had a score of 10/10. Main Stem Tributary I was one of only three small tributaries to have optimal ratings for both the left and right side of the corridor. Scores recorded for the left and right vegetated buffers of reach WSMSI02 were above the respective Small Tributary averages of 9/10 and 8.8/10 for the left and right corridors respectively.

3.1.2.6.2.2 FLOODPLAIN VEGETATION

The floodplain vegetation within the Main Stem Tributary I watershed was mature forest, although shrubs and understory trees were also present, especially near the stream channel where there is increased light availability. The score for this parameter (17/20) was rated as “optimal” and was slightly higher than the Small Tributary average (16.2/20) which was also rated as “optimal.” Aside from Rex Avenue, there has been limited development and associated tree clearing within the stream corridor allowing for the establishment of a relatively dense distribution of large, mixed hardwood species.

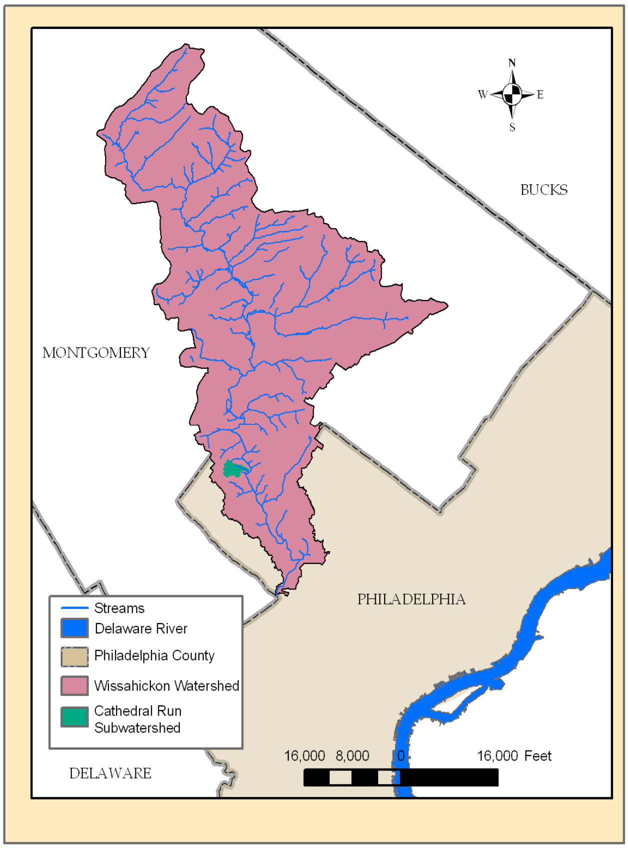
3.1.2.6.2.3 FLOODPLAIN HABITAT

Floodplain habitat other than fallen trees and snags was limited in reach WSMSI02. The score for this parameter was only 5/20 and was rated as “poor.” The Small Tributary average (5.6/20) was only slightly higher and was rated towards the lower end of the marginal range. The deeply entrenched channel of reach WSMSI02 rarely accessed the floodplain which precludes the formation and maintenance of many types of floodplain and wetland habitat.

3.1.2.6.2.4 FLOODPLAIN ENCROACHMENT

The score for the *Floodplain Encroachment* parameter (14/20) was rated as “suboptimal” due to the close proximity of Rex Avenue to most of the DSR side of the stream channel. Along the DSL side of the corridor, the floodplain was extensive with no development within 500 feet of the channel. The score for reach WSMSI02 was considerably higher than the Small Tributary average (11/20) which was rated as “marginal.”

3.1.3 CATHEDRAL RUN WATERSHED AND REACH CHARACTERISTICS



Cathedral Run is a small first-order tributary to Wissahickon Creek. The stream originates from springs downstream of Courtesy Stables near the intersection of Cathedral and Glen Campbell roads. Cathedral Run then travels approximately 2,500 feet through a wooded section of Fairmount Park before entering Wissahickon Creek. The stream is relatively steep with an average gradient of 8.5%; however, the downstream half of the tributary is steeper than the upstream reach.

The watershed is highly developed with 31% impervious cover and 361 homes. The natural drainage area is 116 acres; however two outfalls collect stormwater from an additional 40 acres. Baseflow is low and was measured to be 0.06 cfs during August 2005. One outfall (WSout760) located at the headwaters of the tributary drains approximately 91 acres of residential and commercial property. A second 36-inch outfall (WSout511), located at the intersection of Cathedral and Glenroy roads, drains approximately 38 acres of mostly residential property.

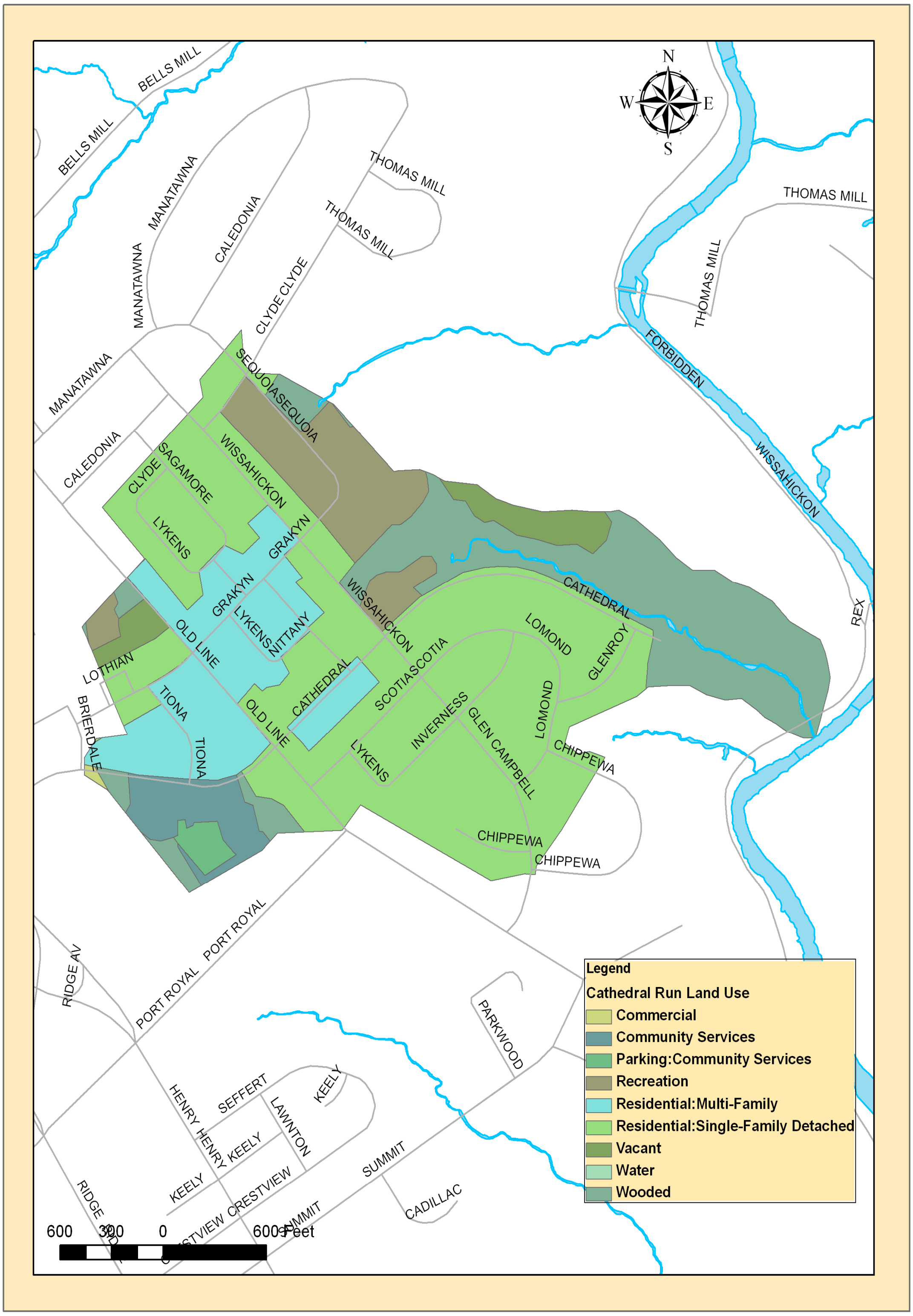


Figure 3-16: Cathedral Run Watershed Land Use

3.1.3.1 GEOLOGY

The Cathedral Run watershed is completely underlain by the Wissahickon Formation. The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

3.1.3.2 SOILS

According to the National Resource and Conservation Service Soil Survey, all soils for the Cathedral Run watershed are classified as hydrologic group B. These soils have a moderate rate of infiltration when the soils are wet. Water movement through these soils is considered moderately rapid.

Table 3-17: Distribution of NRCS Soil Types in Cathedral Run Watershed

Group	Area (ft^2)	Percent of Total Area
B	5,052,960	100%
Total Area	**5,052,960**	**100%**

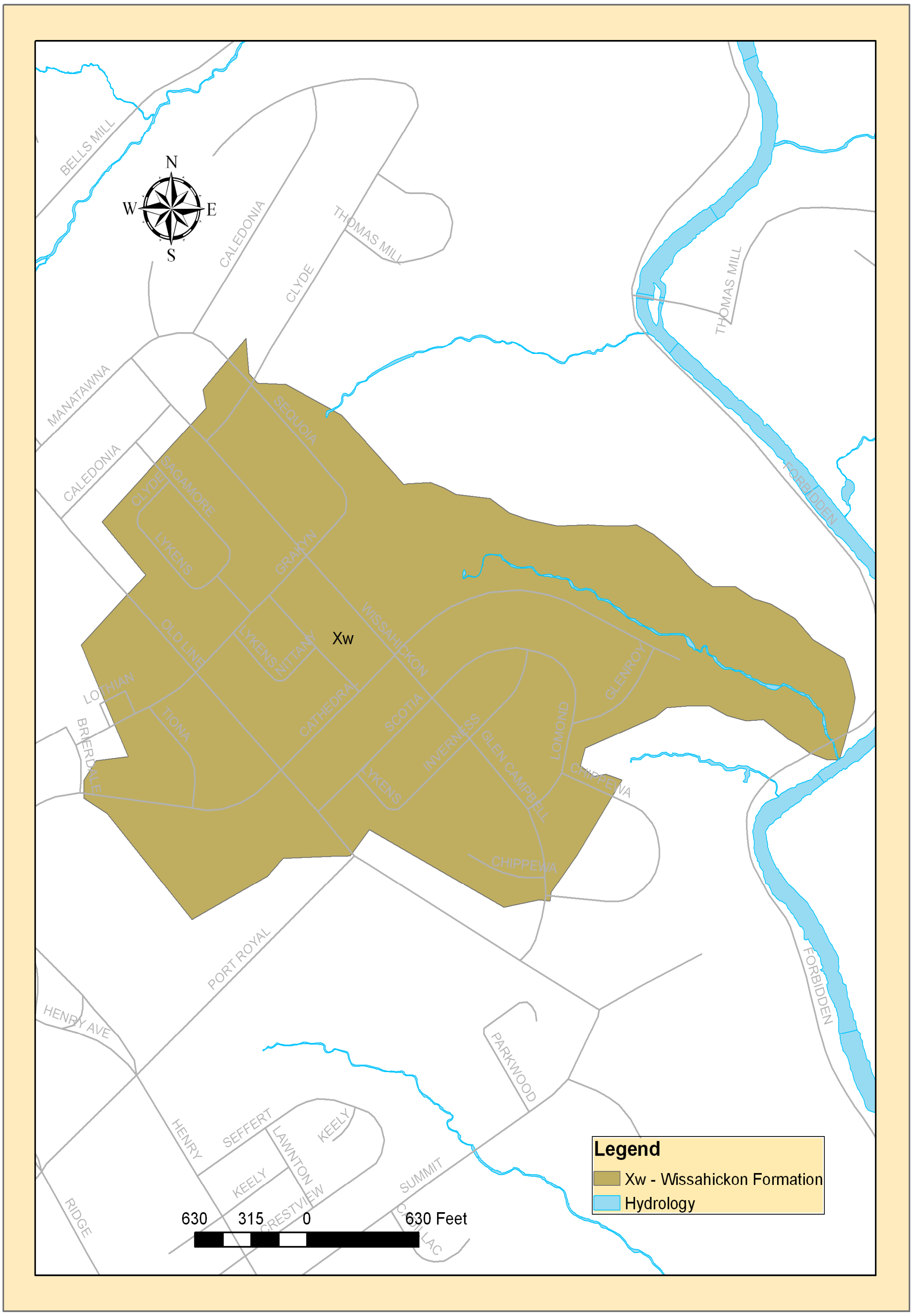


Figure 3-17: Geology of Cathedral Run Watershed

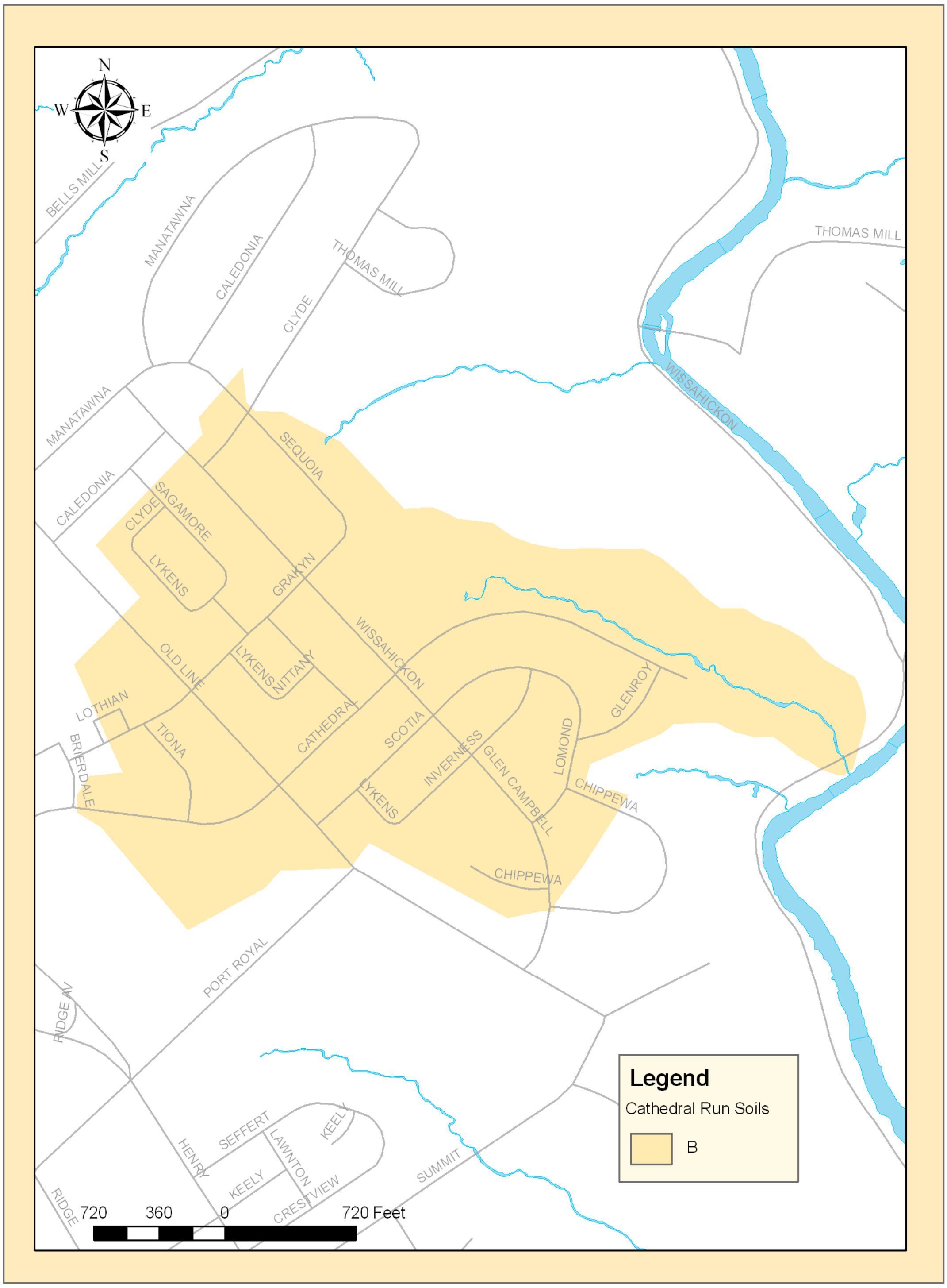


Figure 3-18: Distribution of NRCS Soil Types in Cathedral Run Watershed

3.1.3.3 Bank Erosion

There were 10 bank pin locations along Cathedral Run (Figure 3-19). The calculated erosion rates at each bank pin location are included in Table 3-18. The spatial distribution of BEHI assessment results were represented graphically (Figure 3-19) for each of the segments assessed on Cathedral Run. Each bank within a respective segment was assessed and rated separately; however, channelized and culverted segments were not assessed as they confer a high degree of protection from bank erosion.

Table 3-18: Cathedral Run Bank Pin Locations

	BEHI	NBS	Baseline Reading	Most Recent Reading	Erosion Rate (ft)	Erosion Rate (ft/yr)	Eroding (-) or Aggrading (+)
Cathedral Run							
CR12	Moderate	Very High	8/21/2006	8/13/2009	-0.20	-0.068	E
CR13	High	Low	10/31/2005	8/13/2009	-0.44	-0.12	E
CR1370	Moderate	Low	5/11/2006	8/22/2007	0.30	0.23	A
CR14	Moderate	Low	10/31/2005	8/11/2008	0.076	0.027	A
CR16	Moderate	High	10/31/2005	8/13/2009	-1.63	-0.43	E
CR18	Moderate	Very Low	10/31/2005	8/13/2009	-0.088	-0.023	E
CR3	High	Low	10/31/2005	8/13/2009	0.22	0.058	A
CR510	Moderate	Low	5/21/2006	8/11/2008	0.077	0.035	A
CR7	High	High	8/16/2007	8/11/2008	0.26	0.27	A
CR250	Moderate	Very Low	5/11/2006	8/11/2008	0.069	0.031	A

Total erosion rates were also calculated for the entire length of each tributary within the lower Wissahickon (Table 3-19). To assess the normalized erosion potential of each tributary, the erosion rate per acre of drainage area per year and the erosion rate per foot of stream length per year were calculated. This allowed direct comparison between each of the tributaries with respect to both watershed size and the length of the tributary. Cathedral Run was ranked seventh out of the twelve tributaries within the lower Wissahickon for erosion rate per foot of stream length. The rankings were based on a scale of one being the highest erosion rate and twelve being the lowest erosion rate.

Table 3-19: Erosion Rates for Lower Wissahickon Tributaries

Tributary	Drainage Area (Acres)	Stream Length (feet)	*2009*		
			Erosion Rate (lb/yr)	*Erosion Rate Per Acre*	*Erosion Rate Per Foot of Stream*
Bell's Mill	323	6,722	420,000	1,307	63
Cathedral Run	160	2,790	150,000	913	52
Cresheim Creek	1,218	16,431	840,000	690	51
Gorgas Run	499	2,170	170,000	345	79
Hartwell Run	217	3,530	200,000	918	56
Hillcrest	144	5,272	90,000	597	16
Kitchen's Lane	234	7,753	200,000	850	26
Monoshone Creek	1,056	6,926	160,000	156	24
Rex Ave	137	1,903	150,000	1,131	81
Thomas Mill Run	104	4,008	320,000	3,058	79
Valley Green Run	128	2,874	140,000	1,086	48
Wise's Mill Run	446	7,056	490,000	1,090	69
Total/*Average*	**4,666**	**67,435**	**3,300,000**	***1,012***	***54***

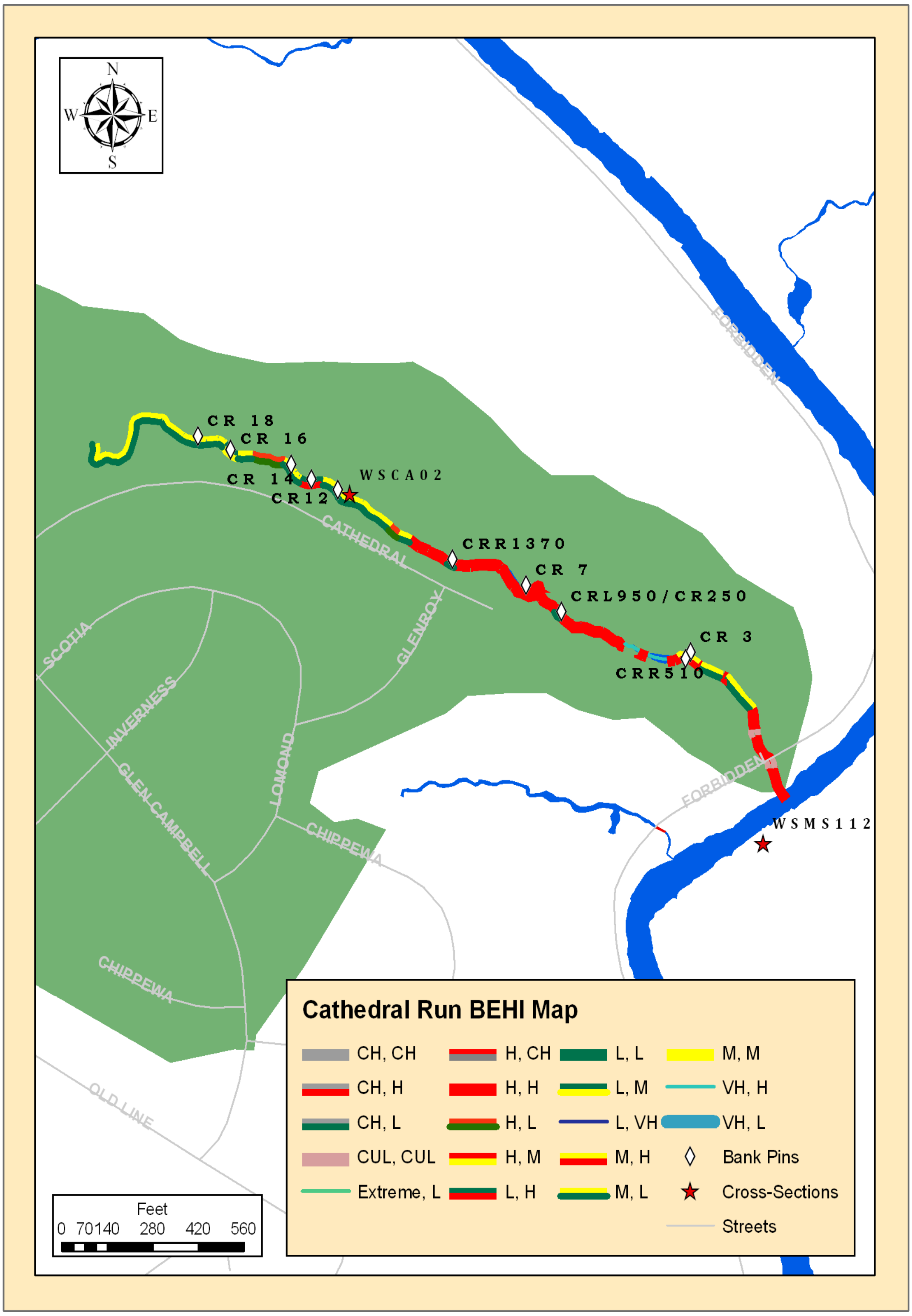


Figure 3-19: Cathedral Run Watershed BEHI Ratings and Bank Pin Locations

3.1.3.4 INFRASTRUCTURE TRACKDOWN SUMMARY

The Cathedral Run stream channel was located entirely within Fairmount Park. The tributary runs adjacent to Cathedral Road and as such was impacted by stormwater runoff from the adjacent neighborhood. There were five infrastructure points (Table 3-20) on the Cathedral Run tributary which included two culverts (WScul93 and WScul95) and three outfalls (WSout511, WSout726 and WSout760). Similar to some of the other tributaries along the Wissahickon corridor, Cathedral Run had culverts directly upstream of the confluence with the main stem of Wissahickon Creek due to Forbidden Drive and the Park trail system.

The two culverts account for only 2% of the entire stream length; however, they have the potential to dramatically alter the conveyance of water and sediment from the tributary to the main stem. Similar to the other tributaries, Cathedral Run has also been impacted dramatically by stormwater runoff, which is conveyed by the two outfalls discharging runoff from Cathedral Road as well as the residential neighborhood stretching out past Wissahickon Avenue. WSout760 (W-076-01) discharges stormwater from a 48-inch diameter pipe and WSout511 (W-076-02) discharges from a 36-inch diameter pipe. The flow from these two outfalls was likely a contributing factor to the impaired state of the stream. Streambank erosion, poor water quality, and a "flashy" hydraulic regime can all be attributed to the extreme flows caused by wet weather conditions. None of the infrastructure on Cathedral Run was found to be in poor condition. The infrastructure may be influenced significantly in the future by the Cathedral Run Stormwater Treatment Facility that will create a headwater wetland complex to absorb the energy of stormwater flows and retain some of the stormwater volume.

Table 3-20: Summary of Cathedral Run Infrastructure Points

Section ID	Culvert Count	Outfall Count	Infra Point Count	Combined Outfall Area (ft^2)
WSCA02	2	3	5	26.71

Table 3-21: Summary of Cathedral Run Infrastructure Linear Features

Section ID	Segment Length (ft)	Culvert Length (ft)	Percent Culverted	Channel Length (ft)	Percent Channelized
WSCA02	3123	50	1.60	0	0

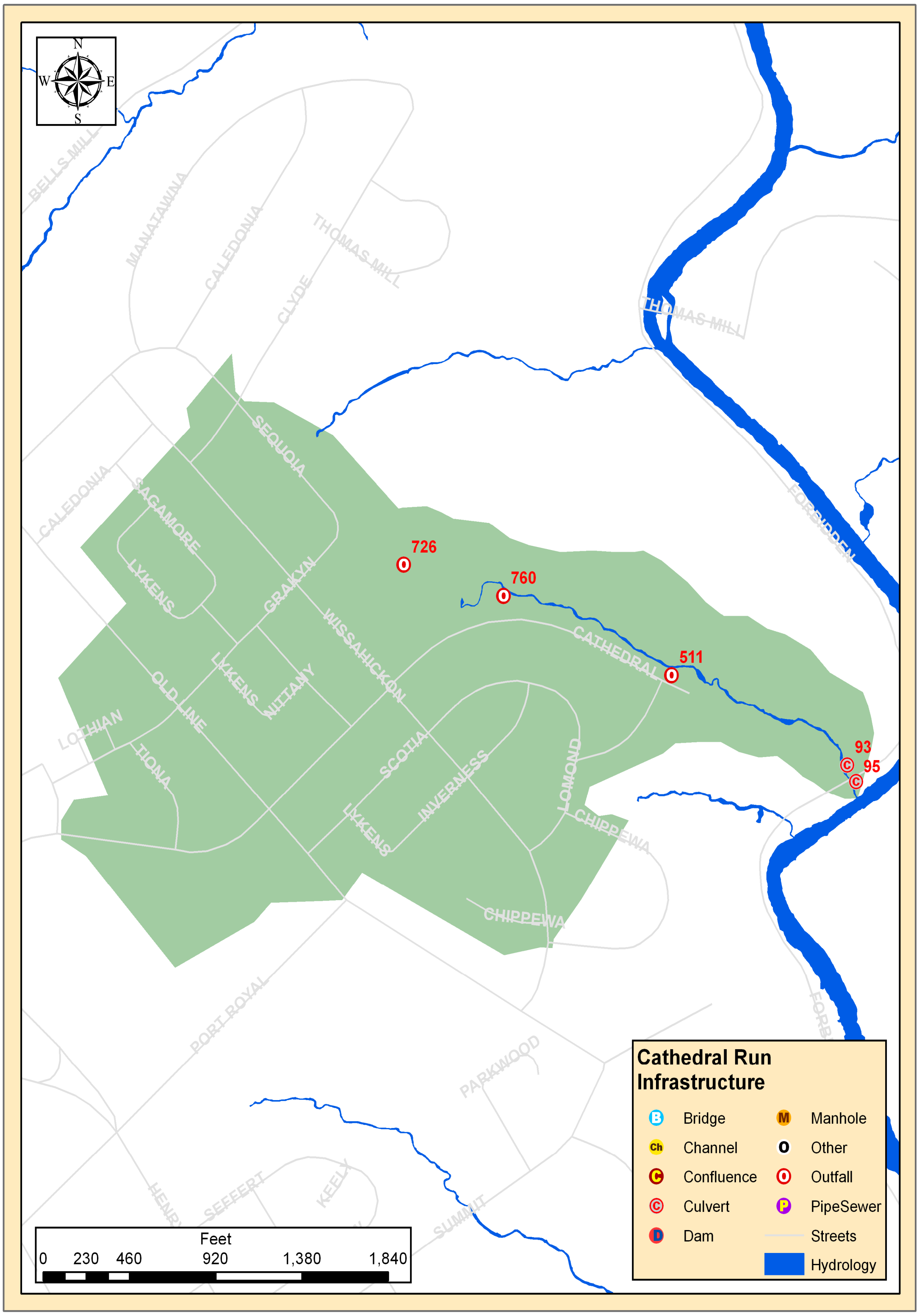


Figure 3-20: Cathedral Run Infrastructure Locations

3.1.3.5 UNIFIED STREAM ASSESSMENT RESULTS FOR THE CATHEDRAL RUN WATERSHED

The Cathedral Run watershed had a single first-order channel that was located almost entirely within Fairmount Park. There was a short segment of the channel upstream of WSout511 located outside of the Park, although the land cover in this segment was forest. The upstream half of the channel was abutted by residential land-use however the downstream half of the channel was abutted by an extensive forested corridor on both sides of the channel. The Center for Watershed Protection's (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and watersheds within the Lower Wissahickon Basin.

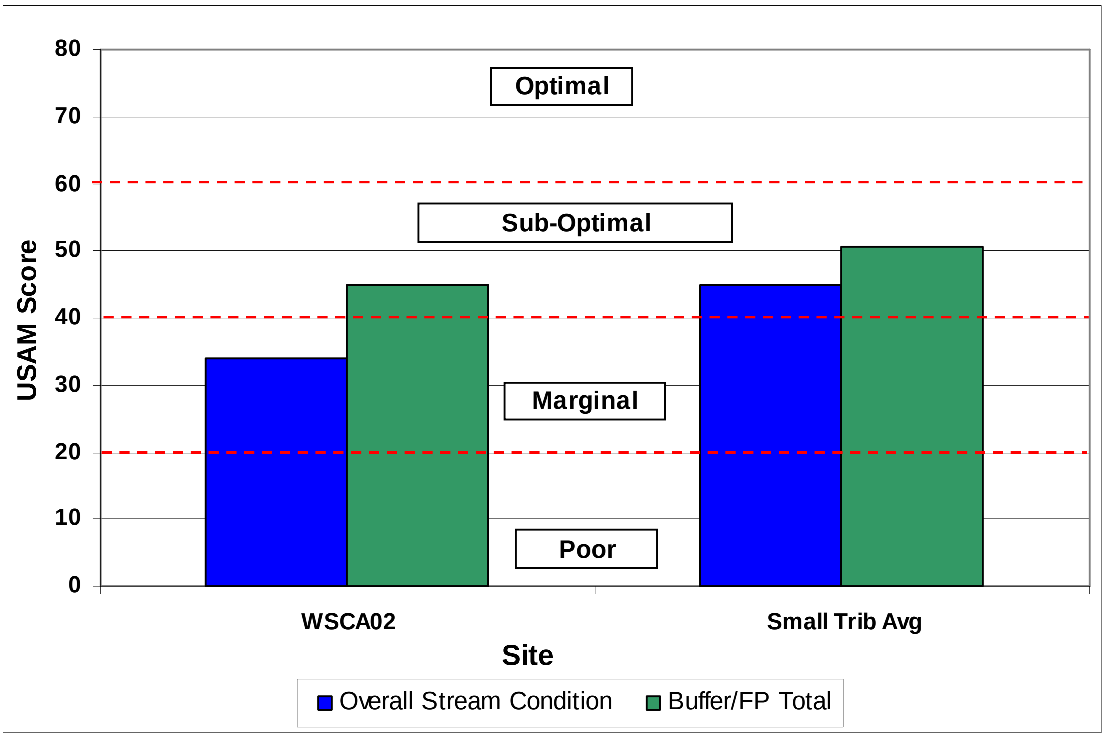


Figure 3-21: Results for Cathedral Run USAM Components

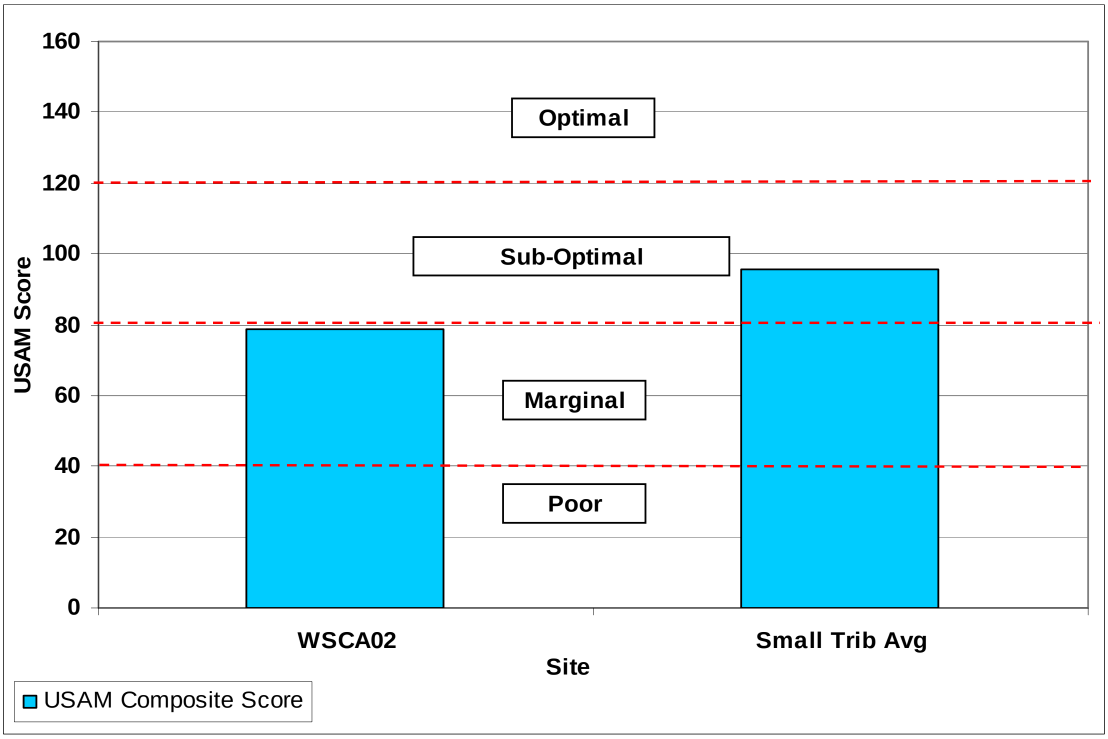


Figure 3-22: Cathedral Run USAM Results

3.1.3.5.1 WSCA02

The headwaters of reach WSCA02, located about 75 feet north of Cathedral Road, began as a zero order stream at the base of a steep swale that receives runoff from Courtesy Stables as well as WSout726. The WSCA02 channel was rather small with a bankfull cross sectional area of 6.9 ft^2, although the drainage area for the reach (0.19 mi^2) was relatively small as well. WSCA02 was dominated by gravel (55%) with cobble and boulders observed in much smaller proportions. A relatively high width to depth ratio was observed for WSCA02 as well as a moderately entrenched channel (ER=1.7). The reach was classified as a B4 type channel. The USAM composite score for the reach was 79/160 (Figure 3-22).

3.1.3.6 SUMMARY OF UNIFIED STREAM ASSESSMENT RESULTS

The mean watershed scores for both the individual USAM components as well as the overall USAM score ranged from marginal to sub-optimal (Table 3-22). Observed conditions for the Cathedral Run *Buffer and Floodplain Condition* parameters were slightly better than the observed *Overall Stream Condition* parameters. For the *Overall Stream Condition* component, Cathedral Run scores were lower than the Small Tributary average for all four parameters. Similarly, the Small Tributary average was higher than Cathedral Run scores for all the *Overall Buffer and Floodplain Condition* parameters except for the *Vegetated Buffer Width* parameter, in which the left bank on reach WSCA02 had a higher score than the Small Tributary average and the *Floodplain Encroachment* parameter in which the WSA02 score and the Small Tributary Average were equal. As such, the USAM composite score for Cathedral Run (79/160) was considerably lower then the mean Small Tributary USAM score of 95.4/160 which was classified as "suboptimal."

Table 3-22: USAM Results for Cathedral Run Watershed

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP Condition	USAM Score
WSCA02	Cathedral	34	45	79
Small Tributary Average	**----**	**44.8**	**50.6**	**95.4**

3.1.3.6.1 SUMMARY OF OVERALL STREAM CONDITION SCORES IN THE CATHEDRAL RUN WATERSHED

The *Overall Stream Condition* scores for Cathedral Run were lower than the mean scores of the other "Small Tributaries" in the Lower Wissahickon for each parameter within this component of the USAM assessment (Table 3-23). Scores ranged from poor to sub-optimal in the watershed, and no parameter was rated as optimal. The largest discrepancy between the WSCA02 reach and the Small Tributary average was observed for the *Vegetative Protection* parameter. Both banks of reach WSCA02 were rated as poor (2/10) and were among the worst stream banks assessed in the Lower Wissahickon behind WSBM02 (both banks scored 1/10) and WSWM06 (both banks scored 2/10). The parameter that was rated the highest in the reach was the *Instream Habitat* parameter (13/20), which was a result of the relatively stable substrate in the reach which was comprised of 38% cobble (64-256mm).

Table 3-23: USAM Overall Stream Condition Scoring for Cathedral Run Watershed

OVERALL STREAM CONDITION								
Reach ID	Sub-watershed	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	Overall Stream Condition
			Left	Right	Left	Right		
WSCA02	Cathedral	13	2	2	5	5	7	34
Small Tributary Average	**----**	**15.8**	**4.4**	**4.2**	**5.6**	**5.8**	**9**	**44.8**

3.1.3.6.1.1 INSTREAM HABITAT

The *Instream Habitat* parameter was rated as "suboptimal" for WSCA02. Habitat scores in this reach were heavily influenced by the high proportion of stable substrate (i.e. cobble and boulders) observed within the reach as well as the presence of cover in the form of coarse woody debris (CWD) and undercut banks. Cobble and boulder substrate comprised 40% of the substrate observed in the reach, whereas the majority of the substrate was gravel of various size classes (55%). Coarser gravels (16-64 mm) may offer habitat value although the stability of these particles is questionable during high flows. Moderate amounts of CWD were observed in the channel although the narrow, deeply incised channel prevented many large fallen snags and CWD from being inundated. WSCA02 had a lower score (Table 3-23) than the Small Tributary average (15.8/20) which was classified as "optimal."

3.1.3.6.1.2 VEGETATIVE PROTECTION

Reach WSCA02 had very low scores for both the left and right bank for this parameter. Both banks had scores of (2/10) which classified them as poor. Under the USAM framework, poor vegetative protection is characterized by patchy distributions of vegetation, streambanks with less than 50% of their surface area covered with vegetation as well as the predominance of bare soil. The Small Tributary averages for the left (4.4/10) and right (4.2/10) banks were both higher than the WSCA02 scores, however the marginal rating of the Small Tributary average may be an indication of a larger issue. Smaller channels have less buffering capacity against flashy storm flows compared to larger systems which can more easily attenuate high volume, flashy flows. Many of the smaller tributaries in the Wissahickon may thus be predisposed to less than favorable conditions for the establishment of near-bank vegetation. Both the high rates of erosion observed among the small tributaries and frequent disturbance are the most likely factors contributing to the lack of adequate vegetative protection in the small Lower Wissahickon tributaries.

3.1.3.6.1.3 BANK EROSION

Bank erosion was moderate on reach WSCA02, with a score of 5/10 for both the right and left banks. The Small Tributary average was slightly higher at 5.6/10 and 5.8/10 respectively, although WSCA02 and the Small Tributary average were both rated as "marginal." The marginal rating for WSCA02 was attributed to the large proportion of the middle and lower segments of the reach that had high BEHI designations. The occurrences of high BEHI scores in the middle and lower reaches can be attributed to the stormwater outfall at the intersection of Cathedral Road and Glenroy Avenue and the culvert beneath Forbidden Drive respectively. Most of the upper portion of the reach had a medium BEHI score on the DSL bank and a low BEHI score on the DSR bank; however, there were sections of the upper reach that had high BEHI scores as a result of localized scour.

3.1.3.6.1.4 FLOODPLAIN CONNECTION

The *Floodplain Connection* parameter evaluates a stream channel's entrenchment ratio (ER), which is a geomorphic property that governs the frequency and occurrence of floodplain inundation during bankfull events. The entrenchment ratio calculated at cross section WSCA02 was (1.7), which was rated as marginal with a USAM score of 7/20. The Small Tributary average entrenchment ratio was 1.9 which was also rated as marginal (9/20). The entrenchment ratio at cross section WSCA02 was indicative of a deeply entrenched channel (a result of "downcutting") such that flows in excess of the estimated bankfull discharge (22.6 cfs) are fully contained within the channel and do not inundate the floodplain.

3.1.3.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE CATHEDRAL RUN WATERSHED

The *Overall Buffer/Floodplain Condition* score (Table 3-24) for Cathedral Run (45/80) was considerably lower than the Small Tributary average (50.6/80); however WSCA02 was still rated as "sub-optimal." Scores for the various parameters ranged from "poor" to "optimal" on reach WSCA02. The Small Tributary average scores were higher than Cathedral Run's scores for every parameter except for the left bank *Vegetated Buffer Width*. The close proximity of Cathedral Road to reach WSCA02 had a direct, adverse impact on both the *Vegetated Buffer Width* (right bank only) and the *Floodplain Encroachment* parameters.

Table 3-24: USAM Buffer and Floodplain Condition Scoring for Cathedral Run Watershed

OVERALL BUFFER AND FLOODPLAIN CONDITION							
Reach ID	Sub-watershed	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	Buffer/FP Condition
		Left	Right				
WSCA02	Cathedral	10	5	14	5	11	45
Small Tributary Average	**----**	**9**	**8.8**	**16.2**	**5.6**	**11**	**50.6**

3.1.3.6.2.1 VEGETATED BUFFER WIDTH

The riparian corridor of Cathedral Run was heavily influenced by Cathedral Road on the downstream right side of the valley in the upper half of Cathedral Run. The scores for the left (10/10) and right (5/10) bank of the corridor were rated as "optimal" and "marginal" respectively (Table 3-24). The left bank compared favorably to the Small Tributary average (9/10) however the condition of the right bank of WSCA02 was considerably worse than the Small Tributary average for the right bank (8.8/10). Comparisons to Small Tributary averages for this parameter may have a spatial bias in that some of the riparian corridors on the smaller tributary reaches are limited by residential development on one side and the location of developed lands with respect to each stream valley varies between watersheds.

3.1.3.6.2.2 FLOODPLAIN VEGETATION

The *Floodplain Vegetation* parameter assesses the predominant vegetation type observed within each reach (e.g. shrub, mature forest or mowed turf) with higher scores for floodplains dominated by mature forests. WSCA02 was rated as "suboptimal" due to the predominance of secondary forest vegetation and saplings (Table 3-24). The Small Tributary average was rated as optimal, with a score of 16.2/20.

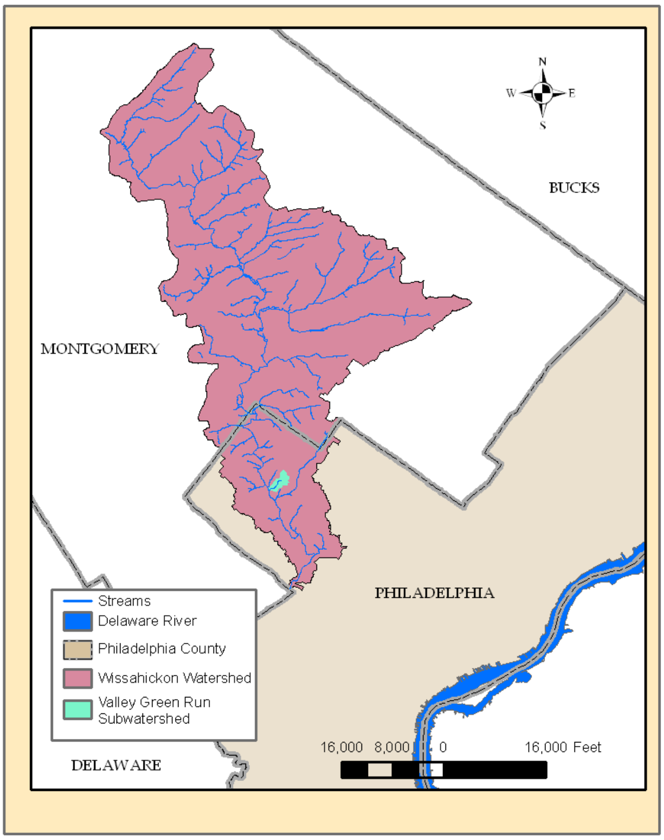
3.1.3.6.2.3 FLOODPLAIN HABITAT

The *Floodplain Habitat* parameter was rated as "poor" in reach WSCA02, due to the fact that the channel's geomorphic properties (low entrenchment ratio) do not permit flood flows to inundate the floodplain except under extreme flow conditions. Similarly, the Small Tributary average was rather low (5.6/10) and was rated as "marginal" (Table 3-24).

3.1.3.6.2.4 Floodplain Encroachment

The *Floodplain Encroachment* parameter evaluates the degree of anthropogenic influence on the function of floodplains throughout a reach. The floodplain function in reach WSCA02 was slightly impinged upon by development in the form of Cathedral Road and associated infrastructure on the upper half of the reach (Figure 3-19). The score of 11/20 for WSCA02 was rated as "marginal" (Table 3-24). The Small Tributary average was also 11/20 and rated as "marginal."

3.1.4 Valley Green Run Watershed and Reach Characteristics



Valley Green Run is a tributary to the main stem of the Wissahickon Creek. Valley Green Run originates from a privately-owned stormwater outfall located within a wooded area. Valley Green Run is a first-order tributary for approximately one half mile before entering into the Wissahickon Creek. The dominant substrate varies from medium gravel to medium cobble material. Both the valley floor and channel have been substantially impacted by past and current land use.

The entire Valley Green Run watershed is 128 acres. Major land use types within the watershed include: wooded (59%), residential – single family detached (33%), and recreation (4%). The lower two-thirds of the tributary are surrounded by Fairmount Park on both sides. The Park buffer ranges from about 20 feet to about 2,000 feet.

The Philadelphia Water Department (PWD) owns and operates one stormwater outfall that releases into Valley Green Run. The entire watershed is drained by a separate storm sewer system that is directly connected to all impervious surfaces. There are an additional three outfalls owned by an entity other than PWD that release into Valley Green Run.

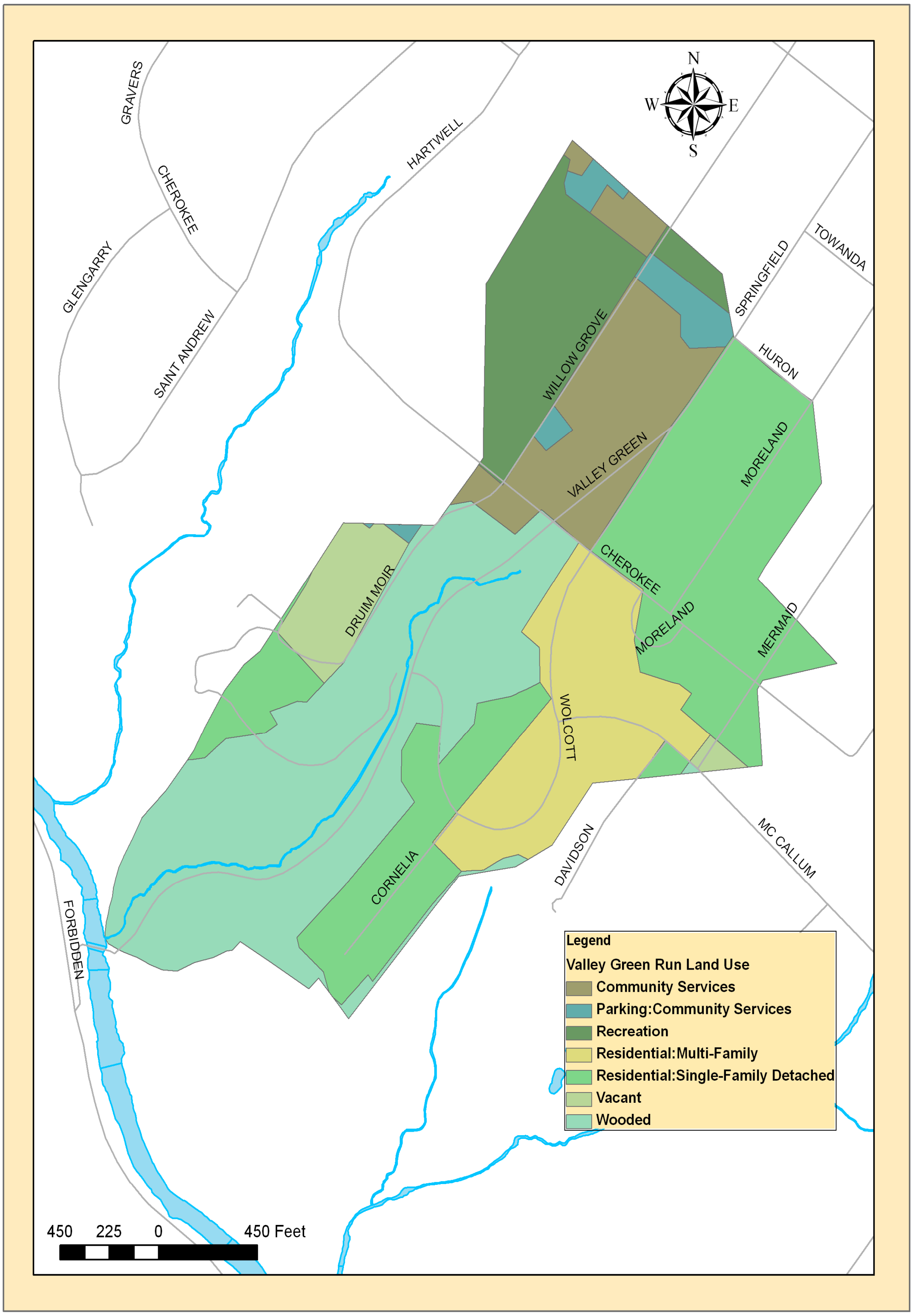


Figure 3-23: Valley Green Run Watershed Land Use

3.1.4.1 GEOLOGY

The entire Valley Green Run watershed is underlain by the Wissahickon Formation. The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

3.1.4.2 SOILS

According to the National Resource and Conservation Service Soil Survey, all soils for the Valley Green Run watershed are classified as hydrologic group B. These soils have a moderate rate of infiltration when the soils are wet (0.50-1.00 in/hr). Water movement through these soils is considered moderately rapid.

Table 3-25: Distribution of NRCS Soil Types in Valley Green Run Watershed

Group	Area (ft^2)	Percent of Total Area
B	5,575,680	100%
Total Area	5,575,680	100%

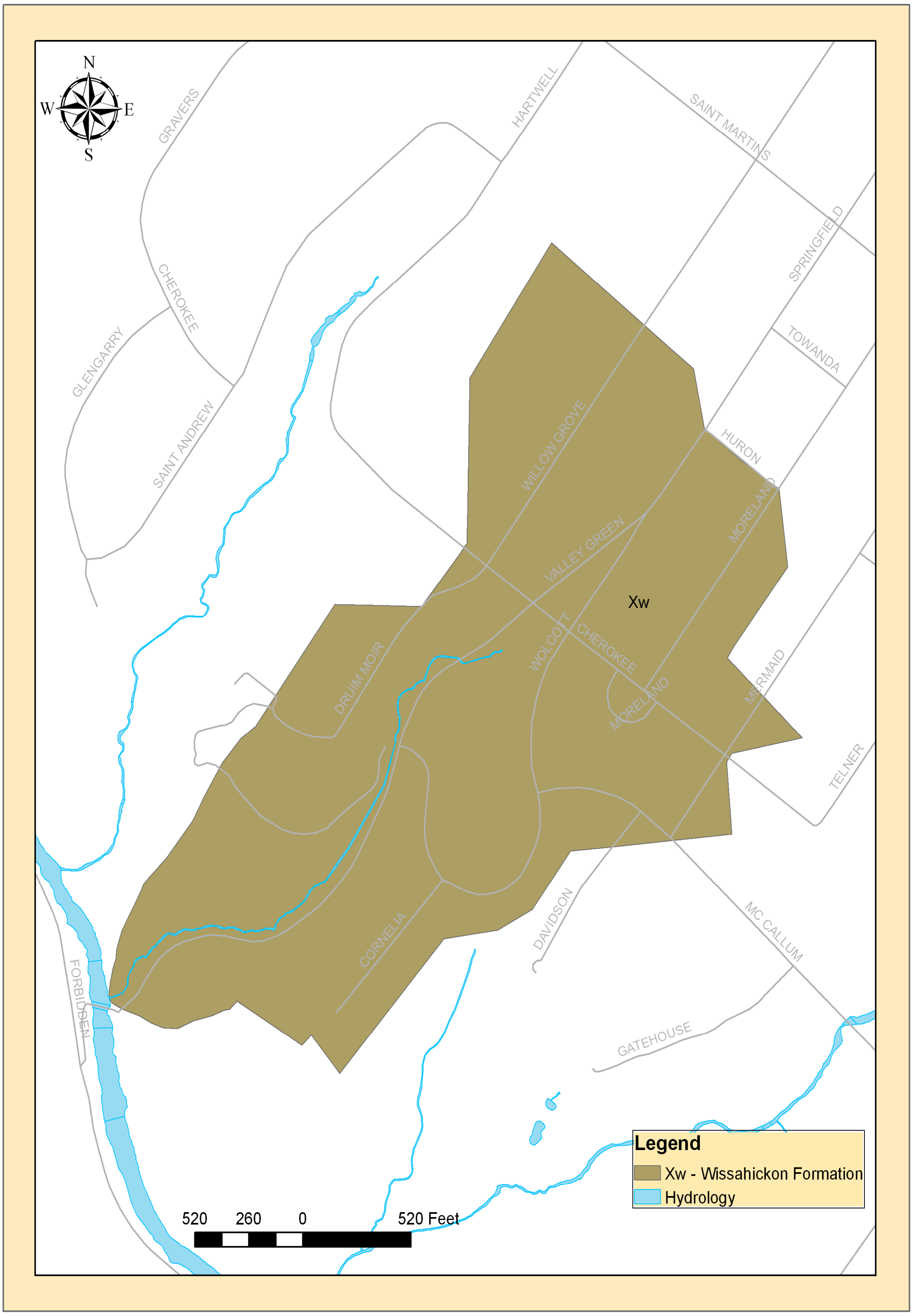


Figure 3-24Geology of Valley Green Run Watershed

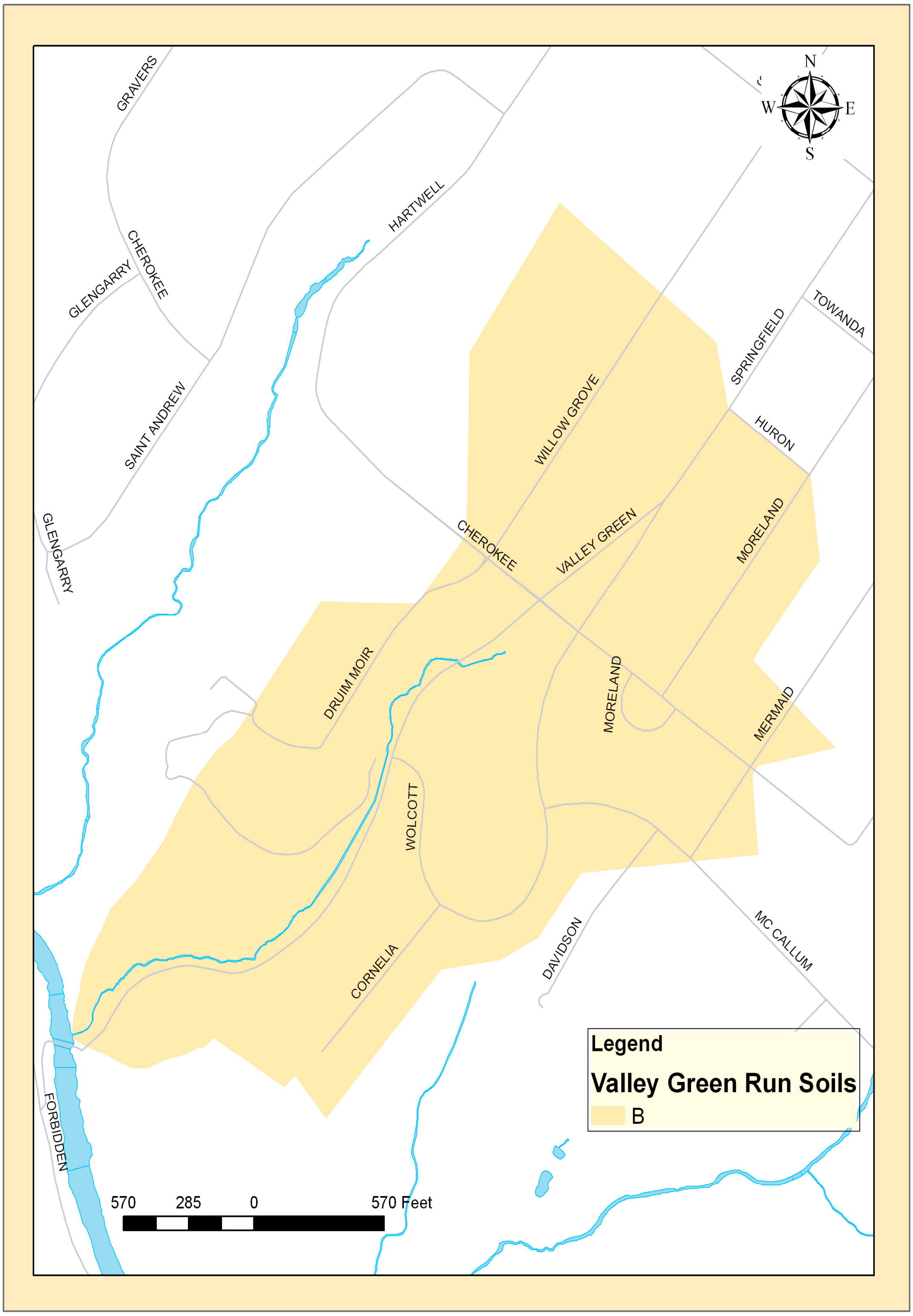


Figure 3-25: Distribution of NRCS Soil Types in Valley Green Run Watershed

3.1.4.3 Bank Erosion

There were two bank pin locations along Valley Green Run (Figure 3-26). The calculated erosion rates are included in Table 3-26. The spatial distribution of BEHI assessment results were represented graphically (Figure 3-26) for each of the segments assessed on Valley Green Run. Each bank within a respective segment was assessed and rated separately; however, channelized and culverted segments were not assessed as they confer a high degree of protection from bank erosion.

Table 3-26: Valley Green Run Bank Pin Locations

	BEHI	NBS	Baseline Reading	Most Recent Reading	Erosion Rate (ft)	Erosion Rate (ft/yr)	Eroding (-) or Aggrading (+)
Valley Green Run							
VG4	High	Low	11/15/2006	8/13/2008	0.15	0.085	A
VG8	High	Low	11/15/2006	8/10/2009	-0.40	-0.15	E

Total erosion rates were also calculated for the entire length of each tributary within the lower Wissahickon (Table 3-27). To assess the normalized erosion potential of each tributary, the erosion rate per acre of drainage area per year and the erosion rate per foot of stream length per year were calculated. This allowed direct comparison between each of the tributaries with respect to both watershed size and the length of the tributary. Valley Green Run was ranked ninth out of the twelve tributaries within the lower Wissahickon for erosion rate per foot of stream length. The rankings were based on a scale of one being the highest erosion rate and twelve being the lowest erosion rate.

Table 3-27: Erosion Rates for Lower Wissahickon Tributaries

Tributary	Drainage Area (Acres)	Stream Length (feet)	*2009*		
			Erosion Rate (lb/yr)	*Erosion Rate Per Acre*	*Erosion Rate Per Foot of Stream*
Bell's Mill	323	6,722	420,000	1,307	63
Cathedral Run	160	2,790	150,000	913	52
Cresheim Creek	1,218	16,431	840,000	690	51
Gorgas Run	499	2,170	170,000	345	79
Hartwell Run	217	3,530	200,000	918	56
Hillcrest	144	5,272	90,000	597	16
Kitchen's Lane	234	7,753	200,000	850	26
Monoshone Creek	1,056	6,926	160,000	156	24
Rex Ave	137	1,903	150,000	1,131	81
Thomas Mill Run	104	4,008	320,000	3,058	79
Valley Green Run	128	2,874	140,000	1,086	48
Wise's Mill Run	446	7,056	490,000	1,090	69
Total/*Average*	**4,666**	**67,435**	**3,300,000**	***1,012***	***54***

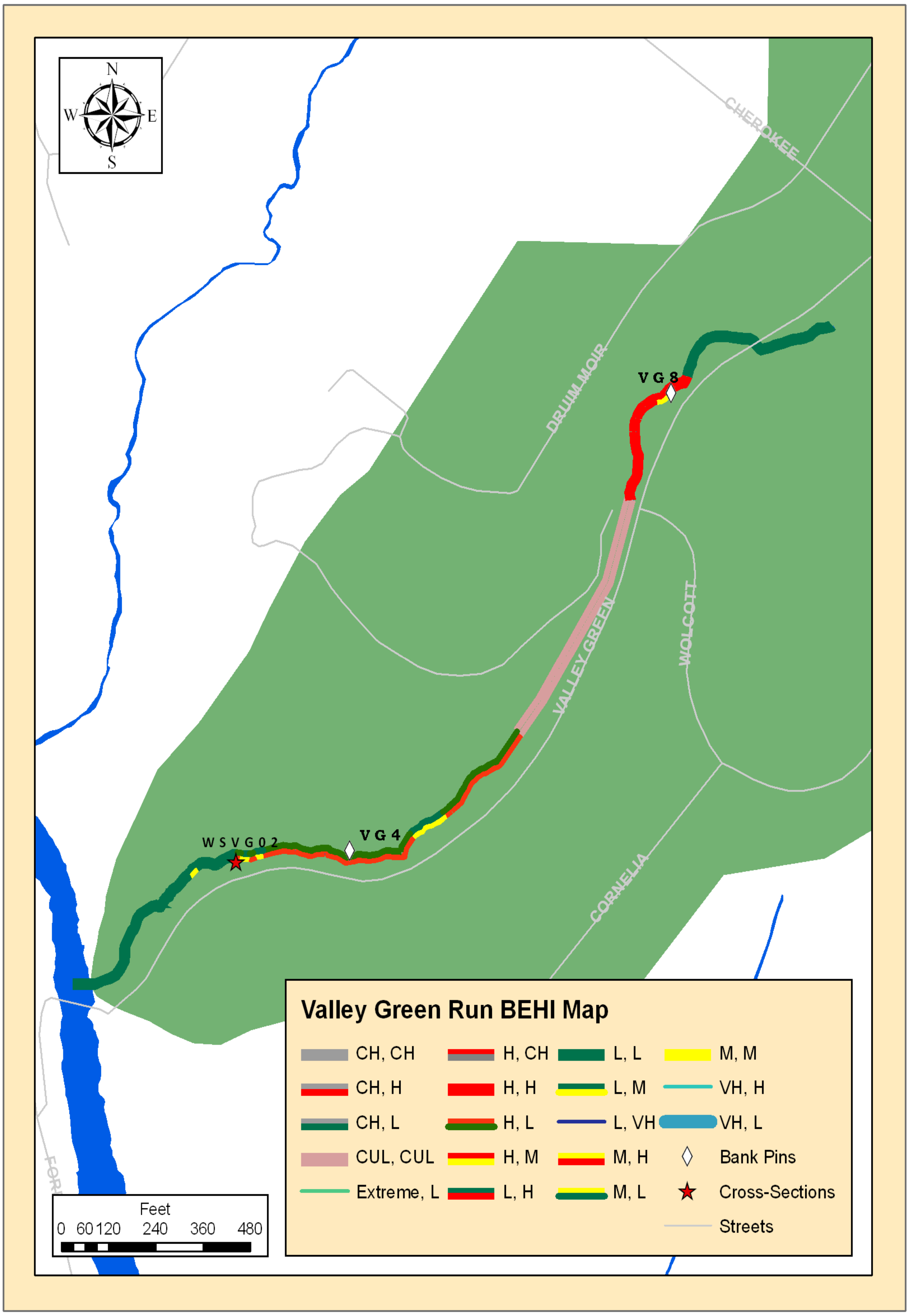


Figure 3-26: Valley Green Run Watershed BEHI Ratings and Bank Pin Locations

3.1.4.4 INFRASTRUCTURE TRACKDOWN SUMMARY

Most of Valley Green Run flows through Fairmount Park although the upper third of Valley Green Run flows through a wooded area that is not Park land. The wooded area on the DSL of this upper portion is vacant land owned by the Natural Lands Trust whereas the land on the DSR is owned by the Springside School. Valley Green Road runs parallel to the stream from the headwaters near Cherokee Street to the confluence with the main stem of Wissahickon Creek. Stormwater runoff from Cherokee Street and Valley Green Road was conveyed through four outfalls (Table 3-28) on the stream. None of these outfalls had very much dry weather flow, as WSout523 (W-076-10) was observed to have only a trickle of flow during dry weather.

Valley Green Road crosses the stream only once, at the upstream-most culvert WScul102. Culverts impacted this stream to a great extent as 24 percent of Valley Green Run was culverted (Table 3-29). The largest culverted segment was WScul104, which was 643 feet long. This culverted segment has the potential to impact large segments of the stream channel upstream and downstream of the culvert. A culvert of that length creates conditions where flow is constricted leading to the loss of conveyance and increased sediment deposition upstream of the culvert as well as high rates of scour at the downstream end. WScul105 was built to protect a 45-inch sanitary interceptor pipe and to convey the flow of Valley Green Run underneath it. Upstream of WScul105, a 15-inch sanitary sewer line runs parallel to the creek below Valley Green Road and discharges into the 45-inch Wissahickon High Level Interceptor next to WScul105.

The density and prevalence of infrastructure within the reach indicates that impairments within this tributary are likely magnified by stormwater flows. None of the infrastructure elements were identified as being in poor condition. There were also two small ephemeral channels that drained into Valley Green Run (WScon166 on DSL and WScon167 on DSR). During the infrastructure trackdown, flow was not observed in these channels although it is highly likely that these channels convey concentrated flow from overland runoff during wet weather events.

Table 3-28: Summary of Valley Green Run Infrastructure Points

Section ID	Culvert Count	Bridge Count	Outfall Count	Confluence Count	Infra Point Count	Combined Outfall Area (ft^2)
WSVG02	3	1	4	2	8	15.93

Table 3-29: Summary Valley Green Run Infrastructure Linear Features

Section ID	Segment Length (ft)	Culvert Length (ft)	Percent Culverted	Channel Length (ft)	Percent Channelized
WSVG02	2849	671	23.6	0	0

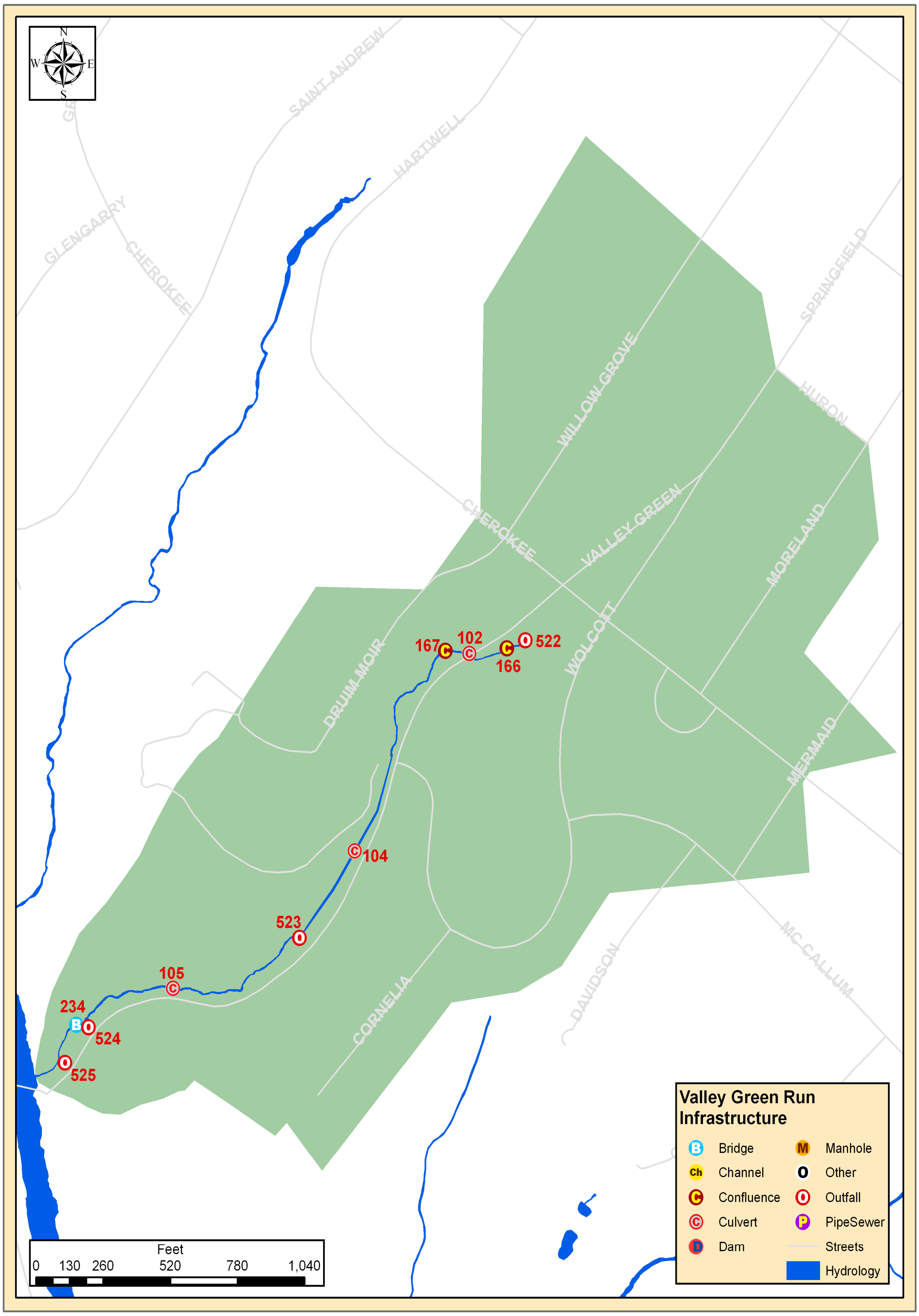


Figure 3-27: Valley Green Run Infrastructure Locations

3.1.4.5 UNIFIED STREAM ASSESSMENT RESULTS FOR THE VALLEY GREEN RUN WATERSHED

The majority of the first-order main stem channel of the Valley Green Run watershed is located within Fairmount Park. The upstream-most third of the channel was located outside of Fairmount Park, although the land cover abutting this segment of channel was forested. The Center for Watershed Protection's (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and watersheds within the Lower Wissahickon Basin.

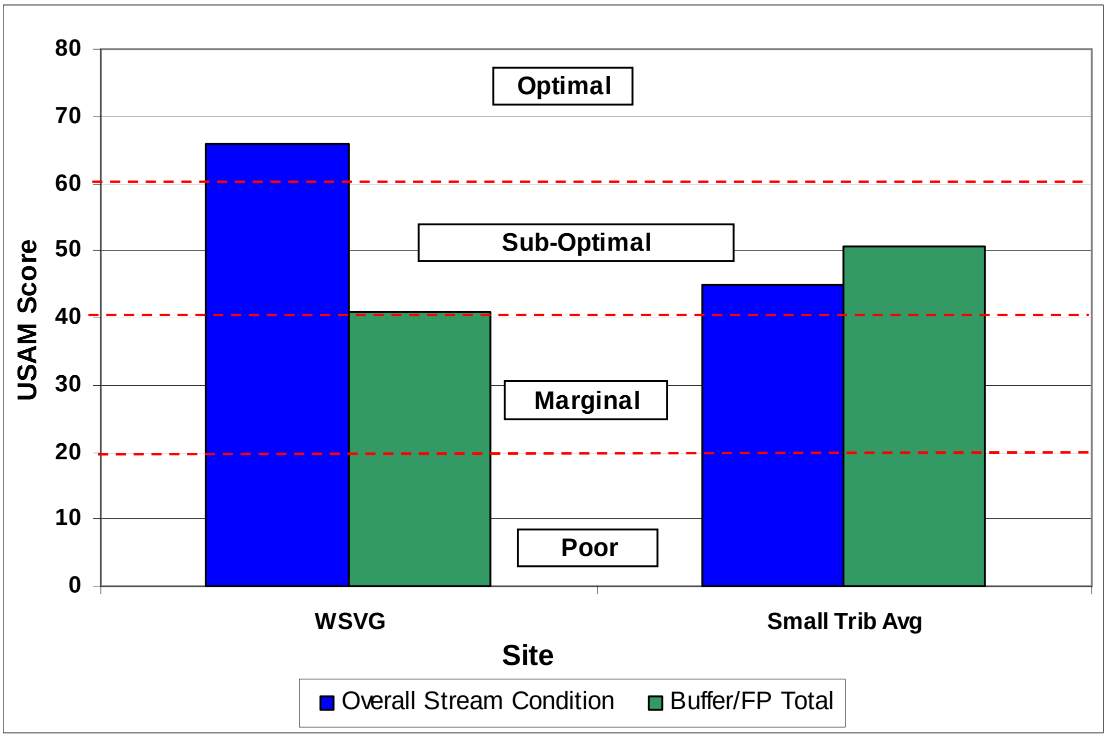


Figure 3-28: Results for Valley Green Run USAM Components

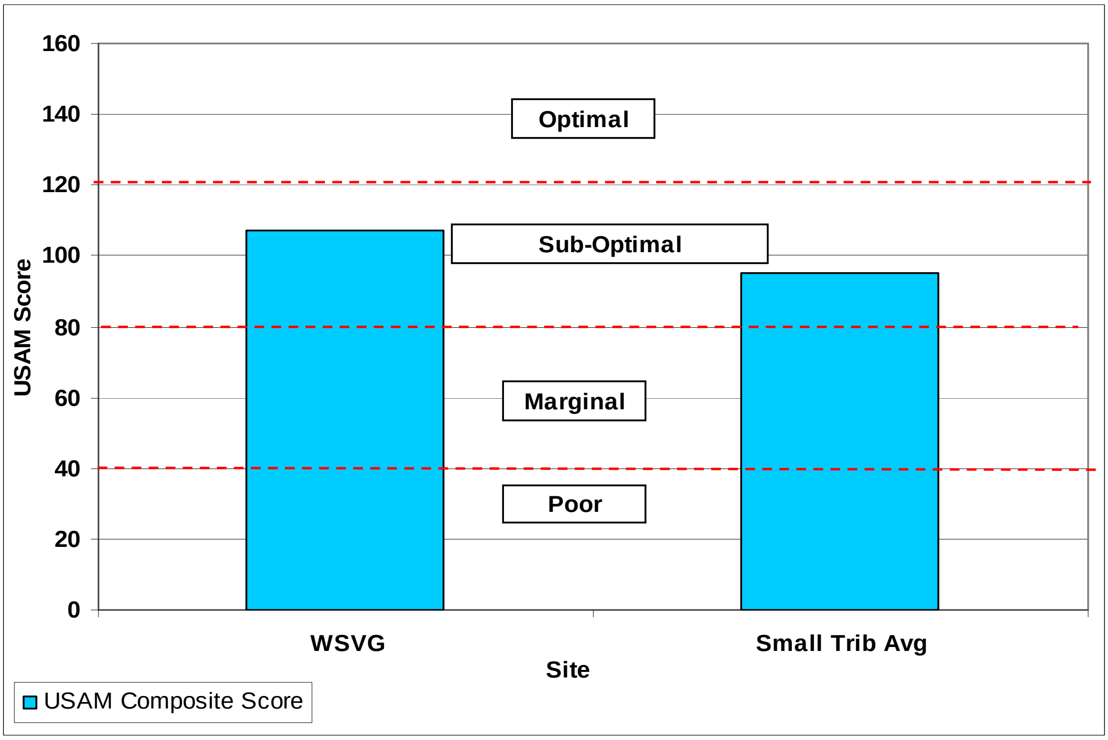


Figure 3-29: Valley Green Run USAM Results

3.1.4.5.1 WSVG02

The headwaters of reach WSVG02 began as flow from a privately owned outfall, WSout522, about 200 feet southwest of Cherokee Road. The total length of the main stem channel was 2,849 feet. The bankfull channel was rather small (6.9 ft^2) with an estimated bankfull capacity of 34.3 cfs. The bankfull discharge to drainage area ratio for WSVG02 was 180.5 cfs/mi^2, which was slightly below the median observation for the Lower Wissahickon Basin (185.6 cfs/ mi^2). The observed stream bed substrate distribution had a nearly equal proportion of gravel (44%) and cobble (37%), with sand (16%) and boulder (1%) particles represented in much smaller proportions. The stream was characterized by a relatively high width to depth ratio (18.9) and a moderately entrenched channel (ER=1.4) such that the reach was classified as a B4/a channel type. The USAM composite score (Figure 3-29) for the reach was 107/160.

3.1.4.6 Summary of Unified Stream Assessment Results

The mean watershed scores for both the individual USAM components as well as the overall USAM score ranged from sub-optimal to optimal (Table 3-30). Average conditions within the Valley Green Run watershed's stream channels were considerably better than the conditions observed within the buffers and floodplains. For the *Overall Stream Condition* component, Valley Green Run scores were much higher than the Small Tributary average for all four parameters (Table 3-31). In fact, Valley Green Run had the highest *Overall Stream Condition* score among all the small Lower Wissahickon tributaries. The Small Tributary average was higher than Valley Green Run scores for all *Overall Buffer/Floodplain Condition* parameters except for the *Floodplain Habitat* and the right bank *Vegetated Buffer Width* parameters; however, the USAM composite score for Valley Green Run (107/160) was considerably higher than the mean Small Tributary USAM score of 95.4/160 which was classified as "suboptimal."

Table 3-30: USAM Results for Valley Green Run Watershed

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP Condition	USAM Score
WSVG02	Valley Green	66	41	107
Small Tributary Average	**----**	**44.8**	**50.6**	**95.4**

3.1.4.6.1 Summary of Overall Stream Condition Scores in the Valley Green Run Watershed

The *Overall Stream Condition* score for the Valley Green Run watershed was the highest score recorded among the small Lower Wissahickon tributaries (107/160) and was rated as "optimal." Each parameter of this component was considerably higher than the small tributary average (Table 3-31). The most notable disparity in scores was for the *Floodplain Connection* parameter in which the watershed score (17/20) was rated as "optimal" compared to the small tributary average (9/20) which was rated as "marginal."

Table 3-31: USAM Overall Stream Condition Scoring for Valley Green Run Watershed

OVERALL STREAM CONDITION								
Reach ID	Sub-watershed	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	Overall Stream Condition
			Left	Right	Left	Right		
WSVG02	Valley Green	18	8	8	7	8	17	66
Small Tributary Average	**----**	**15.8**	**4.4**	**4.2**	**5.6**	**5.8**	**9**	**44.8**

3.1.4.6.1.1 INSTREAM HABITAT

Instream habitat in Valley Green Run was characterized by an abundance of stable habitat features such as cobble and boulder substrate as well as CWD of various sizes and levels of conditioning. The dominant substrate particle class was gravel (44%) although the vast proportion of the gravel in the reach was medium (8-11 mm) to very coarse gravel (32-64 mm). Larger-sized gravels offer moderate stability, but when interspersed with cobbles and boulders, these particles can create a considerable amount of interstitial spaces which serve as optimal habitat for benthic macroinvertebrates. The score of 18/20 was rated as "optimal" and was considerably higher than the Small Tributary average of 15.8/20 (Table 3-31).

3.1.4.6.1.2 VEGETATIVE PROTECTION

Scores for both the left and right banks (8/20) were rated as "marginal" although they were considerably higher than the left (4.4/20) and right (4.2/20) bank Small Tributary averages which were rated as "poor." The vegetative cover along the banks of Valley Green Run was abundant, however it had a patchy distribution due to the rocky soil along the banks as well as localized erosion.

3.1.4.6.1.3 BANK EROSION

Bank erosion was moderate within Valley Green Run as scores for the left (7/10) and right (8/10) banks were both rated as "suboptimal." In comparison, the left (5.6/10) and right (5.8/10) bank Small Tributary averages were both rated as "marginal" (Table 3-31). The abundance of boulders and large cobbles along the margins of the creek conferred extensive protection against localized scour in many segments of the reach.

3.1.4.6.1.4 FLOODPLAIN CONNECTION

The *Floodplain Connection* parameter was one of the highest scoring parameters for the Valley Green Run *Overall Stream Condition* component with a score of 17/20 (Table 3-31). The score was the highest recorded among the small tributaries and was second highest score recorded in the Lower Wissahickon (reaches WSHC02 and WSKL06 both scored 18/20).

3.1.4.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE VALLEY GREEN RUN WATERSHED

The *Overall Buffer and Floodplain Condition* score for the Valley Green Run watershed (41/80) were rated at the low end of the "suboptimal" range of scores. The Small Tributary averages were higher than scores for Valley Green Run (Table 3-31) for all parameters except for *Floodplain Habitat* which was considerably higher in Valley Green Run although the score of 8/20 was rated as "marginal." The *Vegetated Buffer Width* score for the left side of the corridor (5/10) was rated as "marginal" and was the lowest score among all Small Tributaries. The low scores for this as well as the *Floodplain Encroachment* parameter were attributed to the presence of Valley Green Road along the entire DSL extent of the corridor.

Table 3-32: USAM Buffer and Floodplain Condition Scoring for Valley Green Run Watershed

OVERALL BUFFER AND FLOODPLAIN CONDITION							
Reach ID	Sub-watershed	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	Overall Buffer/FP Condition
		Left	Right				
WSVG	Valley Green	5	9	15	8	4	41
Small Tributary Average	**----**	**9**	**8.8**	**16.2**	**5.6**	**11**	**50.6**

3.1.4.6.2.1 VEGETATED BUFFER WIDTH

The vegetated buffer on the downstream right side of Valley Green run was relatively extensive and uninterrupted and as such was given a score of 9/10, which was rated as "suboptimal" (Table 3-32). The downstream left vegetated buffer was impinged upon by Valley Green Road throughout the length of the reach. In some segments of the reach, the road was within twenty feet of the channel. The score for the DSL side of the corridor (5/10) was rated as "marginal" and was the lowest score observed among the small tributaries.

3.1.4.6.2.2 FLOODPLAIN VEGETATION

The dominant floodplain vegetation type throughout reach WSVG02 was young forest. Saplings of early successional and understory species had dense distributions throughout the watershed, although there were distinct stands of mature trees observed. The score for the watershed (15/20) was rated as "suboptimal", slightly lower than the small tributary average score (16.2/20) which was rated as "optimal" (Table 3-32).

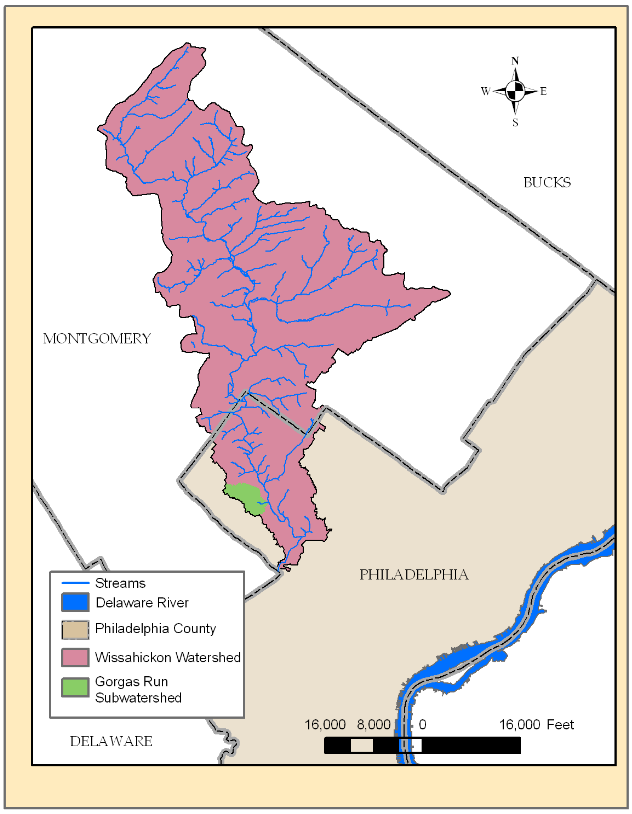
3.1.4.6.2.3 FLOODPLAIN HABITAT

Floodplain habitat was limited within the reach, likely due to the high floodplain bench observed throughout many segments of the reach. These high "benches" preclude the floodplain inundation that creates habitat features such as wetlands, ephemeral pools and backwater channels. The score for reach WSVG02 was 8/20 and was rated as "marginal," which was considerably higher than the small tributary average (5.6/20) which was rated at the low end of the "marginal" range of scores (Table 3-32).

3.1.4.6.2.4 FLOODPLAIN ENCROACHMENT

The presence of Valley Green Road on the DSL side of the corridor fragmented the floodplain and as such had an adverse impact on floodplain function. The DSR side of the corridor was relatively obstruction free; however, the extent of the fragmentation and obstruction on the DSL side of the corridor attributed to the low score for this reach. The score of 4/20 was rated as "poor" (Table 3-32) and was the lowest score recorded among the small Lower Wissahickon tributaries.

3.1.5 GORGAS RUN WATERSHED AND REACH CHARACTERISTICS



Gorgas Run is a tributary to the main stem of the Wissahickon Creek. Gorgas Run is a first-order tributary that is approximately 2,170 feet long. The stream originates from springs approximately 300 feet east of the end of Gorgas Lane. The tributary travels another 225 feet until stormwater outfall (WSout566), which is a 60" x 72" reinforced concrete pipe, discharges into Gorgas Run. The dominant substrate varies from course gravel to medium cobble material. Both the valley floor and channel have been substantially impacted by past and current land use within the watershed.

The Gorgas Run watershed is 499 acres. Major land use types within the watershed (Figure 3-30) include: wooded (53%), residential – row home (19%), residential – single family detached (12%), and residential – multi-family (9%). Gorgas Run is surrounded by Fairmount Park on both sides for the entire length. The Park buffer ranges from about 50 feet to about 2,000 feet.

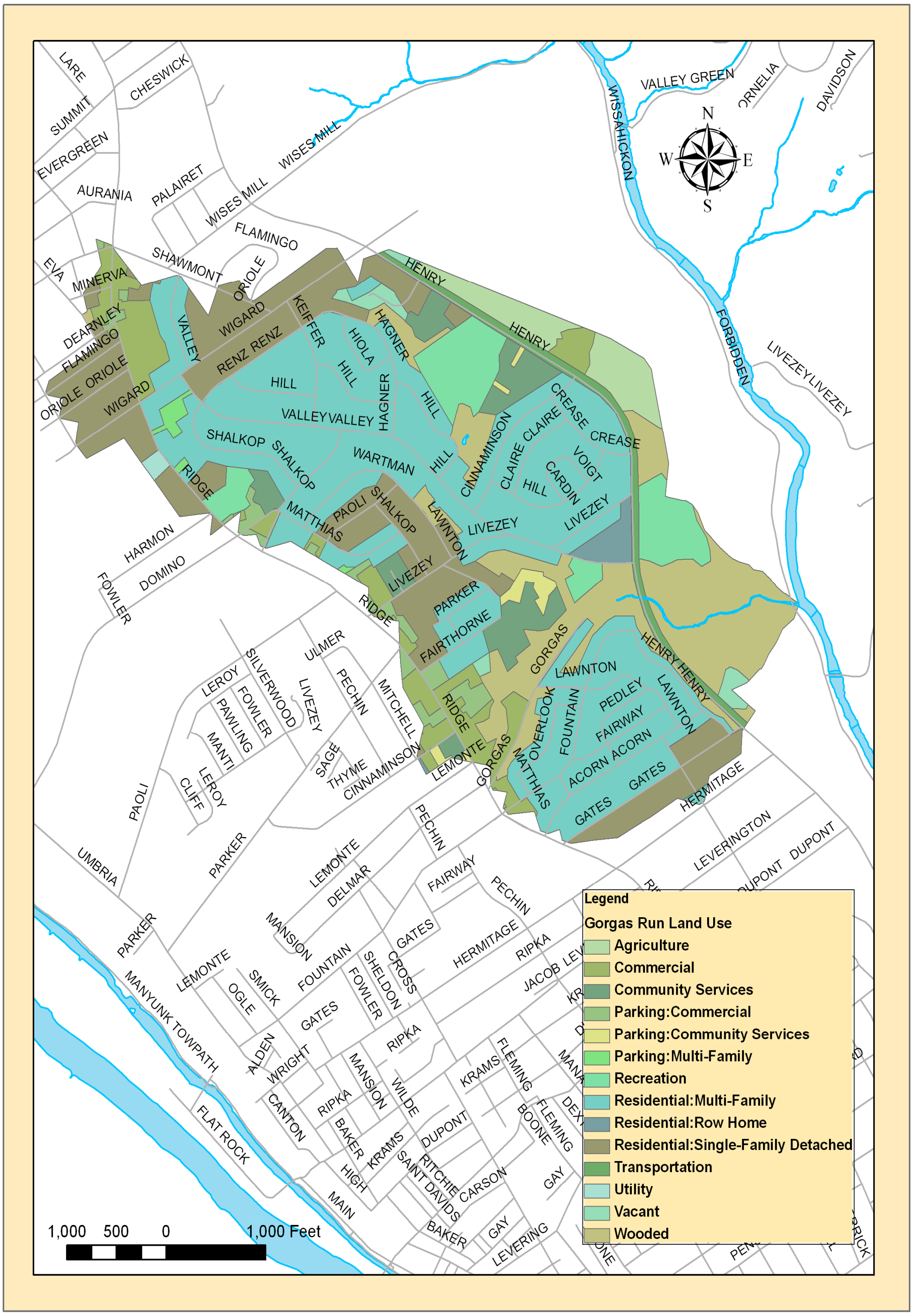


Figure 3-30: Gorgas Run Watershed Land Use

3.1.5.1 GEOLOGY

The Gorgas Run watershed is entirely underlain by the Wissahickon Formation (Figure 3-31). The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

3.1.5.2 SOILS

According to the National Resource and Conservation Service Soil Survey, the majority of soils for the Gorgas Run watershed are classified as hydrologic group B (Figure 3-32). These soils have a moderate rate of infiltration when the soils are wet (0.50-1.00 in/hr). Water movement through these soils is considered moderately rapid. There is a small band of group D soils along Gorgas Run (Table 3-33). These soils have a very slow rate of infiltration when saturated (0.02-0.10 in/hr) resulting in a high runoff potential.

There is a small section of C soils located on the northeast corner of the watershed. Group C soils are also located along Gorgas Run towards the confluence with Wissahickon Creek. Group C soils have a slow rate of infiltration when saturated (0.17-0.27 in/hr). Water movement through these soils is moderate or moderately slow.

Table 3-33: Distribution of NRCSS Soil Types in Gorgas Run Watershed

Group	Area (ft^2)	Percent of Total Area
B	21,571,243	99.24%
C	84,772	0.39%
D	80,424	0.37%
Total Area	**21,736,439**	**100%**

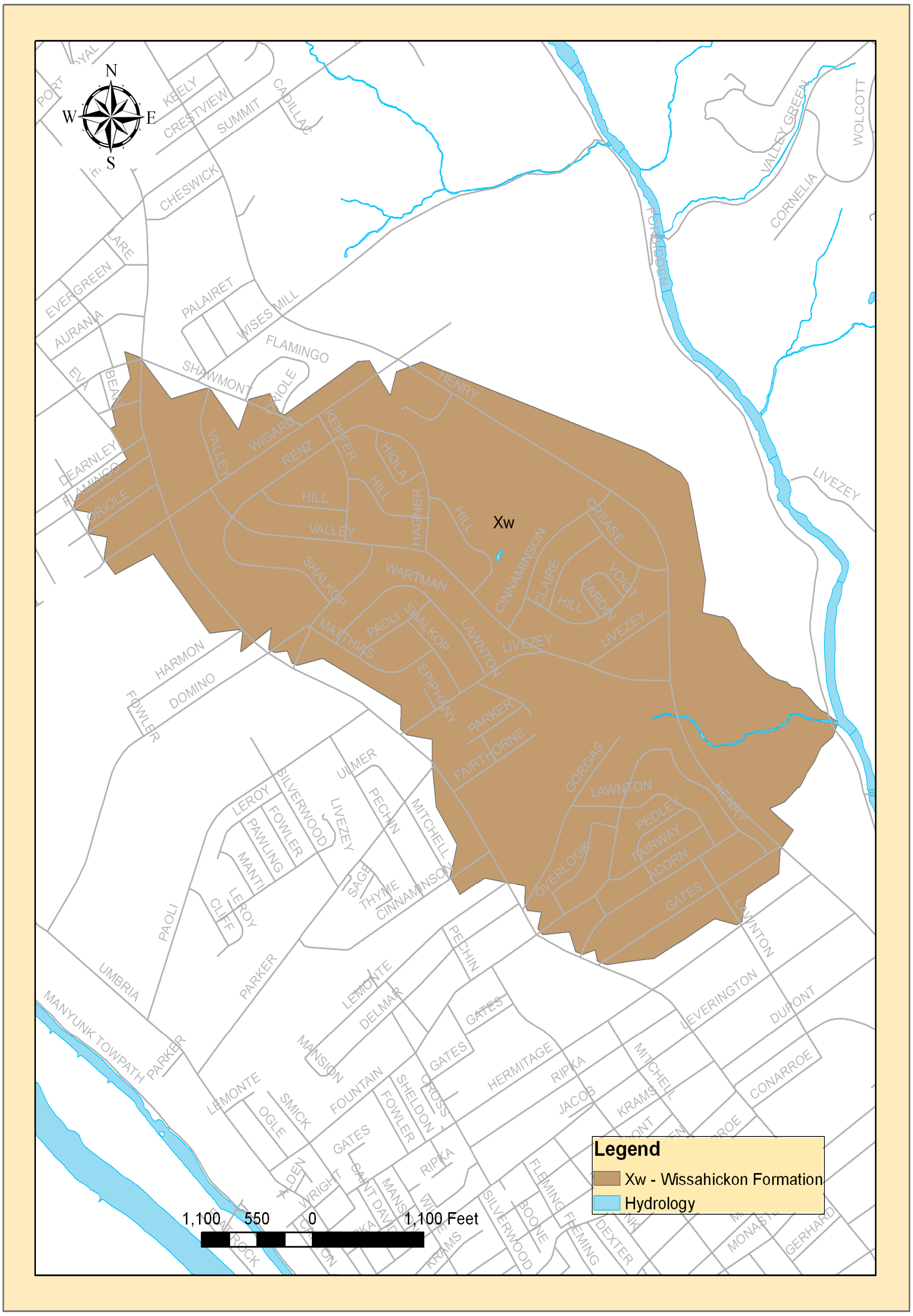


Figure 3-31: Geology of Gorgas Run Watershed

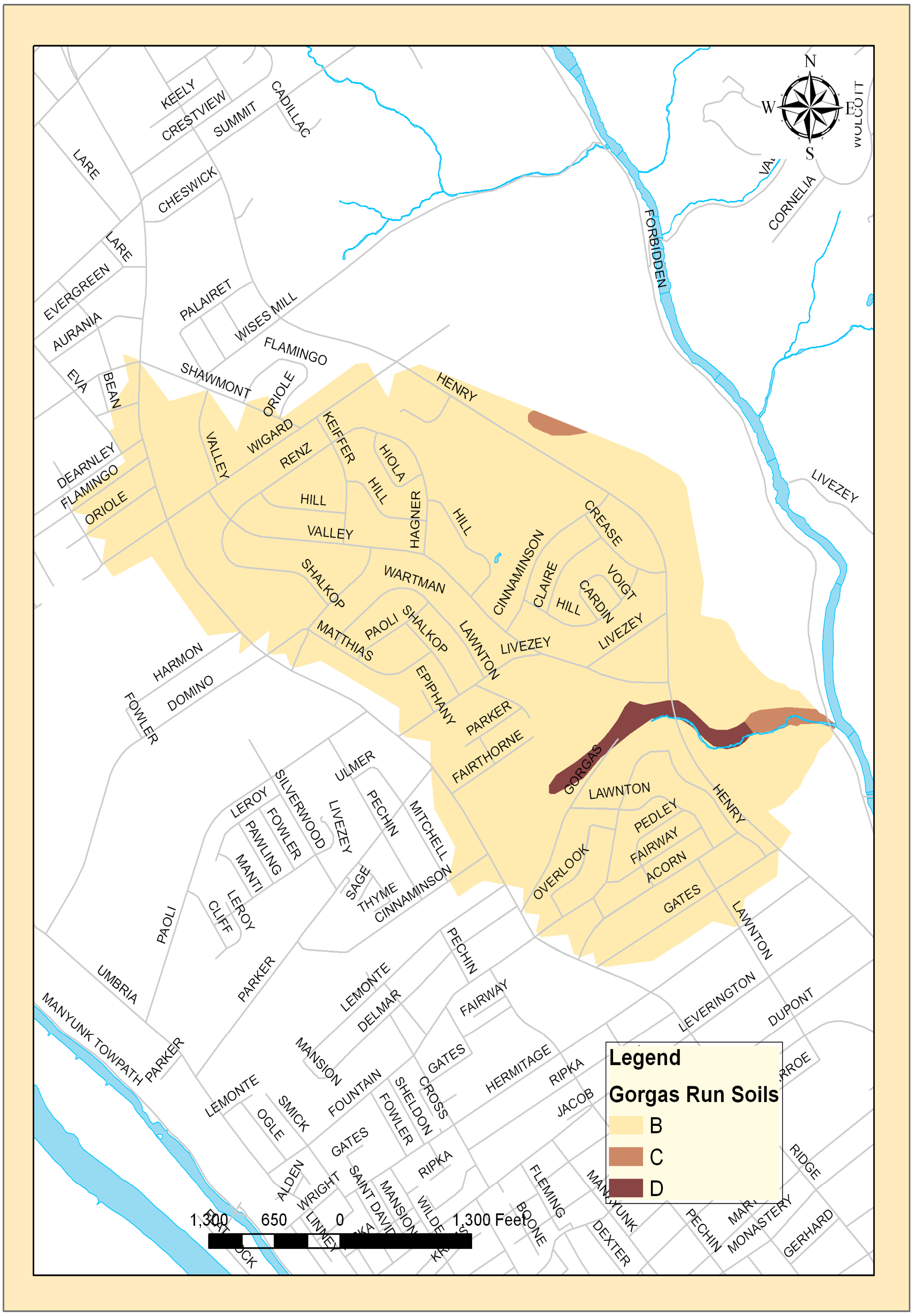


Figure 3-32: Distribution of NRCS Soil Types in Gorgas Run Watershed

3.1.5.3 Bank Erosion

There was one bank pin location along Gorgas Run (Figure 3-33). The calculated erosion rates are included in Table 3-34. The spatial distribution of BEHI assessment results were represented graphically (Figure 3-33) for each of the segments assessed on Gorgas Run. Each bank within a respective segment was assessed and rated separately; however, channelized and culverted segments were not assessed as they confer a high degree of protection from bank erosion.

Table 3-34: Gorgas Run Bank Pin Locations

	BEHI	NBS	Baseline Reading	Most Recent Reading	Erosion Rate (ft)	Erosion Rate (ft/yr)	Eroding (-) or Aggrading (+)
Gorgas							
GO790	Low	Very Low	4/24/2007	8/13/2009	-0.66	-0.29	E

Total erosion rates were also calculated for the entire length of each tributary within the lower Wissahickon (Table 3-35). To assess the normalized erosion potential of each tributary, the erosion rate per acre of drainage area per year and the erosion rate per foot of stream length per year were calculated. This allowed direct comparison between each of the tributaries with respect to both watershed size and the length of the tributary. Gorgas Run was ranked second out of the twelve tributaries within the lower Wissahickon for erosion rate per foot of stream length. The rankings were based on a scale of one being the highest erosion rate and twelve being the lowest erosion rate.

Table 3-35: Erosion Rates for Lower Wissahickon Tributaries

Tributary	Drainage Area (Acres)	Stream Length (feet)	*2009*		
			Erosion Rate (lb/yr)	*Erosion Rate Per Acre*	*Erosion Rate Per Foot of Stream*
Bell's Mill	323	6,722	420,000	1,307	63
Cathedral Run	160	2,790	150,000	913	52
Cresheim Creek	1,218	16,431	840,000	690	51
Gorgas Run	499	2,170	170,000	345	79
Hartwell Run	217	3,530	200,000	918	56
Hillcrest	144	5,272	90,000	597	16
Kitchen's Lane	234	7,753	200,000	850	26
Monoshone Creek	1,056	6,926	160,000	156	24
Rex Ave	137	1,903	150,000	1,131	81
Thomas Mill Run	104	4,008	320,000	3,058	79
Valley Green Run	128	2,874	140,000	1,086	48
Wise's Mill Run	446	7,056	490,000	1,090	69
Total/*Average*	**4,666**	**67,435**	**3,300,000**	***1,012***	***54***

Figure 3-33: Gorgas Run Watershed BEHI Ratings and Bank Pin Locations

3.1.5.4 INFRASTRUCTURE TRACKDOWN SUMMARY

Gorgas Run is a tributary to Wissahickon Creek that exists entirely within Fairmount Park; although, the stream is heavily influenced by infrastructure due to its vicinity to the residential neighborhoods in the watershed. There were 39 infrastructure elements identified on or near the creek with the most influential infrastructure elements being the 7 bridges, 6 channels, 5 outfalls, and 16 manholes (Table 3-36).

Many of the structures found during the assessment were associated with storm and sanitary sewers aligned parallel to the stream channel. A 15-inch vitrified clay sanitary line runs parallel to the channel from Gorgas Lane to the Wissahickon Low Level Interceptor near Forbidden Drive. A 12-inch sanitary line from Fountain Street connects with the 15-inch sanitary line upstream of WSbri247. Three large outfalls (WSout566, WSout762, and WSout764) were found near the creek that conveyed substantial volumes of stormwater to the channel. WSout566 (W-067-01), identified as the headwaters of Gorgas Run, discharges flow from a 6-foot diameter concrete pipe that drains the neighborhood surrounding Valley Avenue to the north and a 48-inch diameter brick pipe from Gorgas Lane to the west. The runoff from Fountain Street, to the southwest of Gorgas Run, is collected by a 42-inch brick storm sewer and is discharged from WSout764 (W-067-02). WSout762 (W-067-03) conveys runoff from Henry Avenue and the adjacent neighborhood to a small, steep tributary (unnamed tributary A) to Gorgas Run. WSout764 is 48 inches in diameter and discharges from a concrete pipe that runs under Henry Avenue. Outfalls WSout566 and WSout764 had dry weather flow during the assessment. All of the 16 manholes found during the study were affiliated with the storm or sanitary sewers in the corridor.

Of the seven bridges identified during the study, three of them were particularly important. Bridges WSbri247, WSbri248, and WSbri249 all span the main channel of Gorgas Run. These bridges create unfavorable hydraulic conditions upstream and downstream of their abutments such that the capacity to transmit peak flows and sediment downstream has been diminished. As a result, bedload sediment consisting of small to large cobble has been deposited upstream of these abutments. At WSbri248 such deposition, especially on the inside of the meander bend (downstream right), has adversely affected the alignment of the channel such that the majority of the streamflow is transmitted through the main span of the bridge and only a trickle of flow is transmitted through the "barrel" culvert on the downstream right. At WSbri247 high flows have been observed to overtop the bridge causing severe scour and degradation of the banks and stone "wing walls" upstream and downstream of WSbri247. The channelized segments within the Gorgas Run main stem and tributaries are another issue that needs to be addressed. There are several rather significant channelized portions within the Gorgas Run stream network (WScha282, Wscha142, and three channels downstream of WSout762). The discharge from WSout764 flows down WScha282 which is a steep, concrete half-pipe for about 200 feet before reaching the stream. During extreme storm events, it has been observed that storm flows escape the downstream portion of the channel and flow down the hill slope towards Gorgas Run causing the formation of rills adjacent to WScha282. These rills have been filled with stone to prevent undermining of the structure.

The stone channels downstream of WSout762, WScha280, WScha284, and WScha285, line the tributary downstream of the outfall for about 35 feet. The bottom (WScha280) and downstream left (WScha285) channels are in poor condition as the last five feet of the channel have broken off. WScha142 is an approximately 12-foot stone channel that lines the main stem of Gorgas Run for about 200 feet upstream of WSbri249 at Forbidden Drive. This channel is in poor condition as part of the wall and associated trail fencing had collapsed into the stream.

Priority infrastructure (Figure 3-36) on Gorgas Run included WScha280 (Figure 3-34), WScha285, WScha142 (Figure 3-34), and WSman57 which had no manhole cover and an exposed pipe orifice.

Figure 3-34: Degraded section of WScha280 (left). Degraded section of WScha142 (right).

Table 3-36: Summary of Gorgas Run Infrastructure Points

Section ID	Culvert Count	Bridge Count	Outfall Count	Channel Count	Confluence Count	Dam Count	Manhole Count	Pipe Sewer Count	Other Count	Infra Point Count	Combined Outfall Area (ft^2)
WSGO02	1	7	5	6	1	1	16	1	2	39	64.06

Table 3-37: Summary Gorgas Run Infrastructure Linear Features

Section ID	Segment Length (ft)	Segment Length (ft), 3 sides	Culvert Length (ft)	Percent Culverted	Channel Length (ft), 1 side	Channel Length (ft), 3 sides	Channel Length (ft)	Percent Channelized
WSGO02	2699	8097	8	0.3	218	215	863	3.3

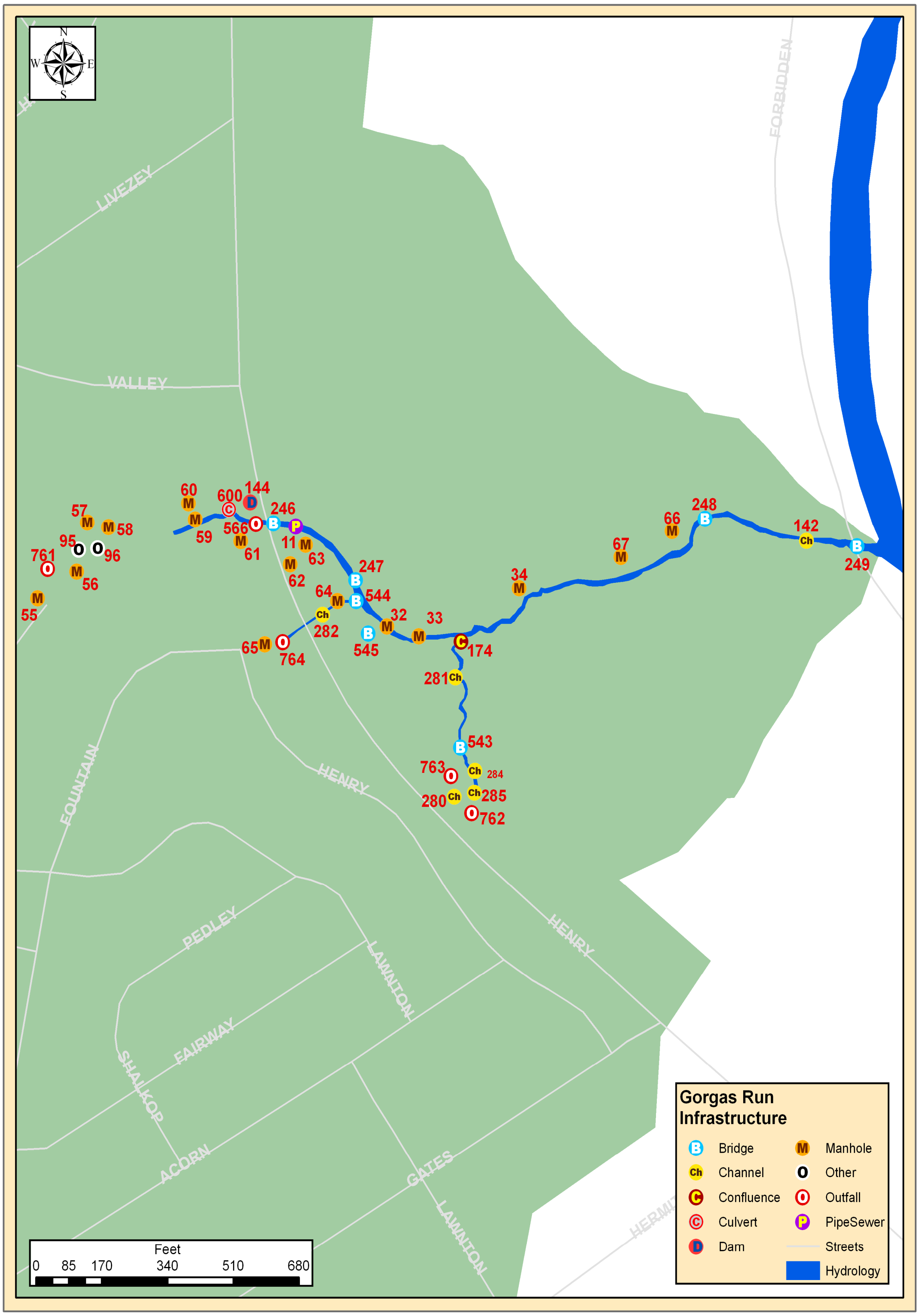


Figure 3-35: Gorgas Run Infrastructure Locations

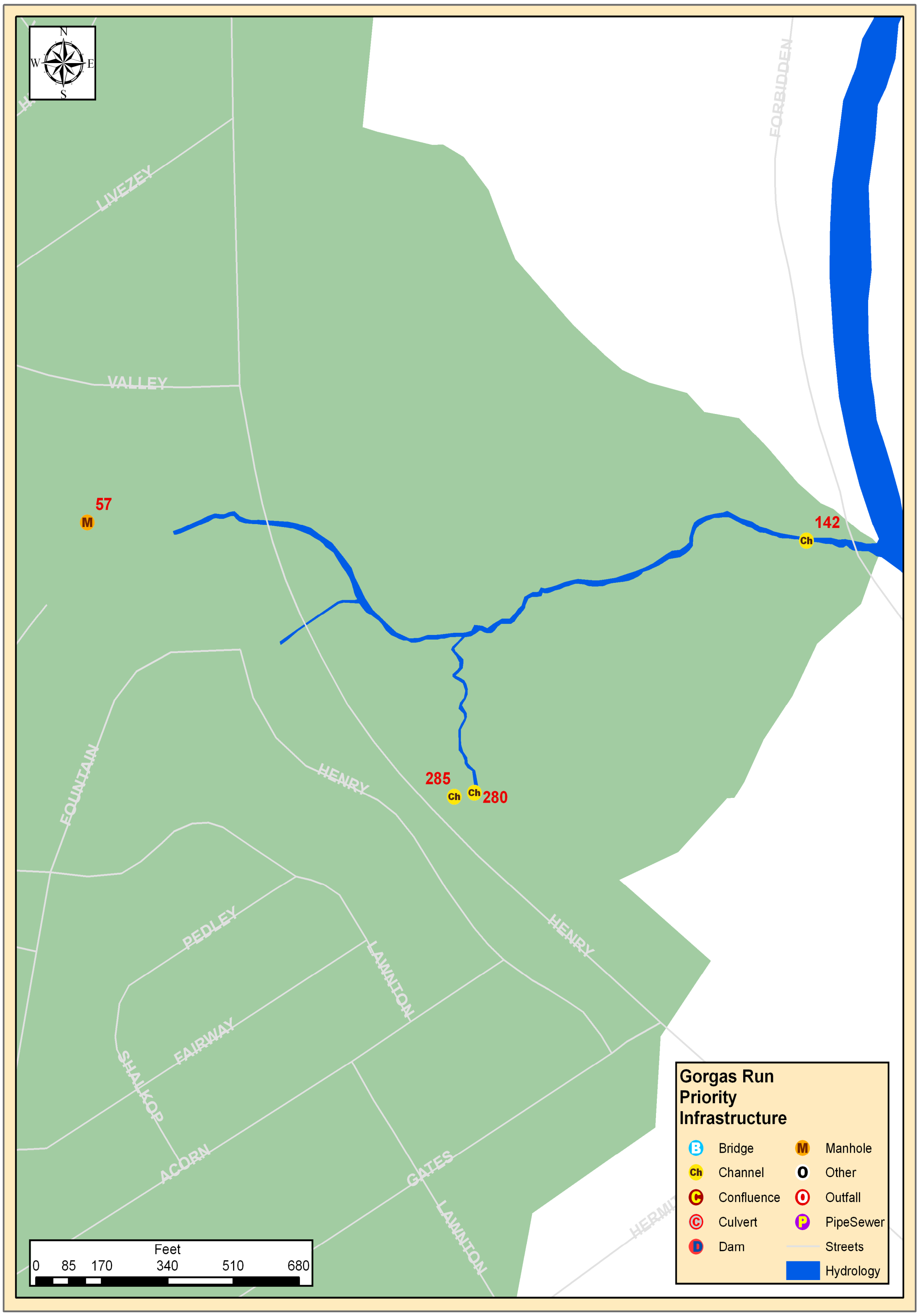


Figure 3-36: Gorgas Run Priority Infrastructure Locations

3.1.5.5 UNIFIED STREAM ASSESSMENT RESULTS FOR THE GORGAS RUN WATERSHED

The Gorgas Run stream channel is a first-order, single thread channel with no tributaries. The majority of the channel is located entirely within Fairmount Park with the exception of an approximately 230-foot segment of the channel upstream of WSout566 (W-067-01). Gorgas Run is the last major tributary on the DSR side of the basin's corridor. The Center for Watershed Protection's (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and subwatersheds within the Lower Wissahickon Basin.

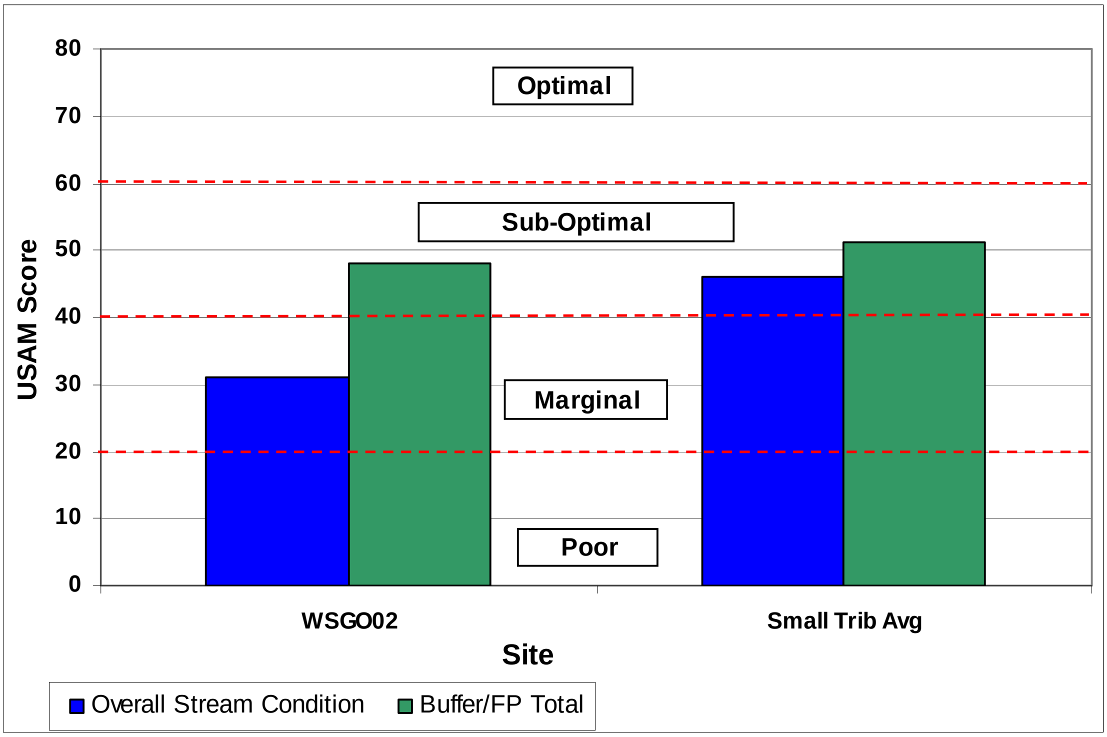


Figure 3-37: Results for Gorgas Run USAM Components

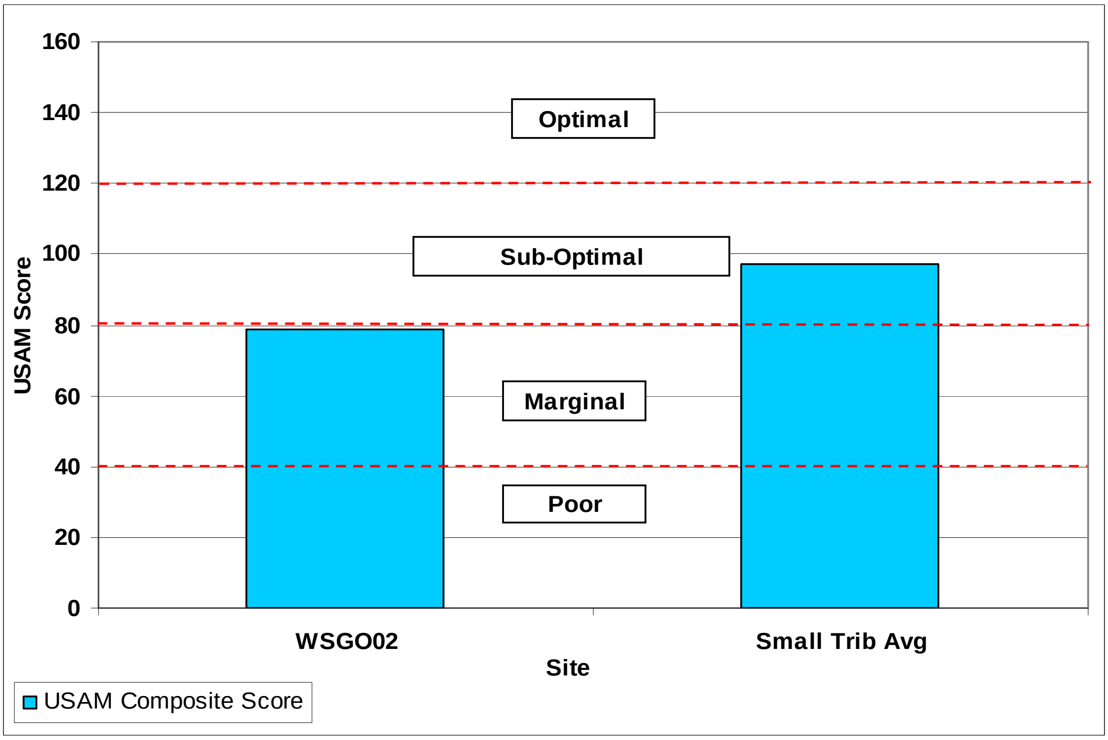


Figure 3-38: Gorgas Run USAM Results

3.1.5.5.1 WSGO02

The headwaters of reach WSGO02 begins approximately 230 feet upstream of WSout566 (W-067-01) and Henry Avenue. The channel is fed mainly by runoff from Gorgas Road as well as the trail adjacent to the channel. The main stem channel had a bankfull channel capacity relatively larger than the other small Lower Wissahickon tributaries; however the Gorgas Run drainage area (0.6 mi^2) was also larger than that of the other small tributaries. The bed substrate within the reach was dominated by cobble (62%) with gravel and boulder comprising the remainder of the substrate distribution. Reach WSGO2 was characterized by a deeply entrenched (Entrenchment Ratio=1.1), moderate gradient (slope of 2.9%) channel and a relatively high width to depth ratio (20.9) which classified the reach as an F3b channel type. The USAM composite score for the reach was 79/160 (Figure 3-38).

3.1.5.6 Summary of Unified Stream Assessment Results

The mean watershed scores for the individual USAM components as well as the overall USAM score ranged from marginal to suboptimal (Table 3-38). Average conditions within the Gorgas Run watershed's floodplains and riparian buffers were slightly better conditions observed in stream channels. There was high variability between scores for the respective parameters of the two USAM components as *Overall Stream Condition* rankings ranged from poor to suboptimal and the *Overall Buffer Floodplain* rankings ranged from poor to optimal. Both the USAM component and composite scores (Table 3-38) were below the respective Small Tributary averages.

Table 3-38: USAM Results for Gorgas Run Watershed

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP Condition	USAM Score
WSGO02	Gorgas	31	48	79
Small Tributary Average	**----**	**44.8**	**50.6**	**95.4**

3.1.5.6.1 Summary of Overall Stream Condition Scores in the Gorgas Run Watershed

The scores for the parameters within the *Overall Stream Condition* component of the USAM assessment ranged from "poor" to "suboptimal". The *Instream Habitat* parameter was the highest scoring parameter of the four *Overall Stream Condition* parameters at (13/20). The remaining parameters were poor to marginal and were affected by factors external to the stream channel such as infrastructure (e.g. Henry Avenue culvert, numerous footbridges and outfalls) and the large, residential drainage basin which delivers vast amounts of stormwater to the reach. The *Overall Stream Condition* score for Gorgas Run (31/80) was rated as "marginal" and compared poorly to the Small Tributary average of 44.8/80, which was rated as "suboptimal."

Table 3-39: USAM Overall Stream Condition Scoring for Gorgas Run Watershed

OVERALL STREAM CONDITION								
Reach ID	Sub-watershed	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	Overall Stream Condition
			Left	Right	Left	Right		
WSGO02	Gorgas	13	3	3	5	5	2	31
Small Tributary Average	**----**	**15.8**	**4.4**	**4.2**	**5.6**	**5.8**	**9**	**44.8**

3.1.5.6.1.1 Instream Habitat

The condition of the instream habitat observed in reach WSGO02 was rated as "suboptimal" with a score of 13/20, which was considerably lower than the Small Tributary average of 15.8/20, although both were rated as "suboptimal." The physical habitat template observed in the reach was characterized by a relatively high availability of stable substrate (i.e. cobble and boulder) which could be used as protective cover or attachment sites for macroinvertebrates. Pebble count results specify a D_{35} of 64.0 mm which can be interpreted to mean that at least 65% of the available substrate in the reach is larger than small cobble, which ranges in size from 64-90mm. One of the factors that reduced the potential for optimal habitat in the reach was the absence of habitat complexity in that adequate amounts of coarse woody debris (CWD) and undercut banks were not observed in the reach. CWD is a valuable component of the habitat template in a stream as it can provide protection from high flows. Similarly, undercut banks provide optimal habitat for many fish species, yet the past channel incision observed in the reach has precluded or eliminated the formation of undercut bank habitat within some segments of the reach where the "toe" of these banks are well above the active channel.

3.1.5.6.1.2 VEGETATIVE PROTECTION

Scores for the *Vegetative Protection* parameter were considerably low (3/10) for both the right and left banks of the reach and were rated as "poor" (Table 3-39). The reach was characterized as having fewer than 50% of the streambank surface covered by vegetation, which can be attributed to the presence of recreation trails along the length of the reach as well as severe erosion. The Small Tributary averages were moderate with scores of 4.4/10 and 4.2/10 for the left and right banks respectively, as both banks were rated as "marginal."

In many instances, the *Vegetative Protection* parameter was limited in many of the smaller tributaries to Wissahickon Creek by anthropogenic factors. Factors such as floodplain development and channelization alter channel and floodplain dynamics leaving stream channels susceptible to severe bank erosion by storm flows. Aside from delivering excess sediment loads to the channel, severe erosion can trigger a succession of events that propagate increased rates of erosion. Frequent disturbance (i.e. scouring) may preclude the establishment of stable, native plant communities such that invasive species such as Japanese knotweed (*Polygonum cuspidatum*) become established. *P. cuspidatum* has very shallow roots which are poor at stabilizing the soil matrix; furthermore, it is notoriously difficult to eradicate once established. Excessive bank erosion can also produce destabilizing undercut banks which ultimately cause trees to fall into the channel thereby causing more erosion and creating an opportunity for the establishment of non-native vegetation.

3.1.5.6.1.3 BANK EROSION

Bank erosion in WSGO02 was rated as "marginal", with a score of 5/10 (Table 3-39). There was evidence of active channel widening as well as observations of very high erosion rates, however bank erosion has yet to threaten property or infrastructure. Bank erosion within the reach can be attributed to a number of factors. Gorgas Run is channeled through an outfall (WSout566/W-067-01) as it flows beneath Henry Avenue and flows beneath four bridges in its short (2,170 feet) length. Furthermore, the steep slope of the channel (2.9%) and large urbanized drainage area (499 acres) in combination with the recreation trail that abuts the reach-produce large volumes of high-energy runoff from both the watershed as well as the hill slopes adjacent to the main channel.

3.1.5.6.1.4 FLOODPLAIN CONNECTION

The score for the *Floodplain Connection* parameter (2/20) was rated as "poor", and positioned WSGO02 among the worst reaches (after WSHW04 and WSCR08) observed in the Lower Wissahickon for this parameter and considerably lower than the Small Tributary average (9/20). The entrenchment ratio at cross section WSGO02 was 1.1, which indicates that only flows that exceed the estimated bankfull discharge of 150.6 cfs by a considerable margin can access the floodplain throughout the reach.

3.1.5.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE GORGAS RUN WATERSHED

The scores for the parameters within the *Overall Buffer and Floodplain Condition* component of the USAM assessment ranged from "poor" to "optimal". Both the *Vegetated Buffer Width* and the *Floodplain Vegetation* parameters were rated as "optimal" for WSGO02, with both parameters scoring higher than the Small Tributary average (Table 3-40). The *Overall Buffer and Floodplain* component for WSGO02 (48/80) was comparable to the score for the Small Tributary average (50.6/80) as both were rated as "suboptimal". It was evident that many of the parameters were significantly impacted by the presence of infrastructure and the effects of stormwater runoff as channel incision or "down-cutting" has worked to isolate the channel from its floodplain.

Table 3-40: USAM Buffer and Floodplain Condition Scoring for Gorgas Run Watershed

OVERALL BUFFER AND FLOODPLAIN CONDITION							
Reach ID	Sub-watershed	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	Buffer/FP Total
		Left	Right				
WSGO02	Gorgas	10	10	17	3	8	48
Small Tributary Average	**----**	**9**	**8.8**	**16.2**	**5.6**	**11**	**50.6**

3.1.5.6.2.1 VEGETATED BUFFER WIDTH

The vegetated buffers on both the right and left banks of WSGO02 were greater than 50 feet and were rated as "optimal" (Table 3-40). The scores for both banks were higher than the Small Tributary average of 9/ 10 and 8.8/10 for the left and right banks respectively. There are trails that abut some segments of the reach, however the trails are located very close to the stream channel and therefore do not significantly divide or impinge upon the width of the reach's riparian buffer.

3.1.5.6.2.2 FLOODPLAIN VEGETATION

Floodplain vegetation was rated as "optimal" in reach WSGO02 with a score of 17/20. Along with the *Vegetated Buffer Width* parameter, this parameter was one of two parameters for the *Overall Buffer and Floodplain Condition* component that scored higher than respective Small Tributary averages (Table 3-40). The dominant floodplain vegetation observed in the reach was characterized as mature forest with a mix of shrub and ground cover vegetation close to the stream banks. The mature forest cover that dominated the upland portions of the corridor precluded the establishment of a dense understory throughout most of the reach.

3.1.5.6.2.3 FLOODPLAIN HABITAT

Floodplain habitat was rated as "poor" throughout the reach with a score of 3 /10. The Small Tributary average was not much higher at 5.6/10, which was rated as "marginal". The low scores for the smaller, single cross section tributaries to Wissahickon Creek reflect a high level of channel incision which is manifested through the low entrenchment ratios observed on these reaches. After a considerable degree of channel incision, the floodplains associated with incised channels confer analogous responses to the lack of floodplain inundation and the subsequent reduction in the elevation of the water table. These responses range from shifts in the dominant vegetation type and the loss of wetland habitat to changes in the stability of stream banks comprised of cohesive soils.

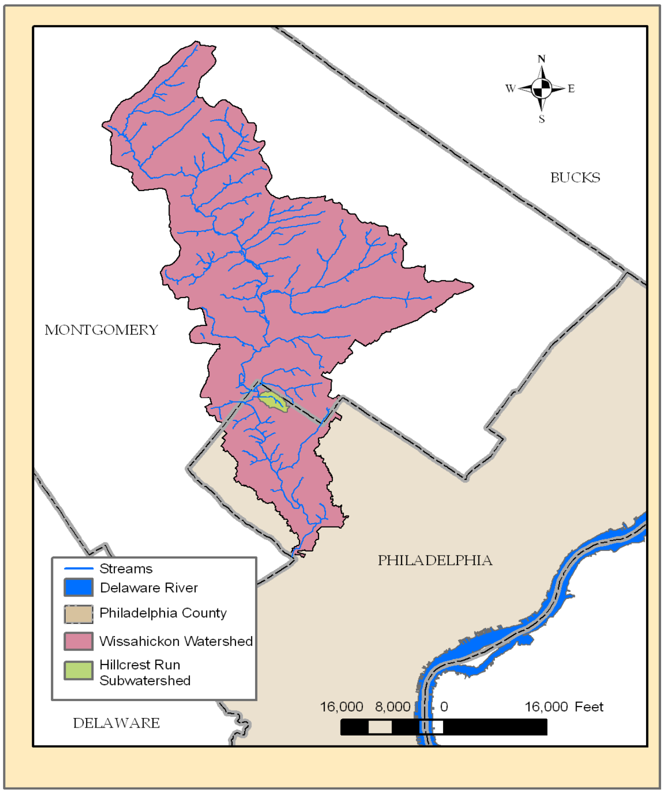
3.1.5.6.2.4 FLOODPLAIN ENCROACHMENT

The *Floodplain Encroachment* parameter was rated as "marginal" with a score of 8/20. The majority of the floodplain encroachment in the reach can be attributed to the presence of a recreational trail and infrastructure throughout the reach. Reach WSGO02 compared poorly to the score for the Small Tributary average of 11/20.

3.2 LARGE TRIBUTARY WATERSHED AND REACH CHARACTERISTICS

The Large Tributaries to Wissahickon Creek were defined as those having more than one cross section and representative reach. In the subsequent sections, "All Reaches Average" refers to the average Lower Wissahickon score for the respective metric excluding the scores for the reaches within the watershed tributary being described.

3.2.1 HILLCREST RUN WATERSHED AND REACH CHARACTERISTICS



Hillcrest Run is a first-order tributary to the main stem of the Wissahickon Creek. The tributary arises from a privately owned outfall northwest of the intersection of Norwood and Chestnut Hill Avenues. It then travels for approximately 5,272 feet before the Confluence with the Wissahickon main stem. The majority of the tributary runs through a residential area. The lower portion of Hillcrest Run is located within Morris Arboretum.

The dominant substrate varies from very fine gravel to large cobble. The watershed is a total of 144 acres. Major land use types within the watershed include: residential – single family detached (86%), water (6%), and recreation (3%).

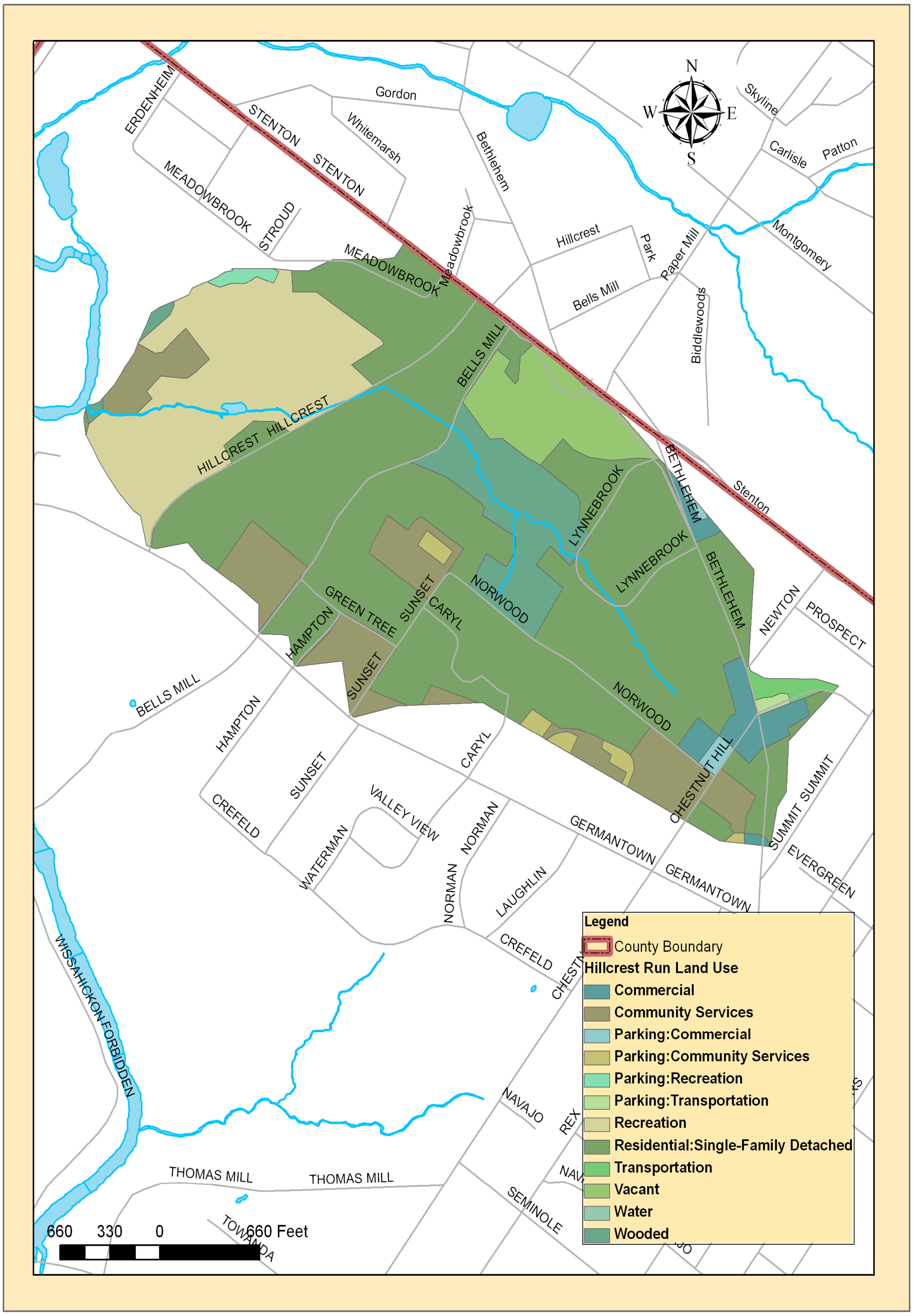


Figure 3-39: Hillcrest Run Watershed Land Use

3.2.1.1 GEOLOGY

The majority of the Hillcrest Run watershed is underlain by the Wissahickon Formation. The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

The northwestern portion of the Hillcrest Run watershed is underlain by the Bryn Mawr Formation. The Bryn Mawr Formation consists of white, yellow and brown gravel and sand. The Bryn Mawr Formation is considered a deeply weathered formation.

There is a small section of the Felsic Gneiss Formation located on the southeastern tip of the watershed. The Felsic gneiss Formation consists of metamorphic rock units that yield small quantities of water due to the cracks, joints and openings within the rock.

3.2.1.2 SOILS

According to the National Resource and Conservation Service Soil Survey, the majority of soils for the Hillcrest Run watershed are classified as hydrologic group B (Figure 3-41). These soils have a moderate rate of infiltration when the soils are wet (0.50-1.00 in/hr). Water movement through these soils is considered moderately rapid.

There is a very small portion of the watershed along the county boundary that is underlain by the Urban Land soils. Urban soils consist of material that has been disturbed by human activity during urbanization. Urban soils have been produced by mixing, filling and contamination of the native soils in both urban and suburban areas.

Table 3-41: Distribution of NRCS Soil Types in Hillcrest Run Watershed

Group	Area (ft^2)	Percent of Total Area
B	6,213,677	99.06%
Urban	58,962	0.94%
Total Area	**6,272,639**	**100%**

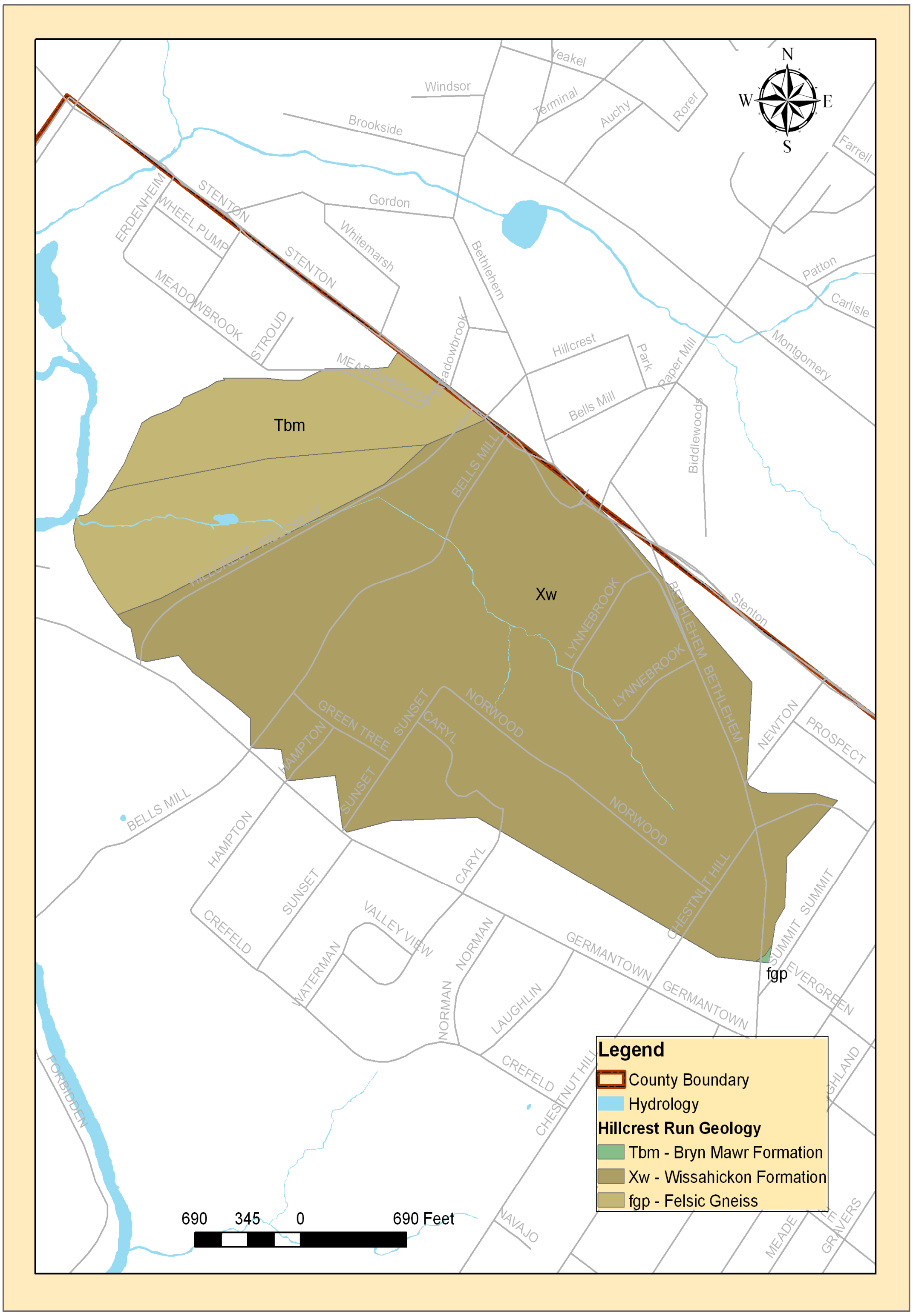


Figure 3-40: Geology of Hillcrest Run Watershed

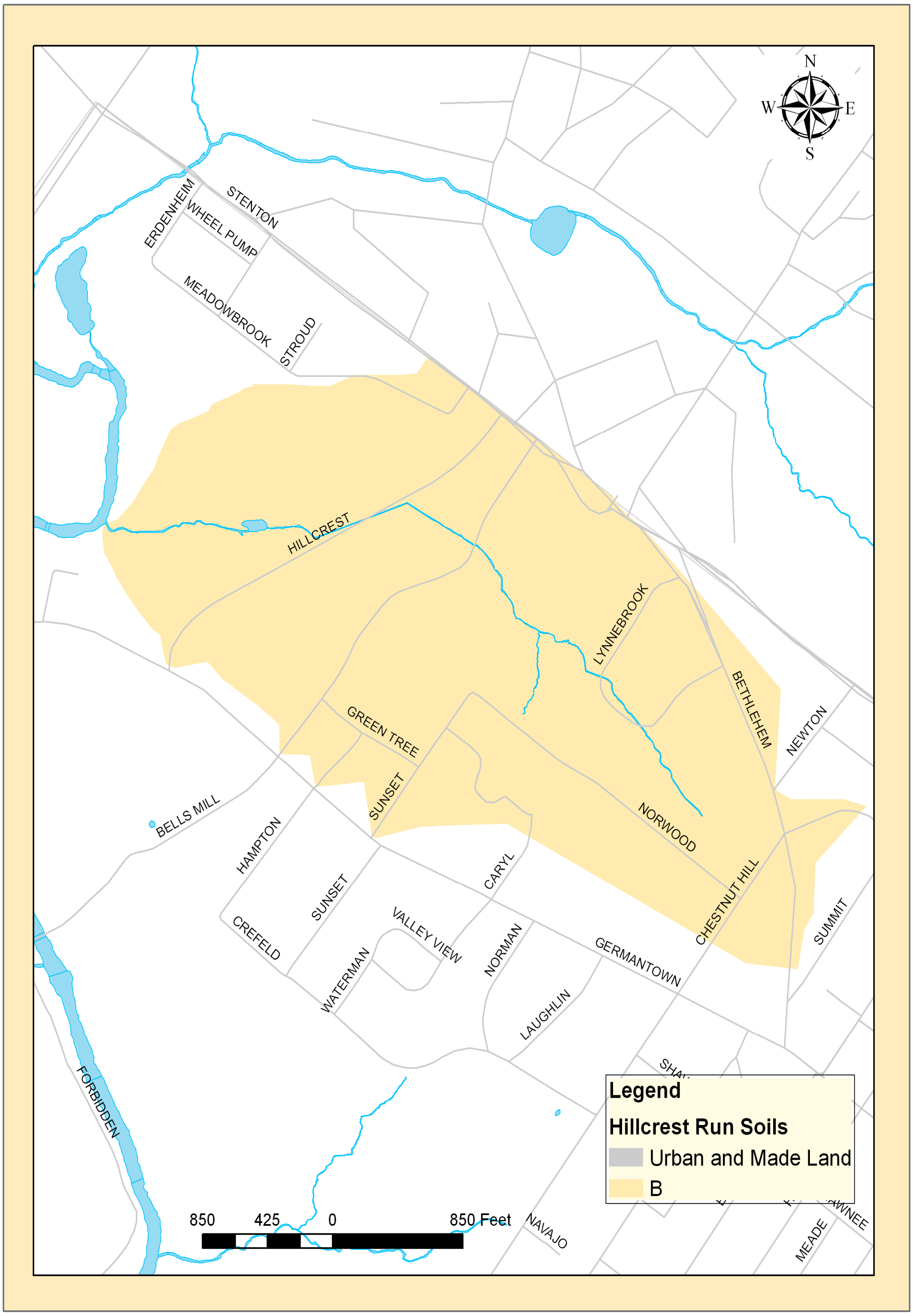


Figure 3-41: Distribution of NRCS Soil Types in Hillcrest Run Watershed

3.2.1.3 BANK EROSION

There was one bank pin location along Hillcrest Run (Figure 3-42). The calculated erosion rates are included in Table 3-42. The spatial distribution of BEHI assessment results were represented graphically (Figure 3-42) for each of the segments assessed on Hillcrest Run. Each bank within a respective segment was assessed and rated separately; however, channelized and culverted segments were not assessed as they confer a high degree of protection from bank erosion.

Table 3-42: Hillcrest Run Bank Pin Locations

	BEHI	NBS	Baseline Reading	Most Recent Reading	Erosion Rate (ft)	Erosion Rate (ft/yr)	Eroding (-) or Aggrading (+)
Hillcrest							
HC303	Low	Very Low	8/24/2006	8/10/2009	-0.22	-0.073	E

Total erosion rates were also calculated for the entire length of each tributary within the lower Wissahickon (Table 3-43). To assess the normalized erosion potential of each tributary, the erosion rate per acre of drainage area per year and the erosion rate per foot of stream length per year were calculated. This allowed direct comparison between each of the tributaries with respect to both watershed size and the length of the tributary. Hillcrest Run was ranked last out of the twelve tributaries within the lower Wissahickon for erosion rate per foot of stream length. The rankings were based on a scale of one being the highest erosion rate and twelve being the lowest erosion rate.

Table 3-43: Erosion Rates for Lower Wissahickon Tributaries

Tributary	Drainage Area (Acres)	Stream Length (feet)	*2009*		
			Erosion Rate (lb/yr)	*Erosion Rate Per Acre*	*Erosion Rate Per Foot of Stream*
Bell's Mill	323	6,722	420,000	1,307	63
Cathedral Run	160	2,790	150,000	913	52
Cresheim Creek	1,218	16,431	840,000	690	51
Gorgas Run	499	2,170	170,000	345	79
Hartwell Run	217	3,530	200,000	918	56
Hillcrest	144	5,272	90,000	597	16
Kitchen's Lane	234	7,753	200,000	850	26
Monoshone Creek	1,056	6,926	160,000	156	24
Rex Ave	137	1,903	150,000	1,131	81
Thomas Mill Run	104	4,008	320,000	3,058	79
Valley Green Run	128	2,874	140,000	1,086	48
Wise's Mill Run	446	7,056	490,000	1,090	69
Total/*Average*	**4,666**	**67,435**	**3,300,000**	***1,012***	***54***

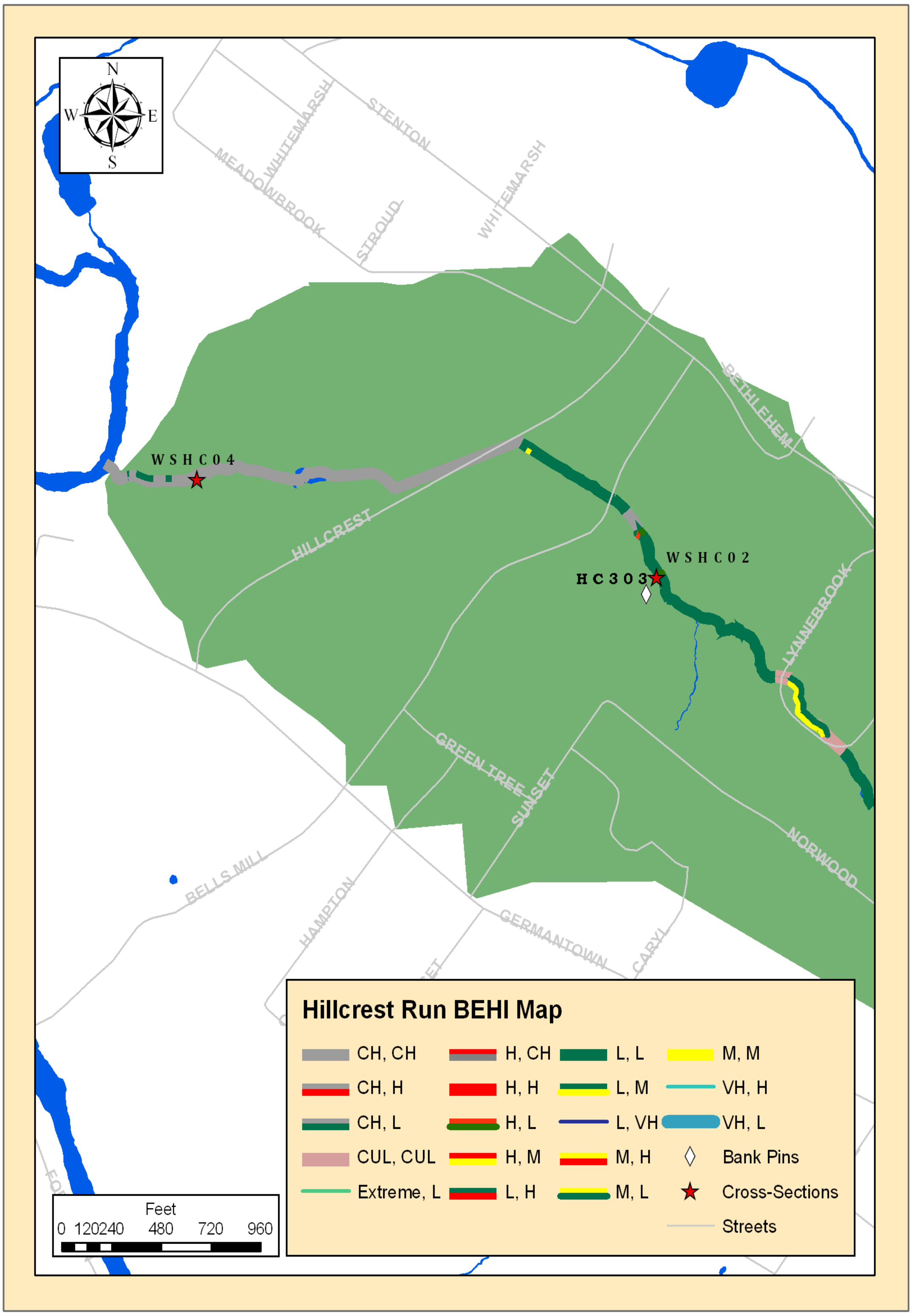


Figure 3-42: Hillcrest Run Watershed BEHI Ratings and Bank Pin Locations

3.2.1.4 INFRASTRUCTURE TRACKDOWN SUMMARY

The Hillcrest Run watershed was heavily influenced by urban residential development as it was one of the only watersheds in the Lower Wissahickon that was not within the Fairmount Park system. The upstream-most reach, WSHC02, had one of the highest infrastructure densities on the Lower Wissahickon with 25 elements within a 4,135 feet reach (Table 3-44). While the narrow riparian buffer does confer some protection from the various impacts of drainage and conveyance infrastructure, anthropogenic impairments to the Hillcrest Run hydrologic regime are evident. Of particular concern are the vast number of dams within the reach (n=11), which cumulatively impound tremendous volumes of streamflow. Impoundments subject streamflow to stagnation and thermal enrichment which can lower dissolved oxygen (DO) concentrations; furthermore, organic matter and sediment transport regimes are adversely impacted by impoundments such that the net impact of dams are manifest both upstream and downstream of the actual structure. Of the eleven dams in the reach, four (WSdam95, WSdam97, WSdam98, WSdam100) were in poor condition such that they functioned more as debris jams than dams given their reduced capacity and “silted-in” impoundments. There was also a considerable length of the stream that was culverted or channelized such that six culverts accounted for nearly 24% percent of the WSHC02 stream length and the entire length of unnamed tributary A (526 feet) was channelized.

Reach WSHC04 had less infrastructure elements than the upstream reach, however the density of infrastructure elements within the reach was far greater than the density observed in WSHC02. There were less dams, outfalls and culverts compared to WSHC02; however, reach WSHC04 was highly channelized (25.6%). In addition, the reach harbored a very large impoundment from WSdam106 on the property of Morris Arboretum which hosted water fowl (swans, ducks, geese) which likely contribute excessive concentrations of nutrients to the downstream segments of the reach.

Table 3-44: Summary Hillcrest Run Infrastructure Point Features

Section ID	Culvert Count	Bridge Count	Outfall Count	Channel Count	Confluence Count	Dam Count	Other Count	Infra Point Count	Combined Outfall Area (ft^2)
WSHC02	6	1	3	4	3	11	2	25	17.6
WSHC04	1	4	1	9	1	2	0	17	16
TOTAL	**7**	**5**	**4**	**13**	**4**	**13**	**2**	**42**	**33.6**

Table 3-45: Summary Hillcrest Run Infrastructure Linear Features

Section ID	Segment Length (ft)	Segment Length (ft), 3 sides	Culvert Length (ft)	Percent Culverted	Channel Length (ft), 1 side	Channel Length (ft), 2 sides	Channel Length (ft), 3 sides	Channel Length (ft)	Percent Channelized
WSHC02	4135	12405	983	23.8	0	617	0	1234	9.9
WSHC04	1468	4404	15	1.0	257	391	30	1129	25.6
TOTAL	**5603**	**16809**	**998**	**17.8**	**257**	**1008**	**30**	**2363**	**14.1**

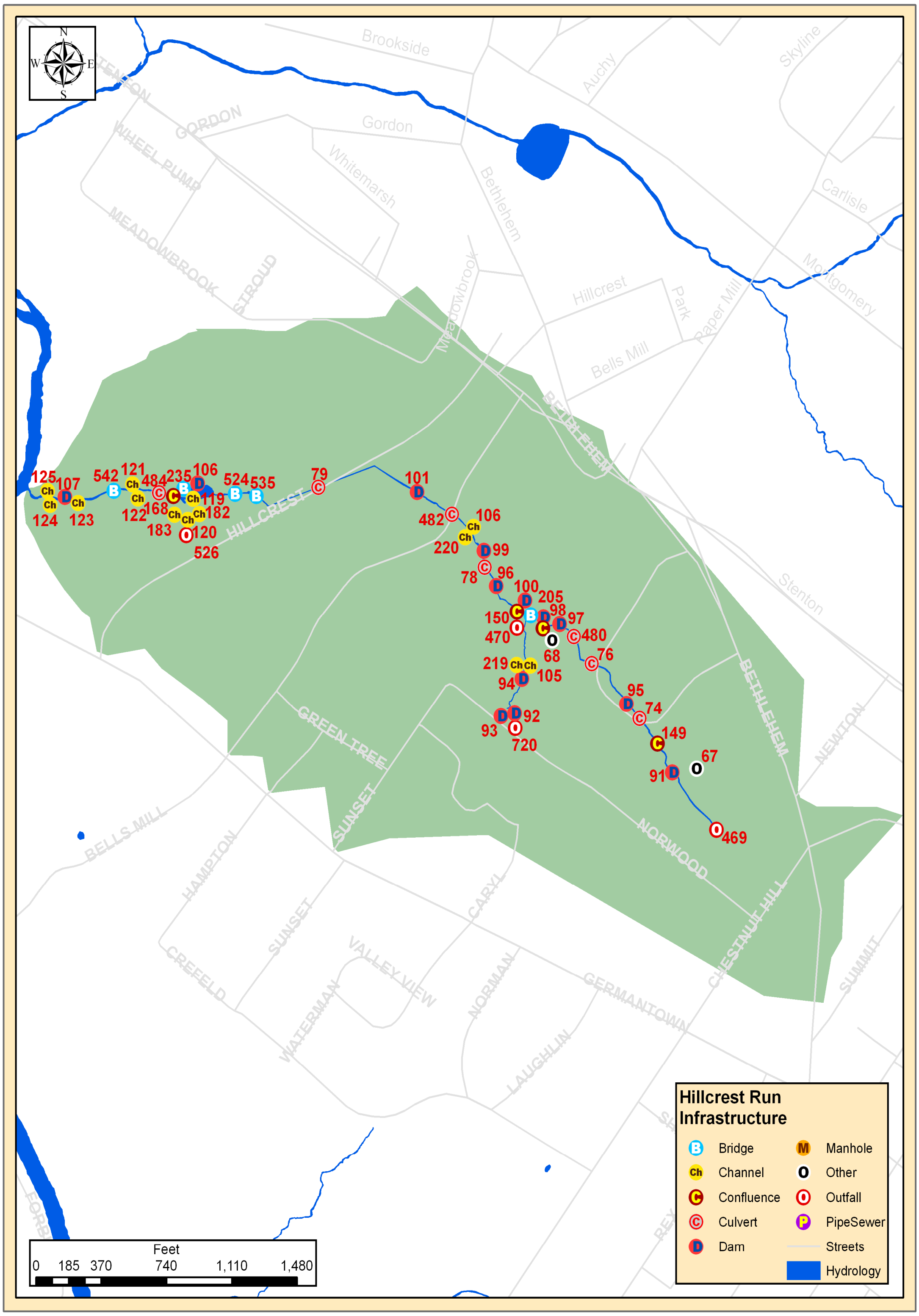


Figure 3-43: Hillcrest Run Infrastructure Locations

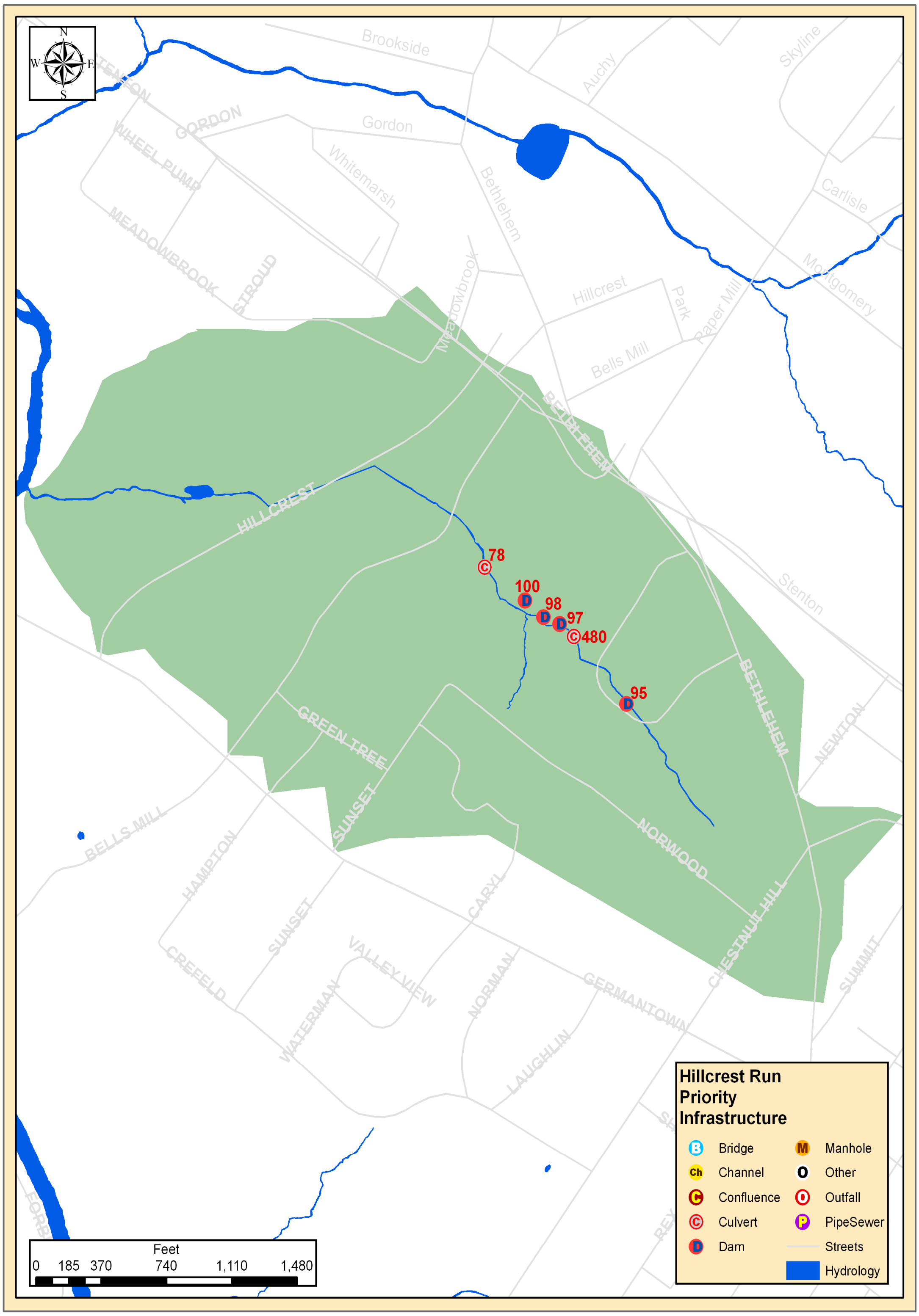


Figure 3-44: Hillcrest Run Infrastructure in Poor Condition

3.2.1.5 UNIFIED STREAM ASSESSMENT RESULTS FOR THE HILLCREST RUN WATERSHED

The Hillcrest Run watershed was the northern-most watershed in the Lower Wissahickon Basin. The majority of the Hillcrest Run main stem channel was second-order (downstream of WSHC02), characterized by a rather steep slope (4.7%) and a substrate distribution dominated by gravel (42%), although isolated areas of the watershed had segments of bedrock-controlled channel.

The Hillcrest Run watershed was heavily developed as the dominant land use was single-family residential. There were no portions of the watershed that are within the boundaries of Fairmount Park, which distinguished the Hillcrest Run watershed from the other watersheds of the Lower Wissahickon Basin. The Center for Watershed Protection's (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and watersheds within the Lower Wissahickon Basin.

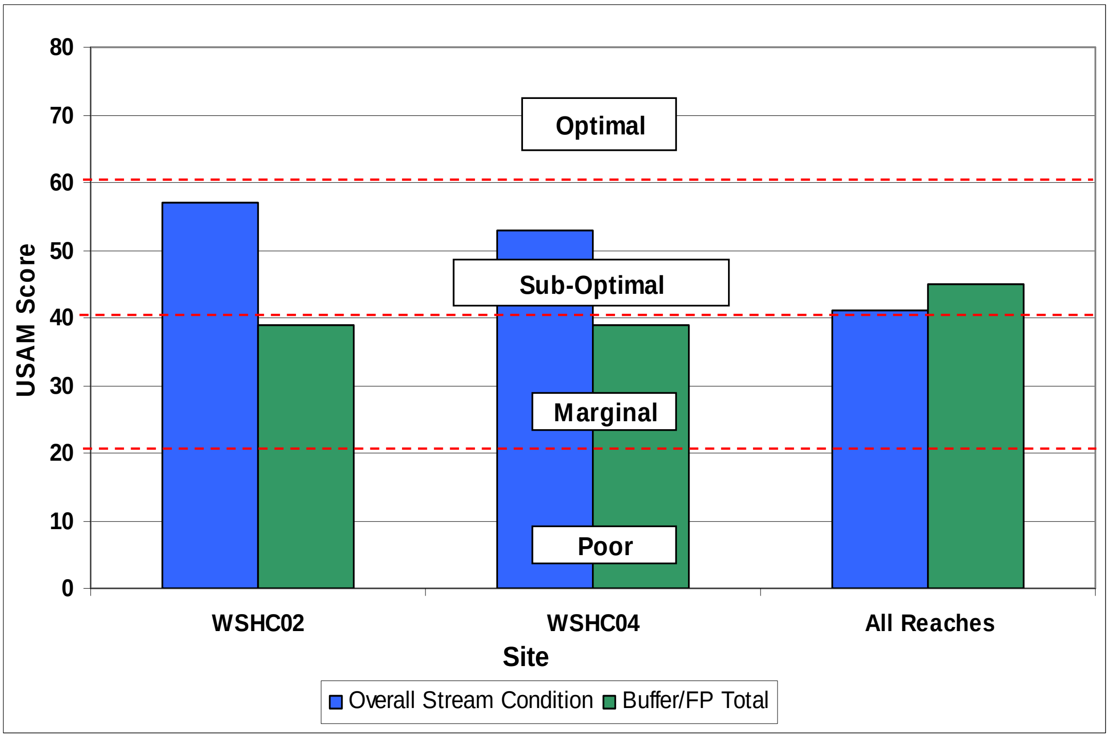


Figure 3-45: Results for Hillcrest Run USAM Components

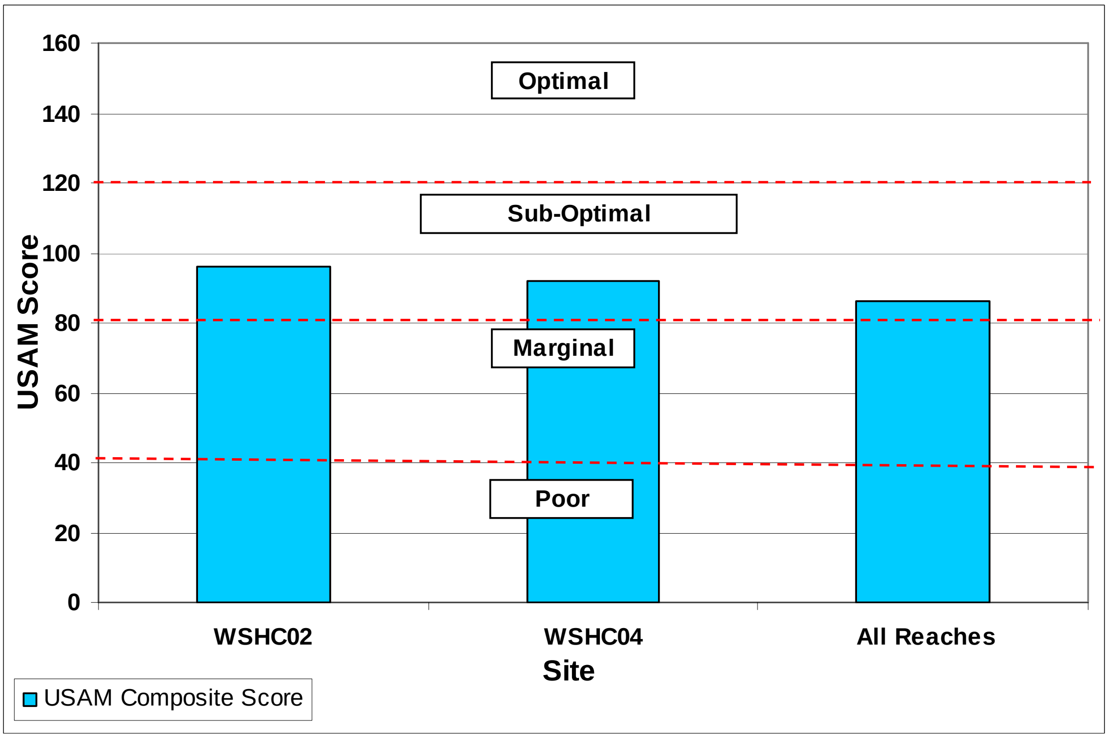


Figure 3-46: Hillcrest Run USAM Results

3.2.1.5.1 WSHC02

The headwaters of reach WSHC02 originated from an outfall, WSout469, located 485 feet from the intersection of Chestnut Hill Avenue and Norwood Avenue. There was a small tributary (530 feet) on reach WSHC02, of which the confluence with the main stem of Hillcrest Run was located 300 feet upstream of cross section WSHC02. In total, reach WSHC02 was 4,135 feet in length and ended at the culverted segment of the reach above Hillcrest Avenue. Reach WSHC02 was characterized by a low width to depth ratio (8.5), a moderately entrenched channel (ER=1.8) and a relatively steep slope (4.7%) which classified the channel as a B4a stream type based upon the Rosgen classification system. The composite USAM score (Figure 3-46) for reach WSHC02 was (96/160).

3.2.1.5.2 WSHC04

Reach WSHC04 began as a culverted segment downstream of Hillcrest Avenue and ended at the confluence of Hillcrest Run and Wissahickon Creek. In total, WSHC04 was 1,468 feet in length. There was a rather large impoundment caused by WSdam106, which was located within the Morris Arboretum complex. Reach WSHC04 was characterized by a low width to depth ratio, a relatively steep slope (4.7%) and a channel that was not entrenched as was observed in reach WSHC02 (ER=3.6). The gravel-dominated reach was classified as a B4a stream type and had a composite USAM score of (92/160).

3.2.1.6 SUMMARY OF UNIFIED STREAM ASSESSMENT RESULTS

The mean scores for both the *Overall Stream Condition* components as well as the composite USAM score were classified as "suboptimal" (Table 3-46). Average conditions within the Hillcrest Run watershed's stream channels were considerably better than conditions observed within the buffers and floodplains. The watershed averages for the *Overall Stream Condition* component as well as the composite USAM were much higher than the respective All Reaches averages, however the *Overall Buffer and Floodplain* component was relatively low compared to the All Reaches average. The scores for individual parameters ranged from poor to optimal, displaying similar levels of variability between reaches.

Table 3-46: USAM Results for Hillcrest Run Watershed

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP Condition	USAM Score
WSHC02	Hillcrest	57	39	96
WSHC04	Hillcrest	53	39	92
WSHC mean		**55**	**39**	**94**
All Reaches Average		**42.4**	**44.5**	**86.9**

3.2.1.6.1 SUMMARY OF OVERALL STREAM CONDITION SCORES IN THE HILLCREST RUN WATERSHED

The scores for the individual parameters of the *Overall Stream Condition* component of the USAM analysis were generally moderate to high as some parameters were ranked among the highest scores recorded for the large, Lower Wissahickon tributaries. In fact, of the twenty-two large tributary reaches assessed, the two Hillcrest Run reaches had two of the top five *Overall Stream Conditions* scores at (57/80) and (53/80). The mean watershed score (55/80) was rated as "suboptimal" and was considerably higher than the All Reaches average score (42.4/80) which was rated towards the lower end of the "suboptimal" classification.

Two parameters had significant importance in terms of their scores relative to the average conditions observed in the Lower Wissahickon. The watershed mean scores for the *Bank Erosion* and *Floodplain Connection* parameters, which were observed to be low to moderate throughout most of the Lower Wissahickon, were rated as "suboptimal." The mean scores for the left and right banks of the corridor were the highest observed in the Lower Wissahickon and the *Floodplain Connectivity* score for reach WSHC02 was the highest score observed for this parameter (tied with reach WSKL06).

Table 3-47: USAM Overall Stream Condition Scoring for Hillcrest Run Watershed

OVERALL STREAM CONDITION								
Reach ID	Sub-watershed	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	Overall Stream Condition
			Left	Right	Left	Right		
WSHC02	Hillcrest	13	5	5	8	8	18	57
WSHC04	Hillcrest	13	5	5	9	9	12	53
WSHC mean		**13**	**5**	**5**	**8.5**	**8.5**	**15**	**55**
All Reaches Average		**13.1**	**4.9**	**4.9**	**6.3**	**7.0**	**6.3**	**42.4**

3.2.1.6.1.1 INSTREAM HABITAT

Scores for the *Instream Habitat* parameter were consistent throughout both reaches in the Hillcrest Run watershed as both reaches were rated as "suboptimal" with scores of (13/20). The watershed mean was negligibly smaller than the All Reaches average (13.1/20). The reaches in Hillcrest Run were characterized by their abundance of stable cobble and boulder substrate which comprised 27% and 14% of the substrate respectively. There was a lack of large coarse woody debris which prevented these reaches from attaining an "optimal" rating however, instream macrophytes were observed in reach WSHC02.

3.2.1.6.1.2 VEGETATIVE PROTECTION

Both banks of reaches WSHC02 and WSHC04 had moderate amounts of bank vegetation and were rated as "marginal." The All Reaches averages for both banks were slightly lower at (4.9/10). The moderate scores for this parameter are attributed to the patchy (although dense) distribution of vegetation along the stream banks. Furthermore, the presence of bedrock outcrops along the stream banks along with erosion along the toe of the banks in these reaches may have precluded the establishment of some vegetation types.

3.2.1.6.1.3 BANK EROSION

Instances of severe bank erosion were minimal throughout the Hillcrest Run watershed. The mean watershed scores for the left and right banks were both (8.5/10) which rated as "suboptimal." The right and left banks of the Hillcrest Run watershed had the highest average scores among all the large tributaries as these averages were much higher than the All Reaches averages for the left (6.3/10) and right (7.0/10) banks which were rated towards the lower end of the "suboptimal" classification. The high scores in this watershed can be attributed to the presence of boulders and bedrock outcrops which offered "toe protection" along most of the length of the creek (although some segments were artificially channelized).

3.2.1.6.1.4 FLOODPLAIN CONNECTION

Scores for the *Floodplain Connection* parameter were among the best scores observed in the Lower Wissahickon. The watershed average score (15/20) was rated as "suboptimal" and was considerably greater then the All Reaches average score (6.3/20) which was rated towards the lower end of the "marginal" classification. The score for reach

WSHC02 (18/20) was rated as "optimal" and was the highest score recorded on the Lower Wissahickon (along with WSKL06). The high degree of floodplain connectivity in the Hillcrest Run watershed is an atypical observation considering the highly urbanized nature of the Wissahickon Creek Watershed and the dense distribution of infrastructure along Hillcrest Run. The presence of boulders and bedrock outcrops within these reaches likely prevented extensive channel incision.

3.2.1.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE HILLCREST RUN WATERSHED

The scores for the individual parameters of the *Overall Buffer and Floodplain Condition* component of the USAM analysis were all low to moderate except for the *Vegetated Buffer Width* parameter. The mean component score for the Hillcrest Run watershed (39/80) was less than the All Reaches average (44.5/80). The reduced function of the floodplains in this watershed can be attributed to a number of factors, with the most influential being development and its associated infrastructure.

There are numerous dams, bridges, culverts and channelized segments on Hillcrest Run, all with distinct impacts on the hydraulic regime of the reach. These impacts culminate in changes in the magnitude and hydraulic properties of flows within the watershed's channels and ultimately influence or restrict dominant floodplain processes such as flooding and sub-surface return flows. The timing, duration and frequency of many floodplain processes or the lack thereof, has vast ecological impacts on riparian fauna, vegetation types and the existence, persistence and maintenance of floodplain habitat.

Table 3-48: USAM Buffer and Floodplain Condition Scoring for Hillcrest Run Watershed

OVERALL BUFFER AND FLOODPLAIN CONDITION							
Reach ID	Sub-watershed	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	Overall Buffer/FP Condition
		Left	Right				
WSHC02	Hillcrest	9	9	6	5	10	39
WSHC04	Hillcrest	9	9	8	7	6	39
WSHC mean		**9**	**9**	**7**	**6**	**8**	**39**
All Reaches Average		**8.1**	**8.6**	**13.8**	**5.5**	**8.5**	**44.5**

3.2.1.6.2.1 VEGETATED BUFFER WIDTH

The widths of the vegetated buffers in both reaches of the Hillcrest Run watershed were rated as "optimal" such that on both the right and left side of the corridor, there were greater than 50 feet of un-impacted riparian zones along the majority of the reach. The mean watershed scores (9/10) for both sides of the corridor were higher than the All Reaches averages for both the right (8.1/10) and the left (8.6/10).

3.2.1.6.2.2 FLOODPLAIN VEGETATION

The dominant vegetation types throughout the reach were shrubs, understory trees, mowed turf and groundcover vegetation. There was a sparse distribution of large, mature trees in reach WSHC02, which had a score of (6/20) for this parameter. In some segments of reach WSHC02, there were distinct patches of both bare vegetation as well as mowed turf grass, often up to the edge of the streambank, which was a primary factor in the "marginal" rating at this site. In reach WSHC04, mature trees were much more abundant than they were in the upstream reach WSHC02. Most of the mature trees in reach WSHC04 were present in a clustered distribution at the top of the reach- west of Hillcrest Road. The mean watershed score (7/20) was rated as "marginal", which was considerably lower than the All Reaches average (13.8/20) which was rated as "suboptimal."

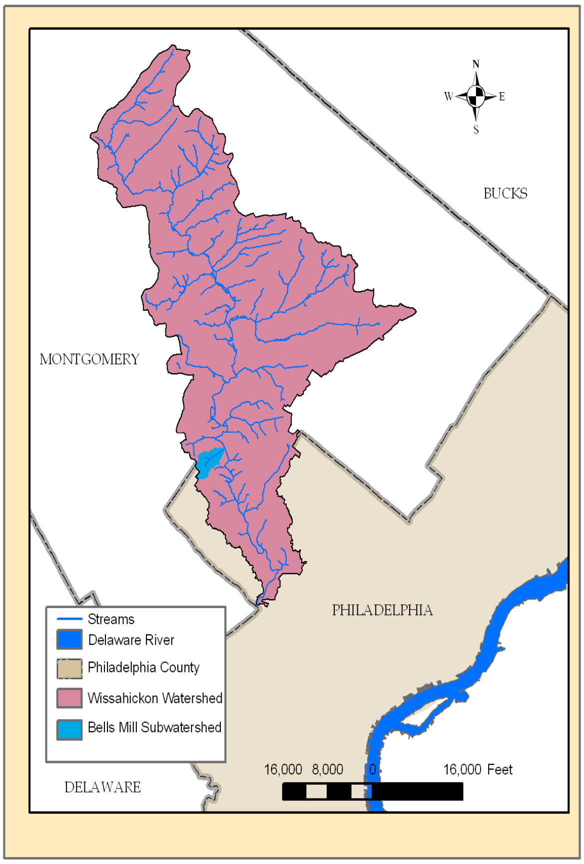
3.2.1.6.2.3 FLOODPLAIN HABITAT

Floodplain habitat was limited throughout the Hillcrest Run watershed. One of the primary causes of habitat limitation was the extent of artificial channelization observed throughout the watershed, especially in reach WSHC04 which was over 90% channelized. Reach WSHC04 had the potential to have more suitable floodplain habitat due to the entrenchment ratio (3.6) which suggest the channel has access to the floodplain during most bankfull events; however, the highly channelized reach was embedded within a highly manicured landscape where flooding was invariably removed from the channel's hydraulic regime. The mean watershed score for this parameter (6/20) was rated as "marginal" and was slightly higher than the All Reaches average score (5.5/20) which was also rated as "marginal."

3.2.1.6.2.4 FLOODPLAIN ENCROACHMENT

Scores for the *Floodplain Encroachment* parameter were low to moderate throughout the watershed. Scores were limited by the extent of development, landscaping and infrastructure which were all very pervasive throughout the watershed. The highest score was recorded in reach WSHC02, which ultimately had a higher density of infrastructure, but it was not as extensively channelized as reach WSHC02. The mean score for the watershed was (8/20) which was slightly lower than the All Reaches average score of (8.5/20) although both averages were rated as "marginal".

3.2.2 Bell's Mill Run Watershed and Reach Characteristics



Bell's Mill Run is a second-order tributary to the main stem of the Wissahickon Creek. The tributary arises from an outfall near the intersection of Lykens and Bell's Mill roads. It then travels parallel to Bell's Mill Road for approximately 5,100 feet before the Confluence with the Wissahickon main stem. The tributary runs through a wooded area of Wissahickon Park; however, there are instances when the streambanks abut Bell's Mill Road. A small un-named tributary enters Bell's Mill approximately 1,300 feet from the headwaters.

Bell's Mill can be characterized as a type B stream for 400 feet until stormwater outfall (WSout472) discharges into it. At this point the tributary becomes entrenched and over-widened. Substrate is composed mainly of course gravel, cobble, and bedrock.

The watershed is a total of 328 acres. The majority of the watershed is comprised of wooded (50%), and residential area (44%). Minor components include parking (2%), agriculture (2%), and commercial area (1%).

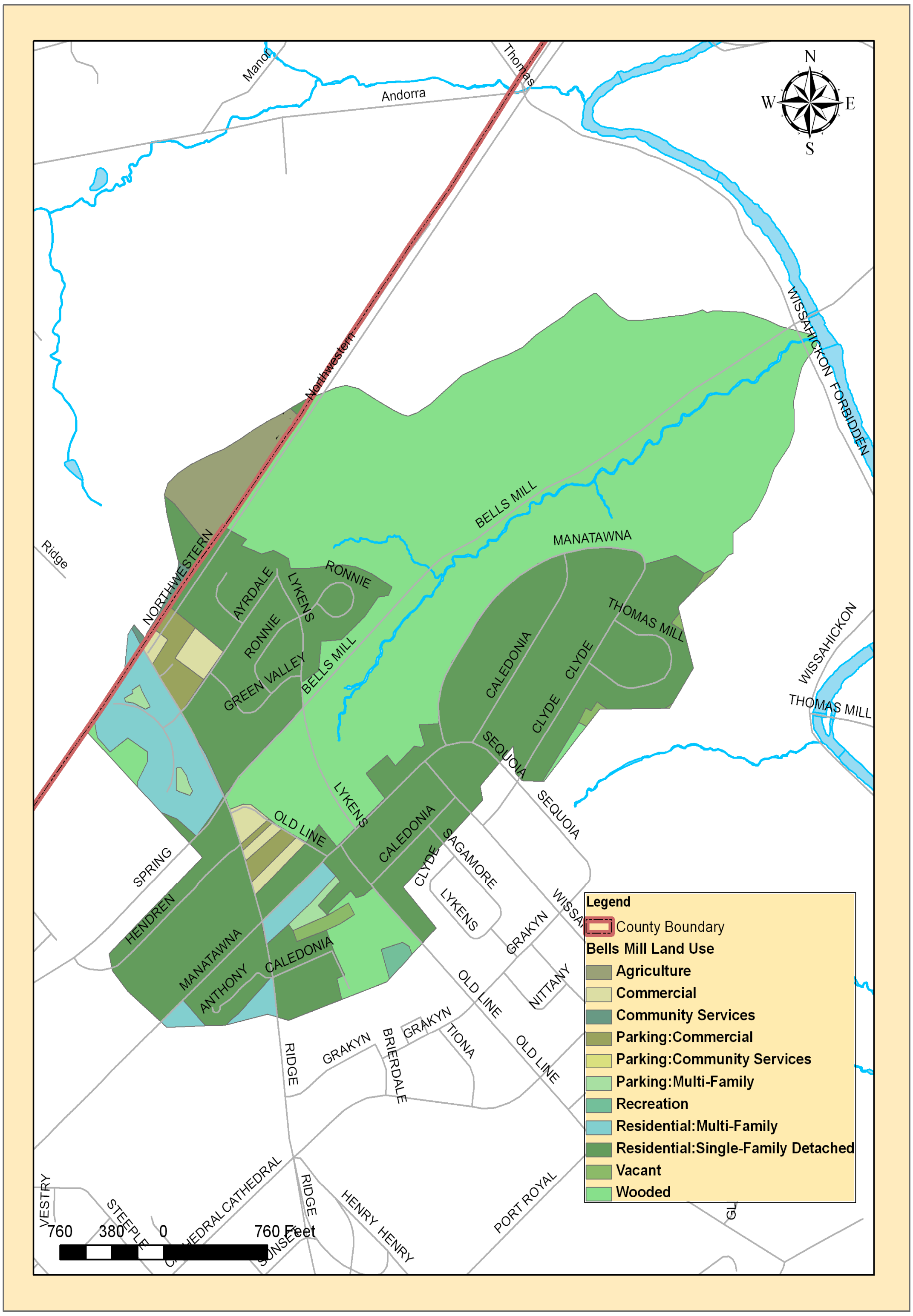


Figure 3-47: Bell's Mill Run Watershed Land Use

3.2.2.1 GEOLOGY

The majority of the Bell's Mill watershed is underlain by the Wissahickon Formation. The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

There is a band of Ultramafic rocks in the location of Bell's Mill Run. Ultramafic rocks are igneous rocks that contain very low silica content. Ultramafic rocks possess good surface drainage while being highly resistant to weathering at the same time.

3.2.2.2 SOILS

According to the National Resource and Conservation Service Soil Survey, the majority of soils for the Bell's Mill Run watershed are classified as hydrologic group B. These soils have a moderate rate of infiltration when the soils are wet. Water movement through these soils is considered moderately rapid. There is a band of alternating B and C soils along Bell's Mill Run. Combined, these soils have a slow rate of infiltration when saturated increasing the runoff potential.

Table 3-49: Distribution of NRCS Soil Types in Bell's Mill Run Watershed

Group	Area (ft^2)	Percent of Total Area
B	14,033,360	98.22%
C	95,727	0.67%
D	158,593	1.11%
Total Area	**14,287,680**	**100%**

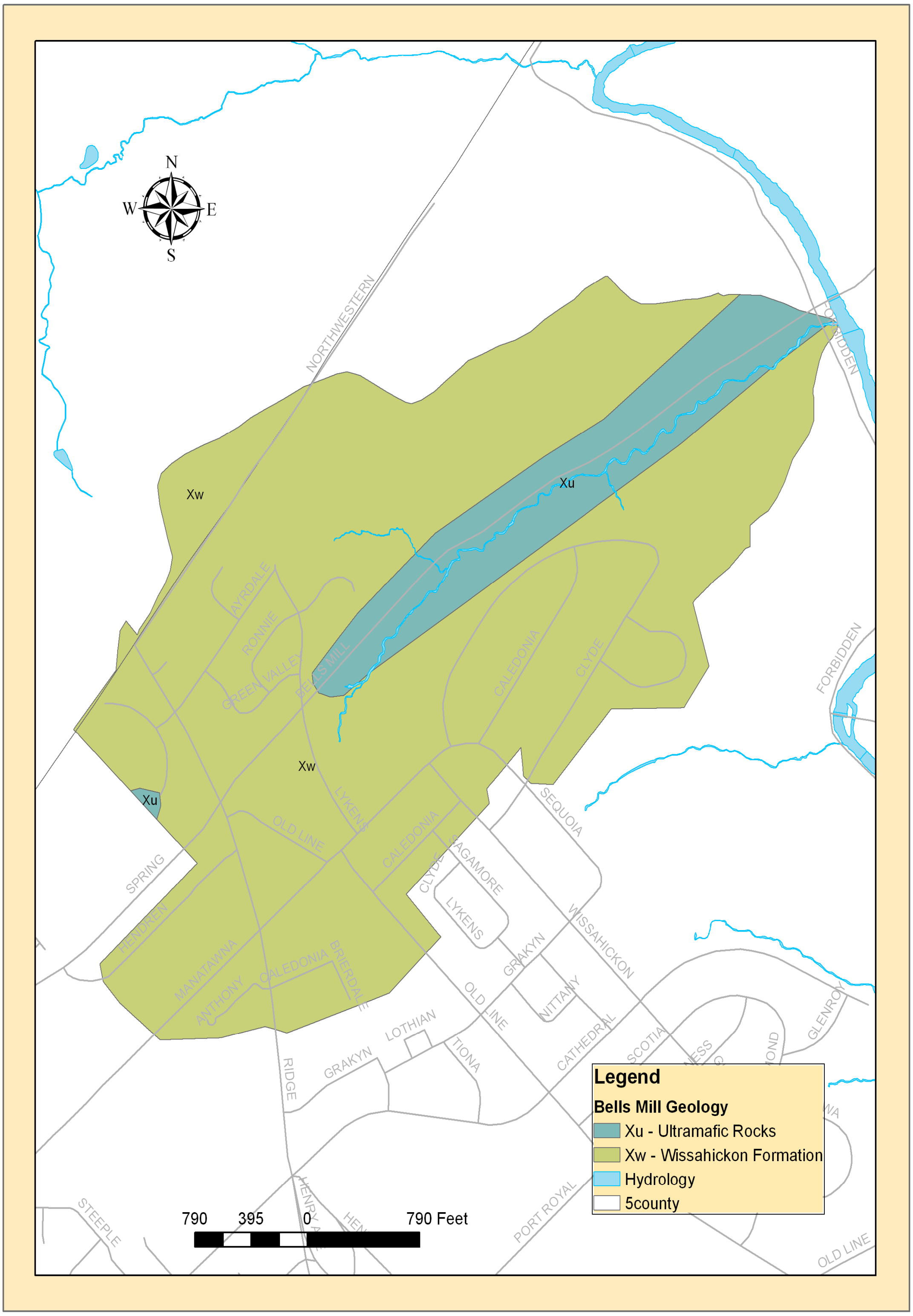


Figure 3-48: Geology of Bell's Mill Watershed

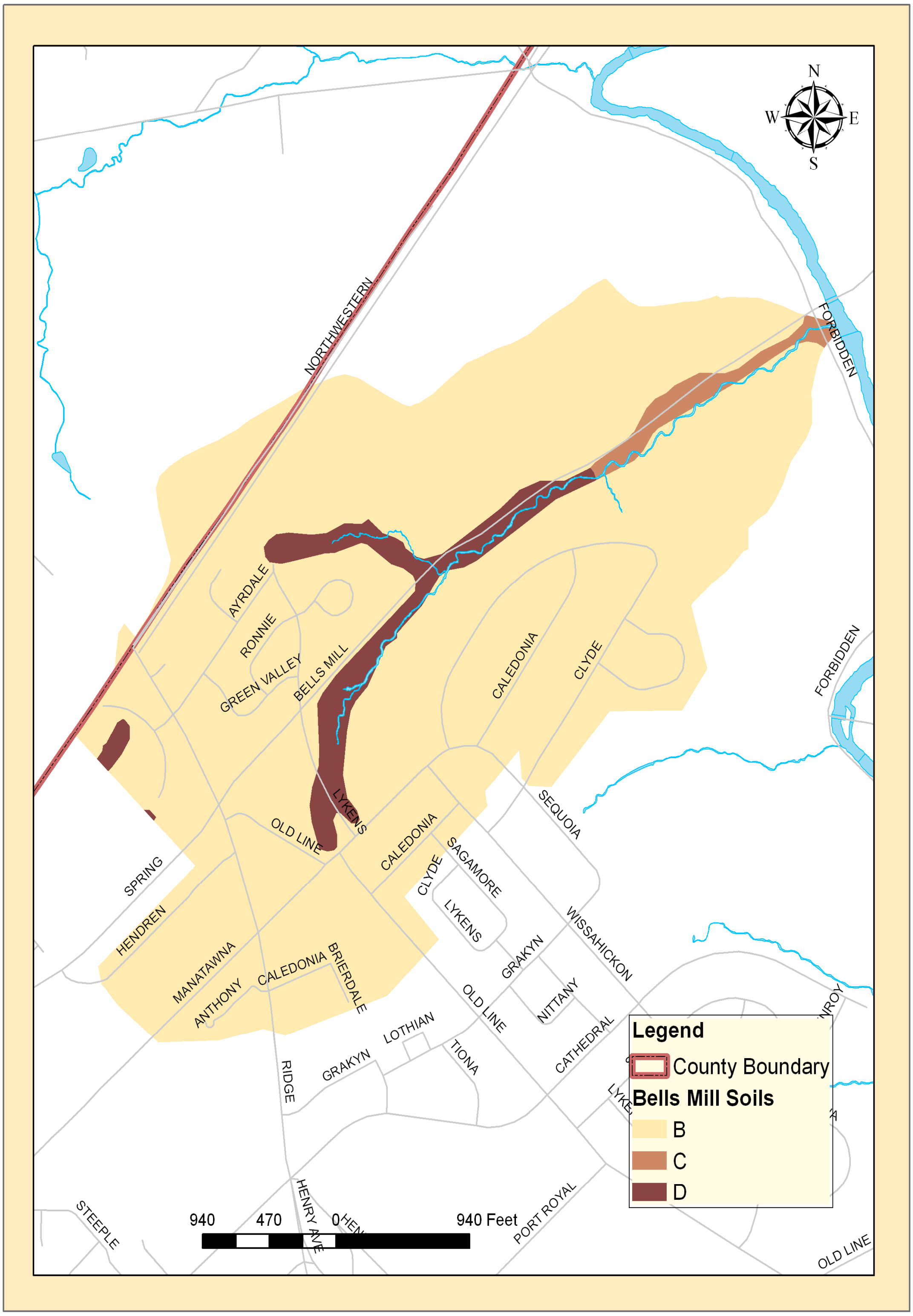


Figure 3-49: Distribution of NRCS Soil Types in Bell's Mill Run Watershed

3.2.2.3 BANK EROSION

There were 13 bank pin locations along Bell's Mill Run (Figure 3-50). The calculated erosion rates are included in Table 3-50. The spatial distribution of BEHI assessment results were represented graphically (Figure 3-50) for each of the segments assessed on Bell's Mill Run. Each bank within a respective segment was assessed and rated separately; however, channelized and culverted segments were not assessed as they confer a high degree of protection from bank erosion.

Table 3-50: Bell's Mill Run Bank Pin Locations

	BEHI	NBS	Baseline Reading	Most Recent Reading	Erosion Rate (ft)	Erosion Rate (ft/yr)	Eroding (-) or Aggrading (+)
Bell's Mill							
BM1120	Moderate	Low	5/11/2006	8/11/2008	0.14	0.063	A
BM13	High	Low	11/7/2005	8/12/2009	-0.81	-0.21	E
BM16	High	Extreme	11/13/2006	8/12/2009	-0.49	-0.18	E
BM21	Moderate	High	11/7/2005	8/12/2009	-0.92	-0.24	E
BM2450	Moderate	Low	5/11/2006	8/11/2008	-0.16	-0.072	E
BM25	Moderate	Moderate	11/7/2005	8/11/2008	-1.04	-0.38	E
BM31	High	Low	11/7/2005	8/11/2008	-0.29	-0.10	E
BM35	High	Moderate	8/7/2007	8/11/2008	0.56	0.56	A
BM4	Moderate	Low	11/7/2005	11/13/2006	-0.040	-0.039	E
BM414	Low	Very Low	8/18/2006	8/12/2009	0.37	0.12	A
BM422	Low	Very Low	8/18/2006	8/11/2008	0.29	0.15	A
BM530	Low	Low	5/15/2006	8/11/2008	-0.19	-0.086	E
BM8	High	High	8/18/2006	8/12/2009	0.15	0.050	A

Total erosion rates were also calculated for the entire length of each tributary within the lower Wissahickon (Table 3-51). To assess the normalized erosion potential of each tributary, the erosion rate per acre of drainage area per year and the erosion rate per foot of stream length per year were calculated. This allowed direct comparison between each of the tributaries with respect to both watershed size and the length of the tributary. Bell's Mill Run was ranked fifth out of the twelve tributaries within the lower Wissahickon for erosion rate per foot of stream length. The rankings were based on a scale of one being the highest erosion rate and twelve being the lowest erosion rate.

Table 3-51: Erosion Rates for Lower Wissahickon Tributaries

Tributary	Drainage Area (Acres)	Stream Length (feet)	*2009*		
			Erosion Rate (lb/yr)	*Erosion Rate Per Acre*	*Erosion Rate Per Foot of Stream*
Bell's Mill	323	6,722	420,000	1,307	63
Cathedral Run	160	2,790	150,000	913	52
Cresheim Creek	1,218	16,431	840,000	690	51
Gorgas Run	499	2,170	170,000	345	79
Hartwell Run	217	3,530	200,000	918	56
Hillcrest	144	5,272	90,000	597	16
Kitchen's Lane	234	7,753	200,000	850	26
Monoshone Creek	1,056	6,926	160,000	156	24
Rex Ave	137	1,903	150,000	1,131	81
Thomas Mill Run	104	4,008	320,000	3,058	79
Valley Green Run	128	2,874	140,000	1,086	48
Wise's Mill Run	446	7,056	490,000	1,090	69
Total/*Average*	**4,666**	**67,435**	**3,300,000**	***1,012***	***54***

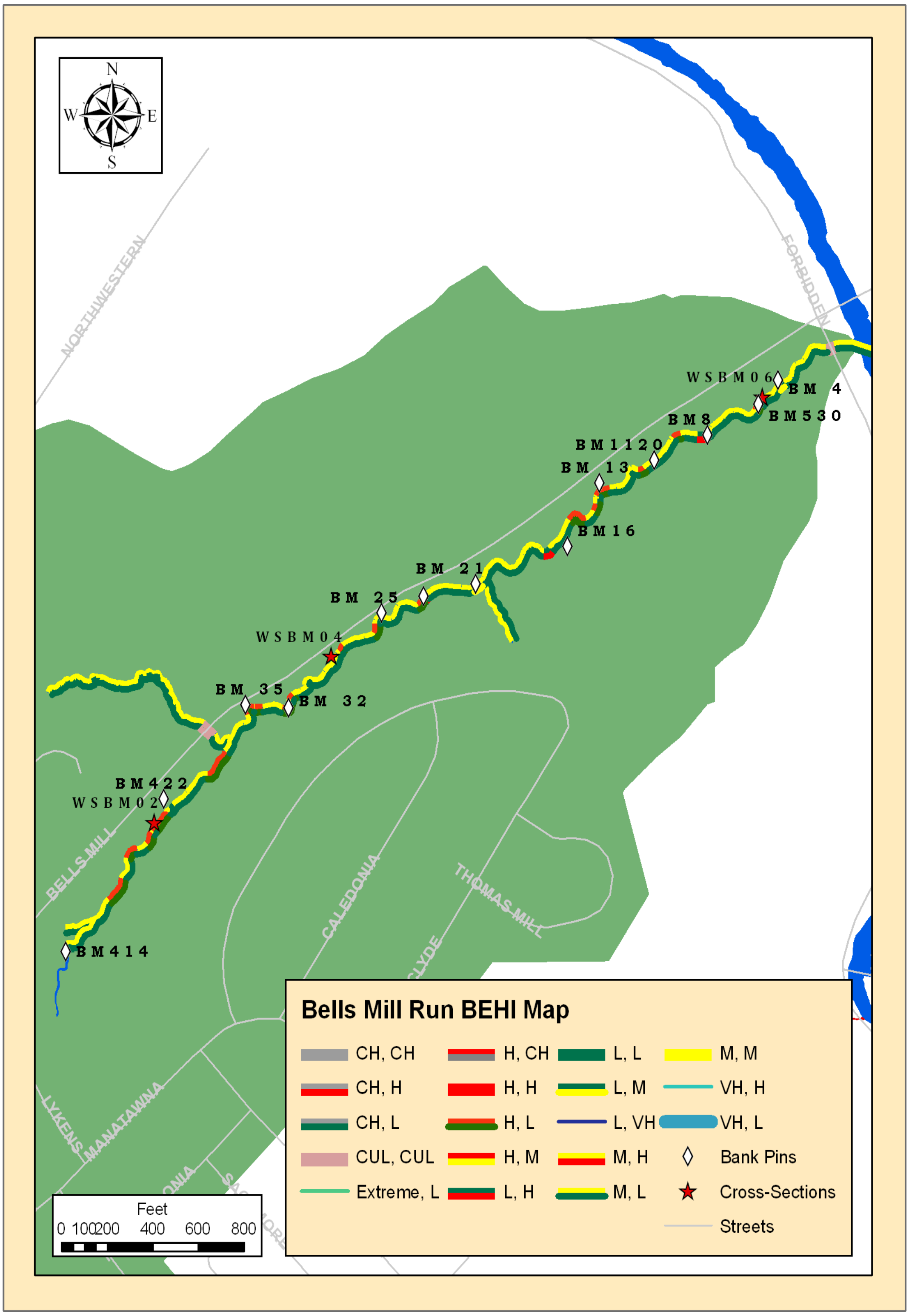


Figure 3-50: Bell's Mill Watershed BEHI Ratings and Bank Pin Locations

3.2.2.4 INFRASTRUCTURE TRACKDOWN SUMMARY

Bell's Mill Run is completely within Fairmount Park, although the sections of the Park closest to the upstream-most portion of the watershed are surrounded by residential neighborhoods and associated roadways. As such, the infrastructure in the Bell's Mill Run watershed reflected the drainage requirements of the dense urban development in the area near the stream. There were numerous outfalls and manholes, both of which comprised the vast majority of infrastructure in the reach. The high number of manholes can be attributed to the 12-inch diameter sanitary sewer line that runs parallel to Bell's Mill Run and passes underneath the stream upstream of the mouth and connects with the Wissahickon Low Level Interceptor about 120 feet south.. About 80 feet downstream of the start of reach WSBM06, the 12-inch sanitary sewer line from Manatawna Avenue crosses under the stream from right to left and connects to the pipe running adjacent to the stream. The large number of outfalls was attributed to Bell's Mill Road and the surrounding neighborhoods which contribute stormwater runoff to the stream. The largest outfall was privately owned outfall WSout473, located on the downstream right at the start of reach WSBM06. This outfall conveys discharge from a 36-inch pipe stemming from Manatawna Avenue.

The only other infrastructure elements throughout Bell's Mill Run were two culverts (WScul081 and WScul083) and a channel (WScha103). WScul083 was located underneath Bell's Mill Road on a small tributary and WScul081 conveyed the stream under Forbidden Drive before the confluence with the main stem of Wissahickon Creek. While these culverts confined the stream locally, they only constituted 2% of the entire stream length. The 39 feet of rip-rap channel in reach WSBM04 provided vital bank protection by restricting the channel from migrating laterally towards the road adjacent to the channel. Most of the infrastructure on Bell's Mill Run is in fair or good condition as only WSout476 was found to be in poor condition due to a debris jam which restricted its flow.

Table 3-52: Summary of Bell's Mill Run Infrastructure Point Features

Section ID	Culvert Count	Outfall Count	Channel Count	Confluence Count	Manhole Count	Other Count	Infra Point Count	Combined Outfall Area (ft^2)
WSBM02	1	1	0	5	1	5	3	12.57
WSBM04	0	4	1	0	2	0	7	6.05
WSBM06	1	2	0	0	6	0	9	16.77
TOTAL	**2**	**7**	**1**	**5**	**9**	**5**	**19**	**35.39**

Table 3-53: Summary of Bell's Mill Run Infrastructure Linear Features

Section ID	Segment Length (ft)	Culvert Length (ft)	Percent Culverted	Channel Length (ft), 1 side	Total Channel Length (ft)	Percent Channelized
WSBM02	2858	68	2	0	0	0
WSBM04	1838	0	0	39	39	0.7
WSBM06	1782	35	2	0	0	0
TOTAL	**6478**	**103**	**2**	**39**	**39**	**0.20**

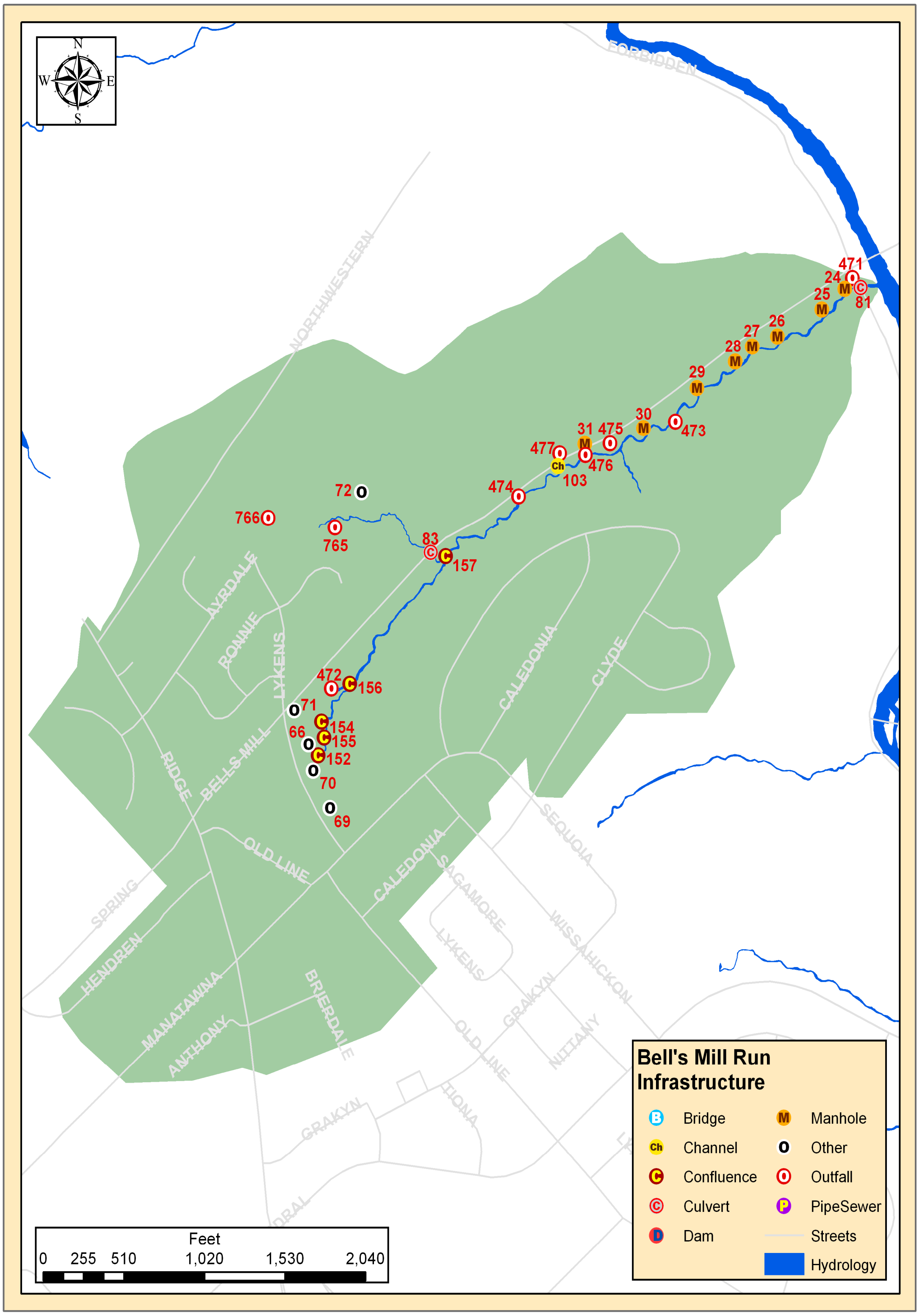


Figure 3-51: Bell's Mill Run Infrastructure Locations

Figure 3-52: Bell's Mill Run Infrastructure in Poor Condition

3.2.2.5 Unified Stream Assessment Results for the Bell's Mill Run Watershed

The Bell's Mill Run watershed's main stem was characterized by a rather shallow gradient, second-order channel. All three of the reaches assessed were dominated by gravel, although there were considerable amounts of cobble present throughout the main stem channel. Isolated segments within reaches WSBM02 and WSBM04 were bedrock-controlled.

The entire main stem channel, its tributaries and a large portion of the watershed were located within the boundaries of Fairmount Park. Greater than 95% of the watershed lies within the Greater Philadelphia proper however there was a small portion of the watershed located on the Montgomery County side of Northwestern Avenue. The Center for Watershed Protection's (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and watersheds within the Lower Wissahickon Basin.

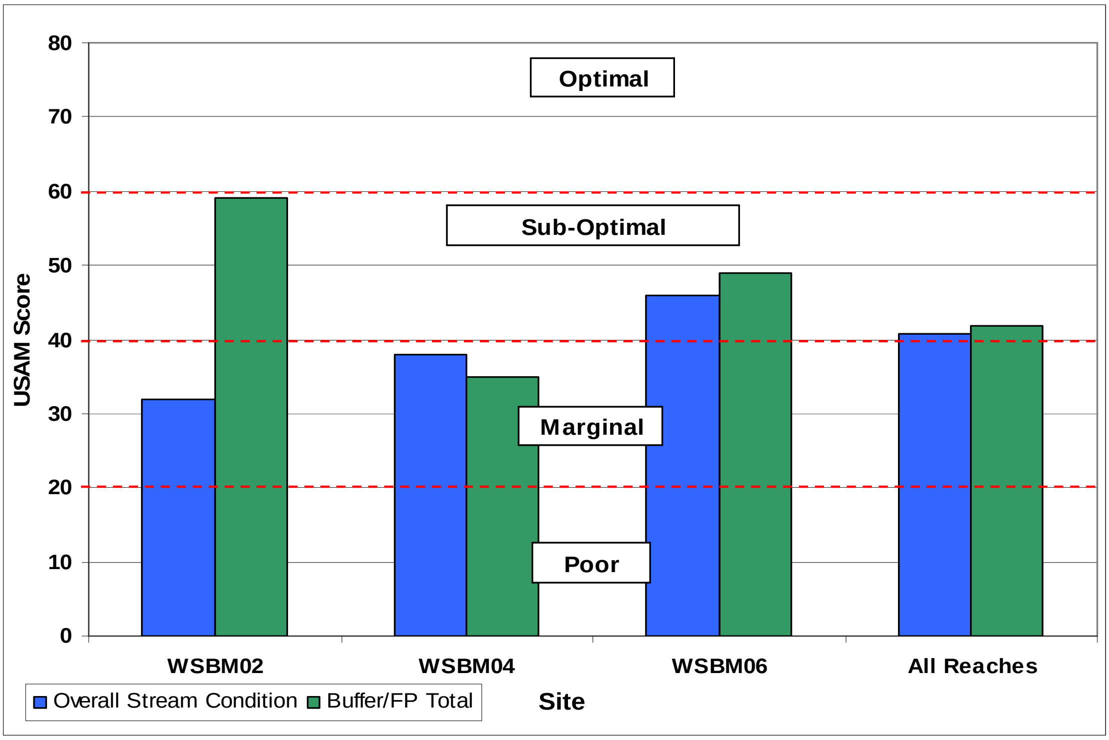


Figure 3-53: Results for Bell's Mill Run USAM Components

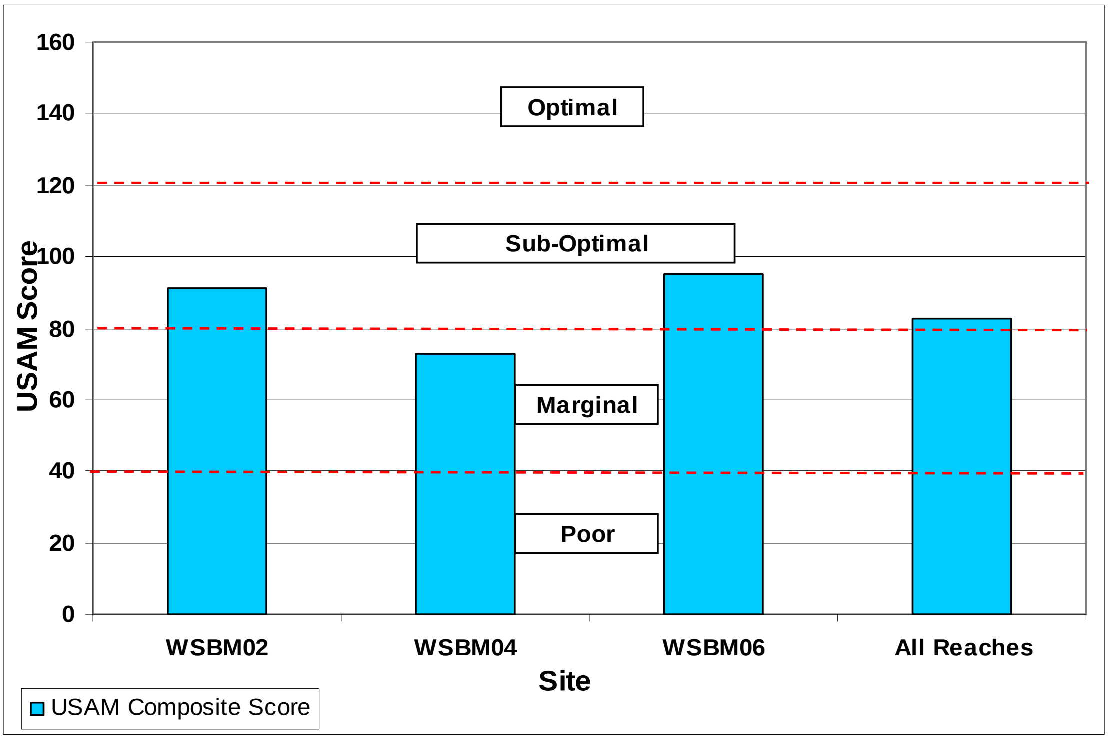


Figure 3-54: Bell's Mill Run USAM Results

3.2.2.5.1 WSBM02

Reach WSBM02 formed the headwaters of Bell's Mill Run and began about 230 feet northeast of Lykens Lane. There were two unnamed tributaries to Bell's Mill Run on reach WSBM02 as well as a number of small, zero order springs and seeps (WSmisc066,WSmisc069, WSmisc070). The upstream-most tributary was a small (125 feet), first-order tributary, which began as flow from WSout472 (W-084-02) which drains the residential neighborhood west of Bell's Mill Road. The second tributary (unnamed tributary B) was much longer (1,060 feet) and was formed as a result of groundwater return flow. Reach WSBM02 was characterized by a shallow slope (1.7%), moderate width to depth ratio (13.6) and a deeply entrenched channel. The reach was classified as a B4c type stream. The composite USAM score for reach WSBM02 was (91/160).

3.2.2.5.2 WSBM04

Reach WSBM04 began approximately 560 feet upstream from cross section WSBM04. There was one tributary (unnamed tributary A) to Bell's Mill Run on this reach, which was approximately 290 feet in length. The reach was characterized by a moderately shallow slope (2.9%), a deeply entrenched channel (ER=1.3) and a relatively high width to depth ratio (16.7). These characteristics classified the reach as a B4c type stream. The composite USAM score for reach WSBM02 was (73/160)

3.2.2.5.3 WSBM06

Reach WSBM06 began approximately 560 feet upstream from cross section WSBM06. There was one tributary (unnamed tributary A) to Bell's Mill Run on this reach, which was approximately 290 feet in length. The reach was characterized by a moderately shallow slope (2.9%), a deeply entrenched channel (ER=1.3) and a relatively high width to depth ratio (16.7). These characteristics classified the reach as a B4c type stream. The composite USAM score for reach WSBM02 was (73/160).

3.2.2.6 SUMMARY OF UNIFIED STREAM ASSESSMENT RESULTS

The mean scores for both the individual USAM components as well as the overall USAM score were classified as marginal to suboptimal (Table 3-54). Average buffer and floodplain conditions within the Bell's Mill Run stream corridors were slightly better than the average overall stream condition although there was high variability between scores for the respective USAM components among individual sites. The mean USAM composite score and *Overall Buffer and Floodplain Condition* score for the three Bell's Mill Run reaches were higher than the average scores respectively for all other reaches (excluding Bell's Mill Run reaches) in the Philadelphia portion of the Wissahickon Creek Watershed.

Table 3-54: Summary of Bell's Mill Run Infrastructure Linear Features

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP	USAM Score
WSBM02	Bells Mill	32	59	91
WSBM04	Bells Mill	38	35	73
WSBM06	Bells Mill	46	49	95
WSBM mean		**38.7**	**47.7**	**86.3**
All Reaches Average		**42.4**	**44.5**	**86.9**

3.2.2.6.1 SUMMARY OF OVERALL STREAM CONDITION SCORES IN THE BELL'S MILL RUN WATERSHED

The mean *Overall Stream Condition* score for the Bell's Mill reaches was slightly lower than the mean score for all reaches in the lower Wissahickon stream network (Table 3-55). The difference between the two scores was small yet significant in that the mean score for Bell's Mill Run reaches was below the marginal/sub-optimal threshold of 40/80. Most parameters were observed to be in the marginal to sub-optimal range for these reaches. None of the reaches on Bell's Mill Run were observed to have optimal conditions for any scoring parameter. Reach WSBM06 was the highest scoring reach (95/160) in the watershed as most of the scoring parameters were observed to be sub-optimal.

The lowest scores were observed for the *Floodplain Connection* parameter. All reaches in the watershed were rated as poor (scores of 0-5/20), which was a result of the low entrenchment ratios (1.2 – 1.3) observed for these reaches. The average score of all reaches in the lower Wissahickon (excluding Bell's Mill Run) was marginal (6.5/20). Due to the low entrenchment ratios, most flows equal to and in excess of the estimated channel-forming discharges (estimated $Q_{bankfull}$ ranged from 47.4 cfs to 62.6 cfs) for this watershed, would not reach the floodplain as these channels were deeply incised.

The highest scores observed among the Bell's Mill Run reaches were for the Instream Habitat parameter. Scores for all reaches in the watershed were rated as sub-optimal. This was the result of the very stable and complex habitat afforded by the abundant supply of cobble and small boulders observed in the watershed. Substantial amounts of CWD were also observed in all reaches.

Table 3-55: USAM Overall Stream Condition Scoring for Bell's Mill Run Watershed

OVERALL STREAM CONDITION								
Reach ID	Sub-watershed	In-Stream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	Overall Stream Condition Score
			Left	Right	Left	Right		
WSBM02	Bells Mill	13	1	1	6	7	4	32
WSBM04	Bells Mill	15	5	5	3	7	3	38
WSBM06	Bells Mill	15	8	8	5	7	3	46
WSBM mean		**14.3**	**4.7**	**4.7**	**4.7**	**7.0**	**3.3**	**38.7**
All Reaches Average		**13.1**	**4.9**	**4.9**	**6.3**	**7.0**	**6.3**	**42.4**

3.2.2.6.1.1 INSTREAM HABITAT

Scores for the *Instream Habitat* parameter were all sub-optimal (Table 3-55). Two of the three reaches were rated higher than the All Reaches average, which was also rated as sub-optimal. The relatively high scores for instream habitat were attributed to the high proportion of cobble and boulder substrate observed in these reaches. The proportion of stable substrate observed in these reaches had a high correlation with the *Instream Habitat* scores as stable particles comprised 30%, 35.5% and 41% of the substrate for WSBM02, WSBM04 and WSBM06 respectively.

3.2.2.6.1.2 VEGETATIVE PROTECTION

The *Vegetative Protection* parameter measures the extent to which stream banks and immediately adjacent riparian areas are covered by vegetation in the form of trees, shrubs and non-woody, emergent macrophytes. Scores for the *Vegetative Protection* parameter ranged from poor to sub-optimal. The reach with the highest score was WSBM06 with a score of 8/10 for both the right and left banks. The lowest scores were observed in reach WSBM02, which received scored of 1/10 for both banks; however, the mean right and left bank scores for the entire watershed were still higher than the mean score for All Reaches. Site WSBM04 was rated as marginal with a score of 5/10 for both banks although these scores were still higher than the All Reaches scores for both the left and right banks (4.9/10).

The low scores for this parameter were most likely the result of channel incision observed throughout this watershed. Localized scour evidenced by exposed tree roots, was noted in each of the Bell's Mill reaches. The high degree of incision in these reaches has created nearly vertical banks in many areas, which precluded the establishment of rooted vegetation along the banks of Bell's Mill Run. The mean score for both the right and left banks of Bell's Mill Run was 4.7/10, which is classified as marginal. Under USAM scoring guidelines, marginal vegetative protection is characterized by obvious disruptions of vegetative production such as bare patches of soil or closely cropped patches of vegetation such that only 50-70% of the streambank surface is covered by vegetation.

3.2.2.6.1.3 Bank Erosion

Scores for the *Bank Erosion* parameter were all sub-optimal for the right bank and ranged from poor to marginal for the left bank. Scores for the right bank were 7/10 for all Bell's Mill Run reaches, which was equal to the "All Reaches" average of 7/10 for the right bank. The highest score for the left bank was observed in reach WSBM02 (6/10) and the lowest score was observed in reach WSBM04 (3/10). None of the Bell's Mill Run reaches scored higher than the "All Reaches" average of (6.3/10) for the left bank. The lower scores on the left bank can be attributed to the proximity of Bell's Mill Road to the channel, which was less than 30 feet from Bell's Mill Road in a number of locations along each of the reaches. The proximity of the road to the stream corridor left the corridor susceptible to high peak flows following storm events as well as hillside erosion from the sheet flow draining from the road. These issues were further exacerbated by the steep valley wall on the DSL side of the valley which increased the velocity of the stormwater runoff draining from the road.

3.2.2.6.1.4 Floodplain Connection

Scores for the *Floodplain Connection* parameter were rated "poor" for all Bell's Mill Run reaches. The mean score for Bell's Mill Run (3.3/10) was substantially lower than the 'All Reaches" average (6.3/10), which was rated "marginal". As mentioned previously, the entrenchment ratios in the Bell's Mill Run watershed were very low (1.2-1.3) and indicated channel incision. Active downcutting and scour were visible on the banks throughout the watershed. Extreme incision ultimately prevents flood waters from entering the floodplain, which has adverse impacts on riparian vegetation and productivity. As the water table lowers, the soils of the streambank do not adequately support vegetation and become less cohesive, making them susceptible to more erosion and channel widening.

3.2.2.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE BELL'S MILL RUN WATERSHED

The *Overall Buffer and Floodplain* component of the USAM composite score was rated "marginal" for the Bell's Mill Run watershed. Scores for individual parameters exhibited substantial variation, ranging form poor to optimal, with the right side of the valley exhibiting the superior condition for parameters in which the right and left banks were assessed separately. This observation was attributed to the proximity of Bell's Mill Road to the left side of the valley, such that contributions of direct runoff from the road have caused localized scour and erosion on a substantial portion of the left bank throughout the watershed. In addition, the proximity to the road has limited the establishment of an adequate riparian buffer on the left banks of the WSBM04 and WSBM06 reaches.

Table 3-56: USAM Buffer and Floodplain Condition Scoring for Bell's Mill Run Watershed

OVERALL BUFFER AND FLOODPLAIN CONDITION							
Reach ID	Sub-watershed	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	Buffer/FP Total
		Left	Right				
WSBM02	Bells Mill	10	10	19	5	15	59
WSBM04	Bells Mill	3	10	13	5	4	35
WSBM06	Bells Mill	8	10	18	5	8	49
WSBM mean		**7**	**10**	**16.7**	**5**	**9**	**47.7**
All Reaches Average		**8.1**	**8.6**	**13.8**	**5.5**	**8.5**	**44.5**

3.2.2.6.2.1 VEGETATED BUFFER WIDTH

Scores for the *Vegetated Buffer Width* parameter ranged from poor to optimal. The right bank for all three reaches was rated as optimal with a score of 10/10. These high scores reflect a vegetated buffer of at least 50 feet, although vegetated buffers on the right side of the valley were in excess of 250 feet for all reaches. Scores on the DSL bank exhibited high variability; whereas scores ranged from poor (3/10) at WSBM04 to optimal (10/10) at WSBM02. The poor rating for WSBM04 reflects the close proximity of the reach to Bell's Mill Road, in that there were substantial segments of the reach that were within 10 feet of the stream channel. Collectively, the right banks of the Bell's Mill reaches compared favorably against the mean vegetated buffer width rating of the other large Wissahickon Creek tributary reaches (8.6/10); however, the mean left bank score for the Bell's Mill reaches (7/10) was slightly lower than the mean score of all other reaches (8.1/10).

3.2.2.6.2.2 FLOODPLAIN VEGETATION

Floodplain Vegetation ratings were based upon the predominant vegetation type (i.e. shrub, mowed turf, mature forest) observed throughout the reach as well as the successional stage of the observed vegetation stands (i.e. secondary forest, mature forest).

Generally, the scores were moderately high for Bell's Mill Run as WSBM02 and WSBM04 were rated as optimal and WSBM04 was rated as sub-optimal. Compared to the mean score for all reaches (13.8/20), the Bell's Mill Run watershed (16.7/20) had a considerably higher score which was classified as optimal. Optimal floodplain vegetation is defined as land cover dominated by mature forest. WSBM04 which was rated sub-optimal was dominated by a young forest comprised of early successional species and saplings.

3.2.2.6.2.3 FLOODPLAIN HABITAT

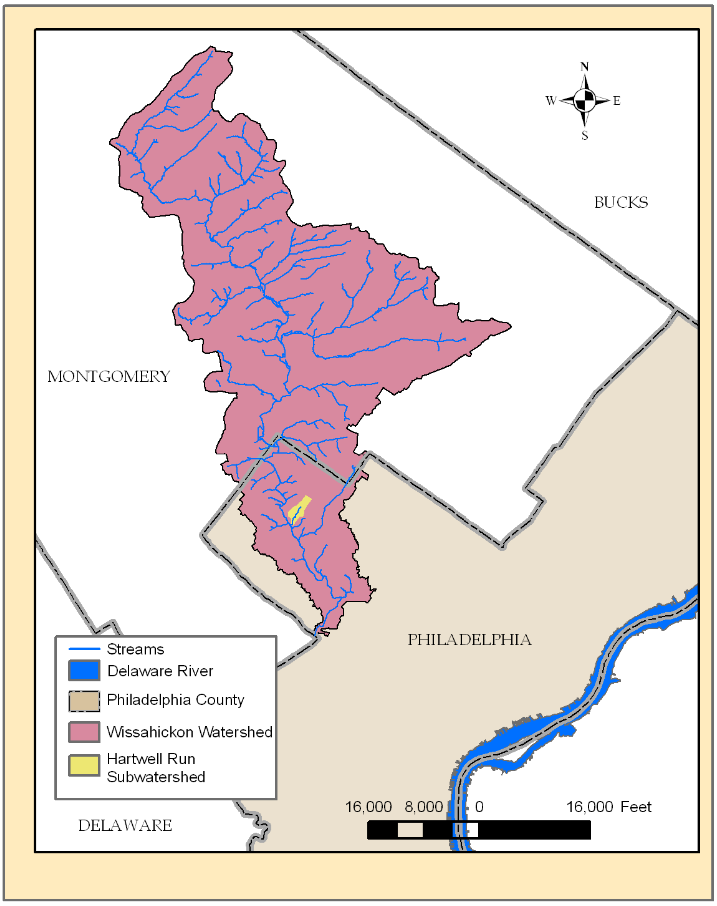
Floodplain Habitat scores were generally low in the Bell's Mill Run watershed. All sites were rated as poor due to the low entrenchment ratio observed at the three reach cross sections. The deeply incised channel precluded the inundation of the floodplain which resulted in poor floodplain habitat as wetland and riparian vegetation can not become established. Most of the reaches analyzed in this study also had poor floodplain habitat. The floodplain habitat score for Bell's Mill Run (5/10) was slightly lower than the "All reaches" mean score of 5.5/10.

3.2.2.6.2.4 FLOODPLAIN ENCROACHMENT

The *Floodplain Encroachment* parameter evaluates the level of floodplain disturbance attributed to human activities and man-made structures such as buildings, roads and other infrastructure or fill material. Scores for this parameter ranged from poor to sub-optimal. The mean score for the Bell's Mill Run reaches was 9/20, which was slightly higher than the mean score for "All Reaches" which was 8.5/20.

The reach that had the least amount of human-related floodplain disturbance was WSBM02 with a score of 15/20. There were short segments of this reach that were close to Bell's Mill Road, although the majority of this reach had extensive floodplain area free of intrusive structures that would adversely affect floodplain function. Conversely, within reach WSBM04 there were considerable segments of the reach where the channel was within 35 feet of Bell's Mill Road on the downstream right side of the valley wall. Reach WSBM06 was rated as marginal due to the fact that most of the reach was greater than 70 feet from Bell's Mill Road.

3.2.3 HARTWELL RUN WATERSHED AND REACH CHARACTERISTICS



Hartwell Run is a tributary to the main stem of the Wissahickon Creek. Hartwell Run originates within the City of Philadelphia. The tributary originates from two privately owned outfalls located in a single family residential neighborhood. Hartwell Run is a first-order tributary and travels approximately 3,530 feet before the confluence with the Wissahickon main stem. The dominant substrate varies from coarse gravel to small boulder material. Both the valley floor and channel have been substantially impacted by past and current land use.

The entire Hartwell Run watershed is 217 acres. Major land use types within the watershed include: wooded (59%), residential – single family detached (35%), recreation (3%), and community service (2%). Hartwell Run is surrounded by Fairmount Park on both sides for most of its length except for the top upstream quarter of the stream. The wooded buffer ranges from 50-2,000 feet.

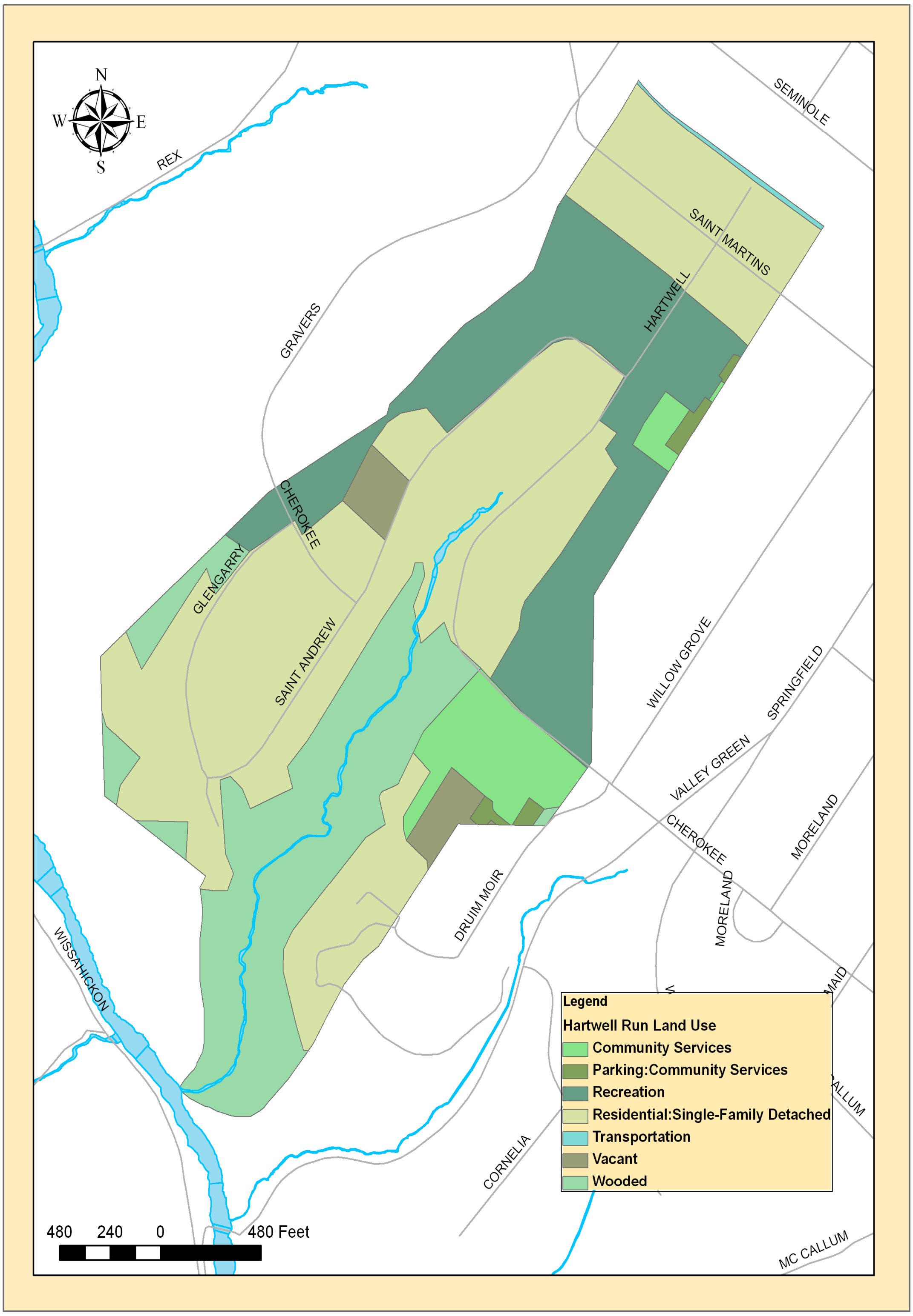


Figure 3-55: Hartwell Run Watershed Land Use

3.2.3.1 GEOLOGY

The Hartwell Run watershed is completely underlain by the Wissahickon Formation. The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

3.2.3.2 SOILS

According to the National Resource and Conservation Service Soil Survey, the soils for the entire Hartwell Run watershed are classified as hydrologic group B. These soils have a moderate rate of infiltration when the soils are wet (0.50-1.00 in/hr). Water movement through these soils is considered moderately rapid.

Table 3-57: Distribution of NRCS Soil Types in Hartwell Run Watershed

Group	Area (ft^2)	Percent of Total Area
B	9,452,520	100%
Total Area	**9,452,520**	**100%**

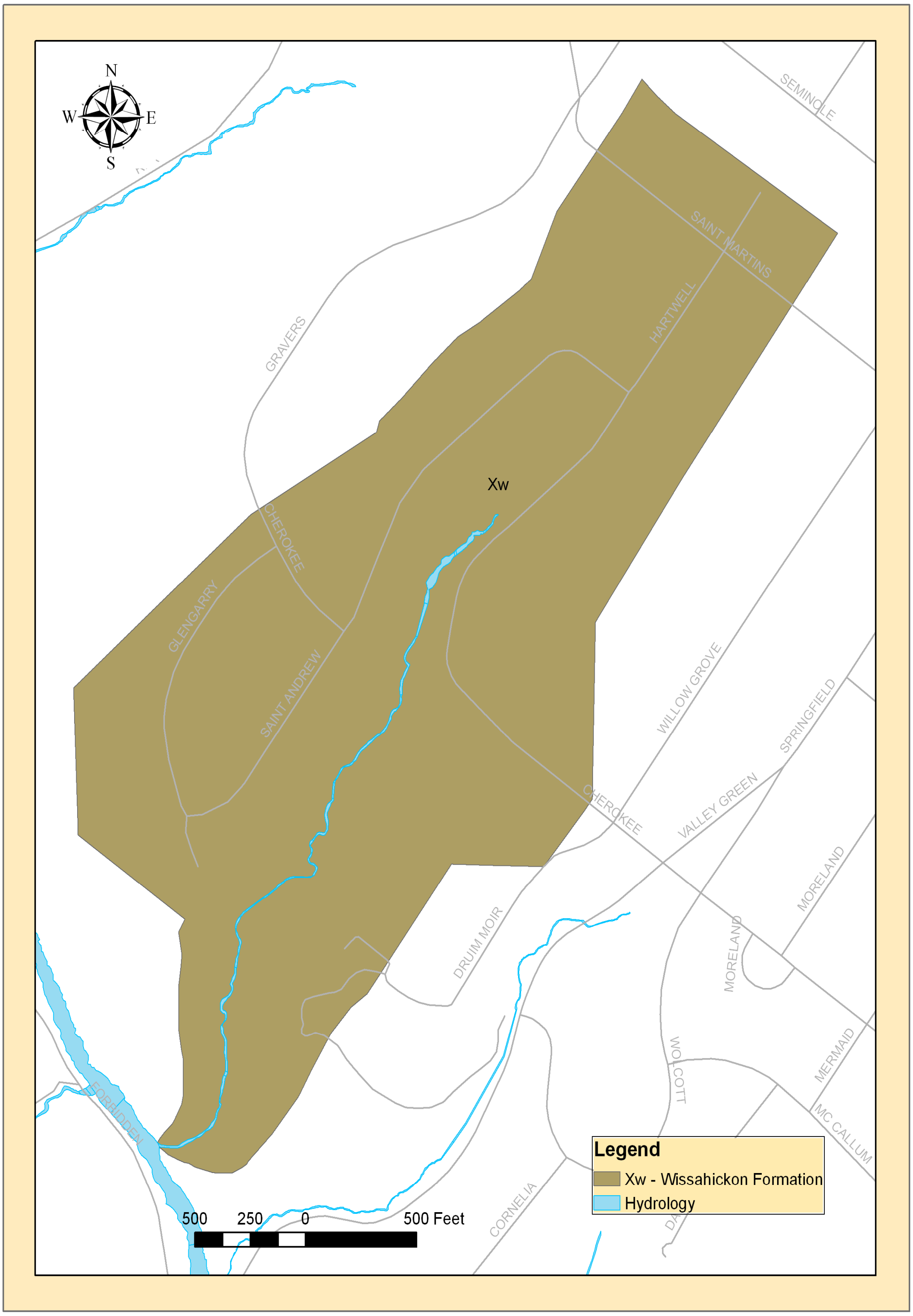


Figure 3-56: Geology of Hartwell Run Watershed

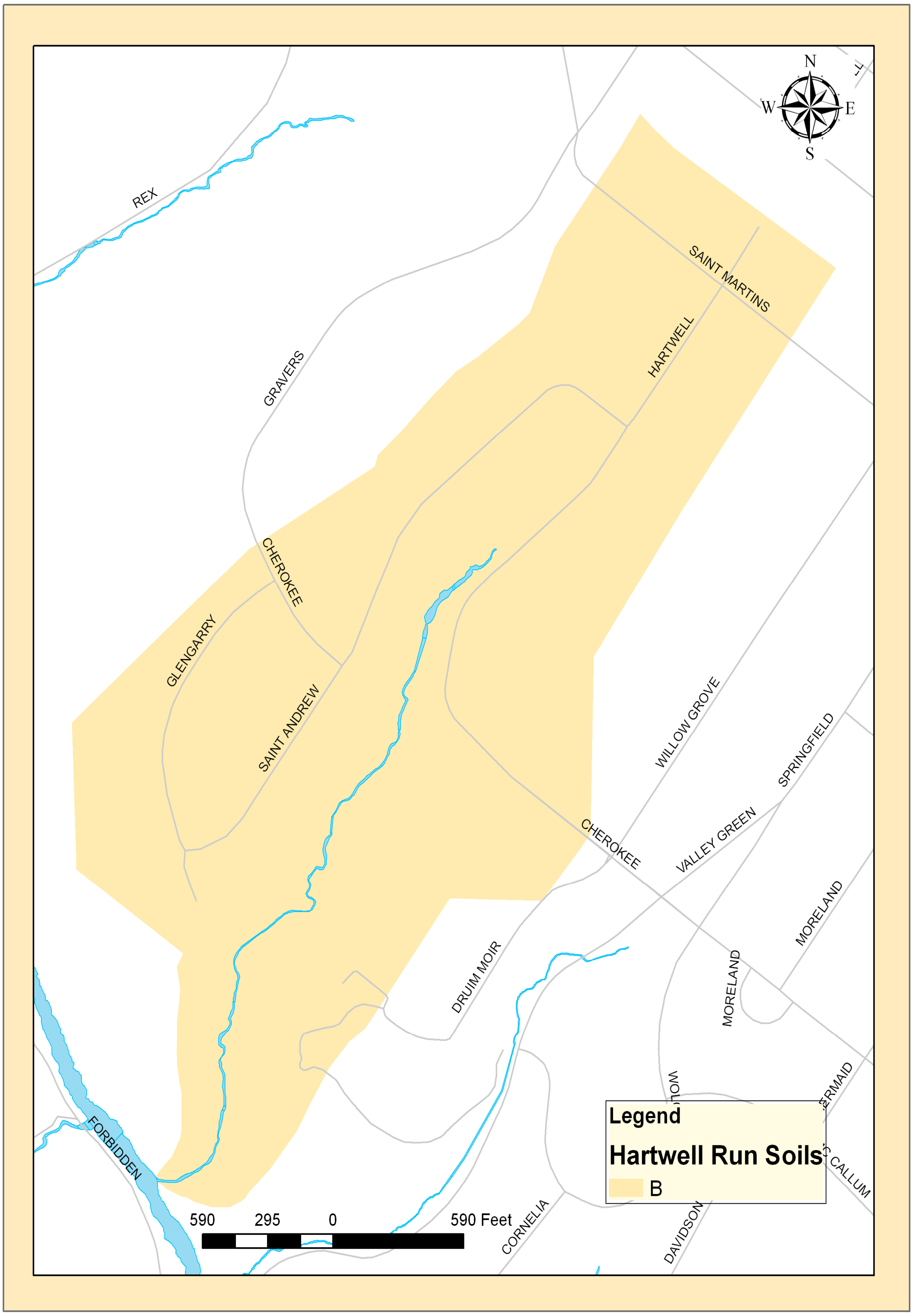


Figure 3-57: Distribution of NRCS Soil Types in Hartwell Run Watershed

3.2.3.3 BANK EROSION

There were four bank pin locations along Hartwell Run (Figure 3-58). The calculated erosion rates are included in Table 3-58. The spatial distribution of BEHI assessment results were represented graphically (Figure 3-58) for each of the segments assessed on Hartwell Run. Each bank within a respective segment was assessed and rated separately; however, channelized and culverted segments were not assessed as they confer a high degree of protection from bank erosion.

Table 3-58: Hartwell Run Bank Pin Locations

	BEHI	NBS	Baseline Reading	Most Recent Reading	Erosion Rate (ft)	Erosion Rate (ft/yr)	Eroding (-) or Aggrading (+)
Hartwell Run							
HW170	Low	Low	8/17/2007	8/10/2009	0.0055	0.0028	A
HW177	Moderate	Low	4/11/2007	8/12/2008	-0.72	-0.54	E
HW179	Low	Low	8/16/2007	8/10/2009	-0.12	-0.059	E
HW4	Very High	Low	8/17/2006	8/10/2009	0.10	0.034	A

Total erosion rates were also calculated for the entire length of each tributary within the lower Wissahickon (Table 3-59). To assess the normalized erosion potential of each tributary, the erosion rate per acre of drainage area per year and the erosion rate per foot of stream length per year were calculated. This allowed direct comparison between each of the tributaries with respect to both watershed size and the length of the tributary. Hartwell Run was ranked sixth out of the twelve tributaries within the lower Wissahickon for erosion rate per foot of stream length. The rankings were based on a scale of one being the highest erosion rate and twelve being the lowest erosion rate.

Table 3-59: Erosion Rates for Lower Wissahickon Tributaries

Tributary	Drainage Area (Acres)	Stream Length (feet)	*2009*		
			Erosion Rate (lb/yr)	*Erosion Rate Per Acre*	*Erosion Rate Per Foot of Stream*
Bell's Mill	323	6,722	420,000	1,307	63
Cathedral Run	160	2,790	150,000	913	52
Cresheim Creek	1,218	16,431	840,000	690	51
Gorgas Run	499	2,170	170,000	345	79
Hartwell Run	217	3,530	200,000	918	56
Hillcrest	144	5,272	90,000	597	16
Kitchen's Lane	234	7,753	200,000	850	26
Monoshone Creek	1,056	6,926	160,000	156	24
Rex Ave	137	1,903	150,000	1,131	81
Thomas Mill Run	104	4,008	320,000	3,058	79
Valley Green Run	128	2,874	140,000	1,086	48
Wise's Mill Run	446	7,056	490,000	1,090	69
Total/*Average*	**4,666**	**67,435**	**3,300,000**	***1,012***	***54***

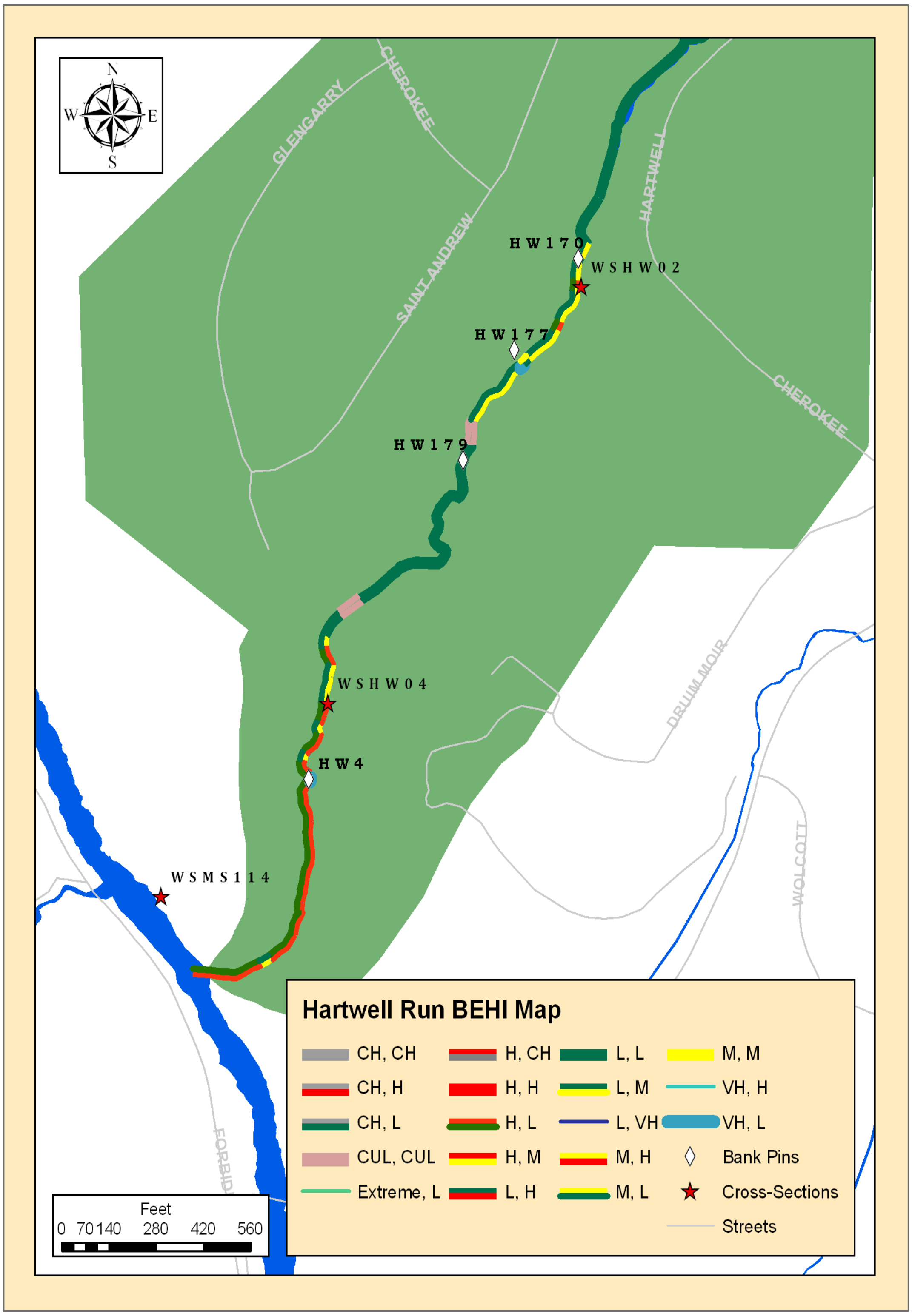


Figure 3-58: Hartwell Run Watershed BEHI Ratings and Bank Pin Locations

3.2.3.4 INFRASTRUCTURE TRACKDOWN SUMMARY

The majority of the Hartwell Run watershed was located within Fairmount Park. Half of reach WSHW02 was located outside Fairmount Park within a residential neighborhood between Hartwell Lane and St. Andrew Road. A substantial amount of infrastructure was observed within this residential corridor and included three (WSdam113, WSdam114 and WSdam115) of the four dams on Hartwell Run and the headwaters of Hartwell, which arose from a network of springs from old mill houses and outfalls (WSout577 and WSout729) that convey stormwater from Hartwell Lane. Downstream of the three dams was a channelized segment (Wscha279) of stream that ran beneath a house on Hartwell Lane. The dams may have been implemented as a means of controlling the amount of flow that passes under the house to prevent flooding.

Downstream in reach WSHW04, the channel was heavily influenced by stormwater. Increased flow from urban development has exceeded the capacity of the two culverts (Wscul13 and WScul114) in the reach. The culverts were built several decades ago and were not designed to transmit the current flow regime; therefore, these culverts can impede the downstream movement of water and sediment. At WScul116, which was constructed to protect the 45-inch Wissahickon High Level Interceptor, this occurred to such an extent that flow swept over the top of the culvert rather than through which caused substantial scour and mass slumping of the bank downstream of the culvert. PWD is currently modifying WScul116 so that it will no longer impede streamflow.

While a large portion of the flow came from the residential area upstream, WSout578 (W-076-07) in the upstream portion of WSHW04 conveyed stormwater from a 42-inch diameter pipe which drained St. Andrew Road and Glengarry Road. The majority of the infrastructure in the upstream residential area of WSHW02 was in good condition and only one infrastructure element, WScul114, was identified as being in poor condition.

Table 3-60: Hartwell Run Infrastructure Point Features

Section ID	Culvert Count	Bridge Count	Outfall Count	Channel Count	Dam Count	Infra Point Count	Combined Outfall Area (ft^2)
WSHW02	1	2	6	1	3	13	19
WSHW04	2	0	1	0	1	4	7.1
TOTAL	**3**	**2**	**7**	**1**	**4**	**17**	**26.1**

Table 3-61: Hartwell Run Infrastructure Linear Features

Section ID	Segment Length (ft)	Culvert Length (ft)	Percent Culverted	Channel Length (ft), 1 side	Channel Length (ft)	Percent Channelized
WSHW02	1752	71	4.1	141	141	2.7
WSHW04	1766	109	6.2	0	0	0
TOTAL	**3518**	**180**	**5.1**	**141**	**141**	**1.30**

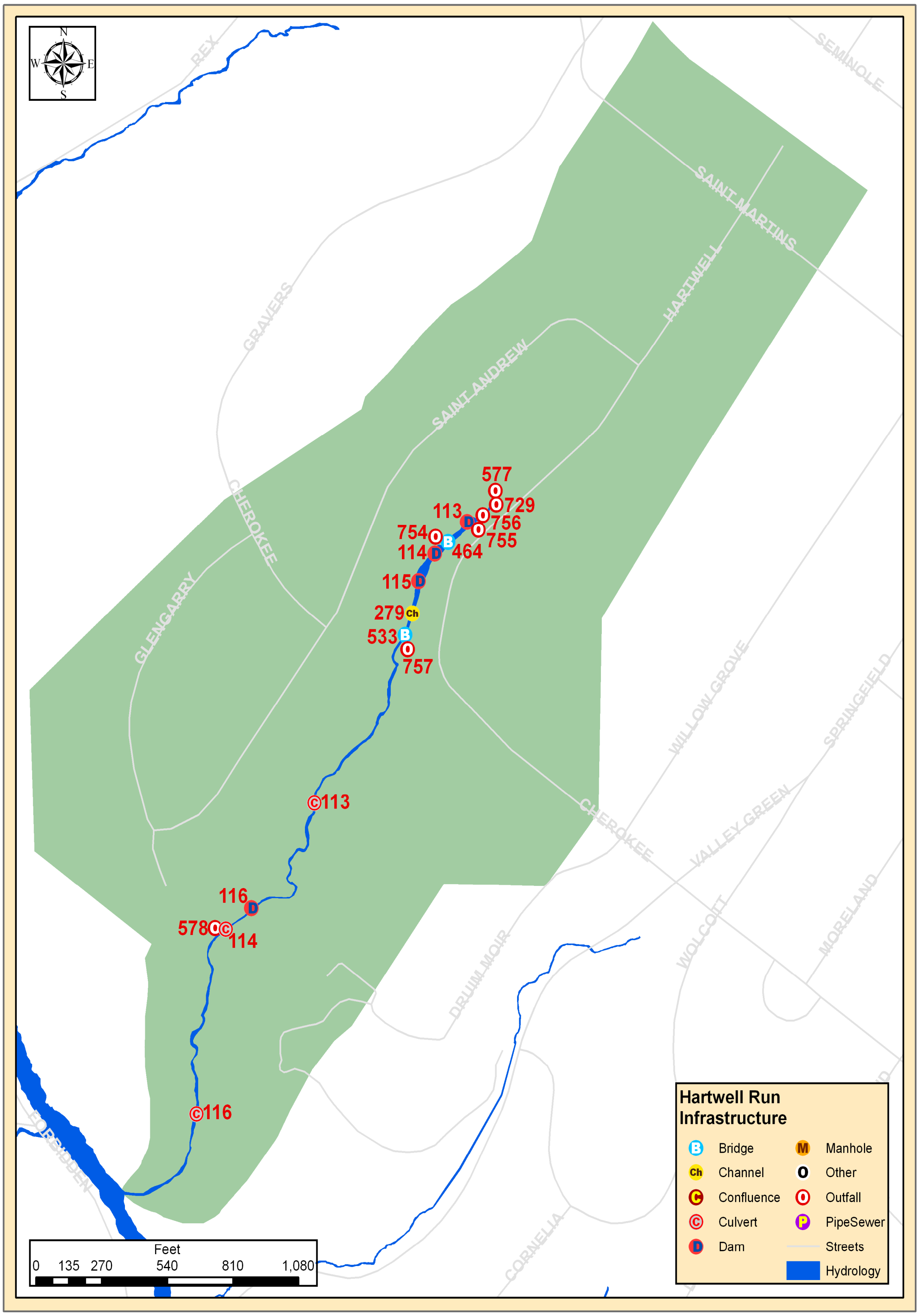


Figure 3-59: Hartwell Run Infrastructure Locations

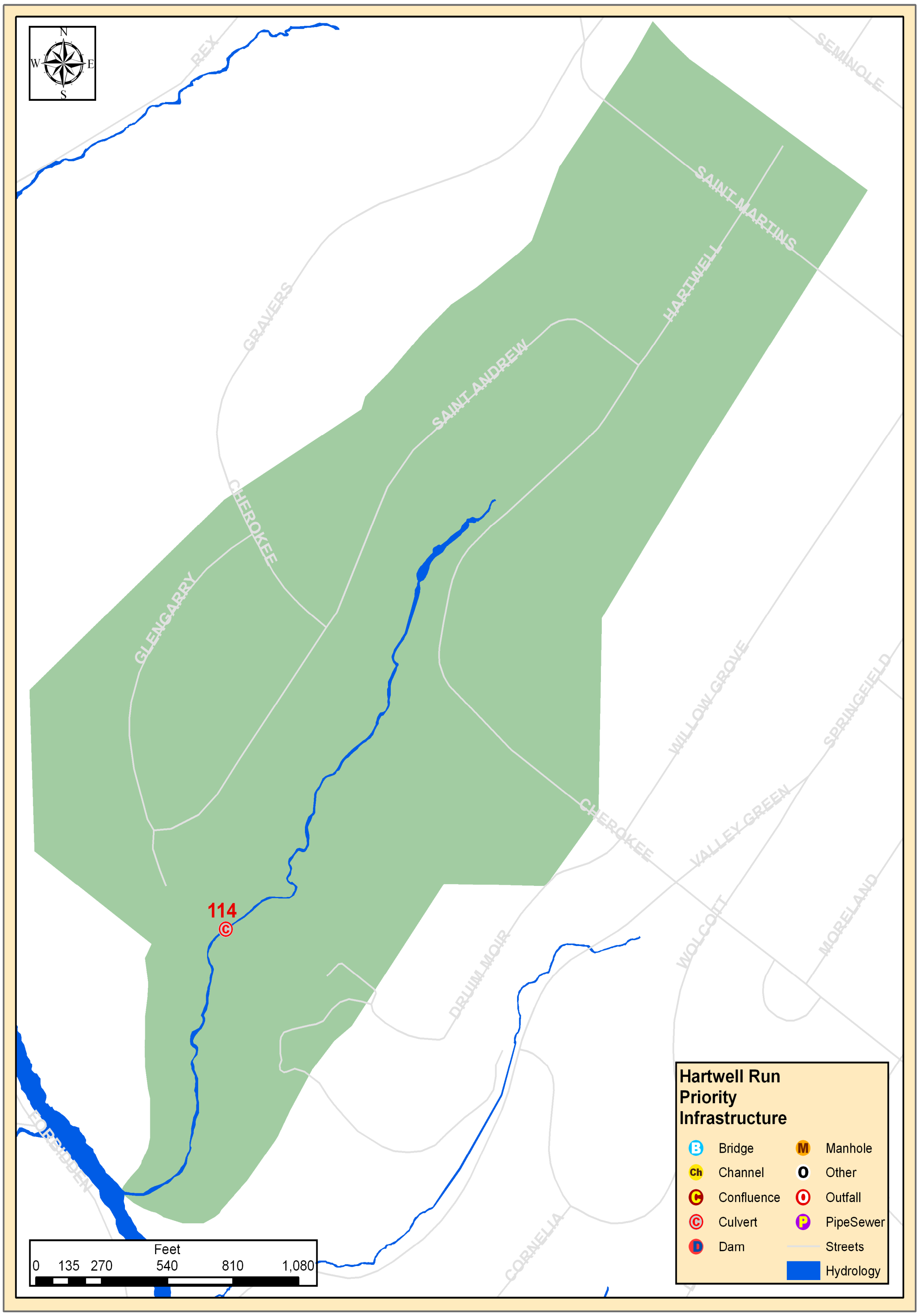


Figure 3-60: Hartwell Run Priority Infrastructure

3.2.3.5 UNIFIED STREAM ASSESSMENT RESULTS FOR THE HARTWELL RUN WATERSHED

The Hartwell Run watershed's stream channel was a first-order stream with no tributaries. The majority of Hartwell Run was situated within the borders of Fairmount Park with the exception of the upper reach which were embedded within a residential neighborhood. Other significant land uses included the Springside School as well as the Philadelphia Cricket Club, with the former having property boundaries that extended across both sides of the Hartwell Run stream corridor. The Center for Watershed Protection's (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and watersheds within the Lower Wissahickon Basin.

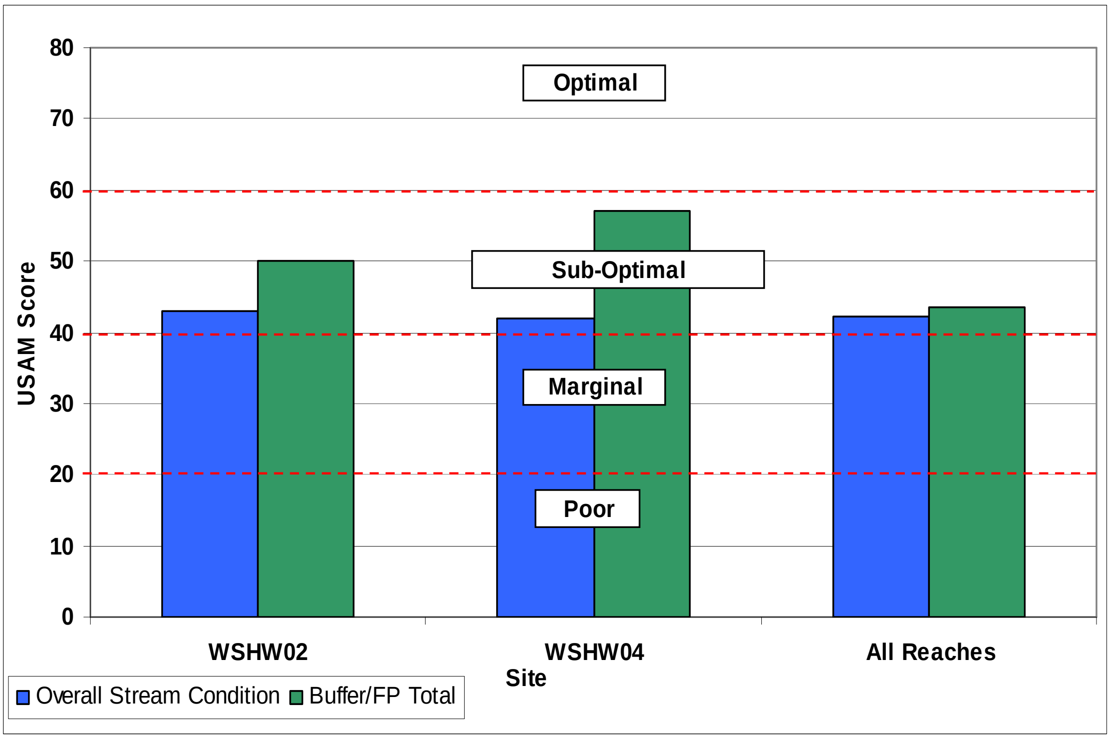


Figure 3-61: Results for Hartwell Run USAM Components

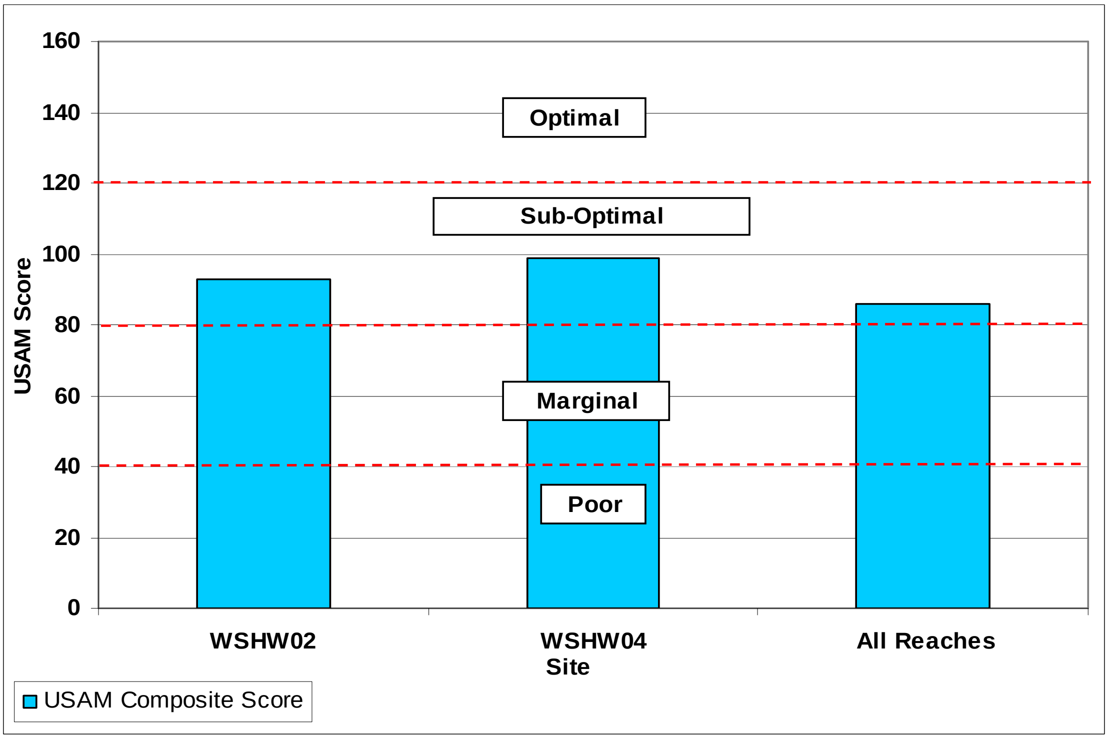


Figure 3-62: Hartwell Run USAM Results

3.2.3.5.1 WSHW02

Reach WSHW02 began as flow from WSout729 which was located 60 feet northwest of Hartwell Road. There were three dams (WSdam113, WSdam114 and WSdam115) located on WSHW02 which impounded considerable volumes of water. The gravel dominated (53%) reach was characterized by a steep slope (6.6%), a moderately entrenched channel (ER=2.2) and a moderate width to depth ratio (11.8). The reach was classified as a B4a type stream channel. The USAM composite score for WSHW02 was 93/160.

3.2.3.5.2 WSHW04

Reach WSHW04 began 230 feet downstream of WScul113. There was one dam (WSdam116) on the reach; however the impoundment caused by WSdam116 was considerably smaller than the upstream impoundments in reach WSHW02. The reach had a gradient (6.6%) and width to depth ratio (14.7) comparable to that of WSHW02; however, the reach WSHW04 channel exhibited a much higher degree of entrenchment (ER=1.1). The reach was classified as a B4a type stream channel and had a composite USAM score of 99/160.

3.2.3.6 Summary of Unified Stream Assessment Results

The mean scores for both of the individual USAM components as well as the overall USAM score were all classified as “suboptimal” (Table 3-62). Average conditions within the Hartwell Run watershed’s buffers and floodplains were considerably better than conditions observed within the stream channels. The watershed averages for each component as well as the composite USAM score compared very well against the All Reaches averages, especially for the *Overall Buffer and Floodplain Condition* component. The scores for individual parameters ranged from poor to optimal, displaying similar levels of variability between reaches.

Table 3-62: USAM Results for Hartwell Run Watershed

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP Condition	USAM Score
WSHW02	Hartwell	43	50	93
WSHW04	Hartwell	42	57	99
WSHW mean		**42.5**	**53.5**	**96**
All Reaches		**42.4**	**44.8**	**86.9**

3.2.3.6.1 SUMMARY OF OVERALL STREAM CONDITION SCORES IN THE HARTWELL RUN WATERSHED

The *Overall Stream Condition* scores recorded in the Hartwell Run watershed were similar in both reaches, yet the two shared few commonalities. The instream habitat in reach WSHW04 was far superior to that observed in reach WSHW02, as the reach WSHW04 had ample amounts of both coarse woody debris (CWD) and stable cobble and boulder substrate. Reach WSHW02 had less than suitable instream habitat characteristics however this reach had higher scores for the *Bank Erosion* and *Floodplain Connection* parameters.

The mean score for the Hartwell Run watershed (42.5/80) was rated as “suboptimal” and was only slightly higher than the All Reaches average score (42.4/80). The mean watershed scores for individual parameters of the *Overall Stream Condition* component were higher than All Reaches average scores for all parameters except the *Floodplain Connection* parameter. Scores for this parameter were consistently low throughout the Lower Wissahickon (average entrenchment ratio of 1.63).

Table 3-63: USAM Overall Stream Condition Scoring for Hartwell Run Watershed

OVERALL STREAM CONDITION								
Reach ID	Sub-watershed	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	Overall Stream Condition
			Left	Right	Left	Right		
WSHW02	Hartwell	9	5	5	7	8	9	43
WSHW04	Hartwell	18	5	5	6	7	1	42
WSHW mean		**13.5**	**5**	**5**	**6.5**	**7.5**	**5**	**42.5**
All Reaches Average		**13.1**	**4.9**	**4.9**	**6.3**	**7.0**	**6.3**	**42.4**

3.2.3.6.1.1 INSTREAM HABITAT

The instream habitat in the Hartwell Run watershed ranged from moderate to excellent and compared well against the habitat conditions observed in the Lower Wissahickon.

The mean watershed score for this parameter (13.5/20) was rated as “suboptimal” and was slightly higher than the All Reaches average score (13.1/20).

The reach with the most suitable habitat, WSHW04, was characterized by an abundance of various size classes of cobble and small boulders. These substrates provide optimal benthic habitat for both macroinvertebrates and cyprinid (minnow) species that prefer steep rocky streams due to their stability and their ability to dissipate flow velocities. There was also an abundance of large CWD which offers stable habitat and can accumulate organic matter and detritus (debris jams) which can serve as an important food supply, especially for organisms in lower trophic levels.

Reach WSHW02 was rated as “marginal” with a score of 9/20. The reduced habitat quality in the upstream-most reach was attributed to the lack of stable substrate, which is one of the most influential factors (aside from water quality) governing the distribution of benthic macroinvertebrates. The substrate was dominated by gravel (2-64 mm), which comprised 54% of the substrate, although there were ample amounts of cobble observed in the reach (34%). Large amounts of sand (9%) and gravel can be problematic from a benthic habitat perspective because these particles can settle between the interstitial spaces between larger cobble and boulders, effectively filling in these spaces. This occurrence, known as embeddedness, decreases the flow of oxygen through the stream bed (hyphoreic exchange) and also decreases the utility of interstitial spaces for foraging and shelter.

3.2.3.6.1.2 VEGETATIVE PROTECTION

Scores for the Vegetative Protection parameter were moderate for both sides of the corridor. Both the right and the left banks had a mean score of 5/10, which was rated as “marginal.” Even with the relatively low scores for this parameter, the Hartwell Run watershed had slightly higher mean scores than the All Reaches average which was (4.9/10) for both the right and the left banks. The amount of vegetated cover established on the banks of these reaches was limited by the extent of erosion and “downcutting” observed, especially in reach WSHW04 where many of the banks had nearly vertical slopes. If the erosion in these reaches were curtailed, it seems feasible that the extent of vegetative bank cover would increase as dense vegetation grew up to the edge of many of the near-vertical slopes.

3.2.3.6.1.3 BANK EROSION

Bank erosion was moderate throughout the Hartwell Run watershed relative to conditions observed in other Lower Wissahickon watersheds. The mean watershed scores for this parameter were rated as “suboptimal” for the both the left (6.5/10) and right banks (7.5/10), both of which scored higher than the left (6.3/10) and right banks (7/10) All Reaches averages. These results are in close agreement with the results of the PWD bank pin study. In the two-year study, estimated erosion rates (normalized to area and stream length) of 918 lbs/acre/yr and 56 lbs/ft/ yr were calculated for Hartwell Run. Similar to the results of the USAM analysis, Hartwell Run was relatively close to the average conditions observed throughout the Lower Wissahickon given the average erosion rates for the entire system were 1,012 lbs/acre/yr and 54 lbs/ft/yr.

3.2.3.6.1.4 FLOODPLAIN CONNECTION

Ratings for this parameter ranged from "poor" to "marginal" however, these results concur with the state of floodplain connection throughout the Lower Wissahickon. Reach WSHW04 (1/20) had the worst score among all of the large Lower Wissahickon tributaries (WSKL02 and WSCR08 also scored 1/20).The mean watershed score of (5/20) was rated as "marginal" and was within the same range as the mean score for the Lower Wissahickon (6.3/10), which was also rated as "marginal." The low scores for this parameter are symptomatic of the channel adjustments observed in many urban stream systems. Stream channels must reach equilibrium with "flashy" flows derived from impervious watersheds by adjusting laterally (channel widening) or vertically (incision or "downcutting").

3.2.3.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE HARTWELL RUN WATERSHED

In general, the *Overall Buffer and Floodplain* conditions observed within the Hartwell Run watershed were favorable. The mean watershed score (53.5/80) was rated as "suboptimal" and was considerably higher than the All Reaches average score (44.5/80) which was rated towards the lower end of the "suboptimal" range of scores. Reach WSHW04 had the second highest score (57/80) among the large, Lower Wissahickon tributaries (reach WSMO02 also scored 57/80) behind reach WSBM02. Reach WSHW02 (50/80) had a moderately high score but was limited by the proximity of Hartwell Road in the upper-most segments of the reach.

Hartwell Run's floodplains and vegetated buffers were rather extensive and consisted of mature and secondary forests; however, from an ecological perspective many floodplain functions and processes have been altered due to the altered channel morphology in both reaches. The stream channels in the Hartwell Run watershed were deeply entrenched and did not inundate their respective floodplains frequently enough to maintain adequate floodplain habitat. Furthermore, the impacts of infrastructure on the reach have altered the hydraulic characteristics of the watershed. There were four dams, three culverted segments, a channelized segment as well as a bridge within the approximately 3,500 feet creek. These infrastructure elements have tremendous impacts on both the flow (i.e. culverts and bridge abutments) and sediment (dam impoundments) regimes, which ultimately impacts floodplain processes such as flooding and sediment deposition.

Table 3-64: USAM Buffer and Floodplain Condition Scoring for Hartwell Run Watershed

OVERALL BUFFER AND FLOODPLAIN CONDITION								
Reach ID	Sub-watershed	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	Buffer/FP Total
		Left	Right				
WSHW02	Hartwell	10	10	17	5	8	50
WSHW04	Hartwell	10	10	17	5	15	57
WSHW mean		**10**	**10**	**17**	**5**	**11.5**	**53.5**
All Reaches Average		**8.1**	**8.6**	**13.8**	**5.5**	**8.5**	**44.8**

3.2.3.6.2.1 VEGETATED BUFFER WIDTH

Scores for the *Vegetated Buffer Width* parameter were very high throughout the entire watershed as both reaches were rated as "optimal" with scores of (10/10) for both sides of the corridor. The Hartwell Run watershed compared well to the left (8.1/10) and right (8.6/10) All Reaches averages, which were rated as "suboptimal." The vegetated buffers on both sides of the corridor were well in excess of 50 feet in most segments of both reaches. In reach WSHW02, Hartwell Road limited the extent of the DSL vegetated buffer near the Hartwell Run the headwaters to just over 50 feet; otherwise, there was no development that impacted the extent of buffer zones in the reach. In reach WSHW04, vegetated buffers on both sides of the corridor were up to 300 feet in width.

3.2.3.6.2.2 FLOODPLAIN VEGETATION

Scores for this parameter were very high in both reaches. The dominant vegetation type within the Hartwell Run floodplains was mature forest, although there was also a well established understory throughout both reaches. The mean watershed score (17/20) was rated as "optimal" and was considerably higher than the All Reaches average (13.8/20) which was rated as "suboptimal."

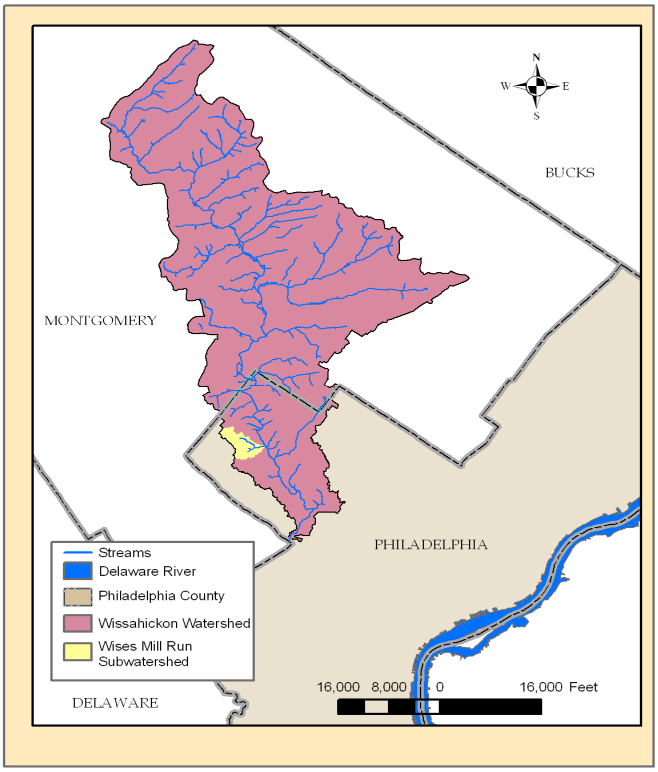
3.2.3.6.2.3 FLOODPLAIN HABITAT

Floodplain habitat was limited in the Hartwell Run reaches. The mean watershed score (5/20) was rated as "poor" and was slightly lower than the All Reaches average (5.5/20). Both reaches in the Hartwell Run watershed were deeply entrenched with entrenchment ratios of 1.9 and 1.0 for reaches WSHW02 and WSHW04 respectively. Reach WSHW04, the most deeply entrenched reach, would have to exceed the estimated bankfull discharge in the reach (230 cfs) by more than 1360% (3,313 cfs) to overtop its banks and access the floodplain. The dominance of mature forests in these reaches provides floodplain habitat in the form of snags and CWD; however, floodplain habitat types (i.e. backwater channels, ephemeral pools and wetlands) dependant on floodplain inundation are not supported or maintained in the Hartwell Run watershed.

3.2.3.6.2.4 FLOODPLAIN ENCROACHMENT

Scores for this parameter ranged from moderate to high. The mean watershed score (11.5/20) was rated as "suboptimal" and was considerably higher than the All Reaches average (8.2/20) which was rated as "marginal." The highest score (15/20) was recorded for reach WSHW04, which had minimal development within the floodplain. Reach WSHW02 had a much lower score (8/20) due to the proximity of Hartwell Road in the upstream-most portions of the reach. Throughout reach WSHW02, the floodplain was extensive, often extending well over 100 feet. However in the vicinity of Hartwell Road the floodplain width was reduced to 50 feet on the DSL side of the corridor.

3.2.4 WISE'S MILL RUN WATERSHED AND REACH CHARACTERISTICS



Wise's Mill Run is a steep first-order tributary to the main stem of the Wissahickon Creek. The tributary consists of a northern branch, which is approximately 3,500 feet in length, and a southern branch, which is approximately 1,700 feet in length. The two branches merge just north of Wise's Mill Road and continue for another 1,900 feet before meeting the Wissahickon Creek. The stream channel is classified as a step-pool, or a Rosgen B3/1 stream. The dominant substrate varies from medium gravel to large cobble material. Both the valley floor and channel have been substantially impacted by past and current land use.

The southern branch originates from a 48-inch reinforced concrete pipe ending at outfall number WSout572 (W-076-13). Channel slopes range between three and six percent as the channel moves downstream to its confluence with the Wissahickon Creek. The watershed of WSout572 is approximately 92 acres. The area is marked exclusively by residential development which includes single-family homes, twins, apartment complexes, and supporting roadways. The entire watershed is drained by a separate storm sewer system that is directly connected to all impervious surfaces.

The northern branch begins from a 66-inch reinforced concrete pipe which ends at outfall number WSout571 (W-075-01). The stream continues for approximately 3,500 feet before merging with the southern branch. In total, the estimated drainage area of the outfalls on the northern branch is 169 acres. This drainage area is characterized by residential development, commercial development and parking, and wooded area.

The entire Wise's Mill Run watershed is 446 acres. Major land use types within the watershed include: wooded (51%), residential – single family detached (22%), residential – multi-family (7%), and vacant (5%). The majority of Wise's Mill Run is surrounded by Fairmount Park. The Park buffer ranges from about 50 feet to about 2,000 feet.

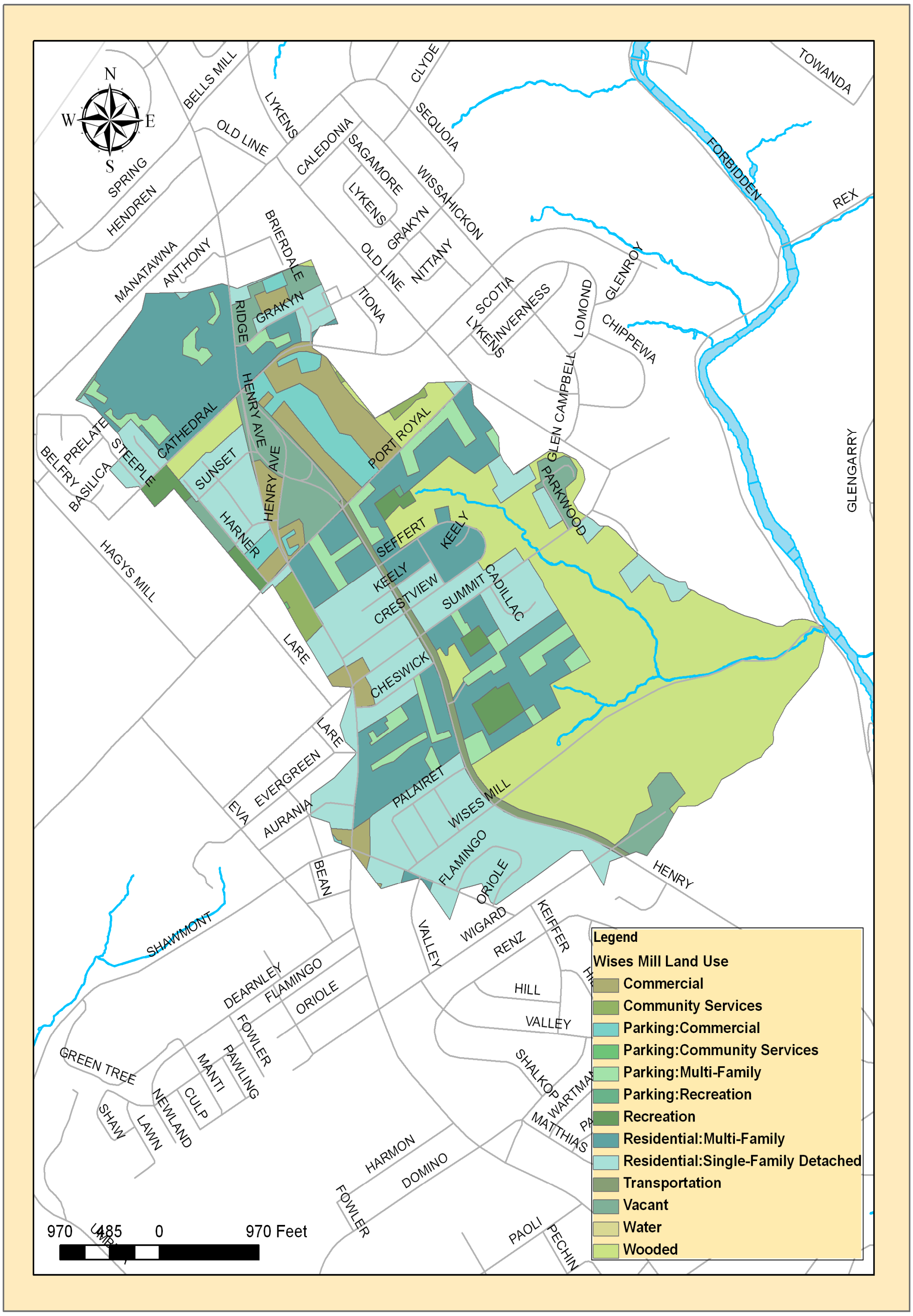


Figure 3-63: Wise's Mill Run Watershed Land Use

3.2.4.1 GEOLOGY

The majority of the Wise's Mill Run watershed is underlain by the Wissahickon Formation. The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

3.2.4.2 SOILS

According to the National Resource and Conservation Service Soil Survey, the majority of soils for the Wise's Mill Run watershed are classified as hydrologic group B. These soils have a moderate rate of infiltration when the soils are wet (0.50-1.00 in/hr). Water movement through these soils is considered moderately rapid.

There is a band of C soils surrounding the tributary on the northern and eastern portion of the watershed. Group C soils have a slow rate of infiltration when saturated (0.17-0.27 in/hr). Water movement through these soils is moderate or moderately slow.

Table 3-65: Distribution of NRCS Soil Types in Wise's Mill Run Watershed

Group	Area (ft^2)	Percent of Total Area
B	19,233,482	99.09%
C	194,277	0.91%
Total Area	**19,427,760**	**100%**

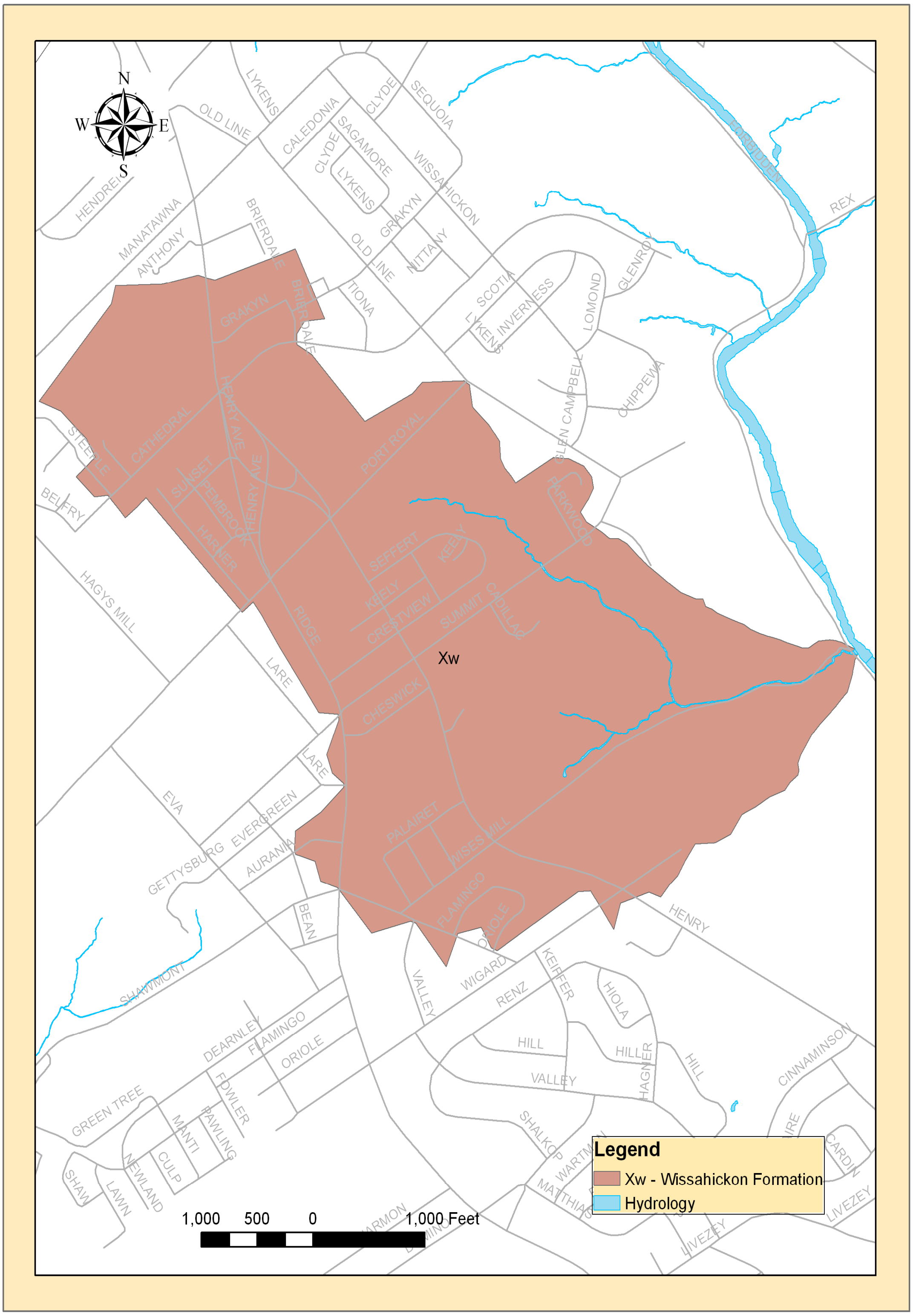


Figure 3-64: Geology of Wise's Mill Run Watershed

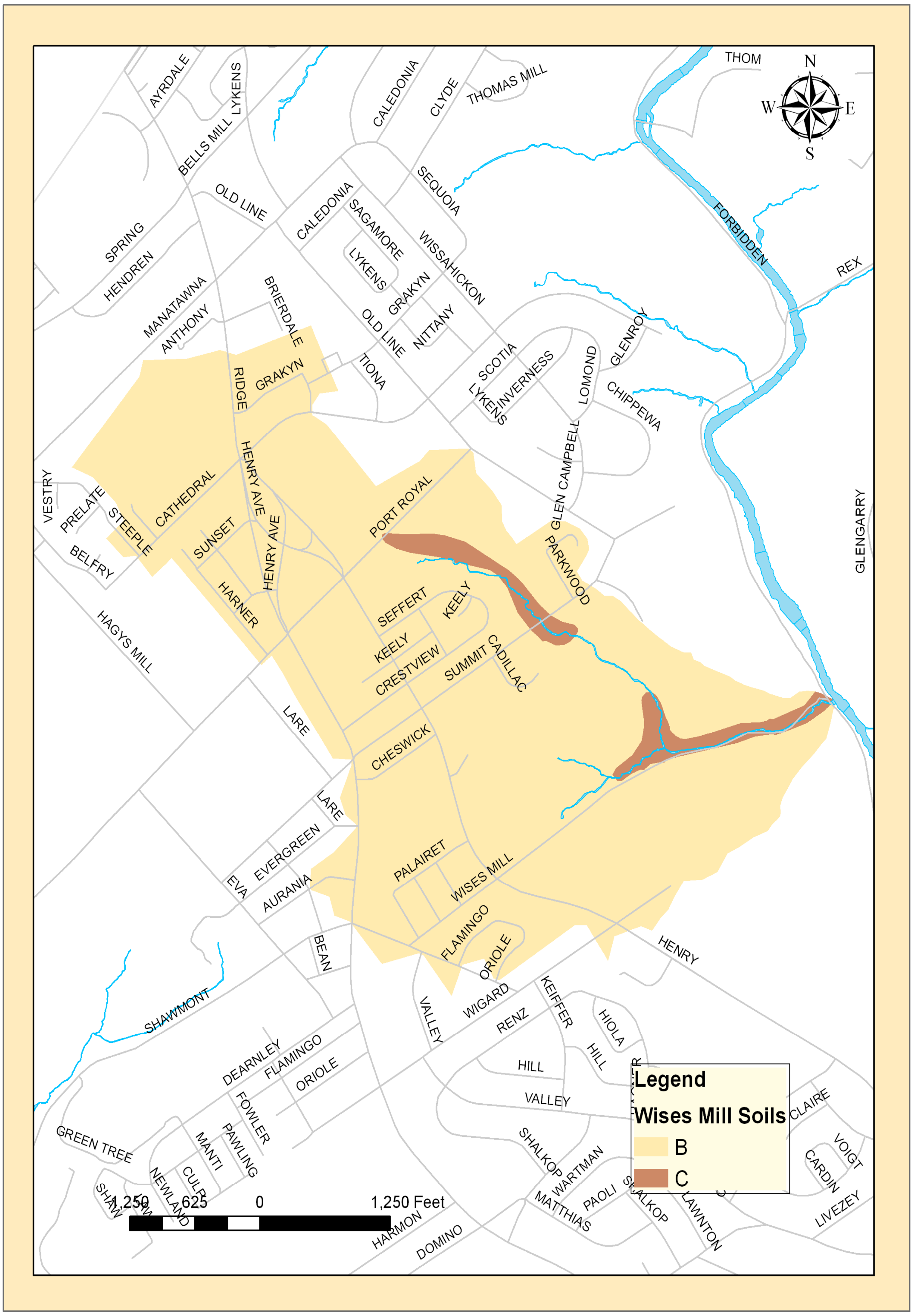


Figure 3-65: Distribution of NRCS Soils Types in Wise's Mill Run Watershed

3.2.4.3 BANK EROSION

There were 13 bank pin locations along Wise's Mill Run (Figure 3-66). The calculated erosion rates are included in Table 3-66. The spatial distribution of BEHI assessment results were represented graphically (Figure 3-66) for each of the segments assessed on Wise's Mill Run. Each bank within a respective segment was assessed and rated separately; however, channelized and culverted segments were not assessed as they confer a high degree of protection from bank erosion.

Table 3-66: Wise's Mill Run Bank Pin Locations

	BEHI	NBS	Baseline Reading	Most Recent Reading	Erosion Rate (ft)	Erosion Rate (ft/yr)	Eroding (-) or Aggrading (+)
Wise's Mill							
WM1260	Moderate	Low	5/15/2006	8/12/2008	-0.13	-0.060	E
WM13	High	Moderate	8/7/2007	8/12/2008	-2.68	-2.63	E
WM18	High	High	8/21/2006	8/12/2008	-0.70	-0.36	E
WM19	High	Low	11/5/2005	8/12/2009	-0.67	-0.18	E
WM21	Moderate	Low	11/5/2005	8/12/2009	-0.24	-0.064	E
WM2160	Low	Low	5/15/2006	8/8/2007	0.39	0.31	A
WM27	Low	High	8/18/2006	8/12/2009	-0.36	-0.12	E
WM29	Moderate	Low	4/22/2008	8/12/2009	0.74	0.57	A
WM3	High	Low	11/23/2005	8/12/2008	-0.72	-0.26	E
WM637	Low	Low	4/22/2008	8/12/2009	1.26	0.97	A
WM652	Low	Low	8/21/2006	8/12/2008	-0.083	-0.042	E
WM681	Very Low	Low	8/21/2006	8/13/2009	0.063	0.021	A
WM9	Moderate	Very Low	11/23/2005	8/12/2008	0.42	0.15	A

Total erosion rates were also calculated for the entire length of each tributary within the lower Wissahickon (Table 3-67). To assess the normalized erosion potential of each tributary, the erosion rate per acre of drainage area per year and the erosion rate per foot of stream length per year were calculated. This allowed direct comparison between each of the tributaries with respect to both watershed size and the length of the tributary. Wise's Mill Run was ranked fourth out of the twelve tributaries within the lower Wissahickon for erosion rate per foot of stream length. The rankings were based on a scale of one being the highest erosion rate and twelve being the lowest erosion rate.

Table 3-67: Erosion Rates for Lower Wissahickon Tributaries

Tributary	Drainage Area (Acres)	Stream Length (feet)	*2009*		
			Erosion Rate (lb/yr)	*Erosion Rate Per Acre*	*Erosion Rate Per Foot of Stream*
Bell's Mill	323	6,722	420,000	1,307	63
Cathedral Run	160	2,790	150,000	913	52
Cresheim Creek	1,218	16,431	840,000	690	51
Gorgas Run	499	2,170	170,000	345	79
Hartwell Run	217	3,530	200,000	918	56
Hillcrest	144	5,272	90,000	597	16
Kitchen's Lane	234	7,753	200,000	850	26
Monoshone Creek	1,056	6,926	160,000	156	24
Rex Ave	137	1,903	150,000	1,131	81
Thomas Mill Run	104	4,008	320,000	3,058	79
Valley Green Run	128	2,874	140,000	1,086	48
Wise's Mill Run	446	7,056	490,000	1,090	69
Total/*Average*	**4,666**	**67,435**	**3,300,000**	***1,012***	***54***

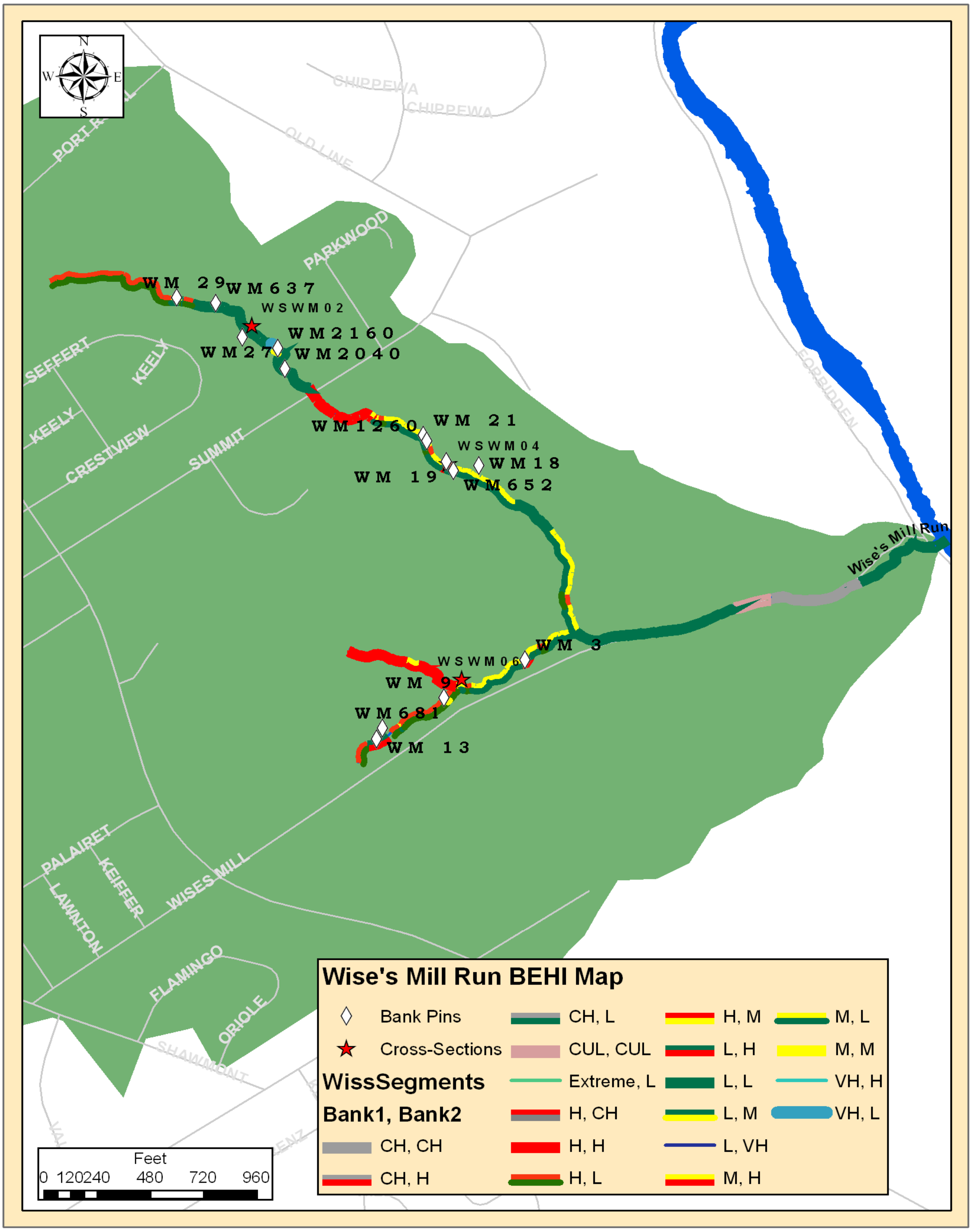


Figure 3-66: Wise's Mill Run Watershed BEHI Ratings and Bank Pin Locations

3.2.4.4 INFRASTRUCTURE TRACKDOWN SUMMARY

Wise's Mill Run exhibited characteristics of a stream that has been affected by infrastructure that is a result of urban development. While nearly the entire stream was within Fairmount Park, it was bordered by apartment complexes and private residences on Henry Avenue and Summit Street, which created the demand for drainage infrastructure. Stormwater outfalls were a major factor in the current condition of the stream as they formed the headwaters to the Wise's Mill main stem as well as the tributary reaches. Reach WSWM02 had three large outfalls, with diameters of 5.5 feet, 3.5 feet, and 2.25 feet. These outfalls conveyed runoff from Port Royal Avenue, Seffert Street, and Crestview Road through 66-inch, 42-inch, and 27-inch diameter pipes respectively. Along Wise's Mill Road there were several outfalls that carried runoff from Henry Avenue and Wise's Mill Road, the largest of which was WSout572 (48 inches). This outfall discharged such high flows that the stream had eroded and scoured the area around the outfall leaving the cascade hanging about five feet above the water level at base flow. Downstream of this outfall were four more outfalls which were 1-1.5 feet in diameter. Currently there is a project on Wise's Mill Road aimed at redirecting stormwater flows to a constructed wetland southwest of reach WSWM06. While there were no infrastructure elements designated as being in poor condition, WSout572 was undermined and its condition will likely worsen over time. There are currently plans being developed to redesign this outfall such that it can accommodate the flows associated with Wise's Mill Run flow regime.

Table 3-68: Wise's Mill Run Infrastructure Point Features

Section ID	Culvert Count	Bridge Count	Outfall Count	Confluence Count	Dam Count	Manhole Count	Infra Point Count	Combined Outfall Area (ft^2)
WSWM02	2	0	3	0	0	1	6	37.36
WSWM04	2	2	2	1	2	3	12	1.6
WSWM06	0	1	6	1	0	0	8	25.2
TOTAL	**4**	**3**	**11**	**2**	**2**	**4**	**26**	**64.08**

Table 3-69: Wise's Mill Run Infrastructure Linear Features

Section ID	Segment Length (ft)	Culvert Length (ft)	Percent Culverted	Channel Length (ft)	Percent Channelized
WSWM02	1271	93	7.3	0	0
WSWM04	3610	241	6.7	0	0
WSWM06	1297	0	0	0	0
TOTAL	**6178**	**334**	**5.4**	**0**	**0**

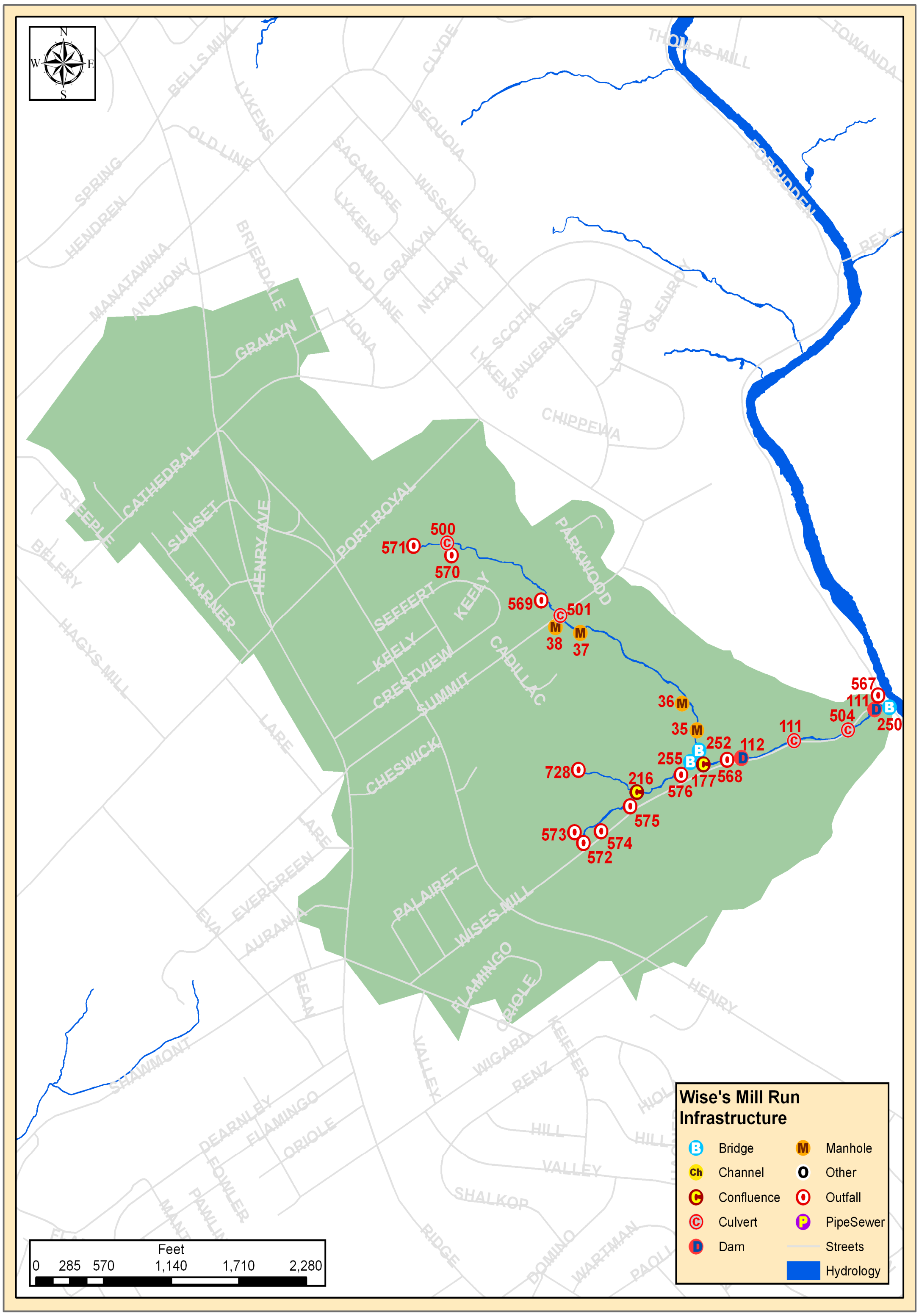


Figure 3-67: Wise's Mill Run Infrastructure Locations

3.2.4.5 UNIFIED STREAM ASSESSMENT RESULTS FOR THE WISE'S MILL RUN WATERSHED

The Wise's Mill watershed's main stem channel was a moderately sinuous first-order channel until it reached the confluence with the southern branch of the creek (WSWM06) just north of Wise's Mill Road, where the channel became a second-order stream channel. The majority of the channel was located within the boundaries of Fairmount Park with the exception of the upstream-most portion of the northern fork of the unnamed tributary as well as the main stem channel and unnamed tributary in the vicinity of their confluence. The Center for Watershed Protection's (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and watersheds within the Lower Wissahickon Basin.

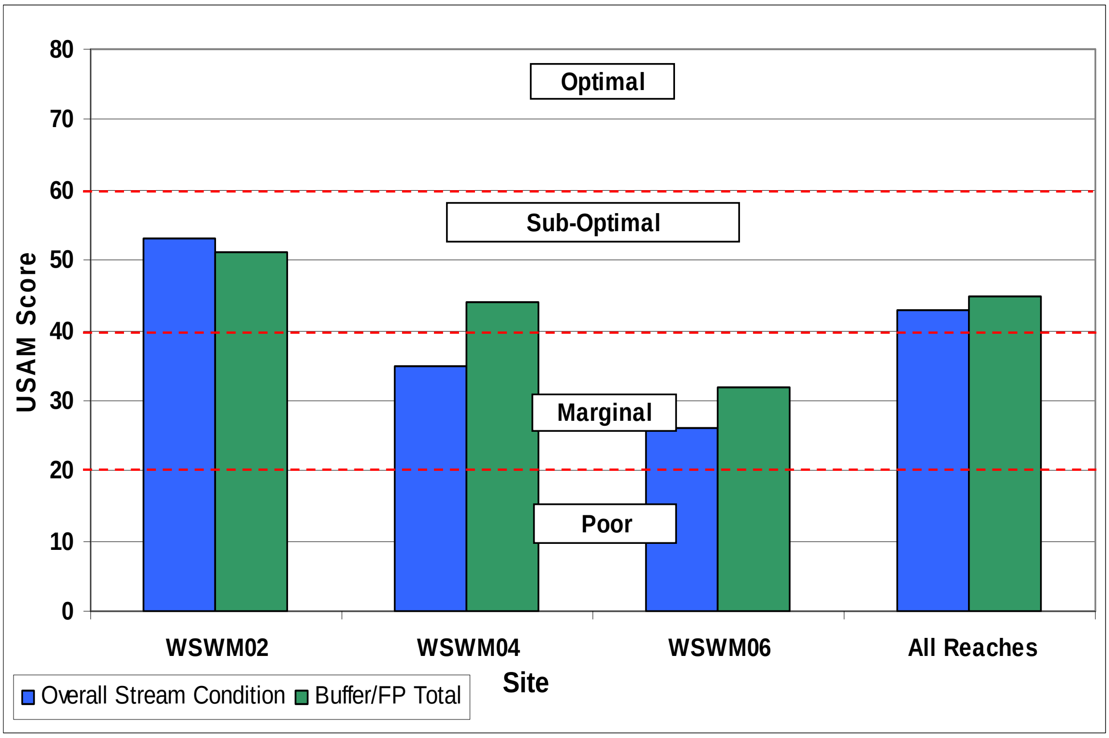


Figure 3-68: Results for Wise's Mill Run USAM Components

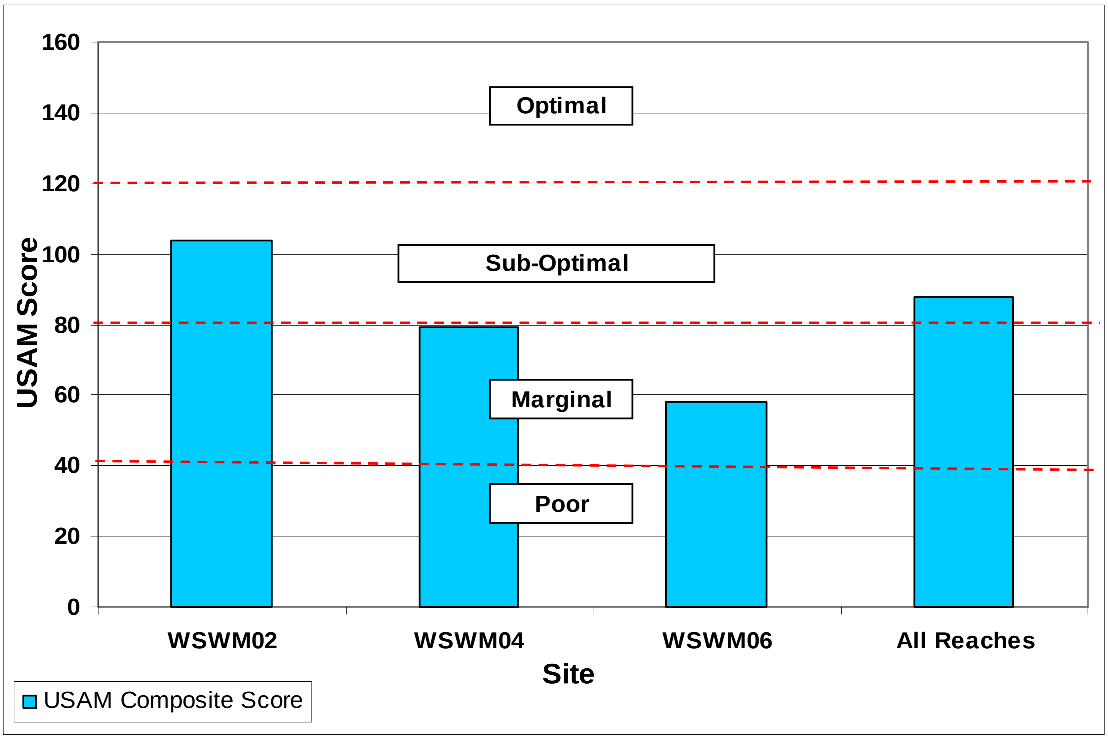


Figure 3-69: Main Stem Wise's Mill Run USAM Results

3.2.4.5.1 WSWM02

Reach WSWM02 began as flow from WSout571 (W-075-01) which was located on the grounds of the Summit Park East Apartment Complex on Henry Avenue. The reach flowed through Fairmount Park for 1,271 feet and ended at culvert WScul501 on Summit Avenue. The substrate particle size distribution was dominated by gravel (54%) although cobble substrate (42%) was present in considerable amounts throughout the reach. Reach WSWM02 had a relatively shallow slope (2.7%) compared to the other Wise's Mill reaches. It was characterized by a high width to depth ratio (30.8) and a deeply entrenched channel (ER=1.3), which classified the reach as a B4 stream channel. The composite USAM score (Figure 3-69) for the reach was (104/160).

3.2.4.5.2 WSWM04

Reach WSWM04 began at WScul501 (Summit Avenue) and ended at the confluence of Wise's Mill Run and Wissahickon Creek. The reach flowed through Fairmount Park for approximately 1,750 before it reached the confluence with the south fork (unnamed tributary A) of Wise's Mill Run. Downstream of the confluence, WSWM04 became a second-order stream as it flowed alongside Wise's Mill Avenue towards the confluence with Wissahickon Creek. The substrate particle size distribution was dominated by gravel (56%) and had comparable amounts cobble (38%) as reach WSWM02. The reach was also similar to reach WSWM02 in terms of cross sectional geometry in that reach WSWM04 likewise had a relatively high width to depth ratio (20.1) and was deeply entrenched (ER=1.4). Reach WSWM04 was classified as a B4a stream channel due to its steep gradient (5.8%) and had a USAM composite score of (79/160).

3.2.4.5.3 WSWM06

Reach WSWM06 represented the south fork (unnamed tributary) of Wise's Mill Run. The main stem of the south fork, which began as flow from WSout572 (W-076-13), had a tributary which began as flow from a privately owned outfall, WSout728, located on the grounds of the Fairfield Henry Apartments located on Henry Avenue. The main stem channel became a second-order stream downstream of WScon216, which was located 30 feet upstream of cross section WSWM06. The substrate particle size distribution was similar to that of the other two Wise's Mill Run reaches assessed, with predominance of gravel (58%) and an abundance of cobble (34%). The channel geometry was similar to that of the other two reaches with a width to depth ratio of 22.1 and an entrenchment ratio of 1.5; however, the slope of reach WSWM06 (5.2%) made it most similar to reach WSWM04. The reach was also classified as a B4a steam type and the USAM composite score was (58/160).

3.2.4.6 Summary of Unified Stream Assessment Results

The mean scores for both the *Overall Buffer and Floodplain Condition* and the *Overall Stream Condition* components as well as the composite USAM score were classified as "marginal" to "suboptimal." (Table 3-70) Average conditions within the Wise's Mill Run watershed's buffers and floodplains were slightly better than conditions observed within the stream channels. The watershed averages for the *Overall Stream Condition* component as well as the composite USAM were fairly lower than the respective All Reaches averages, however the *Overall Buffer and Floodplain* component was relatively close to the All Reaches average. The scores for individual parameters ranged from poor to optimal, displaying similar levels of variability between reaches.

Table 3-70: USAM Results for Wise's Mill Run Watershed

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP Condition	USAM Score
WSWM02	Wises Mill	53	51	104
WSWM04	Wises Mill	35	44	79
WSWM06	Wises Mill	26	32	58
WSWM mean		**38.0**	**42.3**	**80.3**
All Reaches		**42.4**	**44.5**	**86.9**

3.2.4.6.1 Summary of Overall Stream Condition Scores in the Wise's Mill Run Watershed

In general, the mean score for the *Overall Stream Condition* component was 38/80 and was rated as "marginal." Reach WSWM02 was the only reach that had a score greater than the All Reaches average score (42.4/80), which was rated as "suboptimal." There was a trend such that scores were observed to decrease in the downstream reaches (WSWM04 and WSWM06), which could be due to the increased density of infrastructure in the downstream reaches as well the proximity to Wise's Mill Road.

The *Instream Habitat* parameter had relatively high scores among all of the Wise's Mill Reaches as all reaches were rated as "suboptimal" or higher. The presence of a stable substrate (cobble and boulder) and the abundance of coarse woody debris (CWD) throughout the watershed were the factors most responsible for the habitat conditions score. The *Floodplain Connection* and *Bank Erosion* parameters were amongst the worst-scoring parameters. Most bank erosion was observed to be localized; however the lack of floodplain connection (low entrenchment ratios) was characteristic of the entire watershed.

Table 3-71: USAM Overall Stream Condition Scoring for Wise's Mill Run Watershed

OVERALL STREAM CONDITION								
Reach ID	Sub-watershed	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	Overall Stream Condition
			Left	Right	Left	Right		
WSWM02	Wises Mill	18	8	8	8	8	3	53
WSWM04	Wises Mill	13	4	4	5	6	3	35
WSWM06	Wises Mill	13	2	2	2	2	5	26
WSWM mean		**14.7**	**4.7**	**4.7**	**5**	**5.3**	**3.7**	**38**
All Reaches		**13.1**	**4.9**	**4.9**	**6.3**	**7.0**	**6.3**	**42.4**

3.2.4.6.1.1 Instream Habitat

Scores for the *Instream Habitat* parameter were relatively high as ratings at individual reaches ranged from "suboptimal" to "optimal." The watershed mean score (14.7/20) was higher than the All Reaches average (13.1/20) although both were rated as "suboptimal." Instream habitat in the Wise's Mill Reaches was characterized by an abundance of stable habitat features. Reaches WSWM02, WSWM04 and WSWM06 had substrates comprised of 42%, 38% and 34% cobble respectively. Moreover, the dominant size classes of cobble within these reaches were medium to very large cobble, which provides structurally complex and extremely stable habitat templates for a variety of macroinvertebrate and fish species. There were also ample supplies of CWD of various sizes and stages of conditioning.

3.2.4.6.1.2 Vegetative Protection

Scores for the *Vegetative Protection* parameter were moderate as ratings for each reach ranged from "poor" at WSWM06 to "suboptimal" at WSWM02. The mean score of the watershed for both banks was (4.7/10) which was rated as "marginal." The All Reaches average for both the left and right bank was slightly higher (4.9/10) but was likewise rated as "marginal." The worst reach, WSWM06 (2/10), was characterized by patches of bare soil and segments where localized erosion and scour had produced nearly vertical banks which precluded the establishment on bank vegetation. Reach WSWM02, which had the highest score (8/10) was characterized by an abundance of streambank vegetation in the form of shrubs (dominant vegetation type) and small to medium-sized saplings and groundcover vegetation. There were segments of reach WSWM02 where bank erosion had produced patches of bare soil; however, the banks were not scoured to the extent that they were vertical and precluded the establishment of streambank vegetative cover.

3.2.4.6.1.3 BANK EROSION

The Wise's Mill watershed was observed to have moderate to high levels of bank erosion, especially on the middle and lower reaches; however most instances of erosion were localized and rarely affected an entire reach. The mean watershed scores for both the left (5/10) and right banks (5.3/10) were rated as "marginal." The Wise's Mill Run watershed did not compare well against the All Reaches averages for neither the left (6.3/10) nor right banks (7.0/10) which were both rated as "suboptimal." As was noted for the *Vegetative Protection* parameter, the localized erosion observed in the lower reach (WSWM06) had produced nearly vertical banks in many segments of the reach. The high degree of erosion observed in WSMW06 is most likely due to the high density of infrastructure in the reach as there were three outfalls (WSout572, WSout573, and WSout574) in the upper part of the reach.

3.2.4.6.1.4 FLOODPLAIN CONNECTION

Scores for the *Floodplain Connection* parameter were very low and were indicative of the elevated levels of channel incision or "entrenchment" observed in many of the Lower Wissahickon tributaries. The mean watershed score (3.7/20) was rated as "poor" compared to the All Reaches average (6.3/20) which was rated as "marginal." The rather low scores for both the Wise's Mill Run watershed and the larger Lower Wissahickon tributaries indicate the extent to which large-scale, watershed wide imperviousness drives the hydrodynamic forces that influence channel morphology.

Channel incision, symptomatic of urban streams, essentially disconnects stream channels from their respective floodplains. The highly urbanized watersheds of the Lower Wissahickon have stream networks that are predisposed to the "flashy" hydrologic regimes prevalent in urbanized catchments such that stream channels have very low base-flow discharges and extremely high bankfull discharge capacities. The result is often a channel in a continual phase of adjustment (lateral and vertical) in response to a "flashy" hydrologic regime and its associated sediment load.

3.2.4.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE WISE'S MILL RUN WATERSHED

The scores for the *Overall Buffer and Floodplain* component ranged from low to moderate and generally decreased in the downstream direction. The decreasing trend was attributed to the increased density of infrastructure and the presence of roads and development in the downstream reaches. The mean watershed score (42.3/80) was rated as "suboptimal" and compared well with the All Reaches average score (44.8/80) which was also rated as "suboptimal."

The highest scores were observed for the *Vegetated Buffer Width* parameter. On average the DSL side of the corridor was observed to have one of the widest vegetated buffers in the Lower Wissahickon as the average score for the left banks of the watershed was (9.3/10), which was rated as "optimal." The lowest scores in the watershed were recorded for the *Floodplain Encroachment* and *Floodplain Habitat* parameters. As with many other parameters, scores tended to decrease in the downstream reaches.

Table 3-72: USAM Buffer and Floodplain Condition Scoring for Wise's Mill Run Watershed

OVERALL BUFFER AND FLOODPLAIN CONDITION							
Reach ID	Sub-watershed	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	Overall Buffer/FP Condition
		Left	Right				
WSWM02	Wises Mill	10	10	14	6	11	51
WSWM04	Wises Mill	10	7	12	5	10	44
WSWM06	Wises Mill	8	6	14	1	3	32
WSWM mean		**9.3**	**7.7**	**13.3**	**4**	**8**	**42.3**
All Reaches Average		**8.1**	**8.6**	**13.8**	**5.5**	**8.5**	**44.5**

3.2.4.6.2.1 VEGETATED BUFFER WIDTH

Scores for the *Vegetative Buffer Width* parameter were generally high, especially in the upstream reaches. The mean watershed scores for the left (9.3/10) and right (7.7/10) banks were rated as "optimal" and "suboptimal" respectively. The All Reaches averages were (8.1/10) and (8.6/10) for the left and right banks respectively as only the right bank average was higher than the watershed mean scores. The lower scores in the two lower reaches (WSWM04 and WSWM06), especially on the DSR side of the corridor, were attributed to the presence of development (WSWM04) and Wise's Mill Road (WSWM06).

3.2.4.6.2.2 FLOODPLAIN VEGETATION

The *Floodplain Vegetation* parameter serves as an estimate of the dominant vegetation type present within the stream corridor, with mature forest being optimal. Scores for this parameter were high as all reaches were rated as "suboptimal." The watershed average (13.3/20) was slightly lower than the All Reaches average (13.8/20) although both were rated as "suboptimal." A suboptimal rating for this parameter is characteristic of a stream corridor dominated by young or secondary forest, however, mature stands were observed.

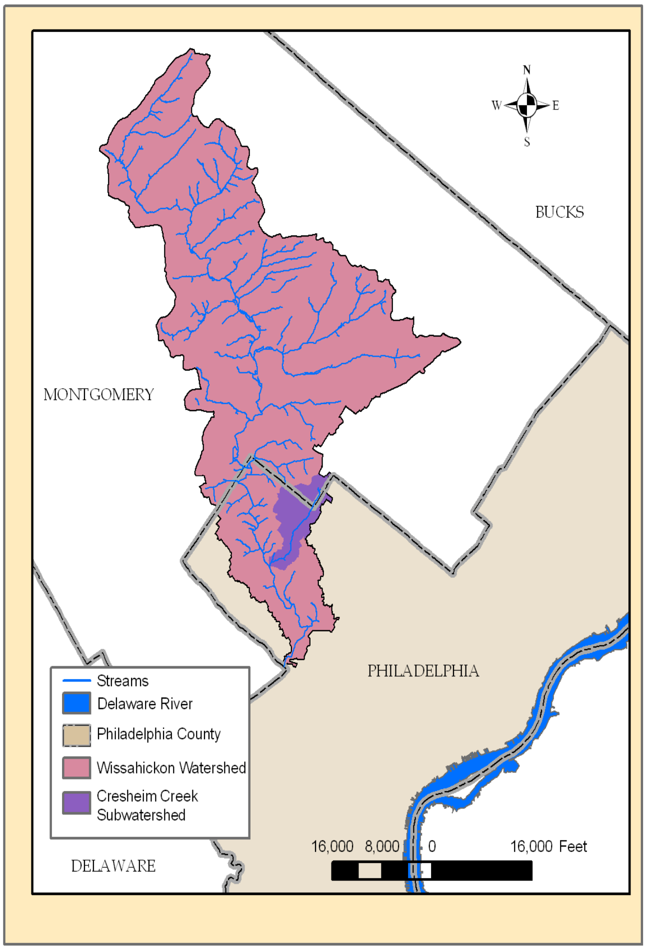
3.2.4.6.2.3 FLOODPLAIN HABITAT

Floodplain Habitat scores were very low throughout the watershed as only one reach (WSWM02) was rated higher than "poor." The watershed average (4/20) was considerably lower then the All Reaches average score (5.5/20) which was rated as "marginal." Many aspects of floodplain habitat rely on occasional or seasonal floodplain inundation (i.e. backwater channels, ephemeral pools), which delivers upstream sediment, nutrients and processed organic matter to the floodplain. Throughout the Wise's Mill watershed, values for the entrenchment ratio (metric that gauges a channel's "floodplain connectivity") were very low, which is an indicator of infrequent inundation. In the context of the USAM, floodplain systems that are infrequently inundated will most likely consist of habitat that is entirely non-wetland, with little evidence of standing water. In this context, such habitat would not be considered optimal because it lacks the potential diversity that would come with a habitat template composed of a combination of wetland and non-wetland habitat.

3.2.4.6.2.4 FLOODPLAIN ENCROACHMENT

Scores for the *Floodplain Encroachment* parameter were low to moderate throughout the watersheds as scores were rated from “poor” to “suboptimal.” Both the mean watershed score (8/20) and the All Reaches average (8.5/20) were rated as “marginal.” Scores were higher in the upstream-most reach (WSWM02) as lower in the watershed, infrastructure such as outfalls, dams, bridges and culverts impinged upon floodplain function. In reach WSWM06, the proximity of Wise’s Mill Road had a considerably adverse effect on floodplain function in the reach as some segments of the reach were within 30 to 40 feet of the road. As such, WSWM06 had a score of (3/20) and was rated as “poor.”

3.2.5 Cresheim Creek Watershed and Reach Characteristics



Cresheim Creek is a tributary to the main stem of the Wissahickon Creek. Cresheim Creek originates outside of the City of Philadelphia and travels for approximately half a mile before entering the City limits. The tributary originates from two outfalls, one from a single family residential neighborhood and one from a light industrial area. Due to the location outside of the City, information on these outfalls is limited. Cresheim Creek is a first-order tributary for approximately 2.6 miles until a smaller 0.3 mile tributary enters Cresheim approximately 0.1 miles from the Confluence with the Wissahickon main stem.. Reaches of the stream channel are classified as a Rosgen type C and a Rosgen type F. The dominant substrate varies from course gravel to small boulder material. Both the valley floor and channel have been substantially impacted by past and current land use.

The entire Cresheim Creek watershed is 1548 acres. Major land use types within the watershed include: residential – single family detached (46%), wooded (15%), residential – row home (7%), and community service (8%). Once the creek enters the City of Philadelphia, it is surrounded by Fairmount Park on both sides for the entire length. The Park buffer ranges from about 50 feet to about 2,000 feet.

The Philadelphia Water Department (PWD) owns and operates 12 stormwater outfalls that discharge into Cresheim Creek. The entire watershed is drained by a separate storm sewer system that is directly connected to all impervious surfaces. There are an additional 9 outfalls owned by an entity other than PWD that release into Cresheim Creek.

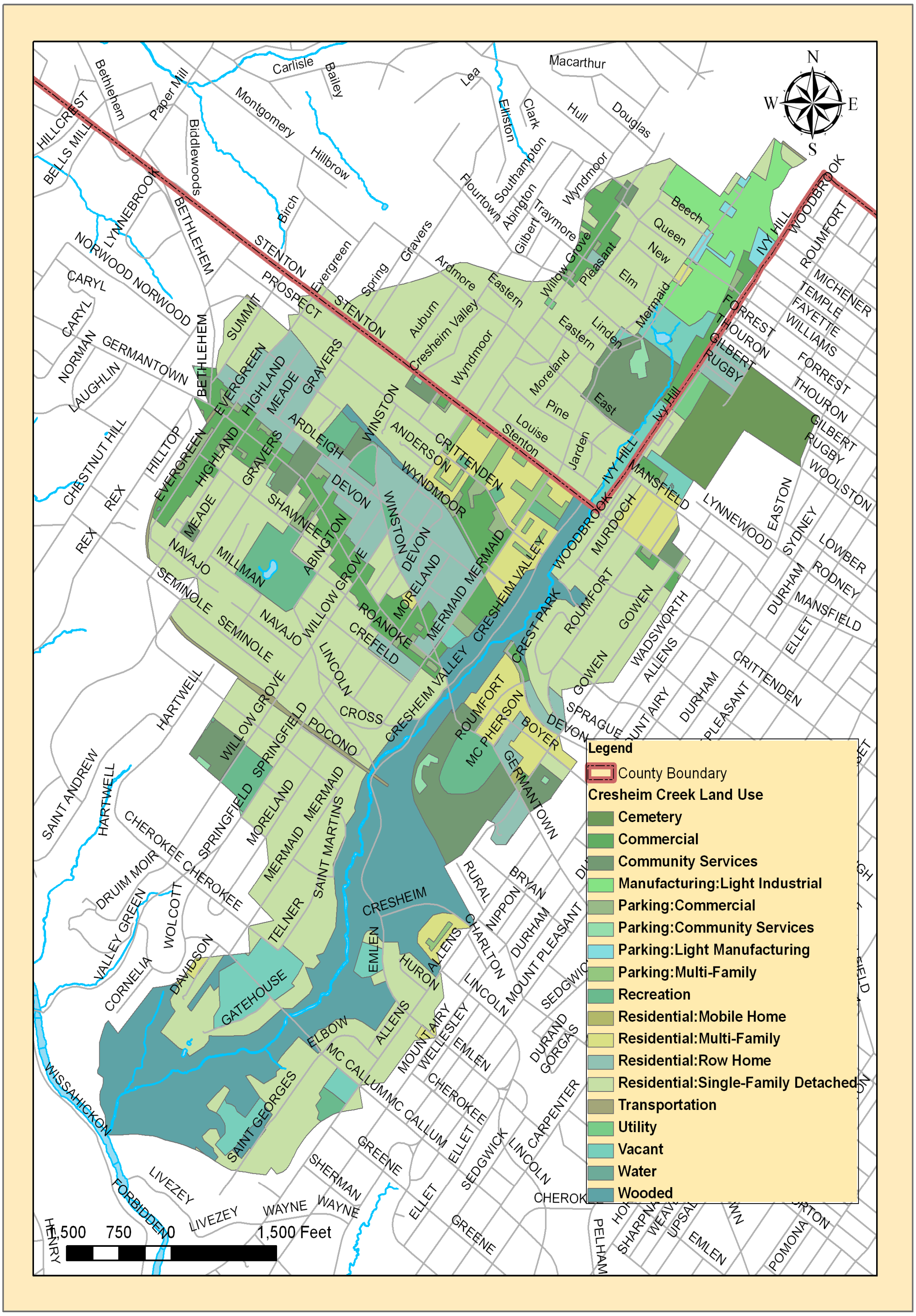


Figure 3-70: Cresheim Creek Watershed Land Use

3.2.5.1 GEOLOGY

The majority of the Cresheim Creek watershed is underlain by the Wissahickon Formation. The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

The northern portion of the Cresheim Creek watershed is underlain by the Bryn Mawr Formation. The Bryn Mawr Formation consists of white, yellow and brown gravel and sand. The Bryn Mawr Formation is considered a deeply weathered formation.

There is a small section of Ultramafic rocks in the southwest corner of the Cresheim Creek watershed. Ultramafic rocks are igneous rocks that contain very low silica content. Ultramafic rocks possess good surface drainage while being highly resistant to weathering at the same time.

3.2.5.2 SOILS

According to the National Resource and Conservation Service Soil Survey, the majority of soils for the Cresheim Creek watershed are classified as hydrologic group B. These soils have a moderate rate of infiltration when the soils are wet (0.50-1.00 in/hr). Water movement through these soils is considered moderately rapid. There is a small band of group D soils along Cresheim Creek. These soils have a very slow rate of infiltration when saturated (0.02-0.10 in/hr) resulting in a high runoff potential.

There is a small section of C soils located on the northeast corner of the watershed. Group C soils have a slow rate of infiltration when saturated (0.17-0.27 in/hr). Water movement through these soils is moderate or moderately slow.

The northern portion of the watershed in Montgomery County is underlain by the Urban Land soils. Urban soils consist of material that has been disturbed by human activity during urbanization. Urban soils have been produced by mixing, filling and contamination of the native soils in both urban and suburban areas.

Table 3-73: Distribution of NRCS Soil Types in Cresheim Creek Watershed

Group	Area (ft^2)	Percent of Total Area
B	9,939,312	14.74%
C	13,486	0.02%
D	87,660	0.13%
Urban	57,390,422	85.11%
Total Area	**67,430,880**	**100%**

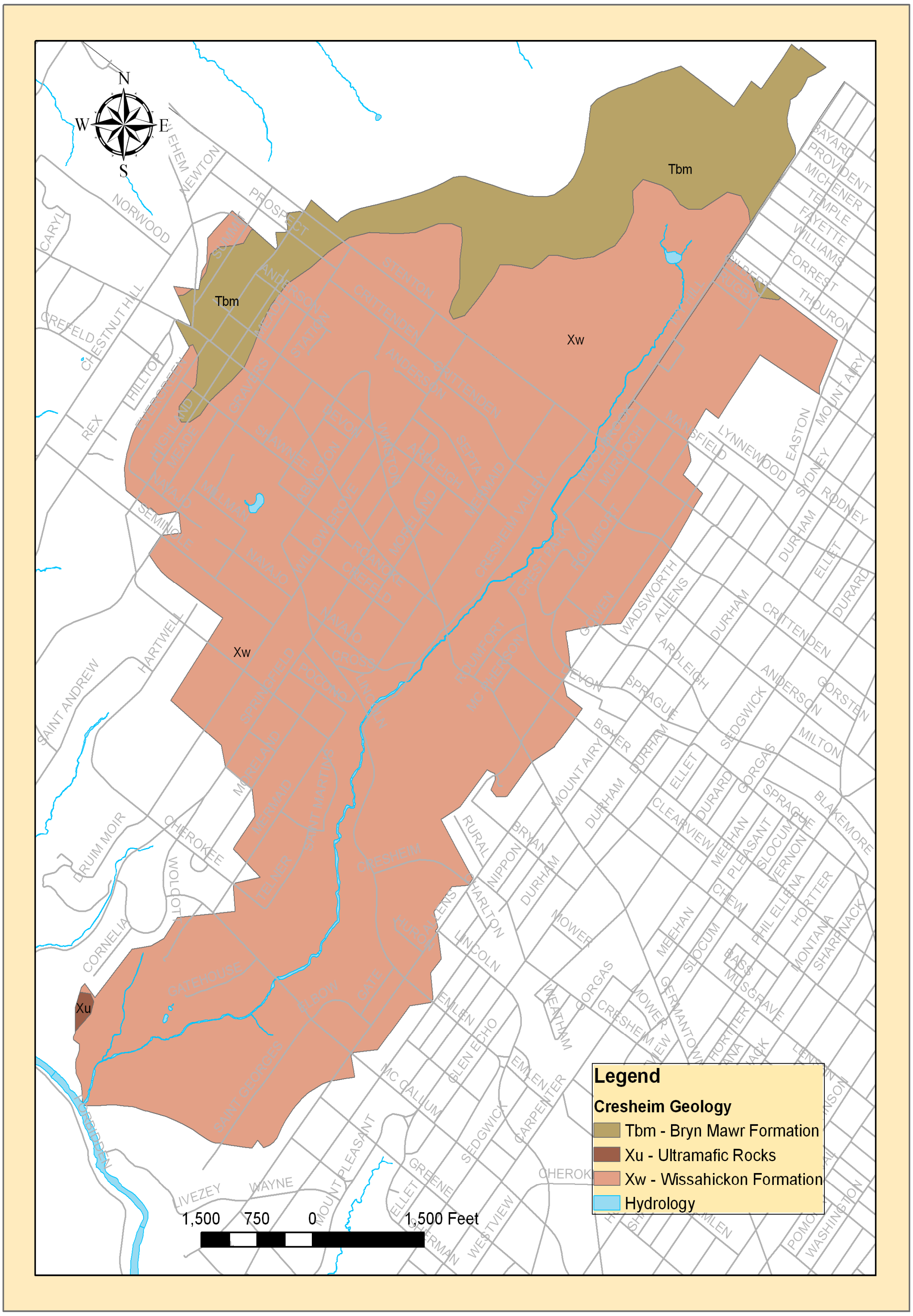


Figure 3-71: Geology of Cresheim Creek Watershed

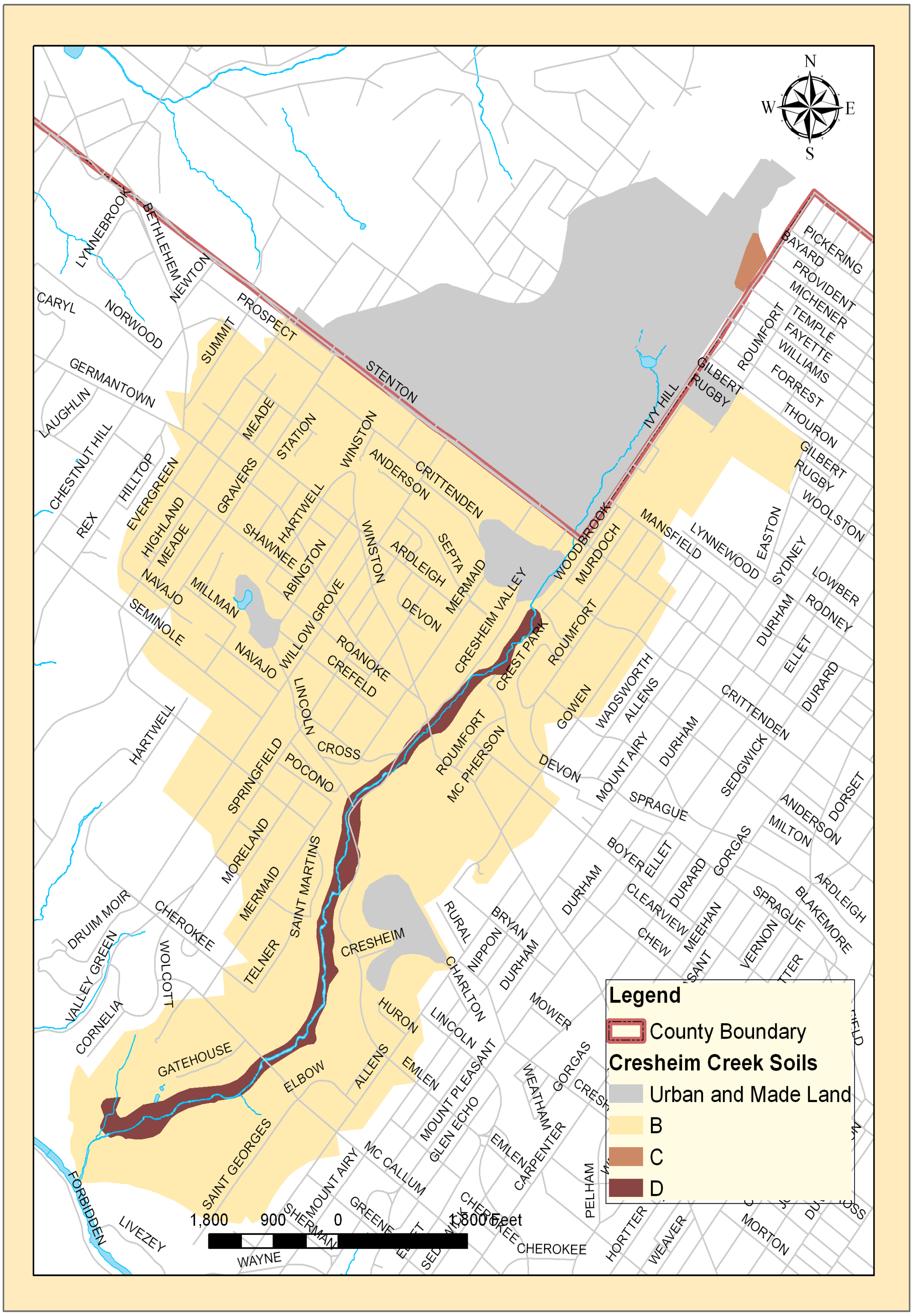


Figure 3-72: Distribution of NRCS Soil Types in Cresheim Creek Watershed

3.2.5.3 BANK EROSION

There were nine bank pin locations along Cresheim Creek (Figure 3-73). The calculated erosion rates are included in Table 3-74. The spatial distribution of BEHI assessment results were represented graphically (Figure 3-73) for each of the segments assessed on Cresheim Creek. Each bank within a respective segment was assessed and rated separately; however, channelized and culverted segments were not assessed as they confer a high degree of protection from bank erosion.

Table 3-74: Cresheim Creek Bank Pin Locations

	BEHI	NBS	Baseline Reading	Most Recent Reading	Erosion Rate (ft)	Erosion Rate (ft/yr)	Eroding (-) or Aggrading (+)
Cresheim Creek							
CC35	Moderate	Low	8/22/2006	8/11/2009	0.42	0.14	A
CC114	Low	Very Low	9/7/2006	8/12/2009	-0.18	-0.062	E
CC18	High	Low	8/22/2006	8/11/2009	-1.28	-0.43	E
CC43	High	Low	8/22/2006	8/11/2009	0.17	0.058	A
CC45	High	Low	8/22/2006	8/11/2009	-0.21	-0.070	E
CC46	High	Low	8/22/2006	8/15/2007	-0.09	-0.09	E
CC64	Low	Very Low	8/22/2006	8/11/2009	0.64	0.22	A
CC74	Low	Low	8/22/2006	8/11/2009	0.38	0.13	A
CC11	High	Low	9/7/2006	8/13/2008	0.87	0.45	A

Total erosion rates were also calculated for the entire length of each tributary within the lower Wissahickon (Table 3-75). To assess the normalized erosion potential of each tributary, the erosion rate per acre of drainage area per year and the erosion rate per foot of stream length per year were calculated. This allowed direct comparison between each of the tributaries with respect to both watershed size and the length of the tributary. Cresheim Creek was ranked eighth out of the twelve tributaries within the lower Wissahickon for erosion rate per foot of stream length. The rankings were based on a scale of one being the highest erosion rate and twelve being the lowest erosion rate.

Table 3-75: Erosion Rates for Lower Wissahickon Tributaries

Tributary	Drainage Area (Acres)	Stream Length (feet)	*2009*		
			Erosion Rate (lb/yr)	*Erosion Rate Per Acre*	*Erosion Rate Per Foot of Stream*
Bell's Mill	323	6,722	420,000	1,307	63
Cathedral Run	160	2,790	150,000	913	52
Cresheim Creek*	1,218	16,431	840,000	690	51
Gorgas Run	499	2,170	170,000	345	79
Hartwell Run	217	3,530	200,000	918	56
Hillcrest	144	5,272	90,000	597	16
Kitchen's Lane	234	7,753	200,000	850	26
Monoshone Creek	1,056	6,926	160,000	156	24
Rex Ave	137	1,903	150,000	1,131	81
Thomas Mill Run	104	4,008	320,000	3,058	79
Valley Green Run	128	2,874	140,000	1,086	48
Wise's Mill Run	446	7,056	490,000	1,090	69
Total/*Average*	**4,666**	**67,435**	**3,300,000**	***1,012***	***54***

* Drainage area listed above for Cresheim Creek reflects the drainage area located within Philadelphia County and not the entire Cresheim Watershed.

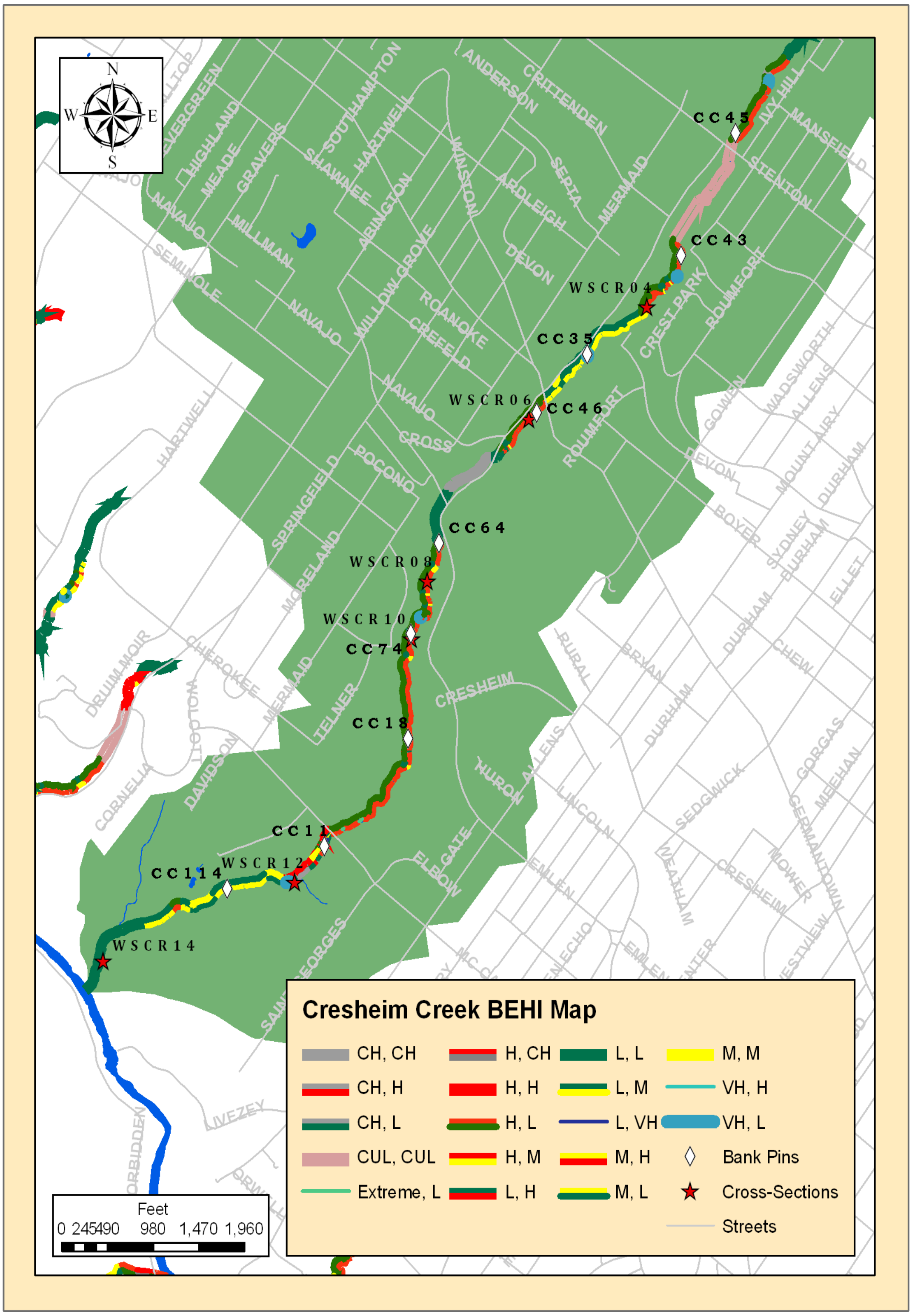


Figure 3-73: Cresheim Creek Watershed BEHI Ratings and Bank Pin Locations

3.2.5.4 INFRASTRUCTURE TRACKDOWN SUMMARY

The Cresheim Creek watershed was one of the downstream-most watersheds of the Lower Wissahickon Creek Watershed. Despite the fact that it was located inside the city of Philadelphia, only part of the stream exhibits the density of infrastructure endemic to such an intensely urban setting. A large proportion of the downstream reaches of Cresheim Creek ran through Fairmount Park which was entirely forested and therefore contained very few infrastructure elements; however, the headwater and upstream reaches of Cresheim Creek were heavily influenced by infrastructure.

Reach WSCR04 contained the highest number of total infrastructure points (i.e. culverts, outfalls, pipe crossings) and the second highest number of channels. The density of infrastructure in WSCR04 was comparatively low given that the reach was approximately 6,700 hundred feet long including 19% of culverted stream length. The remainder of the reaches in Cresheim Creek was about a third of that length. Reach WSCR08 had a large culvert that represented 10% of its length. WSCR06 was the most channelized reach in the watershed with 1,975 feet (33%) of channelization. WSCR08 also had a relatively large amount of channelized portions, as 11% of the total length was channelized. The downstream sections, WSCR10 and WSCR14, had the two dams associated with this creek. Since dams can affect the stream morphology and hydrologic regime for great distances in both directions, these dams were very important when considering the effects of infrastructure.

The Cresheim Creek watershed would likely have been completely besieged with infrastructure had the 3 downstream sections not been within the Park which only contained 9 of the 64 infrastructure points. The total percent of culverted channel length for the watershed was only 9%, which was small considering the large amount of culverts upstream. Most of the negative effects of the infrastructure in this watershed were attributed to the upstream portions of the stream. The majority of the infrastructure in this watershed was in good condition. There were some elements that exhibited signs of long-term use, although none were observed to be in extremely poor condition.

Table 3-76: Summary of Cresheim Creek Infrastructure Point Features

Section ID	Culvert Count	Bridge Count	Outfall Count	Channel Count	Confluence Count	Dam Count	Pipe/ Sewer Count	Other Count	Infra Point Count	Combined Outfall Area (ft^2)
WSCR04	9	1	12	4	0	0	2	1	28	74.5
WSCR06	1	1	9	5	1	0	1	1	17	14.8
WSCR08	1	0	3	2	1	0	1	0	7	25.9
WSCR10	0	0	0	0	0	1	0	0	1	0
WSCR12	0	2	1	1	0	0	0	0	4	1.8
WSCR14	0	1	1	0	1	1	0	0	3	1.8
TOTAL	**11**	**5**	**26**	**12**	**3**	**2**	**4**	**2**	**62**	**118.8**

Table 3-77: Summary of Cresheim Creek Infrastructure Linear Features

Section ID	Segment Length (ft)	Segment Length (ft), 3 sides	Culvert Length (ft)	Percent Culverted	Channel Length (ft), 1 side	Channel Length (ft), 2 sides	Channel Length (ft), 3 sides	Channel Length (ft)	Percent Channelized
WSCR04	6726	20178	1290	19.2	187	48	0	283	1.4
WSCR06	1980	5940	66	3.3	178	48	567	1975	33.2
WSCR08	1427	4281	139	9.7	6	224	0	454	10.6
WSCR10	1927	5781	0	0	0	0	0	0	0
WSCR12	2793	8379	0	0	168	0	0	168	2.0
WSCR14	1551	4653	0	0	0	0	0	0	0
TOTAL	**16404**	**49212**	**1495**	**9.1**	**539**	**320**	**567**	**2880**	**5.9**

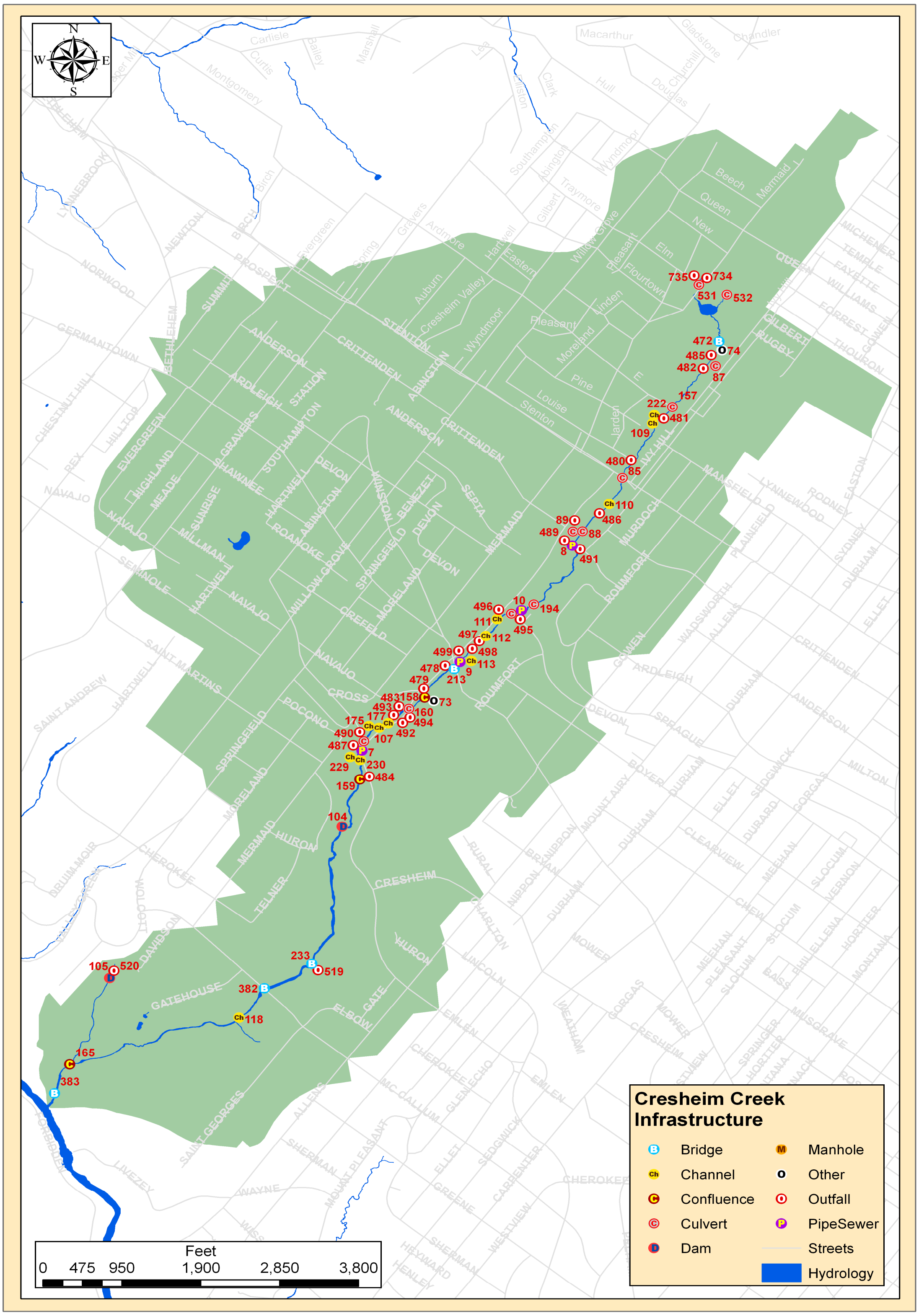


Figure 3-74: Cresheim Creek Infrastructure Locations

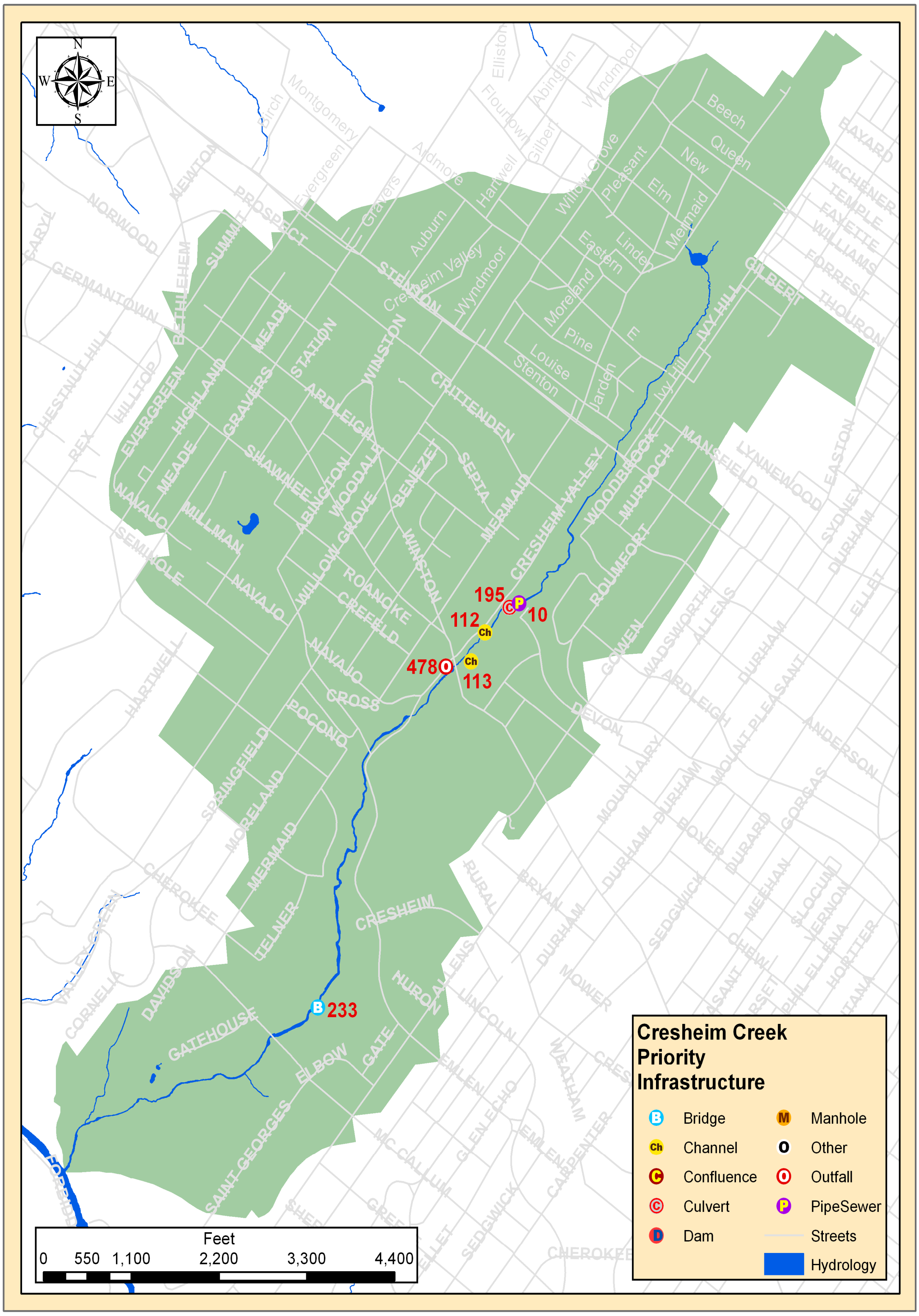


Figure 3-75: Cresheim Creek Priority Infrastructure

3.2.5.5 UNIFIED STREAM ASSESSMENT RESULTS FOR THE CRESHEIM CREEK WATERSHED

The Cresheim Creek watershed is by far the largest watershed of the Lower Wissahickon Basin with a total area of 1,548 acres (2.42 mi²). The majority of Cresheim Creek was within the City of Philadelphia, although the headwaters of the creek as well as an additional 0.5 miles of stream were located in Springfield Township, Montgomery County. Excluding the first 2,500 feet of the main stem channel within Philadelphia, Cresheim Creek and its two small tributaries were contained within Fairmount Park. Large parcels of significance within the watershed included New Covenant Church of Philadelphia and the Ivy Hill Cemetery.

The Center for Watershed Protection's (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and watersheds within the Lower Wissahickon Basin.

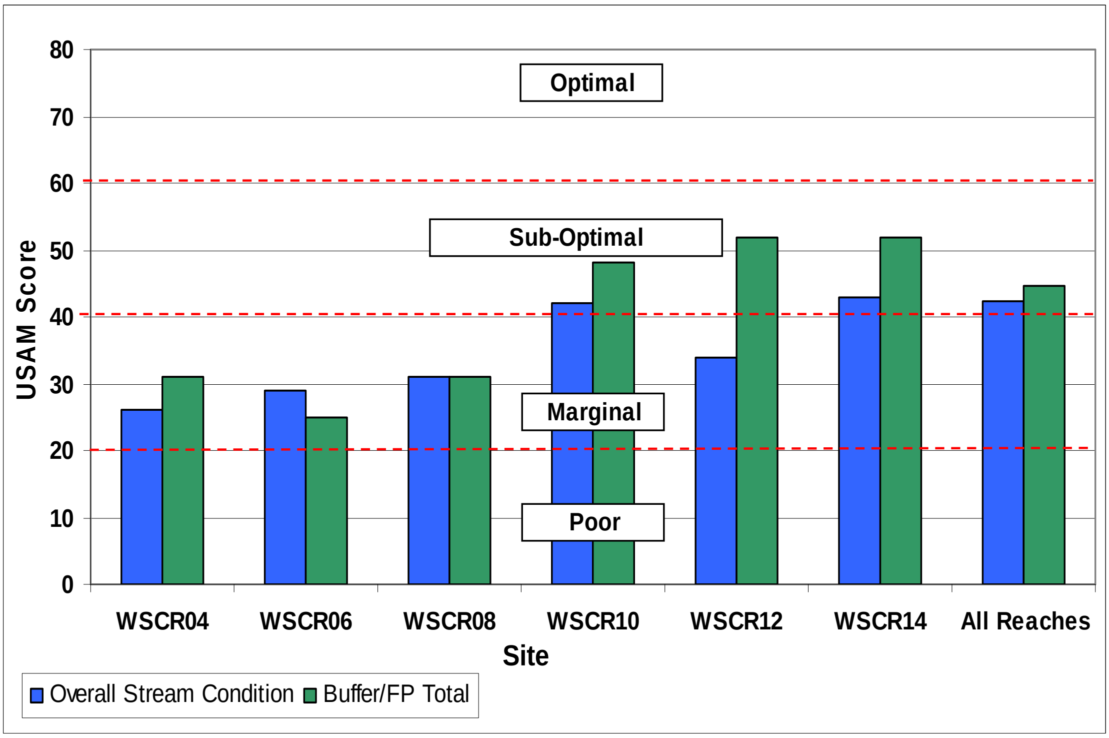


Figure 3-76: Results for Main Stem Cresheim Creek USAM Components

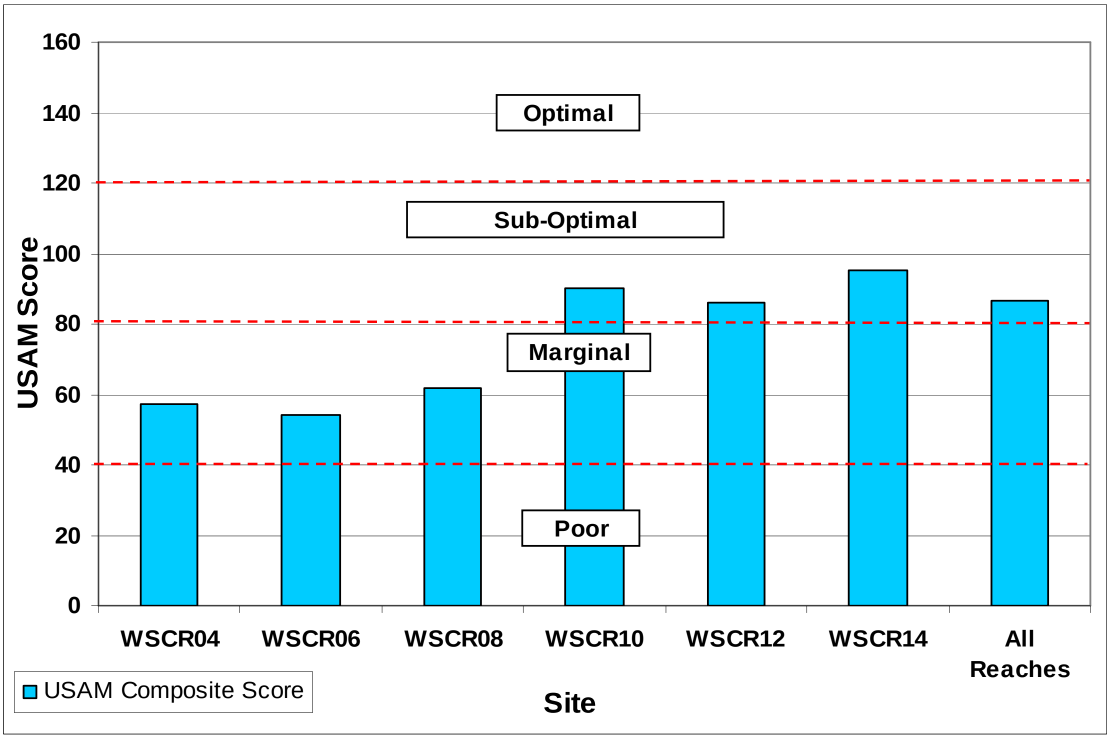


Figure 3-77: Cresheim Creek USAM Results

3.2.5.5.1 WSCR04

Reach WSCR04 formed the headwaters to Cresheim Creek and was the only reach with segments of stream channel in Montgomery County. The reach began as two small outfall-fed channels that drained to a shallow pond located 350 feet east of the intersection of Mermaid Lane and Flourtown Avenue. The larger of the two channels (DSR) received flow from WSout734 and WSout735. The DSL channel received flow from WScul532 which drained a large industrial park. Cross section WSCR04, used to characterize the reach, was located about 4,000 feet downstream within the Philadelphia portion of Cresheim Creek. The gravel-dominated (64%) reach was characterized by a very high width to depth ratio (41.7), a deeply entrenched channel (ER=1.2) and an extremely shallow gradient (0.9%). Overall, the reach was classified as an F4 stream type and had a composite USAM score (Figure 3-77) of (57/160).

3.2.5.5.2 WSCR06

Reach WSCR06 began at the upstream end of WScha112, which was located approximately 560 feet northeast of the Germantown Avenue Bridge (WSbri213). The reach extended 1,980 feet downstream to the end of the channelized segment (WScha175 on DSR and WScha177 on DSL) of stream west of Cresheim Valley Road. The substrate particle size distribution was dominated by gravel (64%) although cobble-sized particles were present in abundance (31%). The reach was characterized by a moderate width to depth ratio (15.6), a deeply entrenched (ER=1.2) channel and a relatively shallow gradient (1.7%). The channel was classified as an F4 stream type and had a USAM composite score of (54/160).

3.2.5.5.3 WSCR08

Reach WSCR08 began approximately 150 feet north of the intersection of Lincoln Drive and Cresheim Valley Road. The upstream segments of the reach were highly channelized (WScha229 on DSR and WScha230 on DSL) and culverted (WScul161 beneath Lincoln Drive). There was a small (approximately 75 feet) ephemeral channel located about 300 feet upstream of cross section WSCR08. This small channel received intermittent flow from WSout484, which drains Cresheim Valley Road. The bottom of the reach was located 150 feet upstream from WSdam104. Reach WSCR08 was characterized by a high width to depth ratio (28.2), a deeply entrenched channel (ER=1.1) and a relatively shallow gradient (1.8%). The reach was classified as an F4 type stream and had a USAM composite score of (62/160).

3.2.5.5.4 WSCR10

Reach WSCR10 began 130 feet upstream of WSdam104, which was the only infrastructure element present within the 1,927-foot reach. The reach was characterized by a high width to depth ratio (25.9), a moderately entrenched channel (ER=1.5) and a mild gradient (1.6%). As opposed to the upstream reaches, WSCR10 had a substrate particle size distribution dominated by cobble-sized particles (52%) although gravel (34%) was abundant throughout the reach. The channel was characterized as a B4c stream type and served as a transitional reach between the upstream B-type stream. Reach WSCR10 had a composite USAM score of (90/160), which was the second highest score observed in the Cresheim Creek watershed.

3.2.5.5.5 WSCR12

Reach WSCR12 began 170 feet downstream of WSbri233, a stone arch bridge that connected a pedestrian footpath. There was a small (approximately 415 feet) tributary on the DSL side of the main stem channel about 75 feet upstream of cross section WSCR12. Reach WSCR12 was the second longest reach (2,793 feet) after reach WSCR04. The substrate particle size distribution was dominated by cobble-sized particles (47%) although gravel was present in a nearly equal proportion (39%). The reach had similar channel morphology to WSCR10 in that the channel had a high width to depth ratio (20.3), a moderately entrenched channel (1.6) and moderately shallow gradient (3%). The reach was classified as a B4 stream channel and had a USAM composite score of (86/160).

3.2.5.5.6 WSCR14

Reach WSCR14 was the downstream-most reach on Cresheim Creek. There was one tributary on the reach, unnamed tributary A, which had a total length of 1,497 feet. As with reach WSCR12, there were few infrastructure elements within the reach. In total, there was one bridge (WSbri213), an outfall (WSout520) and a dam (WSdam105), the latter two were both located near the headwaters of unnamed tributary A. The substrate particle size distribution had a nearly equal proportion of gravel (44%) and cobble-sized particles (42%). Overall, the reach was characterized by a large width to depth ratio (29.7) and an entrenched channel (ER=1.4) and was similar to the channel morphology observed in reaches WSCR10 and WSCR12; however, reach WSCR14 had a much steeper gradient (4.7%) and was classified as a B4a stream type. The reach had a composite USAM score of (95/160), which was the highest score observed for the Cresheim Creek watershed.

3.2.5.6 SUMMARY OF UNIFIED STREAM ASSESSMENT RESULTS

The mean scores for both the individual USAM components as well as the overall USAM score were all classified as “marginal” (Table 3-78). Average conditions within the Cresheim Creek watershed’s buffers and floodplains were slightly better than conditions observed within the stream channels. The watershed averages for each component as well as the composite USAM score did not compare well against the respective All Reaches averages, especially for the *Overall Stream Condition* component. The scores for individual parameters ranged from poor to optimal, displaying similar levels of variability between reaches.

Table 3-78: USAM Results for Cresheim Creek Watershed

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP Condition	USAM Score
WSCR04	Cresheim	26	31	57
WSCR06	Cresheim	29	25	54
WSCR08	Cresheim	29	31	62
WSCR10	Cresheim	42	48	90
WSCR12	Cresheim	34	52	86
WSCR14	Cresheim	43	52	95
WSCR mean		**34.2**	**39.8**	**74.0**
All Reaches Average		**42.4**	**44.5**	**86.9**

3.2.5.6.1 SUMMARY OF OVERALL STREAM CONDITION SCORES IN THE CRESHEIM CREEK WATERSHED

The mean *Overall Stream Condition* score of the Cresheim Creek reaches was 33.8/80, which rated as marginal. In comparison, the All Reaches average was 46/80, which was rated as “suboptimal.” The parameter that compared most favorably with the average conditions present in the other Lower Wissahickon tributaries was the *Bank Erosion* parameter. The mean *Instream Habitat* score for Cresheim Creek (9.3/20) was relatively low compared to average conditions observed in the Lower Wissahickon (14.5/20). This can be partially explained by the characteristically shallow, wide channels observed in the upper reaches of Cresheim Creek. These reaches (WSCR04, WSCR06, WSCR08) had shallow, homogenous depth regimes, substrate distributions skewed toward less stable (i.e. gravel) particles and minimal abundances of coarse woody debris (CWD). The cumulative affects of these factors results in a habitat template that has a reduced ability to provide shelter from high velocity scouring flows and limited food production potential (aside from filamentous algae). From a geomorphic perspective, Cresheim Creek was characteristic of many impacted urban streams as width to depth ratios were relatively high and entrenchment ratios were extremely low. These ratios are manifest in wide, shallow channels with little variation in depth as well as channels that are isolated from their respective floodplains. Both of these factors have adverse effects on benthic macroinvertebrates and fish as well as riparian vegetation.

Table 3-79: USAM Overall Stream Condition Scoring for Cresheim Creek Watershed

OVERALL STREAM CONDITION								
Reach ID	**Sub-watershed**	**Instream Habitat**	**Vegetative Protection**		**Bank Erosion**		**Floodplain Connection**	**Overall Stream Condition**
			Left	**Right**	**Left**	**Right**		
WSCR04	Cresheim	5	3	3	5	8	2	26
WSCR06	Cresheim	5	4	4	5	8	3	29
WSCR08	Cresheim	4	5	5	8	9	1	31
WSCR10	Cresheim	14	6	6	7	4	5	42
WSCR12	Cresheim	14	3	3	4	4	6	34
WSCR14	Cresheim	14	4	4	8	9	4	43
WSCR mean		**9.3**	**4.2**	**4.2**	**6.2**	**6.8**	**3.5**	**33.8**
All Reaches Average		**13.1**	**4.9**	**4.9**	**6.3**	**7.0**	**6.3**	**42.4**

3.2.5.6.1.1 INSTREAM HABITAT

Scores for the *Instream Habitat* parameter ranged from “poor” to “suboptimal” throughout the watershed. The highest scores (14/20) were observed in reaches WSCR10, WSCR12 and WSCR14, which were rated as “suboptimal.” These reaches were characterized by ample supplies of stable substrate (52%, 47% and 42% cobble respectively) and CWD. The moderate entrenchment ratios observed in these reaches (1.5, 1.6 and 1.4 respectively) allowed for the recruitment of CWD from the adjacent floodplain and upland areas while also creating an opportunity for exposed root wads to function as usable instream habitat.

In comparison, the worst reach, WSCR08, had geomorphic characteristics that precluded the establishment of optimal instream habitat criterion. The entrenchment ratio (1.1) in reach WSCR08 effectively isolated the channel from the floodplain, which limits the recruitment of CWD from the “upland fringe.” Furthermore, the substrate in reach WSCR08 was dominated by gravel (2-64 mm), which does not confer the same stability properties as would cobble substrate. The width to depth ratio (28.2) in this reach was elevated compared to the “suboptimal” reaches. An elevated width to depth ratio decreases the depth of flow in the channel such that the depth profile throughout the reach becomes relatively homogenous which limits the potential for habitat suitability amongst a diverse array of aquatic fauna. The width to depth ratio observed in WSCR14 was higher than the ratio observed in WSCR08; however, the colluvial deposits of boulders present at the stream margins of reach WSCR14 function to concentrate a larger volume of stream flow in the center of the channel therefore providing a much more heterogeneous depth profile.

In general, the upstream reaches (WSCR04, WSCR06 and WSCR08) of the Cresheim Creek watershed were observed to have diminished habitat quality when compared to the downstream reaches. Each of the upstream reaches was rated as “poor” compared to the downstream reaches which were all rated as “suboptimal.” In comparison to the rest of the watersheds in the Lower Wissahickon, the mean score for the watershed (9.3/20) was rated as “marginal” whereas the mean *Instream Habitat* score for All Reaches was (13.1/20), which was rated as “suboptimal.”

3.2.5.6.1.2 VEGETATIVE PROTECTION

Scores for the *Vegetative Protection* parameter were generally low to moderate throughout the Lower Wissahickon. The All Reaches averages for the left and right (both 4.9/10) bank were rated as “marginal.” The mean score for both banks of the Cresheim Creek watershed was (4.2/10) and was also rated as “marginal” for this parameter. The highest score (6/10) was observed in reach WSCR10 and the lowest score (3/10) was observed in reaches WSCR04 and WSCR12. The “poor” and “marginal” ratings for the reaches downstream of WSCR10 can be attributed to the extent of localized scour observed at these sites which can preclude the establishment of most rooted vegetation. At sites WSCR12 and WSCR14 the “poor” and “marginal” ratings for these reaches were due to factors other than degradation. The presence of bedrock outcrops and colluvial deposits of boulders, often from the channel margin (edge of water) up to the bankfull elevation in some segments, precluded the establishment of vegetation patches.

3.2.5.6.1.3 BANK EROSION

In general, scores for the *Bank Erosion* parameter were moderate to good in the Cresheim Creek watershed. The mean scores for the watershed’s right (6.8/10) and left (6.2/10) banks were comparable to the respective All Reaches averages with many of the banks at individual reaches scoring higher than the All Reaches averages for both the right (7.0/10) and left (6.3/10) banks. The best reaches within the watershed were WSCR08 and WSCR14 as both were rated as “suboptimal” for both banks. The lowest scores in the watershed for both the right and left banks were recorded for reach WSCR12, which was rated as "marginal."

3.2.5.6.1.4 FLOODPLAIN CONNECTION

All stream reaches within the Cresheim Creek watershed exhibited varying levels of entrenchment and floodplain disconnection. Entrenchment ratios ranged from (1.1–1.6) suggesting that floodplain inundation is very rare in this watershed, except for large events. In comparison, the mean entrenchment ratio for the Cresheim Creek watershed was 1.35 whereas the mean for the large Lower Wissahickon tributaries was considerably higher at 1.8. The bankfull discharge in the reach with the lowest score (i.e. most deeply entrenched reach), WSCR08 (1/20), was 185 cfs. Flows in this reach would have to exceed 428 cfs to inundate the floodplain.

3.2.5.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE CRESHEIM CREEK WATERSHED

The scores for the *Overall Buffer and Floodplain Condition* in the Cresheim Creek stream corridor were generally low to moderate for most parameters. The parameters that were most comparable to the average conditions observed in the other large Lower Wissahickon tributaries were the *Vegetated Buffer Width* and *Floodplain Vegetation* parameters. The other two parameters, *Floodplain Habitat* and *Floodplain Encroachment* were rated in the "poor" to "marginal" range for most parameters. The low scores for the *Floodplain Habitat* parameter were attributed to the fact that the stream channels of the watershed were "disconnected" from their respective floodplains due to corridor-wide channel entrenchment of varying degrees. The scores for the *Floodplain Encroachment* parameter were influenced heavily by the extensive development in the upper portions of the watershed. In many of the upstream reaches, roads were constructed in close proximity to stream reaches either normal or parallel to the respective stream reaches. Development of this nature not only reduces the amount of contiguous floodplain area adjacent to a stream channel, but also contributes extensive volumes of high-velocity stormwater runoff that ultimately degrades channels and has a net adverse impact on downstream reaches as well.

Table 3-80: USAM Buffer and Floodplain Condition Scoring for Cresheim Creek Watershed

OVERALL BUFFER AND FLOODPLAIN CONDITION							
Reach ID	**Sub-watershed**	**Vegetated Buffer Width**		**Floodplain Vegetation**	**Floodplain Habitat**	**Floodplain Encroachment**	**Overall Buffer/FP Condition**
		Left	**Right**				
WSCR04	Cresheim	7	7	8	6	3	31
WSCR06	Cresheim	6	3	8	4	4	25
WSCR08	Cresheim	8	8	9	3	3	31
WSCR10	Cresheim	9	9	12	8	10	48
WSCR12	Cresheim	9	9	17	4	13	52
WSCR14	Cresheim	9	9	17	4	13	52
WSCR mean		**8.0**	**7.5**	**11.8**	**4.8**	**7.7**	**39.8**
All Reaches		**8.1**	**8.6**	**13.8**	**5.5**	**8.5**	**44.5**

3.2.5.6.2.1 VEGETATED BUFFER WIDTH

The vegetated buffer widths throughout the Cresheim Creek watershed were rather extensive. The mean scores for the right (7.5/10) and left (8/10) banks were rated as “suboptimal” and compared favorably with the other large Lower Wissahickon tributaries (Table 3-80). Extensive variation between sites was not observed as all sites except for WSCR06 had ratings of “suboptimal” for both banks.

3.2.5.6.2.2 FLOODPLAIN VEGETATION

The *Floodplain Vegetation* parameter takes into account the dominant vegetation type (i.e. shrub, mature forest, herbaceous ground cover or mowed turf) observed throughout a reach, with mature forest being the optimal condition. The presence of a mature riparian forest is an indicator of low levels of disturbance from factors such as development and extreme flooding given mature forests may take decades to become established. Scores for this parameter exhibited considerable variation between reaches as ratings ranged from “marginal” to “optimal.” The mean score for Cresheim Creek (11.8/20) was lower than the mean condition observed for the Lower Wissahickon (13.8/20) although both were rated as “suboptimal.” A distinct trend was observed where scores increased dramatically in a downstream stream direction. WSCR04 and WSCR06, the upstream-most reaches were rated as “marginal”, with both reaches scoring (8/20). The downstream sites WSCR12 and WSCR14 were both rated as “optimal” with both reaches scoring 17/20. The trend may be attributed to a number a factors such as differences in light availability, slope, hydrology or level of disturbance between the two ends of the watershed.

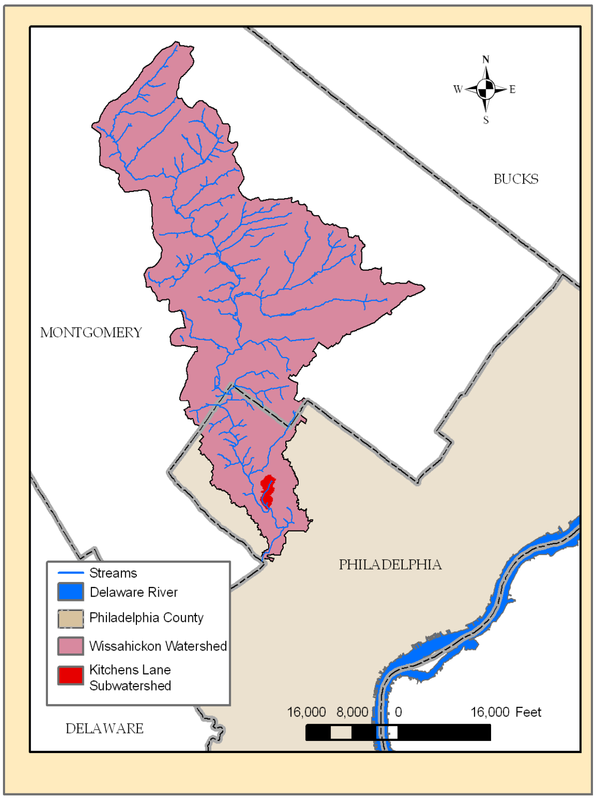
3.2.5.6.2.3 FLOODPLAIN HABITAT

The scores for *Floodplain Habitat* were generally very low and ranged from “poor” to “marginal.” The average score for the watershed was 4.8/20 which was rated as “marginal.” The average score for the large Lower Wissahickon tributaries was 5.5/20, which was also rated as “marginal.” The “poor” and “marginal” ratings observed in the Cresheim Creek watershed can be attributed to the high degree of “floodplain disconnection” within the channels of the corridor as evidenced by the range of low entrenchment ratios (1.1-1.6). Low entrenchment ratios are an indicator that floodplains within the corridor are rarely inundated by flood flows. Over-bank flood flows are vital to a riparian ecosystem because these flows provide inputs of sediment, nutrients and other organic matter such as CWD. Without these inputs and occasional inundation, floodplain habitats such as ephemeral pools and backwater channels cannot be formed or maintained.

3.2.5.6.2.4 FLOODPLAIN ENCROACHMENT

Scores for the *Floodplain Encroachment* parameter ranged from “poor” to “suboptimal” and increased in a downstream trend. The average condition within the watershed’s corridors was rated as “marginal” with a score of 7.7/20. The average condition of the large Lower Wissahickon tributaries was slightly better with a score of 8.5/20. In general, scores in the upstream reaches were low due to the high level of development in these sections of the watershed. WSCR04 and WSCR08, two of the three upstream sites, had the lowest scores in the watershed (3/20) and were rated as “poor.” In contrast the downstream sites WSCR12 and WSCR14, which are closer to Fairmount Park, both scored (13/20) and were rated as "suboptimal."

3.2.6 Kitchen's Lane Watershed and Reach Characteristics



Kitchen's Lane Run is a tributary to the main stem of the Wissahickon Creek. The tributary originates from three outfalls (2 City-owned, 1 privately owned) located within an area of Fairmount Park that is surrounded by a residential neighborhood. Kitchen's Lane Run is a first-order tributary for approximately 1.1 miles until a smaller 0.1 mile tributary enters Cresheim approximately 0.15 miles from the Confluence with the Wissahickon main stem. The dominant substrate varies from course gravel to medium cobble material. Both the valley floor and channel have been substantially impacted by past and current land use.

The entire Kitchen's Lane Run watershed is 234 acres. Major land use types within the watershed include: wooded (46%), residential – row home (27%), and residential – single family detached (26%). Kitchen's Lane Run is surrounded by Fairmount Park on both sides for the entire length. The Park buffer ranges from about 50 feet to about 2,000 feet.

The Philadelphia Water Department (PWD) owns and operates four stormwater outfalls that release into Kitchen's Lane Run. The entire watershed is drained by a separate storm sewer system that is directly connected to all impervious surfaces. There are five additional private stormwater outfalls that release into Kitchen's Lane Run.

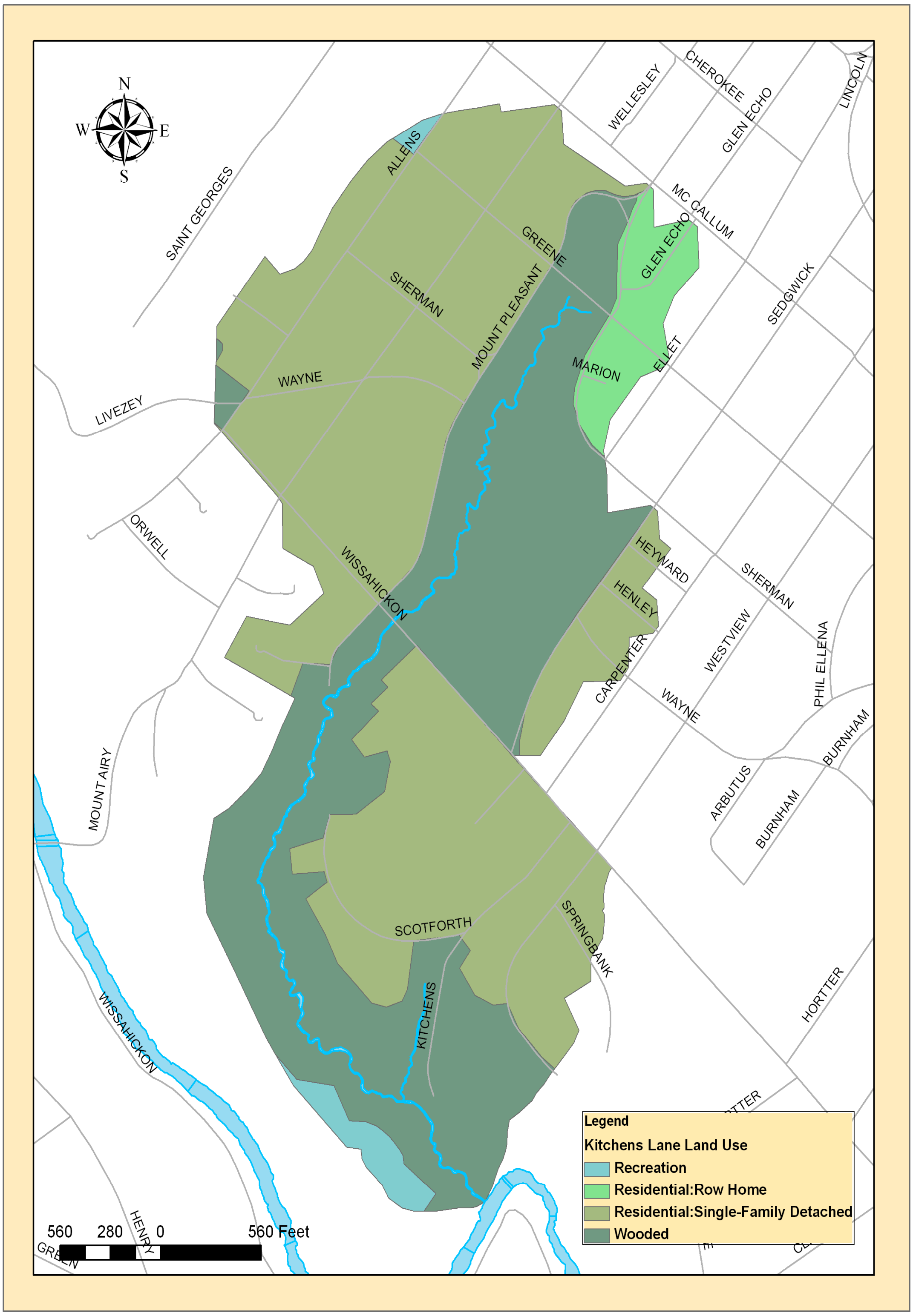


Figure 3-78: Kitchen's Land Watershed Land Use

3.2.6.1 GEOLOGY

The Kitchen's Lane Run watershed is completely underlain by the Wissahickon Formation. The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

3.2.6.2 SOILS

According to the National Resource and Conservation Service Soil Survey, the majority of soils for the Kitchen's Lane Run watershed are classified as hydrologic group B. These soils have a moderate rate of infiltration when the soils are wet (0.50-1.00 in/hr). Water movement through these soils is considered moderately rapid.

There is a small band of group D soils along Kitchen's Lane Run. These soils have a very slow rate of infiltration when saturated (0.02-0.10 in/hr) resulting in a high runoff potential.

There is a small section of C soils located near the confluence with the Wissahickon Creek. Group C soils have a slow rate of infiltration when saturated (0.17-0.27 in/hr). Water movement through these soils is moderate or moderately slow.

There is a small portion of Urban Land soils on the downstream left side of the tributary near the headwaters. Urban soils consist of material that has been disturbed by human activity during urbanization. Urban soils have been produced by mixing, filling and contamination of the native soils in both urban and suburban areas.

Table 3-81: Distribution of NRCS Soil Types in Kitchen's Lane Watershed

Group	Area (ft^2)	Percent of Total Area
B	10,149,210	99.57%
C	11,212	0.11%
D	29,560	0.29%
Urban	3,058	0.03%
Total Area	**10,193,040**	**100%**

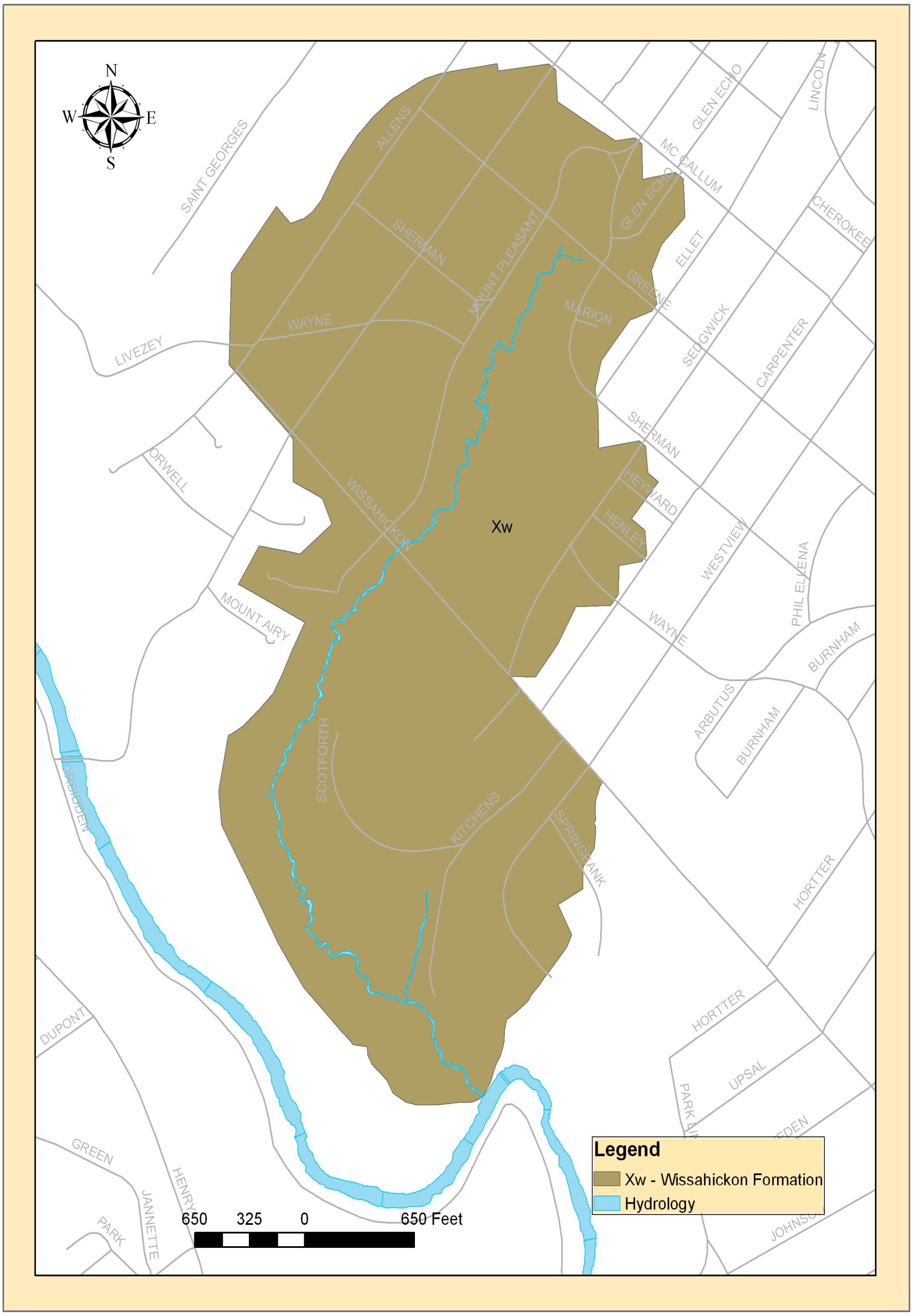


Figure 3-79: Geology of Kitchen's Lane Watershed

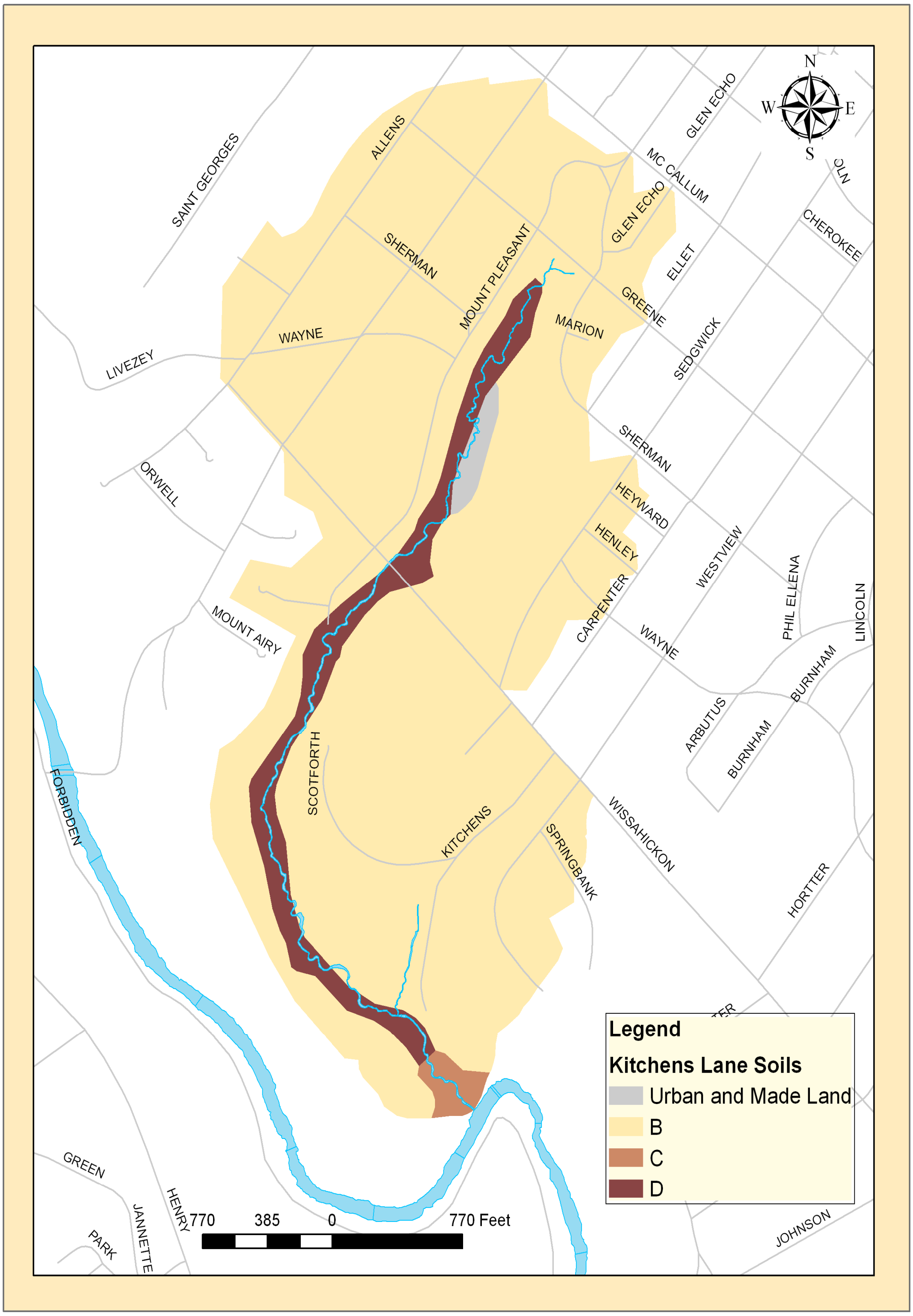


Figure 3-80: Distribution of NRCS Soil Types in Kitchen's Lane Watershed

3.2.6.3 BANK EROSION

There were ten bank pin locations along Kitchen's Lane Run (Figure 3-81). The calculated erosion rates are included in Table 3-82. The spatial distribution of BEHI assessment results were represented graphically (Figure 3-81) for each of the segments assessed on Kitchen's Lane Run. Each bank within a respective segment was assessed and rated separately; however, channelized and culverted segments were not assessed as they confer a high degree of protection from bank erosion.

Table 3-82: Kitchen's Lane Run Bank Pin Locations

	BEHI	NBS	Baseline Reading	Most Recent Reading	Erosion Rate (ft)	Erosion Rate (ft/yr)	Eroding (-) or Aggrading (+)
Kitchen's Lane							
KL32	High	High	8/15/2006	8/11/2009	-0.24	-0.080	E
KL35	Very High	Moderate	8/15/2006	8/11/2009	-0.97	-0.33	E
KL38	High	Low	8/15/2006	8/11/2009	-0.56	-0.19	E
K44L42	Very High	High	8/15/2006	8/11/2009	-0.23	-0.076	E
KL44	High	Very High	8/15/2006	8/14/2008	-0.57	-0.29	E
KL909	Low	Low	8/15/2006	8/11/2009	0.12	0.04	A
KL915	Moderate	Low	8/15/2006	8/11/2009	-0.36	-0.12	E
KL939	Low	Low	8/15/2006	8/11/2009	0.13	0.042	E
KL946	Low	Low	8/15/2006	8/14/2009	-0.16	-0.055	E
KL950	Low	Low	8/14/2006	8/11/2009	-0.41	-0.14	E

Total erosion rates were also calculated for the entire length of each tributary within the Lower Wissahickon (Table 3-83). To assess the normalized erosion potential of each tributary, the erosion rate per acre of drainage area per year and the erosion rate per foot of stream length per year were calculated. This allowed direct comparison between each of the tributaries with respect to both watershed size and the length of the tributary. Kitchen's Lane Run was ranked tenth out of the twelve tributaries within the lower Wissahickon for erosion rate per foot of stream length. The rankings were based on a scale of one being the highest erosion rate and twelve being the lowest erosion rate.

Table 3-83: Erosion Rates for Lower Wissahickon Tributaries

Tributary	Drainage Area (Acres)	Stream Length (feet)	*2009*		
			Erosion Rate (lb/yr)	*Erosion Rate Per Acre*	*Erosion Rate Per Foot of Stream*
Bell's Mill	323	6,722	420,000	1,307	63
Cathedral Run	160	2,790	150,000	913	52
Cresheim Creek	1,218	16,431	840,000	690	51
Gorgas Run	499	2,170	170,000	345	79
Hartwell Run	217	3,530	200,000	918	56
Hillcrest	144	5,272	90,000	597	16
Kitchen's Lane	234	7,753	200,000	850	26
Monoshone Creek	1,056	6,926	160,000	156	24
Rex Ave	137	1,903	150,000	1,131	81
Thomas Mill Run	104	4,008	320,000	3,058	79
Valley Green Run	128	2,874	140,000	1,086	48
Wise's Mill Run	446	7,056	490,000	1,090	69
Total/*Average*	**4,666**	**67,435**	**3,300,000**	***1,012***	***54***

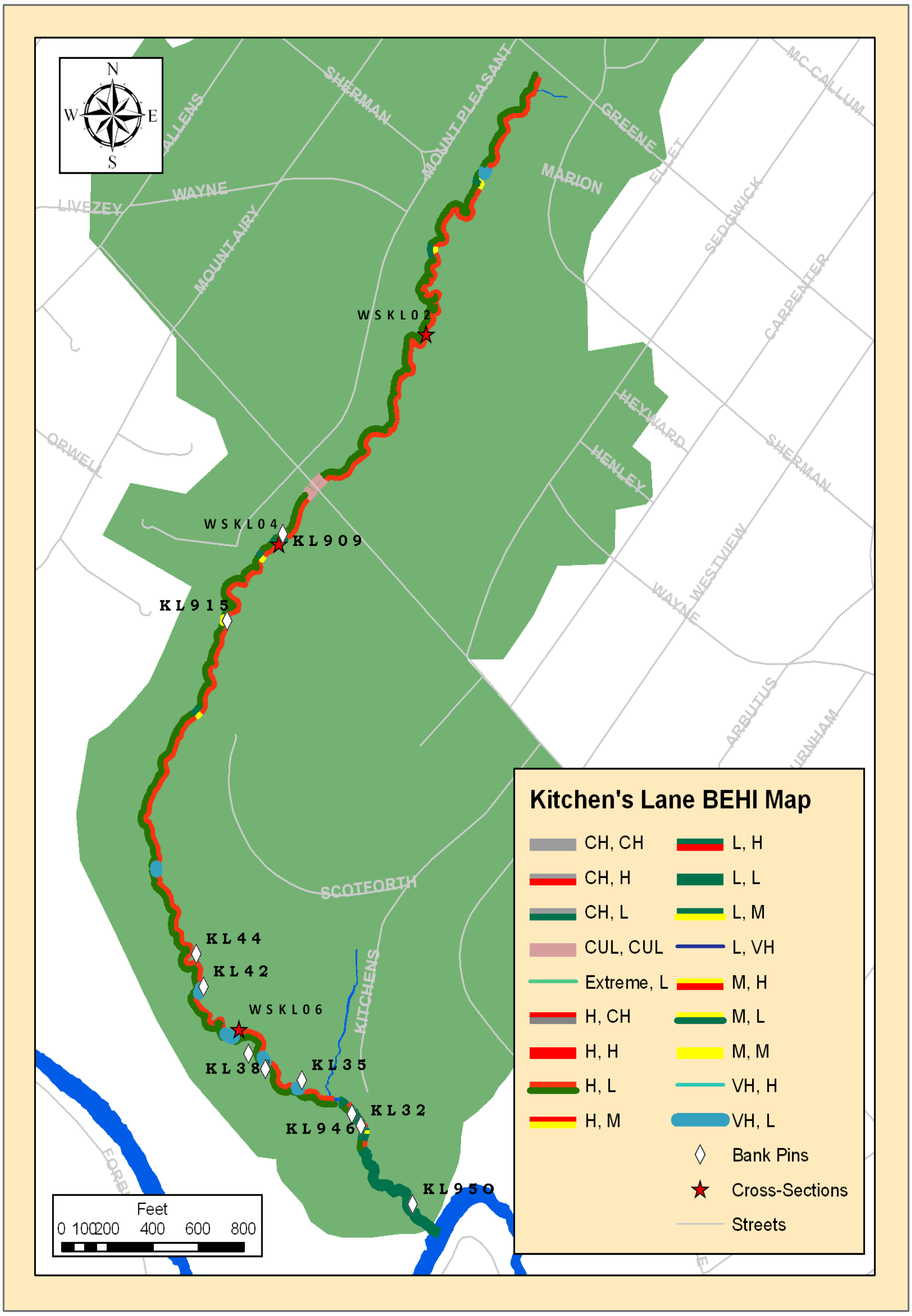


Figure 3-81: Kitchen's Lane BEHI Ratings and Bank Pin Locations

3.2.6.4 INFRASTRUCTURE TRACKDOWN SUMMARY

Kitchen's Lane Run was located entirely within Fairmount Park. Despite its location, the stream had numerous pieces of infrastructure associated with the urban development within the area. The majority of the infrastructure on Kitchen's Lane Run was located in reach WSKL06 on a tributary to Kitchen's Lane. The tributary (unnamed tributary A) ran parallel to Kitchen's Lane and had three homes along its banks. There were two bridges (WSbri230 and WSbri231), two culverts (WScul100 and WScul512), a dam (WSdam103), and 345 feet of channelization on both sides (Wscha117 on DSR and WScha179 on DSL) of the small stream. The channelization accounted for 7% of the stream length of WSKL06 and was the only channelized portion of Kitchen's Lane Run. The bridges and culverts on the tributary can be attributed to residents living in the area and their access to both sides of the creek.

In reach WSKL02 there were five large outfalls, 2-3 feet in diameter, which contributed a considerable amount of stormwater to the channel. There were two culverts on Kitchen's Lane that conveyed the stream under sewer pipes. WScul510 in reach WSKL04 passed a 15-inch sanitary sewer line from Mount Pleasant Road over the stream to the Wissahickon High Level Interceptor east of WScul099, which passes the high level interceptor over Kitchen's Lane Run. These culverts did not appear to have the capacity to convey the necessary flow of water and sediment downstream to stabilize the channel. Evidence of this can be seen in the photos (Appendix B) which show a debris jam behind WScul510 and fine sediment deposition downstream of WScul099. Along Kitchen's Lane Run, there were three infrastructure elements that were in poor condition (WScha117, WScha179 and WScul100), all of which were located on unnamed tributary A.

Table 3-84: Kitchen's Lane Infrastructure Point Features

Section ID	Culvert Count	Bridge Count	Outfall Count	Channel Count	Confluence Count	Dam Count	Infra Point Count	Combined Outfall Area (ft^2)
WSKL02	0	1	5	0	0	0	6	23.6
WSKL04	2	0	1	0	0	0	3	3.1
WSKL06	3	5	3	2	3	1	14	11.0
TOTAL	**5**	**6**	**9**	**2**	**3**	**1**	**23**	**37.7**

Table 3-85: Kitchen's Lane Infrastructure Linear Features

Section ID	Segment Length (ft)	Culvert Length (ft)	Percent Culverted	Channel Length (ft), 2 sides	Channel Length (ft)	Percent Channelized
WSKL02	2223	0	0	0	0	0
WSKL04	1973	128	6	0	0	0
WSKL06	3370	28	1	351	702	6.9
TOTAL	**7566**	**156**	**2**	**351**	**702**	**6.9**

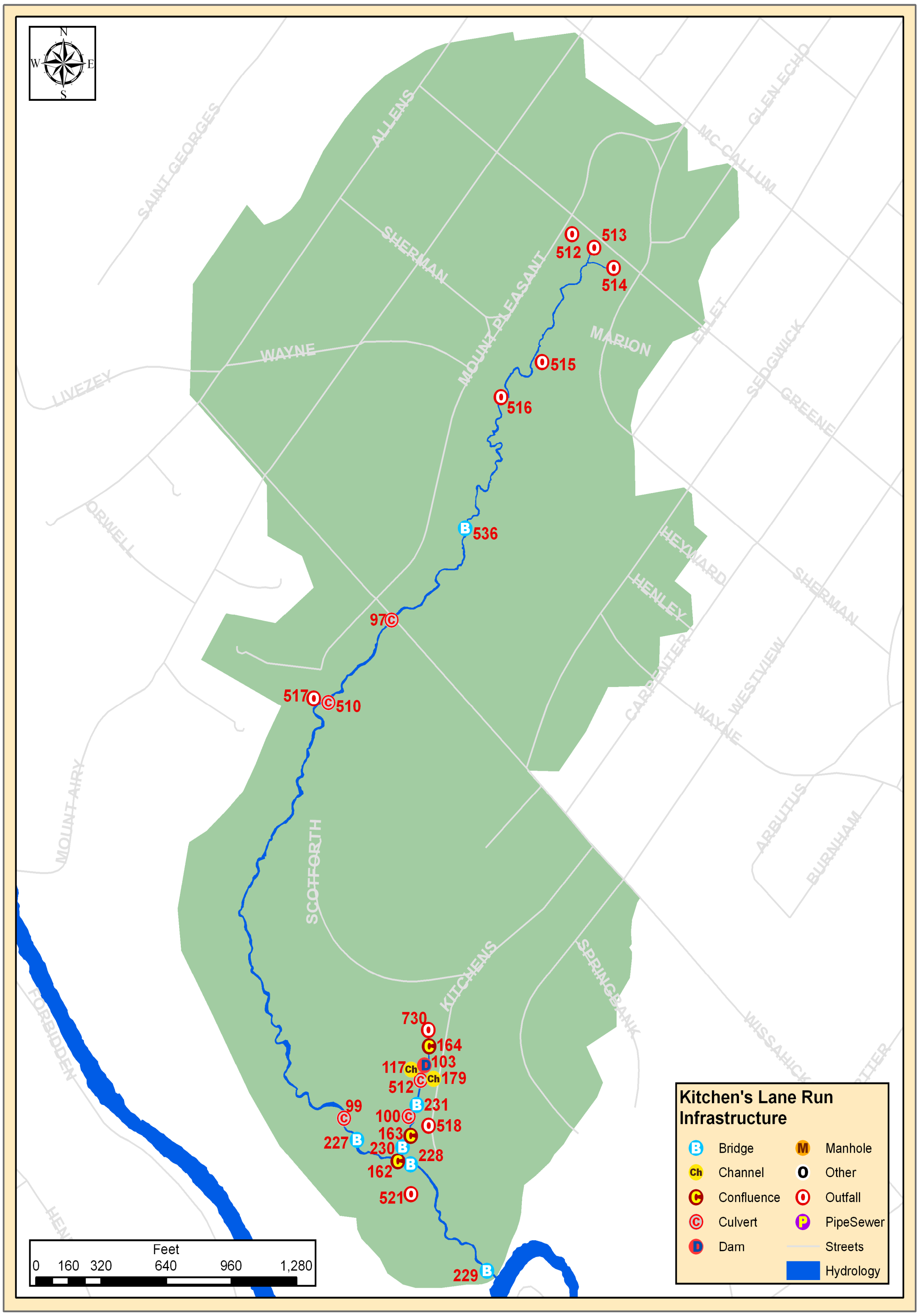


Figure 3-82: Kitchen's Lane Infrastructure Locations

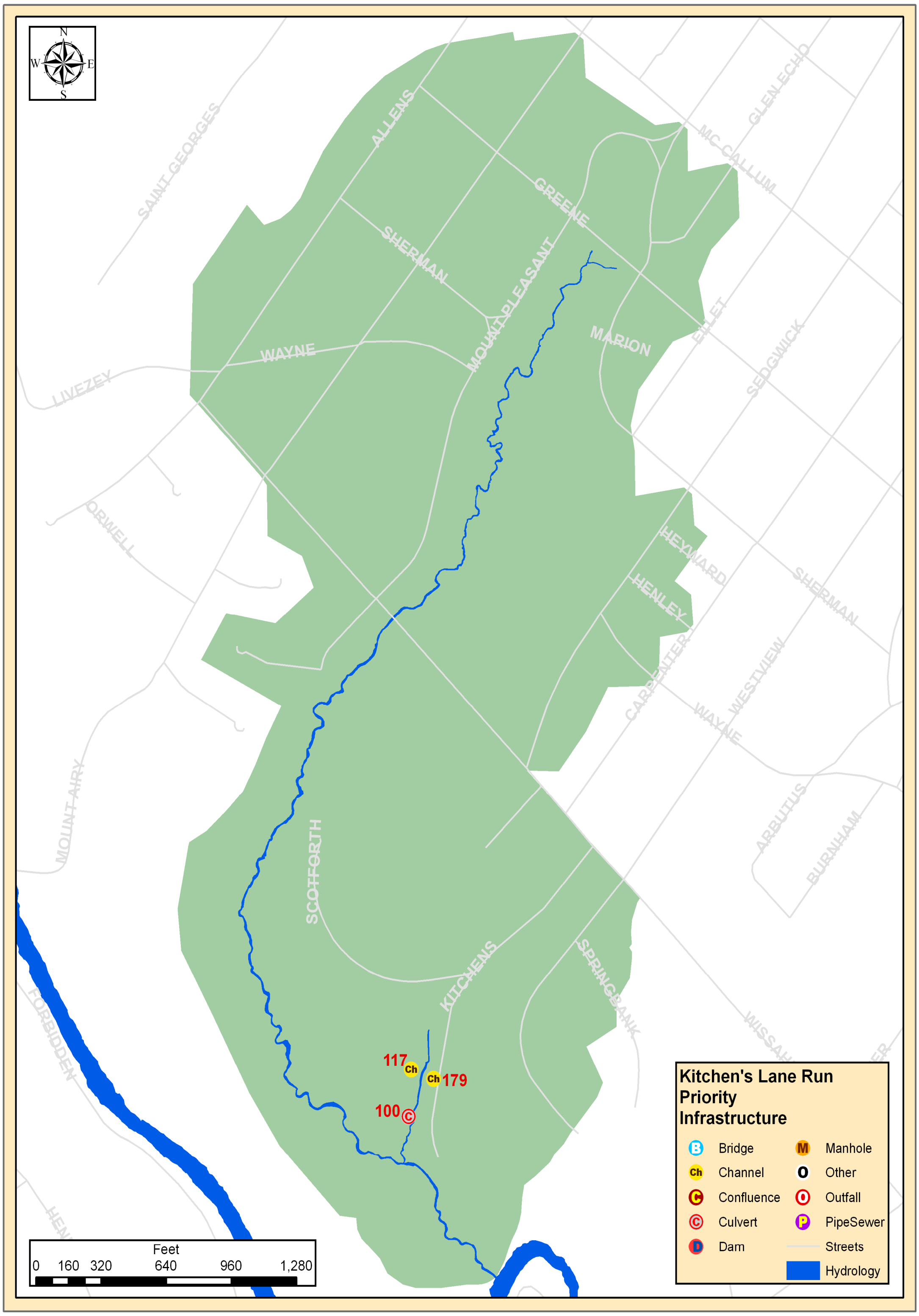


Figure 3-83: Kitchen's Lane Priority Infrastructure

3.2.6.5 UNIFIED STREAM ASSESSMENT RESULTS FOR THE KITCHEN'S LANE WATERSHED

The Kitchen's Lane watershed was extensively developed although the Kitchen's Lane main stem channel and its single tributary were both completely within the boundaries of Fairmount Park. North of Wissahickon Avenue, the Park is referred to as Carpenter's Woods whereas below Wissahickon Avenue, the Park is referred to as Kitchen's Lane. The Center for Watershed Protection's (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and watersheds within the Lower Wissahickon Basin.

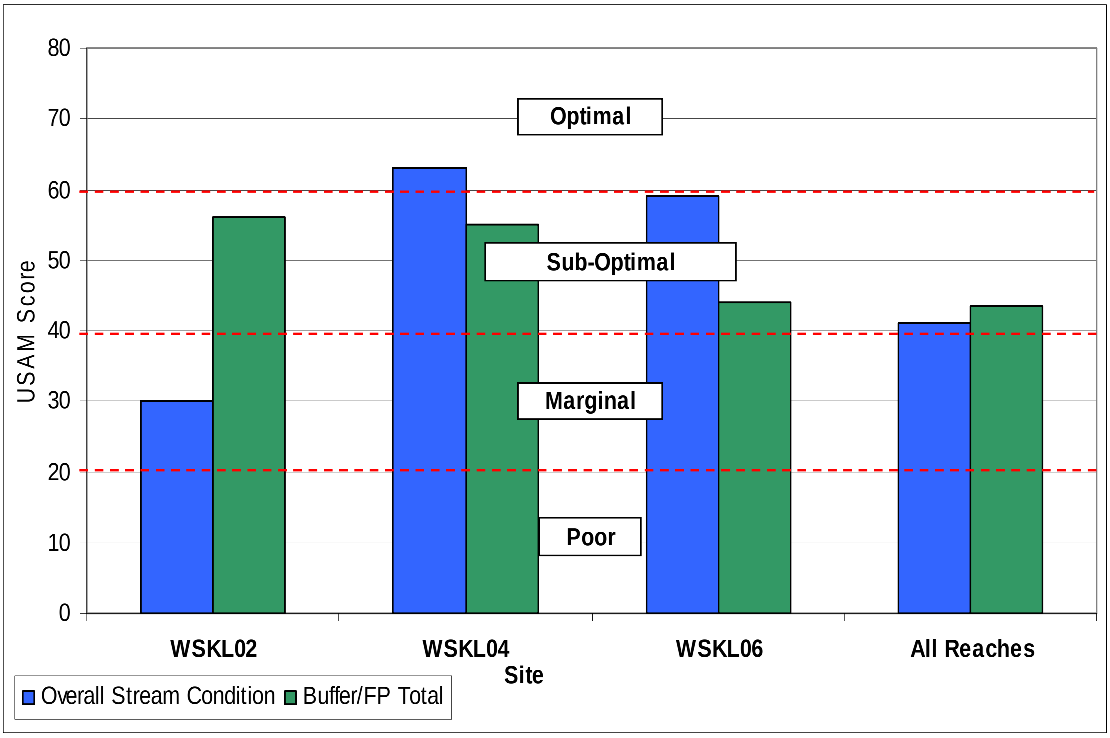


Figure 3-84: Results for Main Stem Kitchen's Lane USAM Components

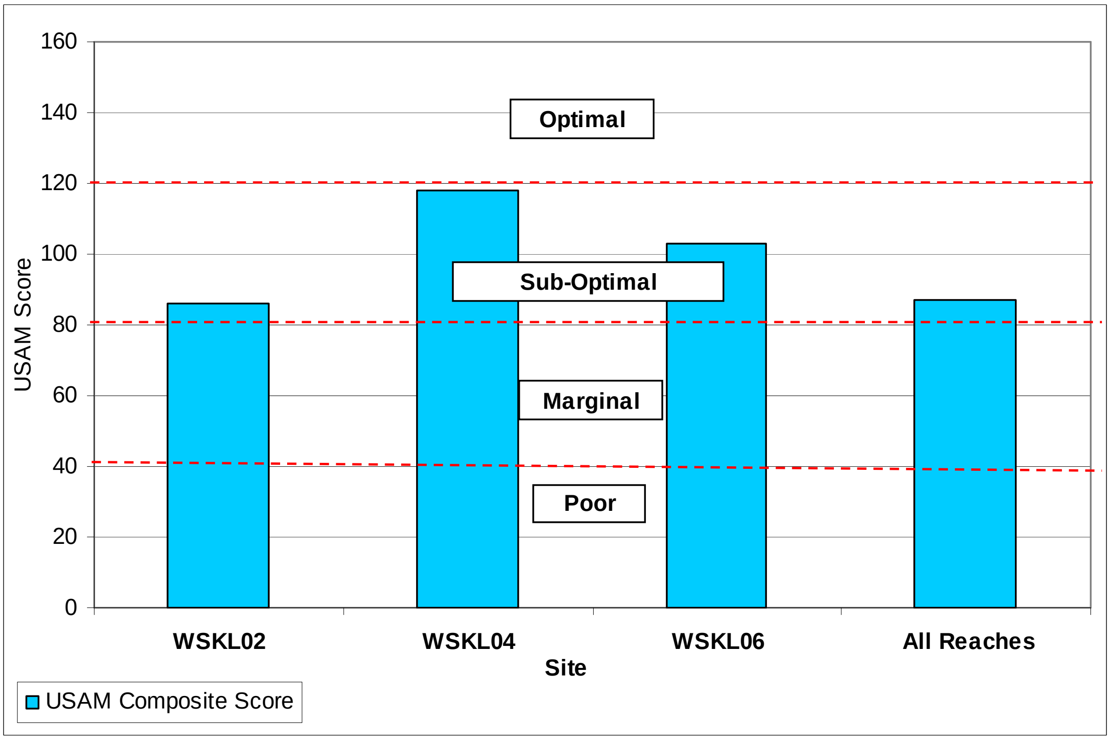


Figure 3-85: Kitchen's Lane USAM Results

3.2.6.5.1 WSKL02

The upstream-most segments of reach WSKL02 formed the headwaters of Kitchen's Lane. Reach WSKL02 began as flow from one privately owned outfall, WSout513, and one City owned outfall, WSout514 (W-068-02), each of which were located approximately 50 feet southwest of Green Street. The flow from each of these outfalls created short channels (80 feet and 145 feet respectively for WSout513 and WSout514) which were consolidated a short distance downstream. There were relatively few infrastructure elements along the length of the highly sinuous reach - there were two additional outfalls (WSout515 and WSout516) and a small pedestrian footbridge (WSbri536) that crossed Kitchen's Lane downstream of cross section WSKL02. The substrate particle size distribution was dominated by gravel-sized particles (64%), while sand (18%) and cobble particles (16%) were observed at much smaller proportions. The reach was characterized by a very high width to depth ratio (30.9), a deeply entrenched channel (ER=1.1) and a shallow gradient (1.7%). Reach WSKL02 was classified as an F4 stream type and had a composite USAM score (Figure 3-77) of (86/160).

3.2.6.5.2 WSKL04

Reach WSKL04 began 350 feet northeast of Wissahickon Avenue. There were very few infrastructure elements along the reach – only two culverts and a 24-inch outfall (WSout517) such that there were very few anthropogenic flow alterations on the reach. The substrate particle size distribution was dominated by gravel (50%) however cobble (27%) and sand (22%) were present in relative abundance throughout the reach. The reach was characterized by a moderate width to depth ratio (16.9), a slightly entrenched channel (ER=2.5) and a steeper gradient (2.3%) than the upstream reach WSKL02. The channel was classified as a type C4b stream channel. The moderately sinuous reach represented a transition between the wide, highly entrenched F-type stream channel in the segments of the reach upstream of WSKL04 and the steeper, more narrow and less entrenched C-type stream channel downstream. The USAM composite score for the reach was 118/160 and was the highest score observed among all reaches in the Lower Wissahickon Basin.

3.2.6.5.3 WSKL06

Reach WSKL06 was the downstream-most reach in the Kitchen's Lane watershed. There was a small tributary (650 feet) to Kitchen's Lane that began as flow from a privately owned outfall, WSout730, which was located approximately 280 feet southwest of the intersection of Scotforth Road and Kitchen's Lane [road]. The majority of the infrastructure elements present in the Kitchen's Lane watershed were located on or in the vicinity (upstream and downstream of the Kitchen's Lane confluence) of the small, highly channelized unnamed tributary. The reach was highly sinuous and ran parallel to Wissahickon Creek until it reached the Wissahickon Creek confluence, which was located about 260 feet downstream of cross section WSMS126. Reach WSKL06 was the only reach with a substrate particle size distribution dominated by cobble (34%) although gravel-sized particles (34%) were present in nearly equal proportions. Reach WSKL06 had channel geomorphology very similar to that of reach WSKL04 and was characterized by a moderate width to depth ratio (17.2), an extremely low degree of entrenchment (ER=2.8) and moderately gradient (2.8%). The reach was classified as a B4c type stream and had a USAM composite score of 103/160.

3.2.6.6 SUMMARY OF UNIFIED STREAM ASSESSMENT RESULTS

The mean scores for both the individual USAM components as well as the overall USAM score were all classified as "suboptimal" (Table 3-86). Average conditions within the watershed's riparian buffers and floodplains were slightly better than conditions observed within the stream channels. The watershed averages for each component as well as the composite USAM score compared well against the respective All Reaches averages, especially for the *Overall Buffer and Floodplain* component. The ratings for individual parameters ranged from poor to optimal, displaying similar levels of variability between reaches.

Table 3-86: USAM Results for Kitchen's Lane Watershed

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP Condition	USAM Score
WSKL02	Kitchen's Lane	30	56	86
WSKL04	Kitchen's Lane	63	55	118
WSKL06	Kitchen's Lane	59	44	103
WSKL mean		**50.7**	**51.7**	**102.3**
All Reaches Average		**42.4**	**44.5**	**86.9**

3.2.6.6.1 SUMMARY OF OVERALL STREAM CONDITION SCORES IN THE KITCHEN'S LANE WATERSHED

Scores for the *Overall Stream Condition* parameter were moderate to high ranging from "marginal" to "optimal". The mean watershed score for all three reaches (50.7/80) was rated as "suboptimal" and compared favorably with the All Reaches average of 42.4/80 which was also rated at the lower end of the "suboptimal" range. The reach observed to be in the best condition was reach WSKL04 (63/80), which was rated as "optimal" and was the highest scoring reach among the large Lower Wissahickon tributaries (second highest in the Lower Wissahickon after WSVG). Reach WSKL06 had a score of (59/80) and was rated as "suboptimal" which ranked this reach as the third highest scoring reach among the large Lower Wissahickon tributaries (fourth in the Lower Wissahickon). With respect to the individual parameters that comprise the *Overall Stream Condition* component, the *Floodplain Connection* parameter exhibited the largest degree of between-reach variation. The reaches WSKL02 and WSKL06 were observed to be in the worst and the best condition, respectively, among all the reaches in the Lower Wissahickon.

Table 3-87: USAM Overall Stream Condition Scoring for Kitchen's Lane Watershed

OVERALL STREAM CONDITION								
Reach ID	Sub-watershed	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	Overall Stream Condition
			Left	Right	Left	Right		
WSKL02	Kitchen's Lane	11	3	4	5	6	1	30
WSKL04	Kitchen's Lane	17	8	8	8	7	15	63
WSKL06	Kitchen's Lane	15	7	7	6	6	18	59
WSKL mean		**14.3**	**6.0**	**6.3**	**6.3**	**6.3**	**11.3**	**50.7**
All Reaches Average		**13.1**	**4.9**	**4.9**	**6.3**	**7.0**	**6.3**	**42.4**

3.2.6.6.1.1 INSTREAM HABITAT

Instream Habitat scores for all three reaches were relatively high and ranged from "marginal" to "optimal." The reach-wide average score (14.3/20) was rated as "suboptimal" and was slightly higher than the All Reaches average (13.1/20) which was rated as "suboptimal" as well. The reach with the highest rating was WSKL04 with a score of 17/20. This reach was the only reach in the Kitchen's Lane watershed that was deemed to have "optimal" instream habitat. The habitat template observed in this reach was characterized by an abundance of cobble (27%) and an even distribution of small boulders. Other habitat features included coarse woody debris (CWD) and the presence of undercut bank habitat, which is an important component of suitable fish habitat-especially on small, low-order tributaries. The lack of extensive channel incision and widening created the opportunity for a heterogeneous depth and velocity regime throughout the reach, which is usually an aspect of habitat suitability absent from urban systems.

Reach WSKL02 had a score of 11/20 for this parameter which put this reach at the threshold between marginal and suboptimal. The reduced habitat quality in this reach can be attributed to a number of factors. This reach had the highest percentage of gravel at 64%. Gravel is a key component of fish spawning habitat, however, it does not convey a high degree of stability [resistance to disturbance] which is an important component of macroinvertebrate habitat suitability. Furthermore, the effect of channel morphology on habitat suitability is evident in this reach. The width to depth (30.9) and entrenchment (1.1) ratios observed in this reach are indicative of an overly widened channel with limited floodplain access. In effect this creates a wide, flat channel that lacks the depth and velocity heterogeneity present in reach WSKL04 as well as the ability to deposit finer sediment onto the floodplain and retain larger more stable particles.

3.2.6.6.1.2 VEGETATIVE PROTECTION

The *Vegetative Protection* parameter reflects the extent to which streambanks are protected by vegetative cover. In general scores were rather high for this parameter in all reaches except for reach WSKL02, in which the left bank was rated as “poor” and the right bank was rated slightly higher with a “marginal” rating. Overall, the Kitchen’s Lane stream corridor offered a great deal of vegetative protection as the mean watershed score for both the left (6/10) and right (6.3/10) banks were higher than the All Reaches averages for the left (4.9/10) and right (4.9/10) banks respectively.

3.2.6.6.1.3 BANK EROSION

Bank Erosion in the Kitchen’s Lane watershed corridor was moderate as the scores for the basin were all rated as “marginal” to “suboptimal” for this parameter. The average watershed score was 6.3/10 for both the left and right banks. The mean score for the left bank of the Kitchen’s Lane corridor was equal to the All Reaches average (6.3/10). However, the average score for the All Reaches right bank (7.0/10) was considerably higher than the Kitchen’s Lane right bank average (6.3/10).

Reach WSKL04 had the highest scores for this parameter with a score of 8/10 for the left bank and a score of 7/10 for the right bank, both of which were rated as “suboptimal”. The worst bank condition was observed in reach WSKL02 with scores of 5/10 and 6/10 for the left and right banks respectively. The disparity in streambank erosion between these two sites can be attributed to distinct features of the two reaches. WSKL04 has a larger proportion of its streambanks covered by vegetation as well as a higher distribution of large cobble and boulders, both mid-channel and along the channel margins. Larger substrate particles such as cobbles and boulders have much higher “roughness” than less coarse substrate such as gravel (65% of the substrate at WSKL02), and work to dissipate much of the kinetic energy conveyed through the channel during bankfull flow events.

3.2.6.6.1.4 FLOODPLAIN CONNECTION

Scores for the *Floodplain Connection* parameter exhibited extreme variation throughout the watershed. Reach WSKL02 had the lowest score (1/20) observed for this parameter throughout the entire Lower Wissahickon; whereas reach WSKL06 had the highest score (18/20) observed in the Lower Wissahickon. Given the extreme variation in floodplain connection, the Kitchen's Lane watershed compared well against the All Reaches average for the larger Lower Wissahickon tributaries. The mean score for the watershed (11.3/20) was rated as "suboptimal", and was considerably higher than the All Reaches average (6.3/20) which was rated as "marginal".

3.2.6.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE KITCHEN'S LANE WATERSHED

The *Overall Buffer and Floodplain* scores for Kitchen's Lane watershed were relatively high for most parameters. Although, scores were low for the *Floodplain Habitat* parameter, the mean watershed score (7.9/20) was relatively high given scores for this parameter were low throughout the Lower Wissahickon (likely due to the high occurrence of stream incision). In general, most of the riparian buffers within the watershed were unperturbed as the scores for the *Vegetated Buffer Width* parameter were rated as "suboptimal" and "optimal" for the left and right banks of the corridor respectively. Mean scores for the Kitchen's Lane watershed were higher than respective All Reaches averages for every parameter except for the left bank *Vegetated Buffer Width* parameter (8/10) which was negligibly less than the All Reaches average of 8.1/10.

Table 3-88: USAM Buffer and Floodplain Condition Scoring for Kitchen's Lane Watershed

OVERALL BUFFER AND FLOODPLAIN CONDITION							
Reach ID	Sub-watershed	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	Buffer/FP Condition
		Left	Right				
WSKL02	Kitchen's Lane	10	10	18	3	15	56
WSKL04	Kitchen's Lane	8	8	15	11	13	55
WSKL06	Kitchen's Lane	6	9	13	8	8	44
WSKL mean		**8.0**	**9.0**	**15.3**	**7.3**	**12.0**	**51.7**
All Reaches Average		**8.1**	**8.6**	**13.8**	**5.5**	**8.5**	**44.5**

3.2.6.6.2.1 VEGETATED BUFFER WIDTH

Vegetated buffers within the watershed were observed to be in good condition. The reach where the largest riparian buffer was observed was WSKL02 (10/10), which was rated as "optimal" and had buffers in excess of 50 feet on both the right and left banks. The watershed averages for the left (8/10) and right (9/10) banks were rated as "suboptimal" and "optimal" respectively and compared well with the All Reaches averages of 8.1/10) for the left bank and 8.6/10 for the right bank.

3.2.6.6.2.2 FLOODPLAIN VEGETATION

The predominant floodplain vegetation within the watershed was consistently observed to be mature and secondary forest although other vegetation types such as shrubs and wetland obligates were also observed. The mean watershed score for this parameter was 15.3/20, which was rated as "suboptimal." Reach WSKL02 had the highest score (18/20) and was rated as "optimal." Overall, the watershed compared favorably against the All Reaches average (13.8/20) which was rated as "suboptimal" as well.

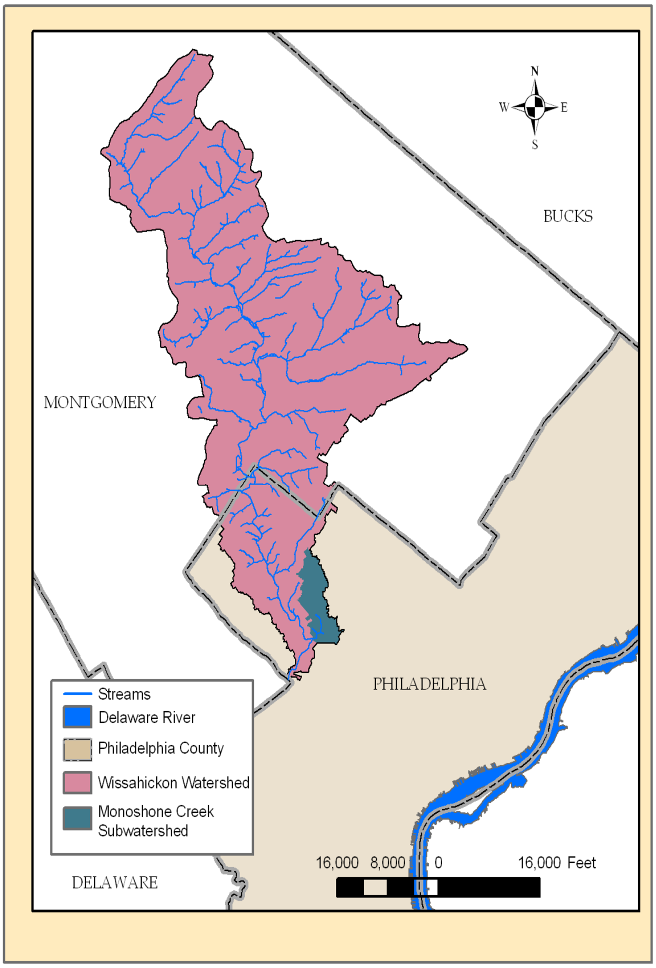
3.2.6.6.2.3 FLOODPLAIN HABITAT

Floodplain Habitat scores were rated as “poor” to “marginal” within the watershed. However, the observed conditions were somewhat better than the average conditions observed in the other large Lower Wissahickon tributaries. The watershed average score was 7.3/20 compared to the All Reaches mean score of 5.5/20, although both were rated as “marginal.” WSKL04 and WSKL06 were not deeply incised indicating that channels in these reaches are able to access the floodplain. Observations of obligate wetland vegetation (Eastern Skunk Cabbage - *Symplocarpus foetidus)* further support the fluvial geomorphology-based assumption of frequent floodplain inundation in these reaches.

3.2.6.6.2.4 FLOODPLAIN ENCROACHMENT

Scores for this parameter ranged from moderate to high throughout the watershed such that there was a relatively small impact of man-made structures and infrastructure on floodplain function. The watershed mean score (12/20) was rated as “suboptimal” and was considerably higher than the All Reaches average (8.5/20) which was rated as “marginal.” Most of the watershed had an extensive, uninterrupted floodplain whereas the only significant encroachment was Kitchen’s Lane, which impinged upon the floodplain in the lower third of WSKL06.

3.2.7 MONOSHONE CREEK WATERSHED AND REACH CHARACTERISTICS



Monoshone Creek is a tributary to the main stem of the Wissahickon Creek. The tributary originates from three outfalls, two privately owned (WSout544 and WSout545) and one city owned, WSout543 (W-068-04). Monoshone Creek is a first-order tributary for approximately 0.5 miles until a smaller 0.1 mile tributary enters the Monoshone approximately 0.4 miles from the confluence with the Wissahickon main stem. Another small 0.25 mile tributary enters Monoshone Creek approximately 0.25 miles from the confluence with the Wissahickon main stem. The substrate varies from clay and silt to large boulders at different sections along the tributary. Both the valley floor and channel have been substantially impacted by past and current land use.

The entire Monoshone Creek watershed is 1,056 acres. Major land use types within the watershed include: wooded (31%), residential – row home (29%), residential – single family detached (21%), and commercial (5%). The Monoshone Creek is surrounded by Fairmount Park on both sides for the entire length. The Park buffer ranges from about 100 feet to about 2,000 feet.

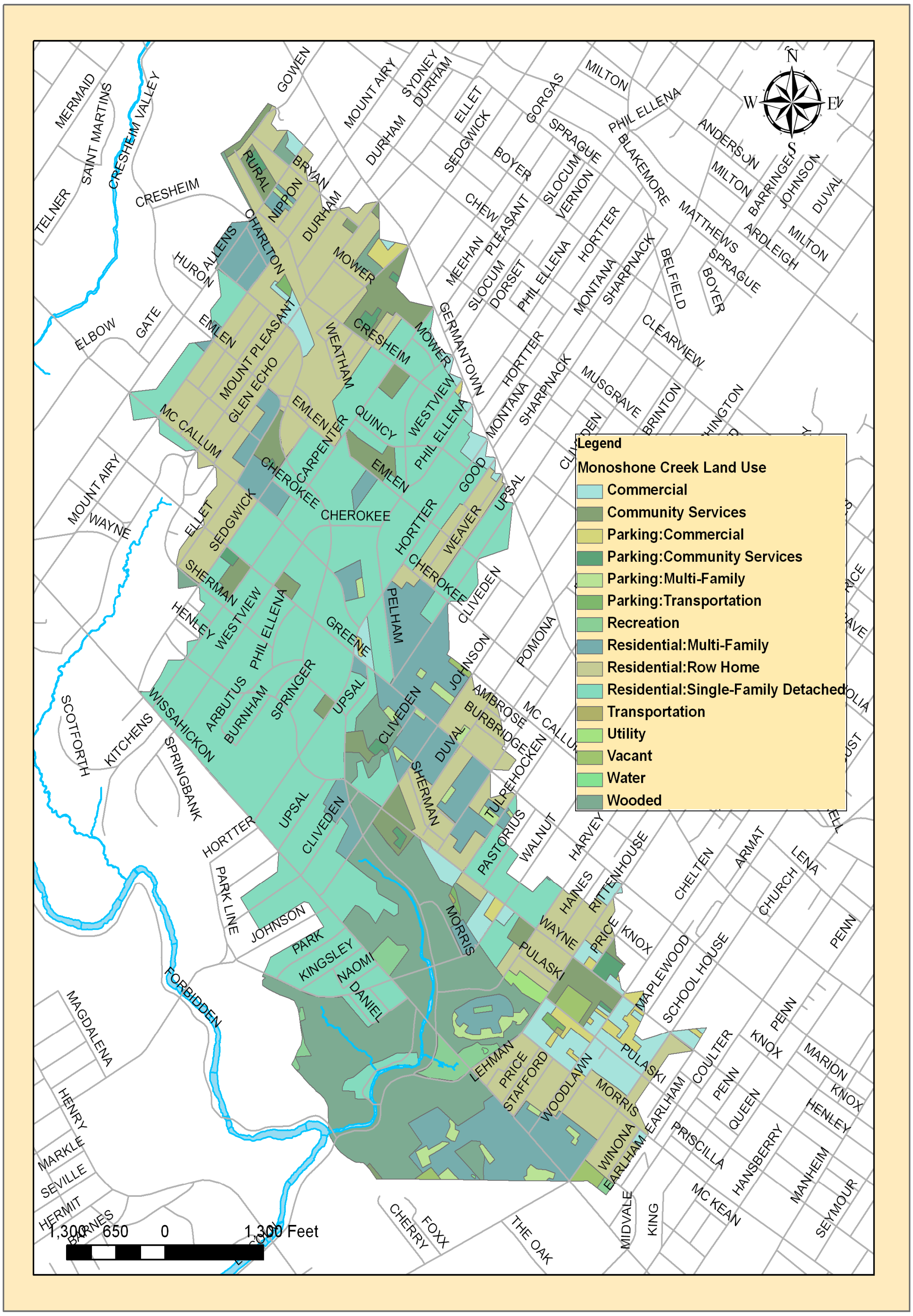


Figure 3-86: Monoshone Creek Watershed Land Use

3.2.7.1 GEOLOGY

The majority of the Monoshone Creek watershed is underlain by the Wissahickon Formation. The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

There is a small section of mafic gneiss in the southern portion of the Monoshone Creek watershed. The mafic gneiss formation consists of weather-resistant rocks that show good surface drainage.

3.2.7.2 SOILS

According to the National Resource and Conservation Service Soil Survey, the majority of soils for the Monoshone Creek watershed are classified as hydrologic group B. These soils have a moderate rate of infiltration when the soils are wet (0.50-1.00 in/hr). Water movement through these soils is considered moderately rapid. There is a small band of B/D soils along the western tributary of the Monoshone Creek. Group D soils have a very slow rate of infiltration when saturated (0.02-0.10 in/hr) resulting in a high runoff potential.

There is a small section of hydrologic group A soils on the southern portion of the tributary. Group A soils have a low runoff potential. These soils also have a high rate of infiltration (1.00-8.3 in/hr) when saturated.

A small band of Urban soils borders the Monoshone Creek. Urban soils consist of material that has been disturbed by human activity during urbanization. Urban soils have been produced by mixing, filling and contamination of the native soils in both urban and suburban areas.

Table 3-89: Distribution of NRCS Soil Types in Monoshone Creek Watershed

Group	Area (ft²)	Percent of Total Area
A	4,600	0.01%
B	7,079,301	15.39%
B/D	4,600	0.01%
Urban	38,910,858	84.59%
Total Area	**45,999,360**	**100%**

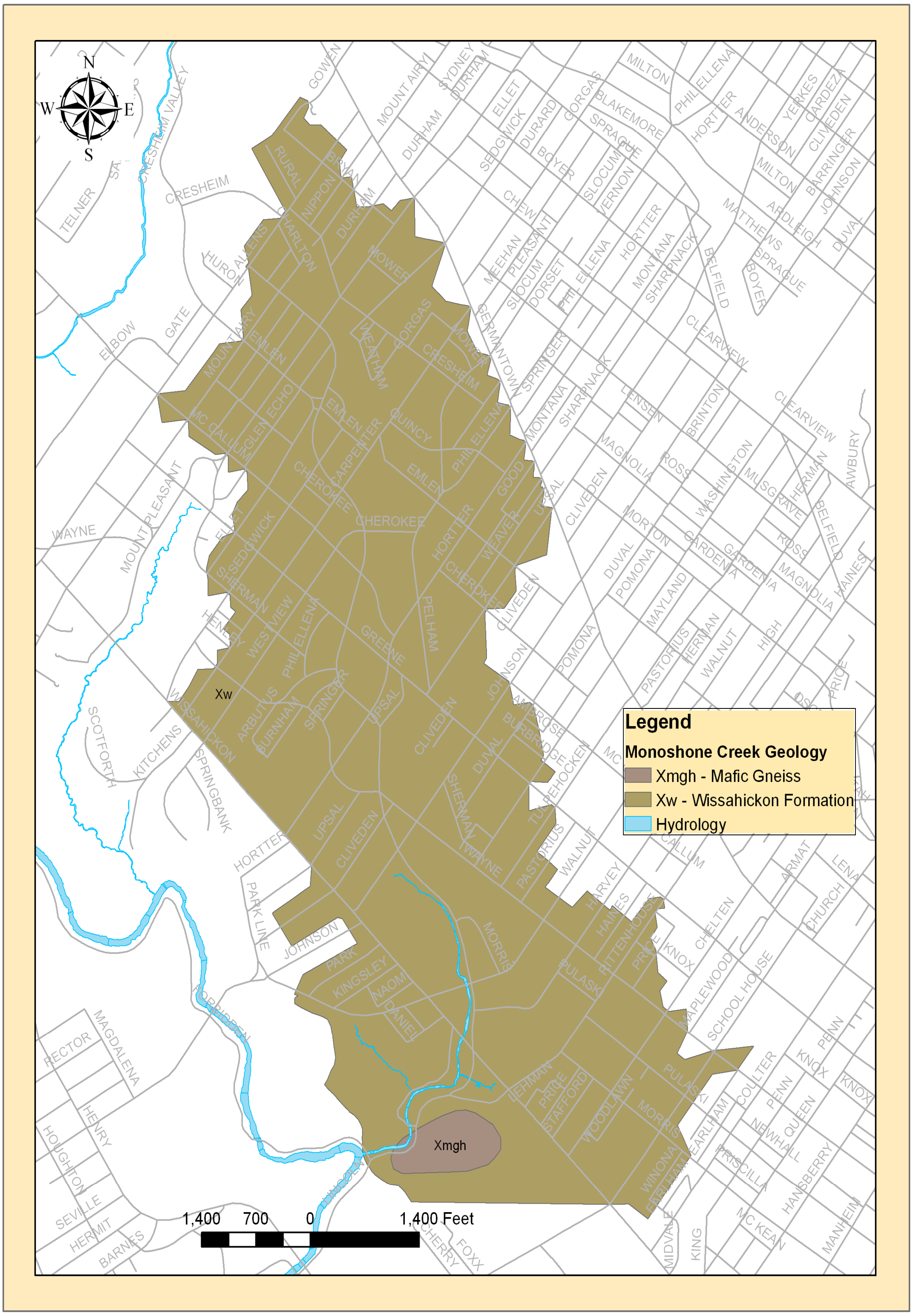


Figure 3-87: Geology of Monoshone Creek Watershed

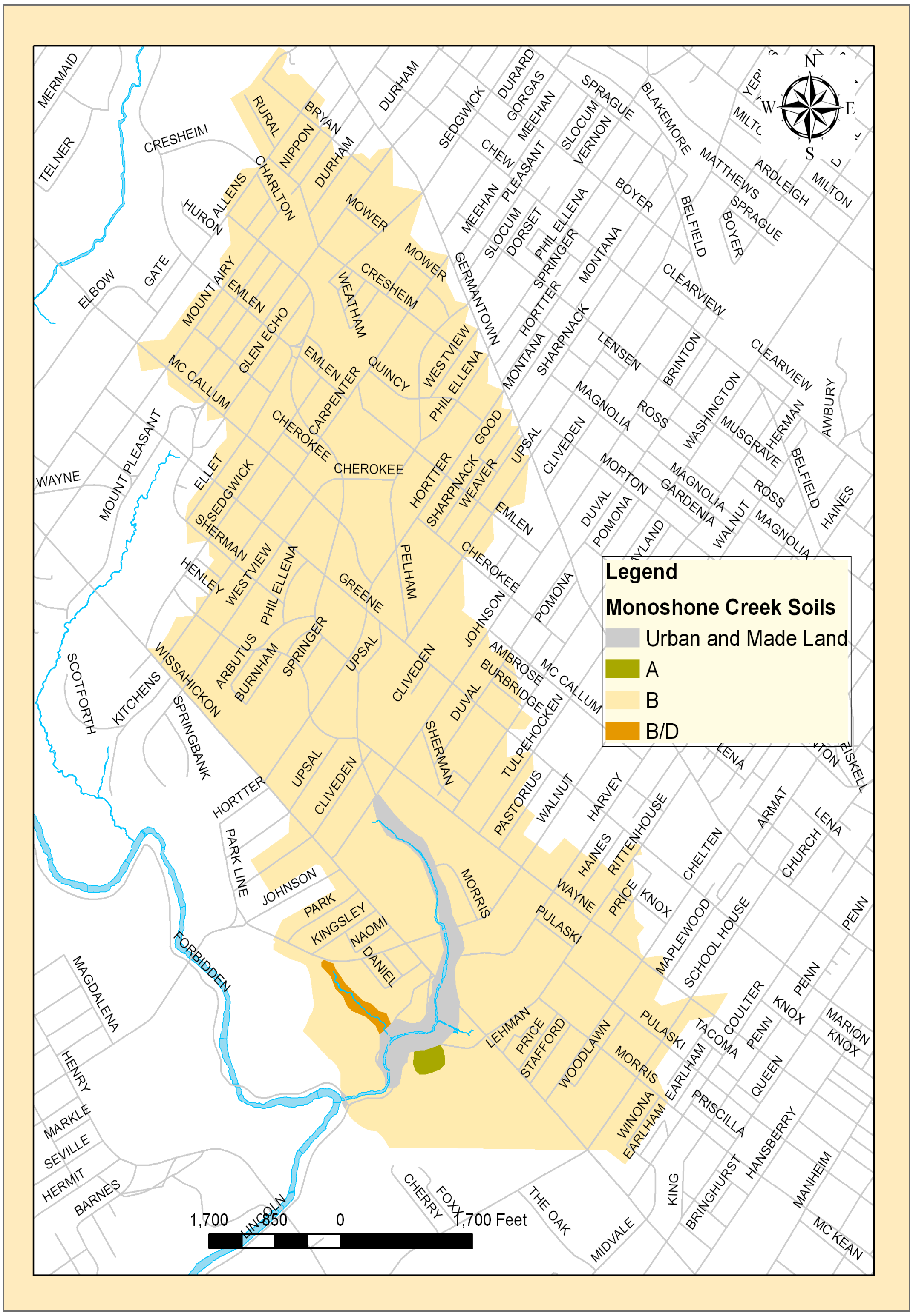


Figure 3-88: Distribution of NRCS Soil Types in Monoshone Creek Watershed

3.2.7.3 BANK EROSION

There were seven bank pin locations along Monoshone Creek (Figure 3-89). The calculated erosion rates are included in Table 3-90. The spatial distribution of BEHI assessment results were represented graphically (Figure 3-89) for each of the segments assessed on Monoshone Creek. Each bank within a respective segment was assessed and rated separately; however, channelized and culverted segments were not assessed as they confer a high degree of protection from bank erosion.

Table 3-90: Monoshone Creek Bank Pin Locations

	BEHI	NBS	Baseline Reading	Most Recent Reading	Erosion Rate (ft)	Erosion Rate (ft/yr)	Eroding (-) or Aggrading (+)
Monoshone Creek							
MN1	Moderate	Very Low	11/2/2005	8/13/2009	-0.55	-0.14	E
MN2	Moderate	High	11/2/2005	8/13/2009	-0.47	-0.12	E
MN3	High	High	11/2/2005	8/13/2009	-0.48	-0.13	E
MN4	Moderate	Low	11/2/2005	8/13/2009	-0.15	-0.04	E
MN962	Low	Low	8/24/2006	8/14/2008	0.19	0.095	A
MN963	Low	Low	8/13/2007	8/13/2009	0.58	0.29	A
MN964	Low	Low	8/13/2007	8/13/2009	-0.081	-0.041	E

Total erosion rates were also calculated for the entire length of each tributary within the Lower Wissahickon (Table 3-91). To assess the normalized erosion potential of each tributary, the erosion rate per acre of drainage area per year and the erosion rate per foot of stream length per year were calculated. This allowed direct comparison between each of the tributaries with respect to both watershed size and the length of the tributary. Monoshone Creek was ranked eleventh out of the twelve tributaries within the lower Wissahickon for erosion rate per foot of stream length. The rankings were based on a scale of one being the highest erosion rate and twelve being the lowest erosion rate.

Table 3-91: Erosion Rates for Lower Wissahickon Tributaries

Tributary	Drainage Area (Acres)	Stream Length (feet)	*2009*		
			Erosion Rate (lb/yr)	*Erosion Rate Per Acre*	*Erosion Rate Per Foot of Stream*
Bell's Mill	323	6,722	420,000	1,307	63
Cathedral Run	160	2,790	150,000	913	52
Cresheim Creek	1,218	16,431	840,000	690	51
Gorgas Run	499	2,170	170,000	345	79
Hartwell Run	217	3,530	200,000	918	56
Hillcrest	144	5,272	90,000	597	16
Kitchen's Lane	234	7,753	200,000	850	26
Monoshone Creek	1,056	6,926	160,000	156	24
Rex Ave	137	1,903	150,000	1,131	81
Thomas Mill Run	104	4,008	320,000	3,058	79
Valley Green Run	128	2,874	140,000	1,086	48
Wise's Mill Run	446	7,056	490,000	1,090	69
Total/*Average*	**4,666**	**67,435**	**3,300,000**	***1,012***	***54***

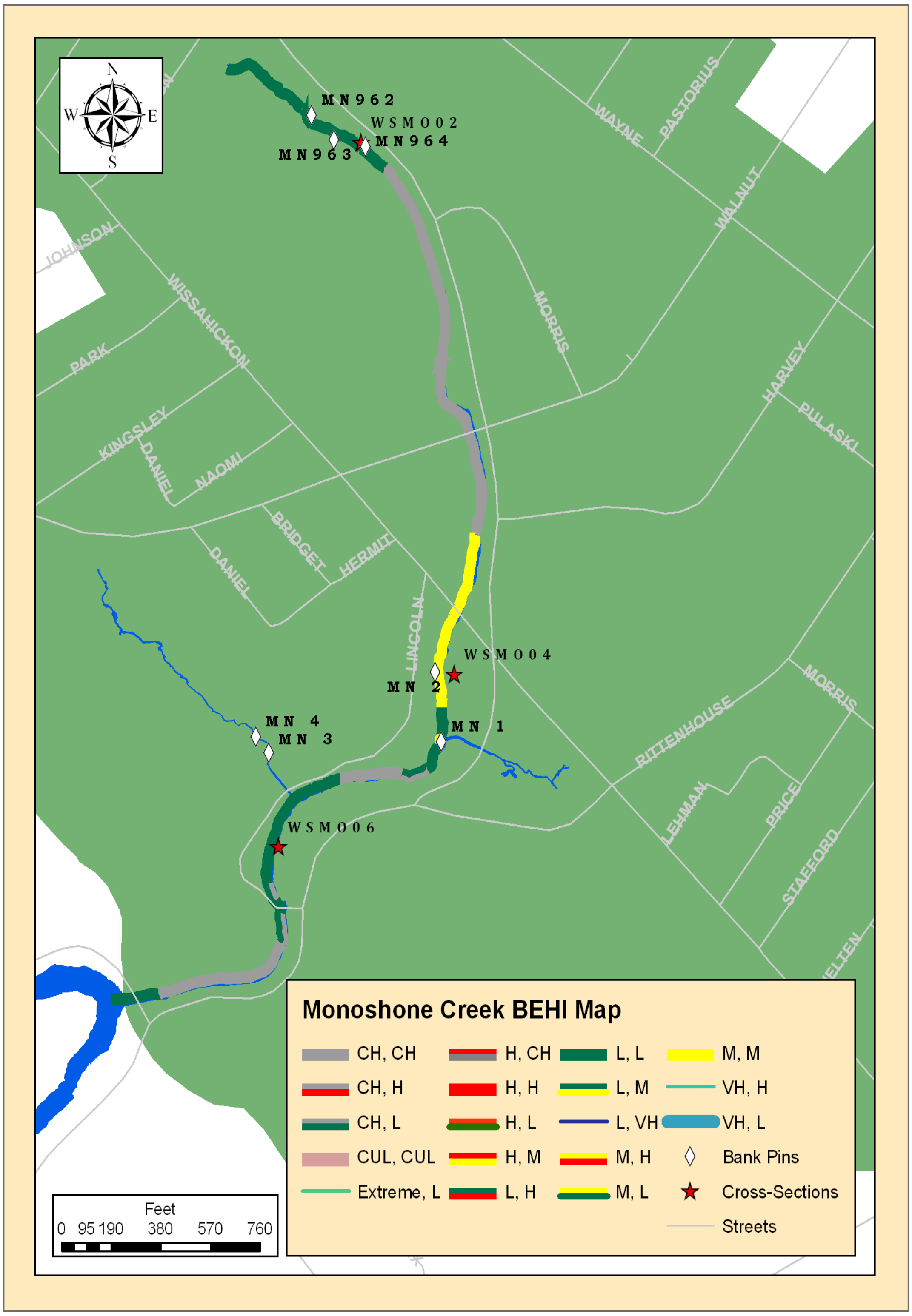


Figure 3-89: Monoshone Creek Watershed BEHI Ratings and Bank Pin Locations

3.2.7.4 INFRASTRUCTURE TRACKDOWN SUMMARY

Monoshone Creek was the furthest downstream of all of the tributaries in the Lower Wissahickon Basin. It ran parallel to Lincoln Drive from Johnson Street to the confluence with Wissahickon Creek. While this stream was located entirely within Fairmount Park, it was heavily influenced by the urban development in the surrounding areas. Several outfalls conveyed direct runoff from Lincoln Drive as well as the cross streets, Walnut Lane, Wissahickon Avenue, Johnson Street, etc. Outfalls were numerous, as there were 23 outfalls throughout the three reaches with a total outfall area of about 240 square feet.

Aside from the outfalls, channelization and dams impacted the stream both locally, as well as upstream and downstream of the respective structures. Over one-fifth of the stream length was channelized. The channels were installed to prevent the lateral movement of the stream and protect other infrastructure within the corridor. Three dams, one in each reach, were impediments to streamflow and sediment transport downstream. The flow from outfalls WSout731 and WSout732 has been captured to a degree by PWD and Fairmount Park's Saylor Grove Wetland Project. The flow from the outfalls is retained in the wetland which settles out sediment and returns flow to Monoshone Creek through WScul519. None of the infrastructure on Monoshone Creek was identified as being in poor condition; however, the cumulative impacts of Monoshone Creek infrastructure caused many of the physical attributes of the stream to be in poor condition.

Table 3-92: Monoshone Creel Infrastructure Point Features

Section ID	Culvert Count	Bridge Count	Outfall Count	Channel Count	Confluence Count	Dam Count	Other Count	Infra Point Count	Combined Outfall Area (ft^2)
WSMO02	1	0	7	2	0	1	1	11	37.76
WSMO04	1	2	6	2	1	1	0	12	75.46
WSMO06	2	2	10	5	1	1	0	20	126.27
TOTAL	**4**	**4**	**23**	**9**	**2**	**3**	**1**	**43**	**239.49**

Table 3-93: Monoshone Creel Infrastructure Linear Features

Section ID	Segment Length (ft)	Culvert Length (ft)	Percent Culverted	Channel Length (ft), 1 side	Channel Length (ft), 2 sides	Channel Length (ft)	Percent Channelized
WSMO02	1665	28	1.7	86	532	1150	23
WSMO04	2083	115	5.5	7	689	1385	22.2
WSMO06	2845	191	6.7	193	727	1647	19.3
TOTAL	**6593**	**334**	**5.1**	**286**	**1948**	**4182**	**21.1**

Figure 3-90: Monoshone Creek Infrastructure Locations

3.2.7.5 Unified Stream Assessment Results for the Monoshone Creek Watershed

The Monoshone Creek watershed was the downstream-most watershed within the Lower Wissahickon Basin. The main stem channel of Monoshone Creek originated near the intersection of Lincoln Drive and Johnson Street. The main stem channel as well as its two tributaries was entirely within the boundaries of Fairmount Park. The main stem channel was relatively short compared to the expanse of the watershed as Monoshone Creek was located entirely within the lower third of the watershed. Historically Monoshone Creek had a much larger stream network, which over time was truncated and encapsulated to allow for development - as were many streams throughout the City of Philadelphia. The historic extent of Monoshone Creek had headwaters near the intersection of Glen Echo Road and Lincoln Drive, as well as an additional three tributaries.

The Center for Watershed Protection's (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and watersheds within the Lower Wissahickon Basin.

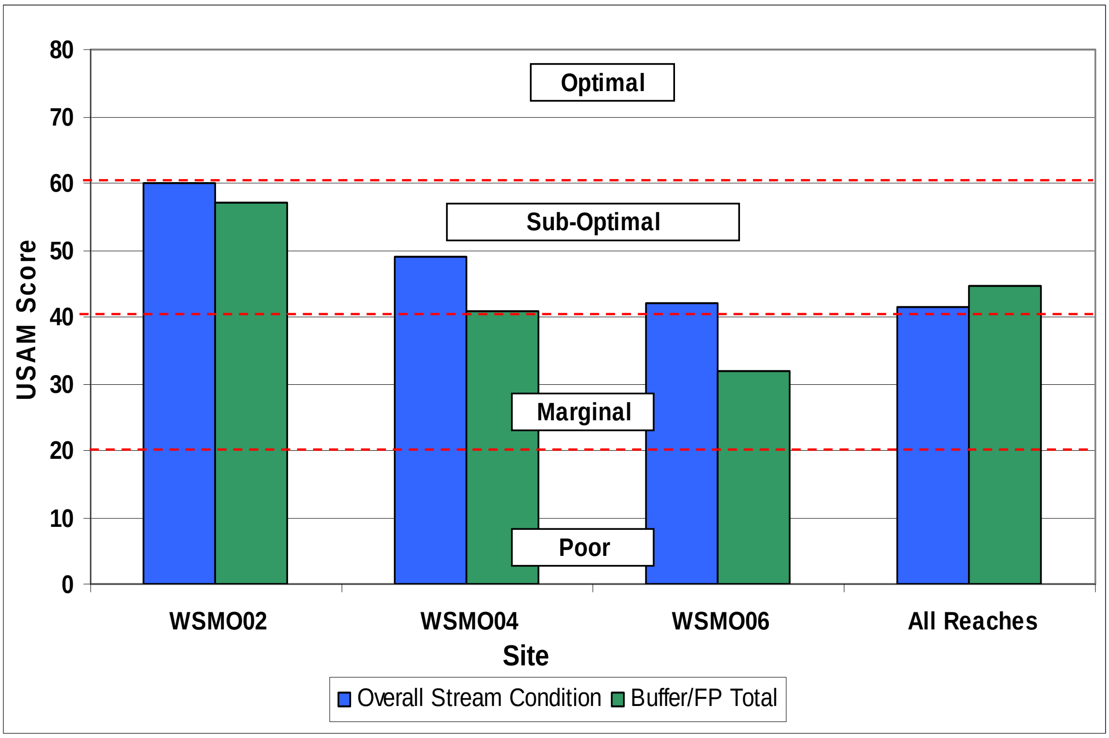


Figure 3-91: Results for Monoshone Creek USAM Components

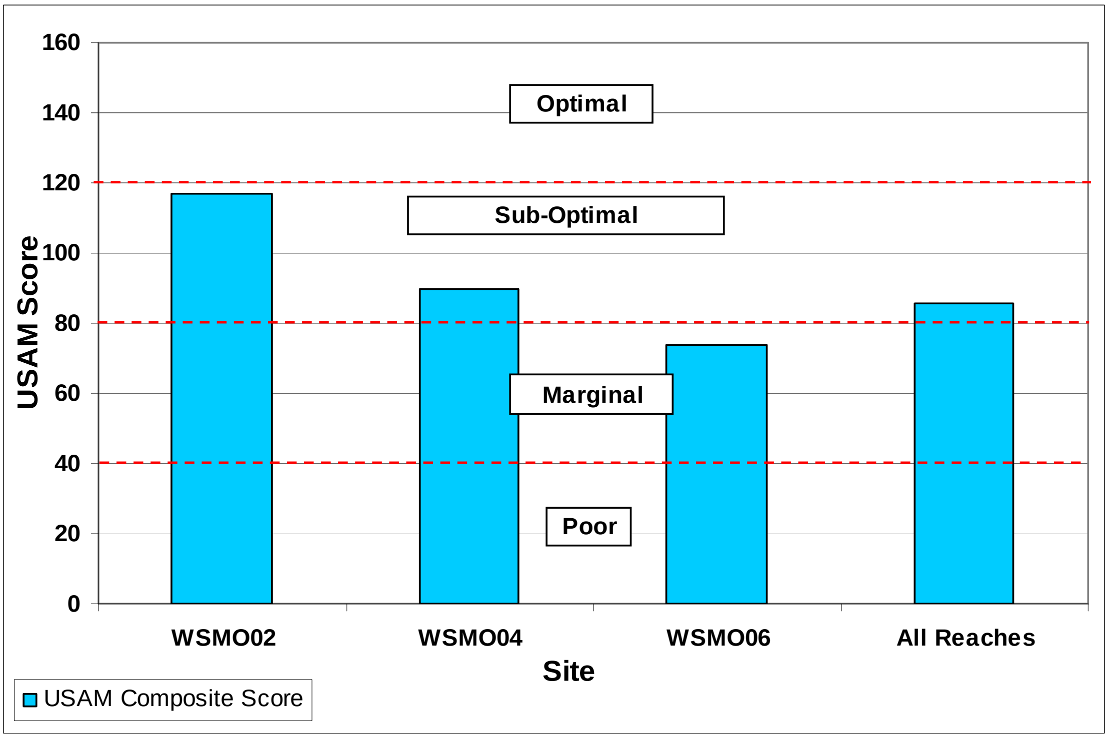


Figure 3-92: Monoshone Creek USAM Results

3.2.7.5.1 WSMO02

Reach WSMO02 contained the headwaters of Monoshone Creek which began as flow from WSout544 located 315 feet southwest of the intersection of Johnson Street and Lincoln Drive. The entire reach ran parallel to Lincoln Drive and was highly channelized (WScha203 on the DSR and WScha132 on the DSL) along the segment of the reach that was located within 40 feet of Lincoln Drive. The substrate particle size distribution was dominated by silt (67%) with sand (33%) comprising the remainder of the sediment in the reach. The channel morphology in reach WSMO02 was characterized by a moderate width to depth ratio (12), a deeply entrenched channel (ER=1.6) and a moderately shallow gradient (3.1%). The reach was classified as a type B6 stream channel and had a USAM composite score (Figure 3-92) of 117/160 which was the second highest score of all reaches assessed in the Lower Wissahickon Basin.

3.2.7.5.2 WSMO04

Reach WSMO04 began about 100 feet upstream of the Walnut Lane Bridge (WSbri242) and ended at a channelized segment (WScha139 on the DSR and WScha140 on the DSL) upstream of a footbridge (WSbri527) within the Rittenhouse Town complex. There was a small tributary on the reach that began as flow from two privately owned outfalls (WSout731 and WSout732) that drained into the PWD treatment wetland, Saylor's Grove, which was bounded by Rittenhouse Avenue to the south and east, Wissahickon Avenue to the north and Lincoln Drive to the west. Flow from the wetland was diverted through WScul519 to the main stem of Monoshone Creek. The substrate particle size distribution was dominated by cobble (46%) although gravel (20%) and sand (17%) were also abundant throughout the reach. The channel morphology of the reach was characterized by a high width to depth ratio (23.6), a deeply entrenched channel (ER=1.7) and a moderately shallow gradient (2.5%). The reach was classified as a B3 stream channel and the USAM composite score for the reach was 90/160.

3.2.7.5.3 WSMO06

Reach WSMO06 began at a channelized segment (WScha139 on the DSR and WScha140 on the DSL) of Monoshone Creek located within the Rittenhouse Town complex and ended at the confluence of Monoshone Creek and Wissahickon Creek. There was a 1,280-foot tributary on the DSR side of the creek that had its headwaters 80 feet south of Walnut Lane between Daniel Street and Kingsley Street and reached its confluence with Monoshone Creek 35 feet downstream of WSdam109. The substrate particle size distribution within the reach was dominated by cobble (58%) with smaller amounts of gravel (20%) and sand (17%) present in nearly equal proportions. The channel morphology was characterized by a high width to depth ratio (18.3), a deeply entrenched channel (ER=1.4) and a shallow slope. The reach was classified as a B3c stream type and had an USAM composite score of 74/160.

3.2.7.6 Summary of Unified Stream Assessment Results

The mean scores for both the *Overall Stream Condition* component as well as the composite USAM score were classified as "optimal" (Table 3-94). Average conditions within the Monoshone Creek watershed's stream channels were slightly better than conditions observed within the buffers and floodplains. The watershed averages for the *Overall Stream Condition* component, as well as the composite USAM score, compared very well against the respective All Reaches averages, however the *Overall Buffer and Floodplain* component was relatively close to the All Reaches average. The scores for individual parameters ranged from poor to optimal, displaying similar levels of variability between reaches.

Table 3-94: USAM Results for Monoshone Creek Watershed

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP Condition	USAM Score
WSMO02	Monoshone	60	57	117
WSMO04	Monoshone	49	41	90
WSMO06	Monoshone	42	32	74
WSMO mean		**50.3**	**43.3**	**93.7**
All Reaches Average		**42.4**	**44.5**	**86.9**

3.2.7.6.1 Summary of Overall Stream Condition Scores in the Monoshone Creek Watershed

The *Overall Stream Condition* scores observed in the Monoshone Creek watershed was among the best in the Lower Wissahickon. The mean *Overall Stream Condition* score for the Monoshone Creek reaches (50.3/80), rated as "suboptimal" and was higher than the All Reaches average (42.4/80) for the large Lower Wissahickon tributaries which was also rated as "suboptimal." The mean watershed scores for each of the four *Overall*

Stream Condition parameters were higher then the respective All Reaches averages. The most notable parameter scores in the watershed were for the *Instream Habitat* and *Bank Erosion* parameters which ranked among the best observed in the Lower Wissahickon.

Table 3-95: USAM Overall Stream Condition Scoring for Monoshone Creek Watershed

OVERALL STREAM CONDITION								
Reach ID	Sub-watershed	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	Overall Stream Condition
			Left	Right	Left	Right		
WSMO02	Monoshone	16	8	6	10	10	10	60
WSMO04	Monoshone	18	5	5	7	7	7	49
WSMO06	Monoshone	15	4	4	7	7	5	42
WSMO mean		**16.3**	**5.7**	**5.0**	**8.0**	**8.0**	**7.3**	**50.3**
All Reaches Average		**13.1**	**4.9**	**4.9**	**6.3**	**7.0**	**6.3**	**42.4**

3.2.7.6.1.1 INSTREAM HABITAT

Instream habitat conditions in the Monoshone Creek watershed were observed to be exceptional, as all sites were rated as “suboptimal” and “optimal.” The mean watershed score (16.3/20) was rated as” optimal” and was considerably higher than the All Reaches average (13.1/20) which was rated as “suboptimal.”

Reach WSMO02 was rated as “optimal” however the habitat template observed in this reach had noticeably different characteristics compared to the other two sites. The dominant substrate within reach WSMO02 was silt (67%) compared to the other two reaches WSMO04 and WSMO06, in which the substrate was dominated by cobble (46% and 58% respectively). The habitat features in the reach WSMO02 that contributed the most to an “optimal” rating were the presence of adequate amounts of CWD as well as emergent macrophytes along the margins of the stream channel. The emergent macrophytes, some of which were obligate wetland species (Eastern Skunk Cabbage - *Symplocarpus foetidus*) offered adequate cover along the margins of the narrow (8.7 feet wide) first-order stream with CWD and a sparse distribution of cobble providing cover in the actual channel. The distribution of CWD in reaches WSMO04 and WSMO06 was not as dense as was observed in WSMO02; however the presence of instream vegetation in WSMO06 and the dominance of stable cobble and boulder (17% and 5% at WSMO04 and WSMO06 respectively) substrate helped compensate for the lack of adequate CWD.

3.2.7.6.1.2 VEGETATIVE PROTECTION

Scores for the *Vegetative Protection* parameter were moderate although the watershed averages for the left (5.7/10) and right (5.0/10) banks were both higher than the All reaches averages for the left and right banks (both 4.9/10). The highest scores observed in the watershed were for the left (8/10) and right (6/10) banks of reach WSMO02. There were minimal indicators of stream bank erosion and degradation in the narrow channel which permitted the growth of vegetation at or near the margins of the channel throughout the reach and up to 90% coverage of the stream bank surfaces. The other reaches, WSMO04 and WSMO06, were rated as “marginal” with scores of 5/10 and 4/10 respectively for both banks. These reaches had adequate vegetative coverage throughout most of the reach although bare patches of soil were observed as a result of localized scour.

3.2.7.6.1.3 BANK EROSION

Bank erosion was minimal throughout the Monoshone Creek watershed. Average watershed scores for the this parameter (both banks 8/10) were rated as "suboptimal" and were considerably higher than the All Reaches averages for both the left (6.3/10) and right (7.0/10) banks. Reach WSMO02 was observed to be in the best condition with an "optimal" rating and a score of 10/10) for both banks. The other reaches were rated as "suboptimal," both with scores of 7/10 for both the left and right banks. In the lower reaches of the watershed (WSMO04 and WSMO06) vegetative cover and the presence of colluvial deposits of small (256-362 mm) to large (1024-2048 mm) boulders offered protection from most erosive forces, although there were short segments of these reaches that were affected by localized scour.

3.2.7.6.1.4 FLOODPLAIN CONNECTION

The *Floodplain Connection* parameter measures the extent to which flood flows within a channel can access the floodplain, which is gauged by entrenchment ratios calculated at riffle cross sections. Scores were moderate to low throughout the watershed but the watershed mean (7.3/20) still compared favorably against the All Reaches average (6.3/20) for the large Lower Wissahickon tributaries. The reach with the highest score (10/20) was WSMO02, which was rated as "marginal." The worst reach was WSMO06, which was rated as "poor" with a score of 5/20.

3.2.7.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE MONOSHONE CREEK WATERSHED

The scores for the *Overall Buffer and Floodplain Condition* parameters ranged from "poor" to "optimal" throughout the watershed, but were generally low to moderate. The watershed mean score for all parameters, except for the average left bank *Vegetated Buffer Width* and *Floodplain Encroachment* parameters, was higher than the All Reaches average for the large Lower Wissahickon tributaries. Of special significance were the scores for the *Floodplain Vegetation* parameter as the watershed mean score was among the highest observed in the Lower Wissahickon.

Table 3-96: USAM Buffer and Floodplain Condition Scoring for Monoshone Creek Watershed

OVERALL BUFFER AND FLOODPLAIN CONDITION							
Reach ID	Sub-watershed	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	Overall Buffer/FP Condition
		Left	Right				
WSMO02	Monoshone	7	10	19	13	8	57
WSMO04	Monoshone	7	9	17	4	4	41
WSMO06	Monoshone	5	8	12	4	3	32
WSMO mean		**6.3**	**9**	**16**	**7**	**5**	**43.3**
All Reaches Average		**8.1**	**8.6**	**13.8**	**5.5**	**8.5**	**44.5**

3.2.7.6.2.1 VEGETATED BUFFER WIDTH

Scores for the *Vegetated Buffer Width* parameter were relatively high for the right bank of the corridor and moderate for the left side. The mean watershed score for the left bank (6.3/10) was rated as “suboptimal” and for the right bank (9/10) was rated as “optimal.” The All Reaches averages for the left and right bank were 8.1/10 and 8.6/10 respectively, both rated as “suboptimal.”

The major impediments to the establishment of optimal (>50 feet) vegetated buffers in the watershed were Lincoln Drive, which explains the lower scores for the downstream left side (DSL) of the stream corridor. Reach WSMO02, which was the least impacted by Lincoln Drive, having over 100 feet of separation from the road at the upstream-most segments and up to 45 feet of separation on the downstream segment of the reach. Conversely, the reach most impacted by Lincoln Drive was WMMO06, which had less than 30 feet of floodplain between the channel and Lincoln Drive on the DSL and less than 40 feet of floodplain on the downstream right (DSR) side of the channel due to Forbidden Drive.

3.2.7.6.2.2 FLOODPLAIN VEGETATION

The scores for the *Floodplain Vegetation* parameter were generally good throughout the watershed. The mean watershed score for this parameter 16/20 rated as “optimal” and compared favorably to the All Reaches average (13.8/20) which rated as “suboptimal.” The dominant vegetation type throughout the watershed was mature forest. However closer to the stream margins, herbaceous ground cover vegetation and shrubs were present in most reaches, especially WSMO02.

3.2.7.6.2.3 FLOODPLAIN HABITAT

Floodplain habitat in the Monoshone Creek watershed was rated as “marginal” with a mean watershed score of 7/20. However, the average floodplain habitat conditions observed in the Lower Wissahickon (5.5/20) were slightly worse and also rated as “marginal.” The most influential factor in determining the condition of floodplain habitat structure is the entrenchment ratio, which is a measure of the likelihood that a channel will overtop its banks at flows in excess of bankfull discharge. This is a crucial process in the formation of floodplain habitat as features such as ephemeral pools, important to macroinvertebrates and amphibians, and backwater channels are not formed or maintained without occasional floodplain inundation.

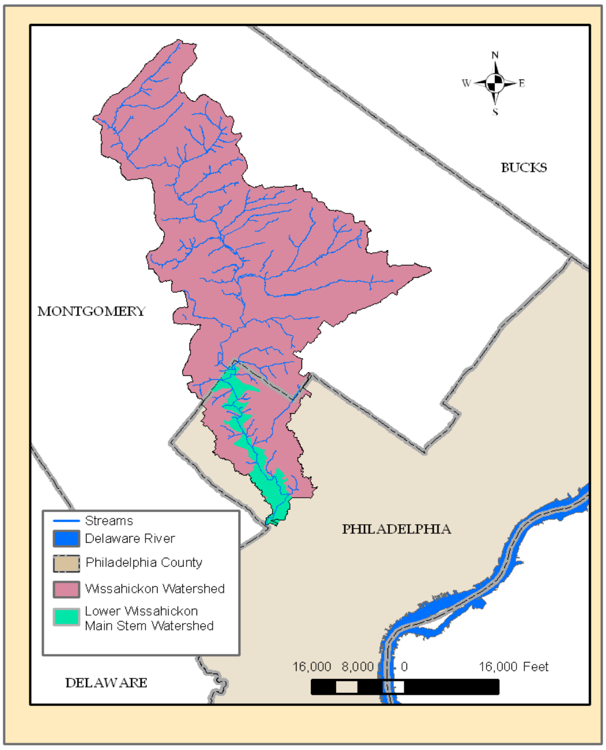
3.2.7.6.2.4 FLOODPLAIN ENCROACHMENT

Scores for the *Floodplain Encroachment* parameter were generally very low with a mean watershed score of 5/20 which was rated as “poor.” The mean score for the large Lower Wissahickon tributaries was considerably higher and was rated as “marginal.” The major floodplain encroachment in the watershed was Lincoln Drive which runs along the DSL side of the Monoshone Creek corridor. The reach least affected by Lincoln Drive was WSMO02, which had a score of 8.5/20 and was rated as “marginal.” There was a trend where the scores for this parameter decreased in the downstream direction as both Lincoln Drive (DSL) and Forbidden Drive (DSR) impinged upon the floodplain in the downstream-most reach WSMO06.

3.3 MAIN STEM LOWER WISSAHICKON WATERSHED AND REACH CHARACTERISTICS

The main stem Lower Wissahickon Creek was defined as the main stem of Wissahickon Creek extending from Northwestern Avenue downstream to the confluence with the Schuylkill River. In the subsequent sections, "All Reaches Average" refers to the average main stem Lower Wissahickon score for the respective metric.

3.3.1 MAIN STEM LOWER WISSAHICKON WATERSHED AND REACH CHARACTERISTICS



The Lower Wissahickon main stem is considered the main stem within Philadelphia City Limits. The headwaters of the Wissahickon main stem originate just below a parking lot at the Montgomeryville Mall complex in Montgomery Township. The main stem then flows for approximately 19 miles before entering into Philadelphia County where it is known as the Lower Wissahickon main stem. The Lower Wissahickon main stem then travels approximately 7.65 miles before reaching its confluence with the Schuylkill River. Both the valley floor and channel have been substantially impacted by past and current land use within the watershed.

The Lower Wissahickon main stem watershed is approximately nine square miles. Major land use types within the watershed (Figure 3-93) include: wooded (23%), residential – single family detached (22%), residential – row home (6%), and recreation (3%). The Lower Wissahickon main stem is surrounded by Fairmount Park on both sides for the entire length.

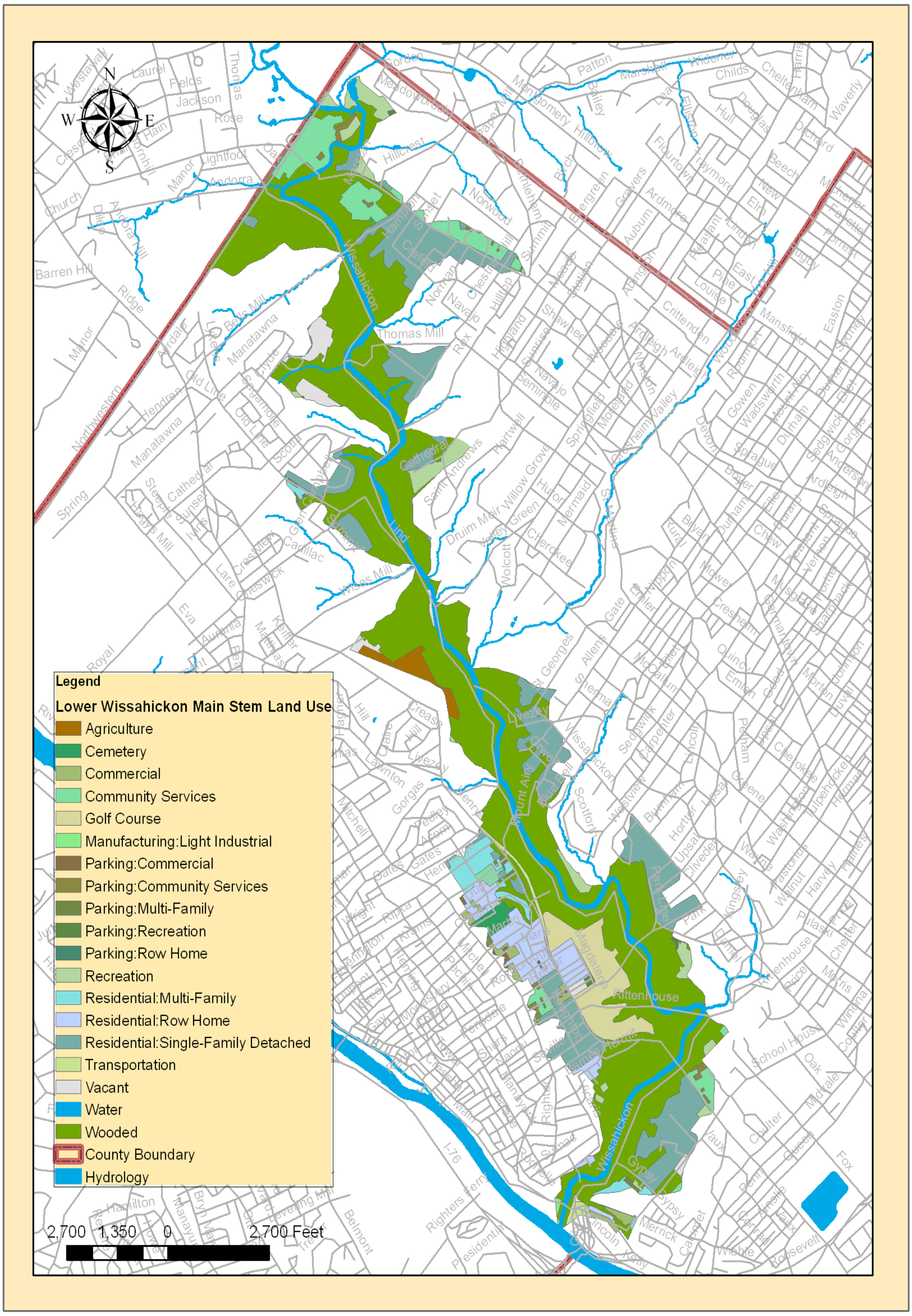


Figure 3-93: Land Use in the Lower Wissahickon Main Stem Watershed

3.3.1.1 GEOLOGY

The majority of the Lower Wissahickon main stem watershed is underlain by the Wissahickon Formation (Figure 3-94). The Wissahickon Formation consists of mica schist, gneiss and quartzite. The exposed schist near the surface is highly weathered. The Wissahickon Formation is also comprised of metamorphosed sedimentary rocks.

There are two bands of the Chickies Formation and the Felsic Gneiss Formation located at the top of the watershed. The Chickies Formation is composed of quartzite and quartz schist. This formation has good surface drainage. The Felsic Formation consists of metamorphic rocks that are resistant to weathering but still show good surface drainage.

There are small sections of the Ultramafic Gneiss Formation located in the center as well as the northern portion of the watershed. This formation consists of highly resistant rocks with good surface drainage. There is a small section of the Pennsauken Formation in the southern portion of the watershed. This formation is composed mostly of quartz, quartzite and chert. These rocks are deeply weathered. Then there is a small section of the Bryn Mawr Formation at the southern tip of the watershed. The Bryn Mawr Formation is made up of deeply weathered gravel and sand.

3.3.1.2 SOILS

According to the National Resource and Conservation Service Soil Survey, the majority of soils for the Lower Wissahickon main stem watershed are classified as hydrologic group B (Table 3-97). These soils have a moderate rate of infiltration when the soils are wet (0.50-1.00 in/hr). Water movement through these soils is considered moderately rapid. There is a small band of group D soils along the northern portion of the Lower Wissahickon main stem (Figure 3-95). These soils have a very slow rate of infiltration when saturated (0.02-0.10 in/hr) resulting in a high runoff potential. There are small sections of C soils located throughout the watershed. Group C soils have a slow rate of infiltration when saturated (0.17-0.27 in/hr). Water movement through these soils is moderate or moderately slow. The northern and southern portions along the main stem are underlain by the Urban Land soils. Urban soils consist of material that has been disturbed by human activity during urbanization. Urban soils have been produced by mixing, filling and contamination of the native soils in both urban and suburban areas.

Table 3-97: Distribution of NRCS Soil Types in Lower Wissahickon Main Stem Watershed

Group	Area (ft^2)	Percent of Total Area
B	222,051,456	88.43%
C	7,527,168	3.0%
D	1,756,339	0.7%
Urban and Made Land	19,570,636	7.8%
Total Area	**250,905,600**	**100%**

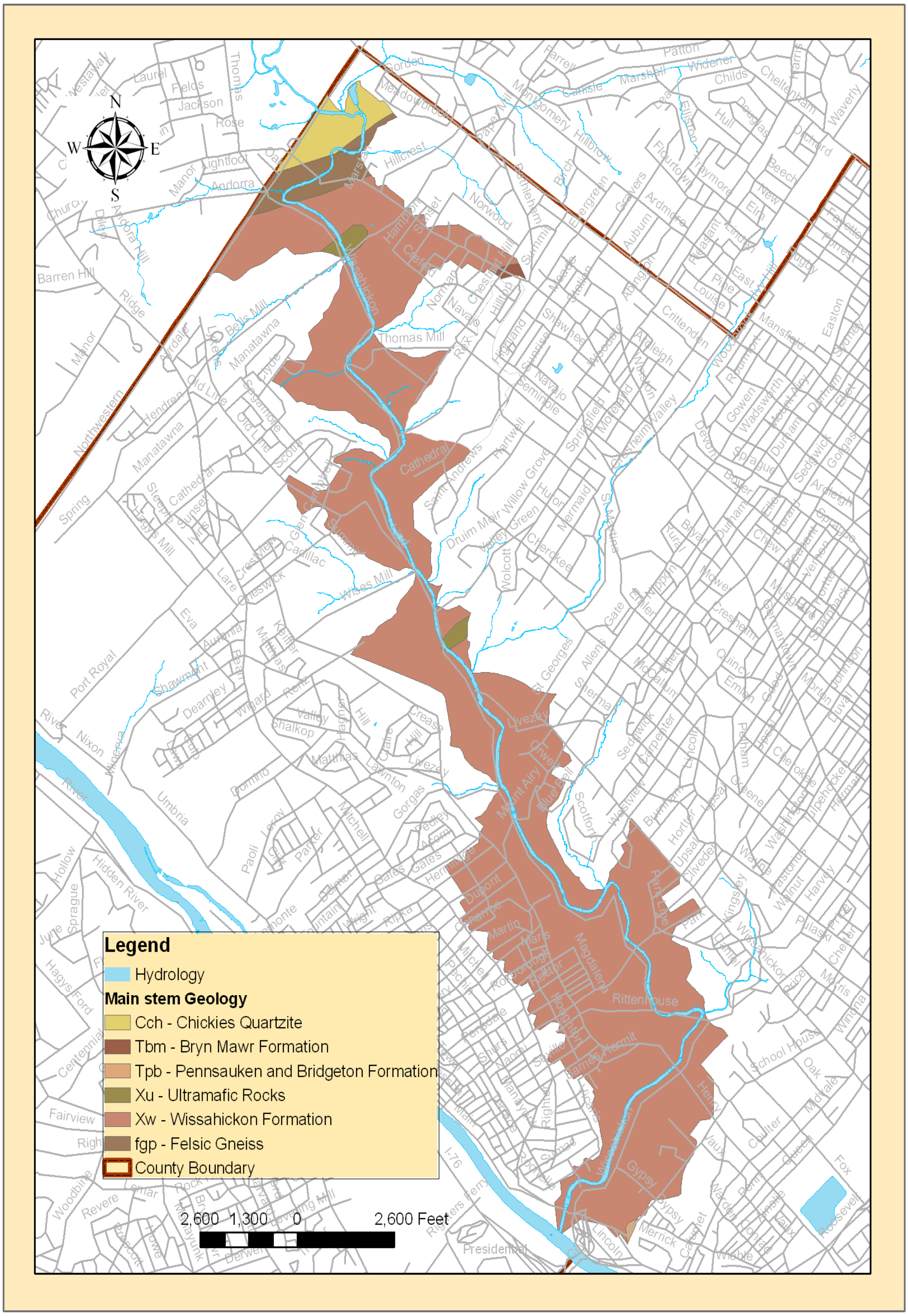


Figure 3-94: Geology of Lower Wissahickon Main Stem Watershed

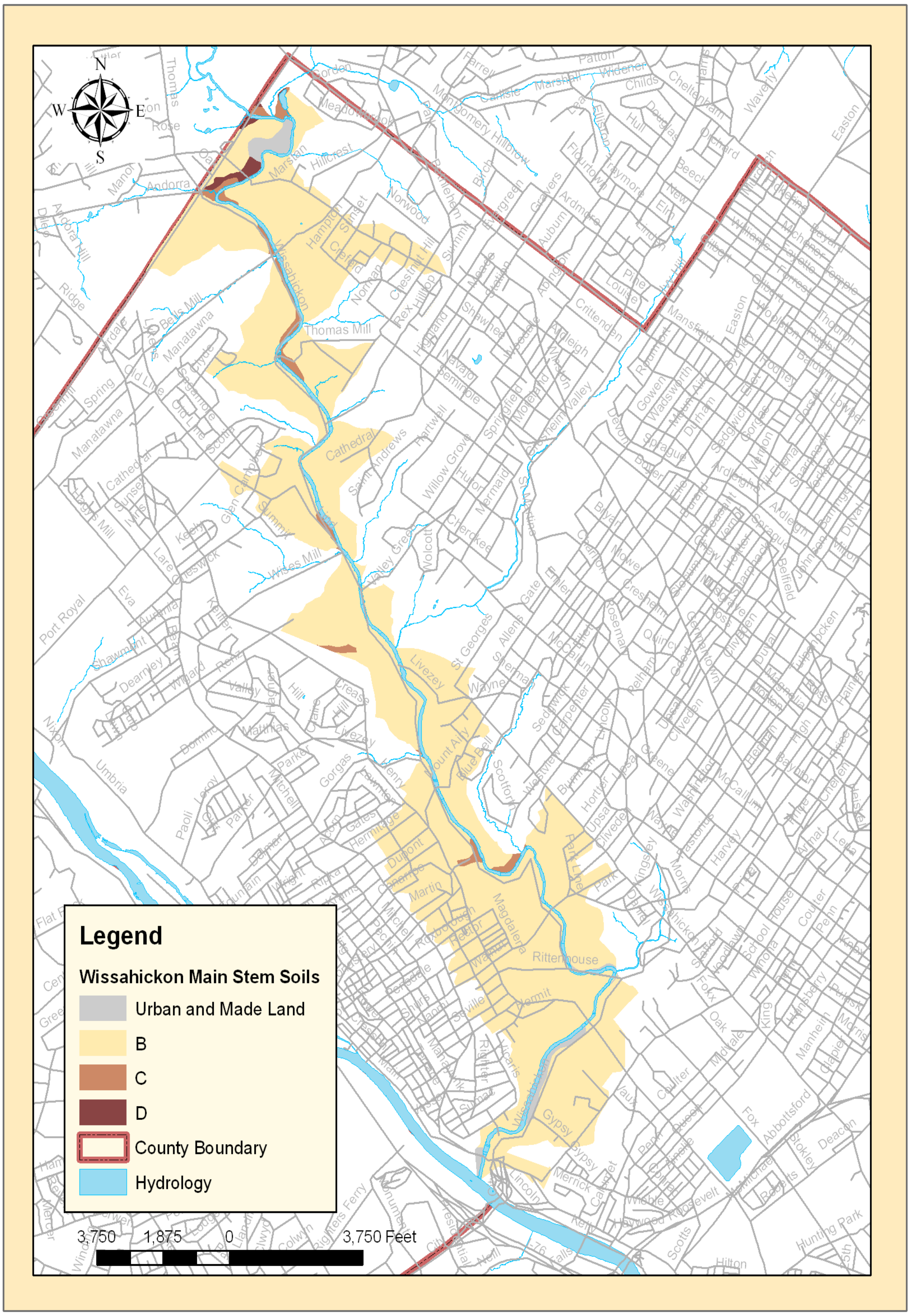


Figure 3-95: Distribution of NRCS Soil Types in Lower Wissahickon Main Stem Watershed

3.3.1.3 BANK EROSION

Refer to section 3.3.1.6.1.3

3.3.1.4 INFRASTRUCTURE TRACKDOWN SUMMARY

The infrastructure assessment of the main stem of Wissahickon Creek illustrates some of the anthropogenic impacts associated with development - both within the stream channel as well as the riparian corridor. These impacts are still quite evident although the main stem of Wissahickon Creek flows within Fairmount Park for the entirety of its length. The main stem channel itself is buffered by Park land, however, its watershed is heavily developed. The high degree of urbanization within the Wissahickon Creek watershed, as well as past land-uses, has resulted in the construction of multiple infrastructure elements. Many of which affect the timing, duration and magnitude of high and low flows within the main stem channel as well as the channel's sediment transport regime. Such infrastructure elements include bridges, dams, stormwater outfalls, channels, etc. Understanding the relationship between development, drainage area, stream hydraulics, and infrastructure constitutes the rationale behind conducting infrastructure assessments.

The Wissahickon Creek main stem possesses many infrastructure elements of a detrimental nature to the hydraulic function of the stream. The most recognizable of these are stream crossings such as culverts, bridges, dams, and pipes. These obstructions control the hydraulic grade line of the creek and render it incapable of transmitting the bulk of the bedload sediment and flow to downstream reaches as it should. The main stem has six dams (Thomas Mill and mill race, Magargee, Livezy, Little Ridge and Big Ridge dams). Some of the dams were once mill dams, but are no longer of importance for industrial use, but have historic significance. These upstream mill dams are major impediments to the flow of sediment and water, and are impediments to fish migration into the upstream tributaries of Wissahickon Creek.

All of the dams on the Wissahickon main stem are quite large. An example is Thomas Mill Dam (WSdam119) in reach WSMS108 which is 150 feet across and 5 feet high. Similarly, pipe crossings such as WSpip004 in reach WSMS120 also serve as formidable obstructions. WSpip004 is only 0.5 feet above of the stream bed, but it still creates enough of an obstruction that it hinders sediment transport and the upstream movement of some aquatic species. It has a dam-like effect although to a much lesser extent than the dams on the main stem.

The large bridges on the main stem channel also affect stream hydraulic function. Bridge abutments along stream banks constrict stream flow, which in turn can cause increased deposition upstream of the abutments and scour downstream. Several of the downstream bridges completely span the valley such as the Henry Avenue Bridge (WSbri311). Bridges that span that much distance have less of an effect on the hydraulic capacity of the stream, but still contribute runoff. There are a total of 16 bridges crossing the main stem, most of which alter stream function to some degree.

All of the culverts associated with the main stem are associated with Forbidden Drive to either convey trail drainage near the creek or to convey tributaries that contribute flow to the Wissahickon beneath the trail system. None of the culverts are within the main channel of Wissahickon Creek as most end near the confluence of tributaries' and the main stem channel.

Two large sanitary sewers run parallel to the Wissahickon Creek main stem. They are the Wissahickon Low Level and High Level Interceptors. The Wissahickon High Level Interceptor extends from Rex Avenue to Lincoln Drive along the downstream left side of the creek. This sewer starts as a 15-inch pipe at Rex Avenue. As the High Level Interceptor approaches the confluence of Wissahickon Creek and Monoshone Creek (WSconf172) its diameter is 60 inches. The diameter increases to 72-inches after merging with 42-inch Monoshone Interceptor which is situated east of Monoshone Creek. The High Level Interceptor crosses each of the eastern tributaries along its alignment and in a few cases necessitated additional infrastructure development such as culverts which were constructed to protect the pipe and convey tributary flow beneath it.

The Low Level Interceptor starts at the county-city boundary at Northwestern Avenue in Germantown. Due to the meandering of the stream the interceptor crosses below the stream a few times before staying on the downstream right side from just downstream of Bells Mill to the Blue Stone Bridge (WSbri313) where Forbidden Drive crosses the stream about 1,500 feet downstream of Walnut Lane. Just upstream of WSbri313, the Low Level Interceptor enters into a siphon, which conveys the interceptor beneath the main stem channel. At Northwestern Avenue the pipe is 20 inches in diameter and reaches 42 inches at Lincoln Drive and then 54 inches when it turns left and follows Ridge Avenue near the confluence with the Schuylkill River.

Outfalls are one of the most notable pieces of infrastructure along the main stem of Wissahickon Creek. With a large amount of impervious surface within the drainage area, the outfalls contribute a significant quantity of flow to the creek. Several of the outfalls are large, at or over three feet in diameter, and one is 9 square feet (WSout591). The main stem has a total of 33 outfalls along its banks with a total outfall area of 99.85 square feet. These outfalls all convey stormwater runoff from the areas adjacent to the creek. These outfalls can be detrimental to the stream's health and function. Combined with the tributaries that also contribute flow and sediment, the Wissahickon main stem takes on a tremendous influx of stormwater flow and sediment.

In an effort to prevent the continued erosion of the banks and protect infrastructure channels were built along parts of the stream. Reaches WSMS116 and WSMS136 were most impacted at 8% and 16% channelized respectively. The channels may prevent erosion over their lengths, but they can create local scour upstream and downstream. This was escalated by the fact that the channels create smooth banks that did nothing to dissipate the energy of the high flows. Furthermore, the channels disconnected the stream from its floodplain and provided poor habitat.

Reach WSMS136 had the largest amount of infrastructure in the Lower Wissahickon main stem. This is due to its proximity to Lincoln Drive which runs parallel to the stream. WSMS136 had the highest amount of several types of infrastructure. The reach had the most bridges and outfalls, and outfall area. It was tied with a few other reaches for the most culverts, channels, and dams. It also had the longest channelized length within the watershed and the highest percentage of channelization. These statistics should be somewhat expected given that WSMS136 was more than 2,000 feet longer than any other reach on the main stem in the Lower Wissahickon.

There were four pieces of infrastructure identified as being in poor condition along the main stem of Wissahickon Creek. They were WScha143 and in WSMS102, and WScha146 in WSMS114, and WScul122 in reach WSMS120. Also WSpip04, a 20-inch water main, in section WSMS120, appeared to be in good condition, but was exposed by the creek.

Table 3-98: Lower Wissahickon Creek Main stem Infrastructure Point Features

Section ID	Culvert Count	Bridge Count	Outfall Count	Channel Count	Conflu-ence Count	Dam Count	Manhole Count	PipeSewer Count	Other Count	Infra Point Count	Combined Outfall Area (ft²)
WSMS102	0	2	2	3	5	0	1	0	0	8	10.2
WSMS104	0	1	3	0	2	0	0	0	1	5	10.6
WSMS106	0	0	1	0	1	0	0	0	0	1	1.8
WSMS108	1	2	1	0	1	2	0	0	0	6	1.8
WSMS110	0	1	1	0	2	0	0	0	0	2	0.8
WSMS112	2	0	1	0	3	0	0	0	0	3	3.1
WSMS114	0	0	0	1	2	1	0	0	0	2	0.0
WSMS116	0	1	2	1	1	0	0	0	0	4	4.9
WSMS120	2	0	3	0	3	1	3	1	0	10	12.9
WSMS122	0	0	0	0	2	0	0	0	0	0	0.0
WSMS124	2	1	3	0	2	0	0	0	0	6	13.1
WSMS126	0	0	1	0	0	0	0	0	0	1	7.1
WSMS128	0	1	0	0	1	0	0	0	0	1	0.0
WSMS130	1	0	0	0	2	0	0	0	0	1	0.0
WSMS132	1	1	0	0	1	0	0	0	0	2	0.0
WSMS134	1	1	3	0	1	0	0	0	0	5	14.3
WSMS136	2	5	12	2	4	2	0	0	0	23	19.2
TOTAL	**12**	**16**	**33**	**7**	**33**	**6**	**4**	**1**	**1**	**80**	**99.9**

Table 3-99: Lower Wissahickon Creek Main Stem Infrastructure Linear Features

Section ID	Total Segment Length (ft)	Total Segment Length (ft), 3 sides	Culvert Length (ft)	Percent Culverted	Channel Length (ft), 1 side	Channel Length (ft), 2 sides	Channel Length (ft), 3 sides	Total Channel Length (ft)	Percent Channelized
WSMS102	6050	18150	0	0	143	0	0	143	1
WSMS104	2102	6306	0	0	0	0	0	0	0
WSMS106	1620	4860	0	0	0	0	0	0	0
WSMS108	2006	6018	0	0	0	0	0	0	0
WSMS110	1502	4506	0	0	0	0	0	0	0
WSMS112	2044	6132	0	0	0	0	0	0	0
WSMS114	2315	6945	0	0	93	0	0	93	1
WSMS116	1654	4962	0	0	405	0	0	405	8
WSMS120	2549	7647	78	3	0	0	0	0	0
WSMS122	2001	6003	0	0	0	0	0	0	0
WSMS124	1732	5196	100	6	0	0	0	0	0
WSMS126	1642	4926	0	0	0	0	0	0	0
WSMS128	1446	4338	0	0	0	0	0	0	0
WSMS130	1342	4026	31	2	0	0	0	0	0
WSMS132	1288	3864	35	3	0	0	0	0	0
WSMS134	1840	5520	51	3	0	0	0	0	0
WSMS136	7570	22710	60	1	3366	112	0	3590	16
TOTAL	**40703**	**122109**	**355**	**1**	**4007**	**112**	**0**	**4231**	**3**

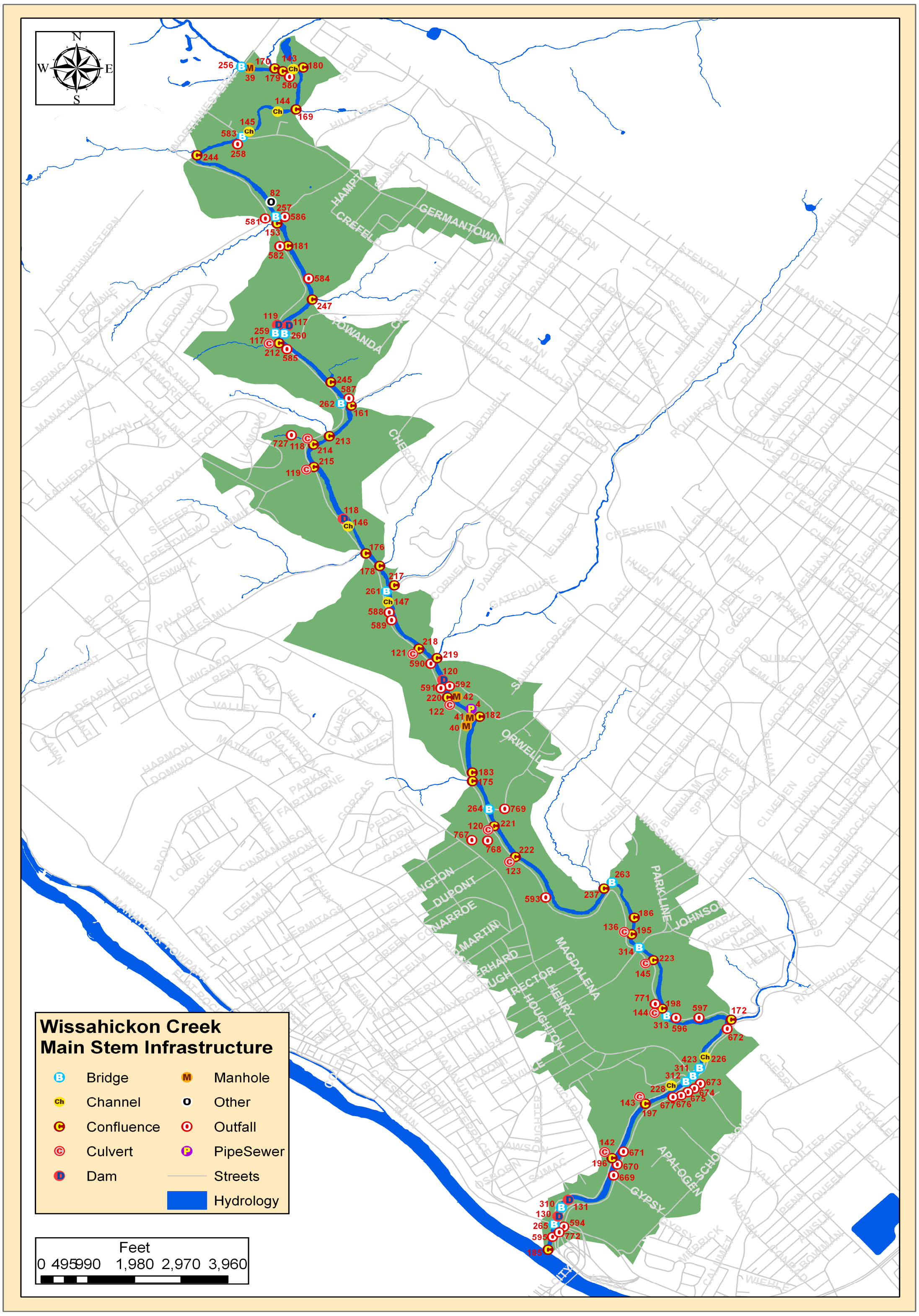


Figure 3-96: Lower Wissahickon Creek Main Stem Infrastructure Locations

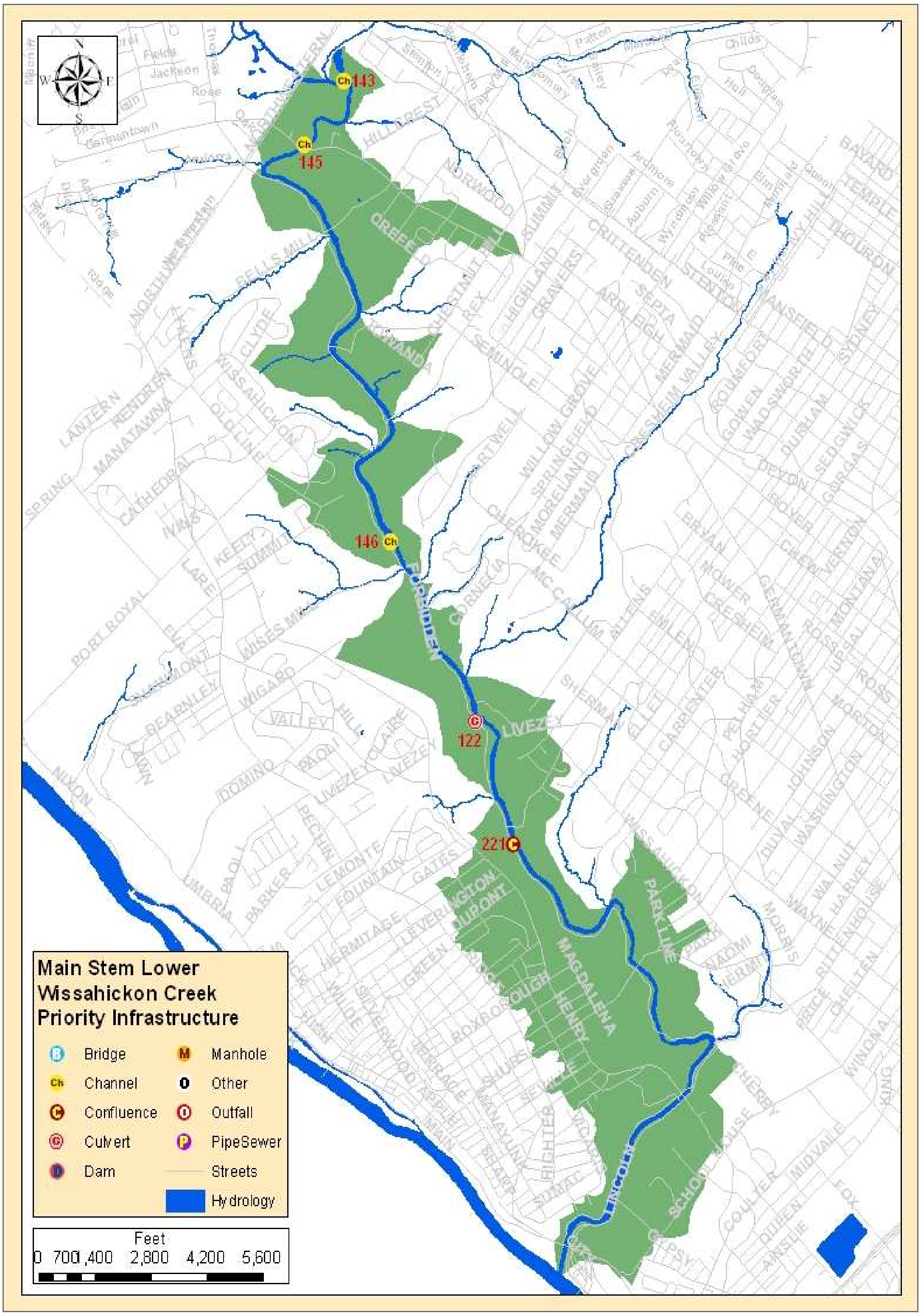


Figure 3-97: Lower Wissahickon Creek Main Stem Priority Infrastructure Locations

3.3.1.5 UNIFIED STREAM ASSESSMENT RESULTS FOR THE LOWER WISSAHICKON MAIN STEM WATERSHED

The Lower Wissahickon main stem channel began at WSbri256 at Northwestern Avenue and was a moderately sinuous channel until it reached the confluence with the Schuylkill River about 500 feet south of Ridge Avenue in reach WSMS136. The Lower Wissahickon main stem channel had a relatively shallow gradient with a 0.23% water surface slope (Appendix A).

The main stem channel was divided into 17 reaches sharing two distinct channel morphology forms. The upstream reaches (WSMS102-WSMS116) were Rosgen type B3c or B4c channels with the exception of WSMS108 which was classified as an F3 channel. The downstream reaches (WSMS120-WSMS136) had either F3 or F4 type channel morphology with the exception of WSMS126, which was classified as a B3c channel type. With the exception of the two upstream-most reaches, the main stem channel was dominated by cobble substrate.

Estimated bankfull flows within the Lower Wissahickon main stem channel exhibited substantial variability whereas discharge was not found to increase along the conventional longitudinal gradient. There is evidence that supports the notion that the main stem Wissahickon Creek is “a losing stream” whereas in some reaches, there is a net export of surface water to the groundwater table. This is a process most likely influenced by the intricacies of the karst geology underlying portions of the main stem channel.

The Center for Watershed Protection’s (CWP) Unified Stream Assessment Methodology (USAM) was used to score and rate the instream, riparian buffer and floodplain conditions of the stream corridor to allow for comparison to other reaches and watersheds within the Lower Wissahickon Basin.

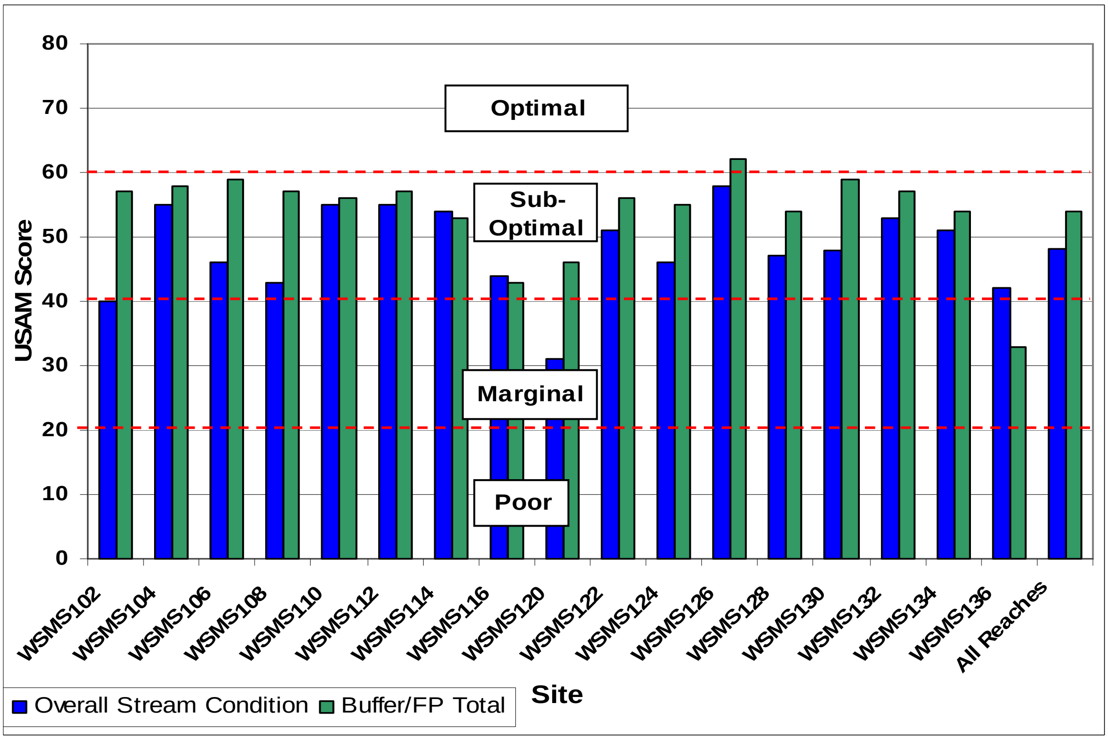


Figure 3-98: Results for Lower Wissahickon Main Stem USAM Components

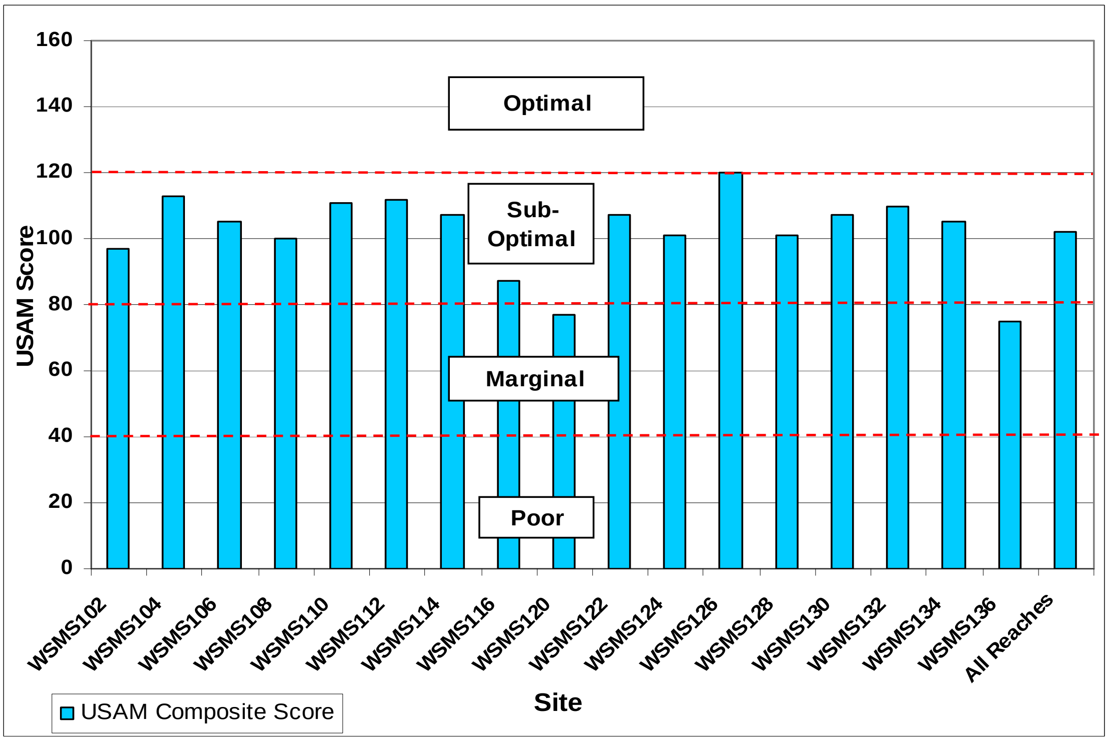


Figure 3-99: Lower Wissahickon Main Stem USAM Results

3.3.1.5.1 WSMS102

Reach WSMS102 began at WSbri256 at Northwestern Avenue, which marks the boundary between Philadelphia and Montgomery counties. The downstream boundary of the reach was situated about 1000 feet downstream of the confluence with a large unnamed tributary that spans both Philadelphia and Montgomery County. Nestled within the large, upstream meander's belt width was the campus of Chestnut Hill College, which along with the Morris Arboretum comprised the only developed land cover abutting either side of the reach.

The main stem channel in reach WSMS102 had confluences with Papermill Run (WSconf170), a small stream draining a large impoundment (WSconf142), Hillcrest Run (WSconf169) and at the downstream end of the reach the aforementioned unnamed tributary (WSconf214). The reach was classified as a B4c type channel with a moderate degree of entrenchment (ER=1.7), gravel-dominated substrate (71%) and a very shallow gradient (0.25%).

3.3.1.5.2 WSMS104

Reach WSMS104 was approximately 2,100 feet in length and was bisected by Bell's Mill Road towards the downstream half of the reach. There were relatively few infrastructure elements within the reach, with the largest being the Bell's Mill Road bridge (WSbri257) and the confluence with Bell's Mill Run (WSconf153) which was about 120 feet downstream of the Bell's Mill Road bridge. There were three outfalls within the reach (WSout581, WSout586 and WSout582) - two provided drainage to WSbri257 and the third (WSout582) provided drainage to Forbidden Drive on the DSR side of the reach.

In reach WSMS104, the main stem was classified as a Rosgen type B4c channel and was similar to WSMS102 in some respects. Like WSMS102, reach WSMS104 had a moderately shallow gradient (0.25% water surface slope), moderate entrenchment ratio (ER=1.8) and a gravel-dominated substrate (54%); however, the estimated bankfull discharge within reach WSMS104 (3,093.7 cfs) was more than double that of the estimated bankfull discharge in reach WSMS102 (1533.7 cfs). This discrepancy may speak to the difference in cross sectional area between the two reaches, the uncertainty associated with identifying bankfull indicators in urban systems, karst geology and "losing streams" or aspects of each of these potential explanations.

3.3.1.5.3 WSMS106

Reach WSMS106 was approximately 1,600 feet in length and contained only two infrastructure elements within the reach, an 18-inch outfall (WSout584) and a pedestrian footbridge over Thomas Mill Run. The land cover within the areas immediately adjacent to the reach was forested with the exception of Forbidden Drive. The confluence of the main stem Lower Wissahickon channel and Thomas Mill Run (WSconf247) was a few hundred feet downstream of the WSMS106 cross section (Appendix C).

Reach WSMS106 was similar to the upstream reaches WSMS102 and WSMS104 in regards to gradient; however, the WSMS106 reach had a slightly higher degree of connection to the floodplain (ER=2.0) and was dominated by cobble substrate (48%) such that the channel was classified as a B3c stream.

3.3.1.5.4 WSMS108

Reach WSMS108 was approximately 2,000 feet in length and occupied the meander between Thomas Mill Run and Cathedral Run. There were relatively few infrastructure elements within the reach although many were significant both historically and in terms of size. The historic Thomas Mill Dam (WSdam119) and the dam's mill race (WSdam117) were located in this reach. There was also a large mid-channel island formed from historic deposition along the inside of the meander. Upon this mid-channel island rested the abutments of another historic feature, the Thomas Mill Road Covered Bridge (WSbri259), which was built in 1737 to connect the Chestnut Hill and Roxborough communities ("Bridges", Friends of the Wissahickon). Approximately 175 feet downstream of WSbri259, an unnamed tributary (2,000 feet in length) reached its confluence (WSconf212) with the main stem channel after passing beneath Forbidden Drive through a culvert (Wscul117).

Reach WSMS108 represented a change in channel type from the upstream Rosgen type "B" channels to an F3 channel type. The reach had a higher degree of entrenchment (ER=1.3) and a steeper gradient (0.35%) than the upstream channels (WSS=0.25%), most likely a product of the elevated water surface caused by WSdam119. Another characteristic of this reach that was likely a product of the dam is the coarse, armored streambed. There was a relative paucity of fine grained sediment downstream of the dam and an abundance of large cobble (59%). The D_{50} in the reach was 84.5 mm and represented the third largest D_{50} among all Lower Wissahickon main stem reaches. Reach WSMS108 also contained the largest proportion of bed rock (5%) among all Lower Wissahickon main stem reaches.

3.3.1.5.5 WSMS110

Reach WSMS110 was approximately 1,500 feet in length and had only two infrastructure elements associated with the main stem channel. There were two confluences with small tributaries in the reach. A small unnamed tributary (1,100 feet in length) came to a confluence (WSconf245) with the main stem channel about 200 feet downstream of the beginning of the reach. Approximately 650 feet downstream from WSconf245, Rex Avenue Run reached its confluence (WSconf161) with the main stem channel. The only structural infrastructure elements were the Rex Avenue Bridge (WSbri262) and an outfall (WSout587) which received stormwater runoff from Rex Avenue.

Reach WSMS110 was classified as a B3c stream channel. The substrate was dominated by cobble (55%) although the D_{50} was only 32.6 mm, which is within the coarse gravel substrate size class. The channel was slightly entrenched, with an entrenchment ratio of 1.9, Relative to the reaches both upstream and downstream of WSMS110, the reach had a very shallow gradient. The water surface slope was 0.17% compared to the steeper gradients observed upstream in WSMS108 (0.35%) and downstream at WSMS112 (0.32%).

3.3.1.5.6 WSMS112

Reach WSMS112 was approximately 2,050 feet in length not including the three tributaries that reach a confluence with the main stem channel in the reach. The reach was classified as a B3c type channel and was a relatively stable reach aside from the moderate to severe localized erosion and scour. This reach had the highest degree of floodplain connectivity amongst all the Lower Wissahickon main stem reaches. The substrate was dominated by cobble (50%) and gravel (40%) and had a D_{50} of 74.2 mm which corresponds to the small cobble substrate size class.

There were no infrastructure elements along the main stem; likewise, no development or manmade structures abutted the reach with the exception of Forbidden Drive on the DSR side of the channel. The upstream-most confluence was Cathedral Run followed by a small (approximately 950 feet) unnamed tributary that reached its confluence with the main stem 370 feet downstream of the Cathedral Run confluence. Both of these tributaries have outfalls that receive stormwater from the Roxborough neighborhood bounded by Cathedral Road to the north and west and Glenroy and Chippewa Roads to the south. WSout727, which was included in the infrastructure assessment of WSMS112 discharges stormwater to the aforementioned small unnamed tributary. The downstream-most tributary was a very small unnamed spring. The two small tributaries pass through culverts beneath Forbidden Drive as they approach the main stem channel. These culverts (WScul214 and WScul215) were included within the WSMS112 infrastructure assessment.

3.3.1.5.7 WSMS114

Reach WSMS118 was one of the longest reaches at 2,315 feet in length. There was no development of man-made structures that abutted the main stem channel with the exception of Forbidden Drive. There were only two infrastructure elements within the reach, although they had significance in that they were large and had considerable upstream and downstream impacts. The historic Magargee Dam (WSdam118) was situated at the upstream end of the reach. About 140 feet downstream of the dam, the main stem was channelized (WScha145) for 80 feet on the DSR side of the channel. The tributaries, Wise’s Mill and Hartwell Run reached confluences (WSconf176 and WSconf178 respectively) with the main stem channel in WSMS114.

Reach WSMS114 was very similar to reach WSMS112 in slope, dimension and substrate composition; likewise, it was also classified as a B3c type channel. Reach WSMS114 was more entrenched than WSMS112 with an entrenchment ratio of 1.7. The substrate in the reach was composed mainly of cobble (53%) and gravel (40%) with a D_{50} of 72.1 mm which corresponds to the small cobble substrate size class.

3.3.1.5.8 WSMS116

Reach WSMS116 began about 200 feet upstream of the Valley Green Bridge (WSbri261) and extended 1000 feet downstream of the historic Valley Green Inn for a total reach length of 1,650 feet. Just upstream of the bridge, Valley Green Run reached its confluence (WSconf217) with the main stem channel. Reach WSMS116 was one of the more developed reaches with the Lower Wissahickon main stem, though most development was centered around the Inn. Aside from the bridge, there was also a parking lot adjacent to the main stem channel (DSR) as well a 405-foot stone retaining wall (WScha17).

Reach WSMS116 was very similar to reach WSMS110 in that it was a B3c type channel with a water surface slope (WSS=0.13%) much lower than the reaches upstream and downstream of it. The two reaches also had almost identical substrate composition with 55% cobble and 40% gravel although WSMS110 had more boulders and bedrock outcrops whereas there was no bedrock in WSMS116. The D_{50} in WSMS116 was 71mm which corresponds to the small cobble substrate size class.

3.3.1.5.9 WSMS120

Reach WSMS120 was a rather large reach at just over 2,550 feet in length. There were a total of four confluences within the reach, with the largest being the Cresheim Creek confluence (WSconf219) with the main stem channel. The other three confluences were very small brooks that originated as springs on the valley walls of the Lower Wissahickon. A large portion of the reach was within the Livezy Dam (WSdam120) impoundment, thus the WSMS120 riffle cross section was about 975 feet downstream of the dam. Near the riffle was the Upper Roxborough transmission gravity main (WSpip004) which crossed the main stem channel just upstream of the riffle cross section.

The main stem channel downstream of the dam was classified as an F3 channel. As such, much of the channel was deeply entrenched and disconnected form the floodplain. The entrenchment ratio (1.2) in reach WSMS120 was the second worst among all the Lower Wissahickon main stem reaches. The substrate distribution was dominated by cobble (52%) although there was a considerable amount of gravel (43%) within the reach as well.

3.3.1.5.10 WSMS122

Reach WSMS122 was approximately 2,000 feet in length. There was no infrastructure along the reach although there were two confluences (WSconf175 and WSconf183). A small brook (approximately 650 feet in length), which originated at the base of a swale reached its confluence (WSconf183) with the main stem 300 feet upstream of the WSMS122 cross section. Approximately 200 feet downstream of WSconf183, Gorgas Run reached its confluence with the main stem (Wsconf175).

Reach WSMS122 had some similarity to reach WSMS120. Both reaches were classified as deeply entrenched (ER=1.2) Rosgen type F3 channels and had similar substrate distributions.

3.3.1.5.11 WSMS124

Reach WSMS124, one of the least sinuous reaches along the Lower Wissahickon main stem was approximately 1,730 feet in length. Aside from the Mount Airy Avenue Bridge (WSbri264), there were no infrastructure elements situated along or within the main stem channel. Four outfalls situated within the reach WSMS124 corridor flowed to the main stem channel and were included in the WSMS124 infrastructure assessment. There were also two culverts (WScul120 and WScul123) which conveyed enough drainage from Forbidden Drive and the adjacent valley wall, to form confluences (Wsconf221 and WSconf222) with the main stem channel.

Reach WSMS124 was similar two the upstream reaches WSMS120 and WSMS124 in dimension and substrate composition. Like the two upstream reaches, it was also a Rosgen type F channel. The substrate distribution was dominated by cobble (49%) in reach WSMS124 although there was a considerable proportion of gravel (45%) throughout the reach. The reach D_{50} was 64mm, which is the threshold dimension between the gravel (2mm - 64mm) and cobble (64mm-256 mm) size classes. The reach was classified as an F4 channel given that very coarse gravel particles (45-64 mm) are more likely to be mobilized given the reduced slope of the reach (WSS=0.10%).

3.3.1.5.12 WSMS126

Reach WSMS126 was approximately 1,640 feet in length and comprised half of the large meander bend that encompasses Fairmount Park's historic Monastery Stables. Aside from the stables, non-forested land cover was scarce with the exception of Forbidden Drive. Infrastructure within the reach was limited to a sole stormwater outfall (WSout593) from Henry Avenue to the west.

Reach WSMS126 was the downstream-most Rosgen type B3c channel type on the Lower Wissahickon main stem. It was the also the last reach in the main stem study area with the potential for moderate levels of floodplain access at flows in excess of bankfull with an entrenchment ratio of 1.5. The substrate distribution was dominated by cobble (54%) and had a relatively abundant proportion of boulders (7%).

Downstream of reach WSMS126 the remainder of the Wissahickon main stem was a Rosgen type F channel with relatively high width to depth ratios (16.9-24.7).These high width to depth ratios were associated with relatively low shear stresses which may ultimately preclude the transport of boulders in the downstream-most reaches. The diminished competency of the downstream reaches to move boulders was further supported by the observations of the boulder distributions upstream and downstream of reach WMMS126. Upstream of reach WSMS126, boulders comprised an average of only 3% of the substrate distribution (reaches WSMS102-WSMS124); however, downstream of reach WSMS126, boulders comprised an average of 10.4% of the substrate distribution (reaches WSMS1280-WSMS36).

3.3.1.5.13 WSMS128

Reach WSMS128 was approximately 1,445 feet in length. The only infrastructure within the reach was the Kitchen's Lane Bridge (WSbri263) which links Kitchen's Lane with Forbidden Drive. Kitchen's Lane reached its confluence (WSconf237) with the main stem channel 150 feet upstream of the bridge.

Reach WSMS128 was classified as an F3 stream channel. The channel was deeply entrenched and characterized by extremely coarse substrate. The cobble-dominated reach was distinct from other main stem reaches in that it had the highest percentage (59%) of cobble and boulder (13%) substrate and the largest D_{50} at 109.2mm (medium cobble).

3.3.1.5.14 WSMS130

Reach WSMS130 was approximately 1,340 feet in length. The surrounding land cover was completely forested and there were no significant infrastructure elements within the reach. A very small, unnamed tributary reached its confluence (WSconf186) with the main stem channel 100 feet upstream from the WSMS130 cross section. Farther downstream another very small unnamed tributary reached its confluence (WSconf195) with the main stem channel after flowing through a culvert (WScul136) under Forbidden Drive.

Reach WSMS130 was classified as an F3 channel. As was observed in the upstream reach WSMS128, this reach had a substrate composition dominated by cobble (56%) and boulder (11%). The severely entrenched (ER=1.1) reach was relatively steep (WSS=0.31%) compared to the three reaches immediately downstream of WSMS130, which had water surface slopes between 0.13-0.15%.

3.3.1.5.15 WSMS132

Reach WSMS132 was approximately 1,290 feet in length. At the upstream end of the reach was the Walnut Lane Bridge (WSbri22) which comprised the entirety of the infrastructure in the reach. There was a confluence with a small tributary that flowed beneath Forbidden Drive through culvert WScul145 15 feet downstream of the WSMS132 cross section.

Reach WSMS132 was a deeply entrenched F3 stream channel. The substrate composition was dominated by cobble (53%). There was a high percentage of sand (12%) throughout the reach as WSMS132 had the highest relative abundance of sand of all Lower Wissahickon main stem reaches with the exception of WSMS130.

3.3.1.5.16 WSMS134

Reach WSMS134 was approximately 1,840 feet in length. This reach was the last relatively undeveloped reach on the Lower Wissahickon main stem. The most significant infrastructure feature present within the main stem channel was the Blue Stone Bridge trail crossing for Forbidden Drive. There were a total of three stormwater outfalls in the reach, all situated in the vicinity of Forbidden Drive. The upstream-most outfall (WSout771, privately owned) was rather large with a diameter of 4 feet and conveyed stormwater runoff from the Roxborough neighborhood bordered by Henry Avenue and the Walnut Lane Golf Course. The other two outfalls were not connected to the PWD stormwater network, but rather convey overland flow from inlets on Forbidden Drive.

The reach WSMS134 channel was very similar in substrate composition, profile and dimension as the reach WSMS132 channel. Likewise, the channel was classified as an F3 channel type with a substrate composition dominated by cobble (49%) and gravel (31%).

There was also a considerable proportion of boulder (10%) and sand (11%) throughout the reach.

3.3.1.5.17 WSMS136

Reach WSMS136 was the downstream-most reach within the Lower Wissahickon and was by far the longest reach amongst all the main stem reaches at 7,570 feet in length. The reach was the most developed and heavily impacted reach along the Wissahickon. Near the top of the reach, Monoshone Creek reached its confluence with the main stem channel (WSconf178) as the channel alignment followed a sharp meander that put the channel parallel with Lincoln Drive in the historic Rittenhouse Town area. Here the main stem channel was channelized (WScha228 on the DSR and WScha226 on the DSL) for over 3,500 feet along Lincoln Drive. Other large structures included the Henry Avenue and Ridge Avenue Bridges (WSbri310 and WSbri311 respectively) as well as the two Ridge Avenue Dams (WSdam130 and WSdam131).

The WSMS136 riffle cross section was purposely located upstream from the numerous bridges and dams which significantly altered the sediment regime and flow conditions of the channel, thus the results of the fluvial geomorphic study reflected upstream conditions in WSMS136 more so than downstream conditions. WSMS136 had a strong semblance to all the main stem reaches downstream of WSMS126 in terms of substrate composition, dimension and stream type.

3.3.1.6 SUMMARY OF UNIFIED STREAM ASSESSMENT RESULTS

The mean scores for the *Overall Buffer and Floodplain Condition*, *Overall Stream Condition*, and composite USAM score were classified as “suboptimal” (Table 3-100). Average conditions within the Lower Wissahickon main stem’s buffers and floodplains (53.9/80) were slightly better than conditions observed within the stream channels (48.2/80). The scores for individual parameters ranged from poor to optimal, displaying similar levels of variability between reaches.

Table 3-100: USAM Results for the Lower Wissahickon Main Stem

Reach ID	Sub-watershed	Overall Stream Condition	Overall Buffer/FP Condition	USAM Score
WSMS102	Main stem	40	57	97
WSMS104	Main stem	55	58	113
WSMS106	Main stem	46	59	105
WSMS108	Main stem	43	57	100
WSMS110	Main stem	55	56	111
WSMS112	Main stem	55	57	112
WSMS114	Main stem	54	53	107
WSMS116	Main stem	44	43	87
WSMS120	Main stem	31	46	77
WSMS122	Main stem	51	56	107
WSMS124	Main stem	46	55	101
WSMS126	Main stem	58	62	120
WSMS128	Main stem	47	54	101
WSMS130	Main stem	48	59	107
WSMS132	Main stem	53	57	110
WSMS134	Main stem	51	54	105
WSMS136	Main stem	42	33	75
All Reaches		**48.2**	**53.9**	**102.1**

3.3.1.6.1 SUMMARY OF OVERALL STREAM CONDITION SCORES IN THE LOWER WISSAHICKON MAIN STEM WATERSHED

In general, the mean score for the *Overall Stream Condition* component (48.2/80) was moderately high and fell within the suboptimal range of scores. Within individual reaches, all but two (WSMS102 and WSMS120) were rated as "suboptimal." The highest score (58/80) was observed in reach WSMS126. Reach WSMS126 had an extensive riparian buffer interrupted only by the presence of Forbidden Drive; furthermore, the only infrastructure within the reach was an outfall (WSout593) which was situated about 100 feet from the channel on the DSR side of the corridor. The reach with the worst score was WSMS120 with a score of 31/80 which was rated as "marginal.'' The relatively low score for this reach was attributed to the presence of development and infrastructure within the reach. The most adversely influential infrastructure element within the reach was the Livezy Dam (WSdam120) due to the extent of its impoundment. The impoundment had an affect on streamflow and floodplain function for almost 2,500 feet upstream close to the location of the Valley Green Inn. The majority of the reach upstream of the dam contained segments where low velocities deposited fine sediment, thus creating poor instream habitat conditions.

The *Instream Habitat* parameter had very high scores among many of the main stem reaches, as 13 of the 17 reaches were rated as "optimal" with scores greater than 15/20. The presence of stable substrate (cobble and boulder) throughout these reaches was the single-most factor responsible for the habitat conditions observed. The *Floodplain Connection* parameter was the worst-scoring parameter with an average of only 5.1/20 barely above the poor-marginal threshold score of 5/20. Most bank erosion was observed to be localized; however, the lack of floodplain connection (e.g. low entrenchment ratios) was a factor which could exacerbate bank erosion and was characteristic of the vast majority of main stem reaches.

Table 3-101: USAM Overall Stream Condition Scoring for the for Lower Wissahickon Main Stem

OVERALL STREAM CONDITION								
Reach ID	Sub-watershed	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	Overall Stream Condition
			Left	Right	Left	Right		
WSMS102	Main stem	13	5	5	5	5	7	40
WSMS104	Main stem	18	7	8	6	8	8	55
WSMS106	Main stem	16	6	4	5	5	10	46
WSMS108	Main stem	18	5	5	6	6	3	43
WSMS110	Main stem	18	7	5	8	8	9	55
WSMS112	Main stem	18	8	4	9	4	12	55
WSMS114	Main stem	19	7	7	7	7	7	54
WSMS116	Main stem	12	5	4	8	8	7	44
WSMS120	Main stem	5	5	5	7	7	2	31
WSMS122	Main stem	19	7	7	8	8	2	51
WSMS124	Main stem	14	8	6	6	9	3	46
WSMS126	Main stem	19	9	7	9	9	5	58
WSMS128	Main stem	19	5	7	5	8	3	47
WSMS130	Main stem	17	7	7	9	7	1	48
WSMS132	Main stem	17	8	8	9	9	2	53
WSMS134	Main stem	19	7	7	9	7	2	51
WSMS136	Main stem	10	6	7	8	8	3	42
All Reaches		**15.9**	**6.6**	**6.1**	**7.3**	**7.2**	**5.1**	**48.2**

3.3.1.6.1.1 INSTREAM HABITAT

Scores for the *Instream Habitat* parameter were relatively high as 13 of 17 reaches were rated as "optimal" with scores greater than 15/20. The main stem mean score (15.9/20) was higher than both the Small Tributary average (15.8/20) as well as the Large Tributary average (13.1/20). Instream habitat in the Lower Wissahickon main stem was characterized by an abundance of stable cobble and boulder habitat features. On average, the main stem reaches had substrate particle distributions containing 49.5% cobble and 5.4% boulder

Four reaches, WSMS114, WSMS122, WSMS126 and WSMS128 has scores of 19/20. Reach WSMS128 was distinguished in that it contained 59% cobble, 13% boulder and a D50 of 109.2 mm. All of these metrics were the highest observed among main stem Lower Wissahickon reaches. The reach with the lowest score was WSMS120, which was rated as "poor" with a score of 5/20. Near the bottom of the reach where the WSMS120 cross section was located, the instream habitat was superb given the abundance of shading and coarse substrate in the form of cobble (52%), boulders (2%) and bedrock outcrops. The upstream two thirds of the reach was heavily impacted by the Livezy Dam (WSdam120) impoundment. Impoundments are characterized by extreme depths and very low velocities such that they create conditions where fine sediment deposition, low dissolved oxygen and high temperature produce suitable habitat for very few species-usually only the most hardy, non-specialized species.

3.3.1.6.1.2 VEGETATIVE PROTECTION

The *Vegetative Protection* parameter reflects the extent to which stream banks are protected by vegetative cover in the form of trees, shrubs and non-woody, emergent macrophytes. In general scores were moderate and ranged from marginal to suboptimal. The highest scores were recorded in reach WSMS132 as both the left and right banks had scores of 8/10 and were rated as "optimal". Reach WSMS126 also scored well with a score of 9/10 on the left bank and 7/10 on the right bank. Both of these reaches compared well to the main stem averages of 6.6/10 for the left bank and 6.1/10 for the right bank. The lowest scores were recorded in reach WSMS116, with the left bank having a score of 5/10 and the right bank scoring 4/10.

3.3.1.6.1.3 BANK EROSION

Bank Erosion scores along the main stem were rather high considering the high flows that the channel conveys. The scores ranged from marginal to suboptimal with many sites having one bank with a marginal score and the other scoring in the suboptimal range. The main stem averages for the left (7.3/10) and right (7.2/10) banks were rather high and were well within the suboptimal range of scores.

In many sites there were bedrock outcrops and boulder or cobble depositional features that precluded severe erosion, although localized scour was evident in many reaches. Larger substrate particles such as cobbles and boulders have much higher "roughness" than smaller substrate such as gravel, dissipating kinetic energy in the channel during bankfull flow events. There were only a few sites with bedrock located within the channel (reaches WSMS106 through WSMS110), however many sites had large bedrock outcrops on or near the stream banks which prevented substantial bank erosion. One such reach was WSMS132 which had a score of 8/10 on both banks. The DSL bank in WSMS132 was protected by boulders and bedrock outcrops while the DSR bank was protected by boulders and cobble deposits.

3.3.1.6.1.4 FLOODPLAIN CONNECTION

Scores for the *Floodplain Connection* parameter were generally very low among the main stem reaches, especially in the Rosgen type F reaches downstream of WSMS116. A total of 10/17 reaches had scores rated as "poor" which signified moderate to severe entrenchment in these channels. The mean score along the main stem was 5.1/20 which corresponds to an entrenchment ratio of 1.5. The reach with the highest degree of floodplain connection was WSMS112 with a score of 12/20, which was rated as suboptimal. Reach WSMS130, an F3 channel, had the lowest score at just 1/20. Deeply entrenched channels such as the WSMS130 reach rarely access their floodplains during flows in excess of bankfull.

3.3.1.6.2 SUMMARY OF OVERALL BUFFER AND FLOODPLAIN CONDITION SCORES IN THE LOWER WISSAHICKON MAIN STEM WATERSHED

The scores for the *Overall Buffer and Floodplain Condition* in the Lower Wissahickon main stem stream corridor were considerably high for all parameters except for *Floodplain Habitat*. The *Overall Buffer and Floodplain* scores for 15/17 reaches fell in the suboptimal range. The two exceptions were WSMS126 which was rated as "optimal" and WSMS136 which was rated as "marginal." Scores for this component of the USAM assessment were consistently high due to the location of the entire Lower Wissahickon main stem inside of Fairmount Park where development is maintained at a minimum. Overall, the average *Buffer and Floodplain Condition* (53.9/80) score for the Lower Wissahickon scored higher than the *Overall Stream Condition* component (48.2/80). In many reaches, there were uninterrupted vegetated buffers that extended well beyond 100 feet, although the presence of Forbidden Drive did in many instances encroach upon the Lower Wissahickon floodplains.

Table 3-102: USAM Buffer and Floodplain Condition Scoring for the Lower Wissahickon Main Stem

Reach ID	Sub-watershed	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	Overall Buffer/FP Condition
		Left	Right				
WSMS102	Main stem	10	9	14	8	16	57
WSMS104	Main stem	10	10	17	6	15	58
WSMS106	Main stem	10	10	16	6	17	59
WSMS108	Main stem	10	10	16	4	17	57
WSMS110	Main stem	10	9	15	6	16	56
WSMS112	Main stem	10	9	15	8	15	57
WSMS114	Main stem	10	9	16	6	12	53
WSMS116	Main stem	8	7	13	5	10	43
WSMS120	Main stem	9	9	13	4	11	46
WSMS122	Main stem	10	9	16	4	17	56
WSMS124	Main stem	10	9	17	5	14	55
WSMS126	Main stem	10	10	17	7	18	62
WSMS128	Main stem	9	8	16	5	16	54
WSMS130	Main stem	10	9	17	4	19	59
WSMS132	Main stem	10	9	17	4	17	57
WSMS134	Main stem	9	9	16	4	16	54
WSMS136	Main stem	2	9	14	5	3	33
All Reaches		**9.2**	**9.1**	**15.6**	**5.4**	**14.6**	**53.9**

3.3.1.6.2.1 VEGETATED BUFFER WIDTH

The vegetated buffers widths throughout the Lower Wissahickon main stem were rather extensive. The mean scores for the left (9.2/10) and right (9.1/10) banks were rated as “optimal” and were higher than both the Small and Large Tributary averages for this parameter. Extensive variation between sites was not observed as most sites had vegetated buffers rated as either “suboptimal” or “optimal” although some had a combination of the two. The one exception was observed in reach WSMS136 where the left side of the corridor was rated as “poor” with a score of 2/10. Reach WSMS136 was channelized for more than half of its length due to the proximity of Lincoln Drive to the channel. In the lower portion of WSMS136, near Ridge Avenue, the vegetated buffer on the DSL was less than 25 feet.

3.3.1.6.2.2 FLOODPLAIN VEGETATION

The *Floodplain Vegetation* parameter takes into account the dominant vegetation type (i.e. shrub, mature forest, herbaceous ground cover or mowed turf) observed throughout a reach, with mature forest being the optimal condition. The presence of a mature riparian forest is an indicator of low levels of disturbance from factors such as development and extreme flooding given mature forests may take decades to become established. Scores for this parameter were generally high throughout the Lower Wissahickon main stem. 11/17 reaches were rated as "optimal" with the remainder of the reaches scoring in the "suboptimal" range. Such high scores for this parameter would be expected given the relatively unaltered and undeveloped nature of Fairmount Park.

3.3.1.6.2.3 FLOODPLAIN HABITAT

The scores for *Floodplain Habitat* were generally very low and ranged from "poor" to "marginal." The average score for the main stem channel was 5.4/20 which was rated as "marginal." The "poor" and "marginal" ratings observed in the Lower Wissahickon main stem can be attributed to the high degree of "floodplain disconnection" within the channels of the corridor as evidenced by the average entrenchment ratio (1.5) for the main stem reaches.

Low entrenchment ratios are an indicator that floodplains within the corridor are rarely inundated by flood flows. Another factor which was present, although not prevalent was channelized segments along the main stem. These vertical walls prevent most flood events from inundating the floodplain. Over-bank flood flows are vital to a riparian ecosystem because these flows provide inputs of sediment and nutrients. Without these inputs and occasional inundation, floodplain habitats such as floodplain wetlands, ephemeral pools and backwater channels can neither be formed nor maintained.

3.3.1.6.2.4 FLOODPLAIN ENCROACHMENT

Scores for the *Floodplain Encroachment* parameter ranged from "poor" to "optimal" but were generally high in most reaches as 10/17 reaches were rated as "optimal". The average condition within the main stem corridor was rated as "suboptimal" with a score of 14.6/20. The two lowest scores were observed in reaches WSMS116 (10/20) and WSMS136 (3/20). The "marginal" rating in WSMS116 was attributed to the proximity of Valley Green Inn, a parking lot, and Forbidden Drive to the main stem channel. This reach also had a channelized segment on both sides of the channel in the vicinity of Valley Green Inn. Reach WSMS136 was rated as "poor" due to numerous factors which included five bridges, the two Ridge Avenue dams, extensive channelization, as well as the proximity of Lincoln Drive which parallels the reach for its entire length. Reach WSMS136 had a length of 7,570 feet yet had 3,590 linear feet of channelization (includes both sides and bottom channelization).

3.4 SUMMARY

Over time, the Wissahickon Creek Watershed has experienced continual and extensive urban land development. More than half of the Wissahickon Creek Watershed is covered by residential development with single family residential and row home residential making up the bulk of that development. A large portion of the riparian corridor of the Wissahickon Creek and its tributaries has remained covered as wooded land, mostly protected through long-term preservation efforts. Additionally, large tracts of privately owned open space such as agricultural land remain undeveloped and are dispersed throughout the watershed, perhaps presenting opportunities for future preservation efforts.

Geology and soils play a role in the hydrology, water quality, and ecology of a watershed. The Lower Wissahickon watershed is within the Piedmont Upland physiographic region, which is underlain by a variety of sedimentary, metamorphic and igneous rocks. The geology of the Lower Wissahickon watershed is mostly underlain by the Wissahickon Formation. Soils beneath the Lower Wissahickon watershed are mainly comprised of Group B soils.

Over the last four years, PWD has conducted a sediment study within the Lower Wissahickon watershed to estimate sediment loading from more than 24 miles of stream bank in the study area. This effort produced data suggesting that roughly 3.3 million pounds of sediment are eroded from the study area annually. Given the relative consistency in this estimate over the last four years, PWD is confident that this estimate can be considered accurate at an order of magnitude level. The sediment loading estimate suggests that the Lower Wissahickon watersheds have been affected by their location within an urban setting.

3.4.1 Small Tributaries

3.4.1.1 Infrastructure

The following tables are a summary of the data presented in previous sections. The purpose of these tables is to allow comparisons between individual reaches such that the relative impacts of point and linear infrastructure elements within each respective reach can be clearly distinguished.

In Table 3-105, select infrastructure metrics have been presented in order to identify the reaches in the Small Tributary infrastructure assessment most impacted by certain types of infrastructure.

Table 3-103: Small Tributary Infrastructure Point Summary

Section ID	Culvert Count	Bridge Count	Outfall Count	Channel Count	Conflu-ence Count	Dam Count	Manhole Count	PipeSewer Count	Other Count	Infra Point Count	Combined Outfall Area (ft^2)
WSCA02	2	0	3	0	0	0	0	0	0	5	26.7
WSGO02	1	7	5	6	1	1	16	1	2	39	64.1
WSTM02	0	3	4	0	1	0	0	0	0	7	22.3
WSMSI02	0	2	3	1	0	0	0	0	0	6	17.5
WSVG02	3	1	4	0	2	0	0	0	0	8	15.9
TOTAL	**6**	**13**	**19**	**7**	**4**	**1**	**16**	**1**	**2**	**65**	**146.5**

Table 3-104: Small Tributary Infrastructure Linear Summary

Section ID	Segment Length (ft)	Segment Length (ft), 3 sides	Culvert Length (ft)	Percent Culverted	Channel Length (ft), 1 side	Channel Length (ft), 2 sides	Channel Length (ft), 3 sides	Total Channel Length (ft)	Percent Channelized
WSCA02	3123	9369	50	2	0	0	0	0	0
WSGO02	2699	8097	8	0	218	0	215	863	11
WSTM02	3648	10944	0	0	0	0	0	0	0
WSMSI02	1865	5595	0	0	45	0	0	45	1
WSVG02	2849	8547	0	0	0	0	0	0	0
TOTAL	**14184**	**42552**	**58**	**0**	**263**	**0**	**215**	**908**	**2**

Table 3-105: Summary of Small Tributary Infrastructure by Reach

Parameter	Small Tributaries	
	Max	Mean
Total Infrastructure	WSGO02 (39)	13
Priority Infrastructure	WSGO02 (4)	1
Culverts	WSVG02 (3)	1.2
Bridges	WSGO02 (7)	2.6
Outfalls	WSGO02 (5)	3.8
Channels	WSGO02 (6)	1.4
Dams	WSGO02 (1)	0.2
Manholes	WSGO02 (16)	3.2
Pipes	WSGO02 (1)	0.2
Outfalls >3 ft diameter	WSGO02 (3)	1.6
Outfall Area	WSGO02 (64.06 ft^2)	29.3
Mean Outfall Area	WSGO02 (12.81 ft^2)	---
Single Outfall	WSGO02 (36 ft^2)	---
Segment Length	WSTM02 (3648 ft)	2837 ft
Culvert Length	WSVG02 (671 ft)	146 ft
% Culverted	WSVG02 (24%)	---
Total Channel Length	WSGO02 (863 ft)	181.6 ft
% Channelized	WSGO02 (11%)	--

3.4.1.2 UNIFIED STREAM ASSESSMENT

The following table has been presented as a means of quickly assessing the performance of individual reaches within the Small Tributary USAM assessment. The reaches presented correspond to the extreme values among the dataset; however by comparing these values to the mean Small Tributary value for each respective metric, it is possible to quickly gauge the variability of conditions within the small tributaries of the Lower Wissahickon watershed. The USAM scores for each Small Tributary watershed are included in Appendix D.

Table 3-106: Summary of Small Tributary USAM Results by Reach

Overall Stream Condition							
Parameter	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	OSC Score
		Left	Right	Left	Right		
MIN	WSCA02 (13)	WSCA02 (2)	WSCA02 (2)	WSCA02 WSGO02 WSMSI02 (5)	WSCA02 WSGO02 WSMTM02 (5)	WSGO02 (2)	WSGO02 (31)
MAX	WSMSI02 (19)	WSVG02 (8)	WSVG02 (8)	WSVG02 (7)	WSVG02 (8)	WSVG02 (17)	WSVG02 (66)
MEAN	15.8	4.4	4.2	5.6	5.8	9	44.8

Overall Buffer Floodplain Condition						
Parameter	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	OBF Score
	Left	Right				
MIN	WSVG02 (5)	WSCA02 (5)	WSCA02 (14)	WSGO02 (3)	WSVG02 (4)	WSVG02 (41)
MAX	WSCA02 WSMSI02 WSTM02 WSGO02 (10)	WSGO02 WSMSI02 WSTM02 (10)	WSTM02 (18)	WSVG02 (8)	WSTM02 (18)	WSTM02 (63)
MEAN	9	8.8	16.2	5.6	11	50.6

3.4.2 LARGE TRIBUTARIES

3.4.2.1 INFRASTRUCTURE

The following tables are a summary of the data presented in previous sections. The purpose of these tables is to allow comparisons between individual reaches such that the relative impacts of point and linear infrastructure elements within each respective reach can be clearly distinguished.

In Table 3-109, select infrastructure metrics have been presented in order to identify the reaches in the Large Tributary infrastructure assessment most impacted by certain types of infrastructure.

Table 3-107: Large Tributary Infrastructure Point Summary

Section ID	Culvert Count	Bridge Count	Outfall Count	Channel Count	Conflu-ence Count	Dam Count	Manhole Count	Pipe-Sewer Count	Other Count	Infra Point Count	Combined Outfall Area (ft^2)
WSBM02	1	0	3	0	5	0	1	0	5	5	20.0
WSBM04	0	0	4	1	0	0	2	0	0	7	6.1
WSBM06	1	0	2	0	0	0	6	0	0	9	16.8
WSHC02	6	1	3	4	3	11	0	0	2	25	17.6
WSHC04	1	4	1	9	1	2	0	0	0	17	16.0
WSHW02	1	2	6	1	0	3	0	0	0	13	19.0
WSHW04	2	0	1	0	0	1	0	0	0	4	7.1
WSWM02	2	0	3	0	0	0	1	0	0	6	28.5
WSWM04	2	2	2	0	1	2	3	0	0	11	1.6
WSWM06	0	1	6	0	1	0	0	0	0	7	25.2
WSCR04	9	1	12	4	0	0	0	2	1	29	74.5
WSCR06	1	1	9	5	1	0	0	1	1	17	14.8
WSCR08	1	0	3	2	1	0	0	1	0	7	25.9
WSCR10	0	0	0	0	0	1	0	0	0	1	0.0
WSCR12	0	2	1	1	0	0	0	0	0	4	1.8
WSCR14	0	1	1	0	1	1	0	0	0	3	1.8
WSKL02	0	1	5	0	0	0	0	0	0	6	23.6
WSKL04	2	0	1	0	0	0	0	0	0	3	3.1
WSKL06	3	5	3	2	3	1	0	0	0	14	11.0
WSMO02	1	0	7	2	0	1	0	0	1	11	37.8
WSMO04	1	2	6	2	1	1	0	0	0	12	75.5
WSMO06	2	2	10	5	1	1	0	0	0	20	126.3
TOTAL	**36**	**25**	**89**	**38**	**19**	**25**	**13**	**4**	**10**	**231**	**553.7**

Table 3-108: Large Tributary Infrastructure Linear Summary

Section ID	Total Segment Length (ft)	Total Segment Length (ft), 3 sides	Culvert Length (ft)	Percent Culverted	Channel Length (ft), 1 side	Channel Length (ft), 2 sides	Channel Length (ft), 3 sides	Total Channel Length (ft)	Percent Channelized
WSBM02	2858	8574	68	2	0	0	0	0	0
WSBM04	1838	5514	0	0	39	0	0	39	1
WSBM06	1782	5346	35	2	0	0	0	0	0
WSHC02	4135	12405	983	24	0	617	0	1234	10
WSHC04	1468	4404	15	1	257	391	30	1129	26
WSHW02	1752	5256	71	4	141	0	0	141	3
WSHW04	1766	5298	109	6	0	0	0	0	0
WSWM02	1271	3813	93	7	0	0	0	0	0
WSWM04	3610	10830	241	7	0	0	0	0	0
WSWM06	1297	3891	0	0	0	0	0	0	0
WSCR04	6726	20178	1290	19	187	48	0	283	1
WSCR06	1980	5940	66	3	178	48	567	1975	33
WSCR08	1427	4281	139	10	6	224	0	454	11
WSCR10	1927	5781	0	0	0	0	0	0	0
WSCR12	2793	8379	0	0	168	0	0	168	2
WSCR14	1551	4653	0	0	0	0	0	0	0
WSKL02	2223	6669	0	0	0	0	0	0	0
WSKL04	1973	5919	128	6	0	0	0	0	0
WSKL06	3370	10110	28	1	0	351	0	702	7
WSMO02	1665	4995	28	2	86	532	0	1150	23
WSMO04	2083	6249	115	6	7	689	0	1385	22
WSMO06	2845	8535	191	7	193	727	0	1647	19
TOTAL	**52340**	**157020**	**3600**	**7**	**1262**	**3627**	**597**	**10307**	**7**

Table 3-109: Summary of Large Tributary Infrastructure by Reach

Parameter	Large Tributaries	
	Max	Mean
Total Infrastructure	WSCR04 (29)	11.1
Priority Infrastructure	WSHC02 (6)	0.8
Culverts	WSCR04 (9)	1.6
Bridges	WSKL06 (5)	1.1
Outfalls	WSCR04 (12)	4.1
Channels	WSHC04 (9)	1.7
Dams	WSHC02 (11)	1.1
Manholes	WSBM06 (6)	0.6
Pipes	WSCR04 (2)	0.2
Outfalls >3 ft diameter	WSCR04 (4)	0.7
Outfall Area	WSMO06 (126.27 ft^2)	25.2 ft^2
Mean Outfall Area	WSMO04 (12.58 ft^2)	---
Single Outfall	WSWM02 (19.63 ft^2)	---
Segment Length	WSCR04 (6726 ft)	2379 ft
Culvert Length	WSCR04 (1290 ft)	163.6 ft
Percent Culverted	WSHC02 (24%)	---
Total Channel Length	WSCR06 (1975 ft)	468.5 ft
Percent Channelized	WSCR06 (33%)	---

3.4.2.2 UNIFIED STREAM ASSESSMENT

The following table has been presented as a means of quickly assessing the performance of individual reaches within the Small Tributary USAM assessment. The reaches presented correspond to the extreme values among the dataset; however by comparing these values to the mean Small Tributary value for each respective metric, it is possible to quickly gauge the variability of conditions within the small tributaries of the Lower Wissahickon watershed. The USAM scores for each Large Tributary watershed are included in Appendix D.

Table 3-110: Summary of Large Tributary USAM Results by Reach

Overall Stream Condition							
Parameter	Instream Habitat	Vegetative Protection		Bank Erosion		Floodplain Connection	OSC Score
		Left	Right	Left	Right		
MIN	WSCR08 (4)	WSBM02 (1)	WSBM02 (1)	WSWM02 (2)	WSWM02 (2)	WSHW04 WSCR08 WSKL02 (1)	WSCR04 WSWM06 (26)
MAX	WSHW04 WSMO04 WSWM02 (18)	WSBM06 WSKL04 WSMO02 WSWM02 (8)	WSBM06 WSKL04 WSWM02 (8)	WSMO02 (10)	WSMO02 (10)	WSKL06 WSHC02 (18)	WSKL04 (63)
MEAN	13.1	4.9	4.9	6.3	7.0	6.3	42.3

Overall Buffer and Floodplain Condition						
Parameter	Vegetated Buffer Width		Floodplain Vegetation	Floodplain Habitat	Floodplain Encroachment	OBF Score
	Left	Right				
MIN	WSBM04 (3)	WSCR06 (3)	WSHC02 (6)	WSWM02 (1)	WSCR04 WSCR08 WSMO06 WSWM06 (3)	WSCR06 (25)
MAX	WSBM02 WSHW02 WSHW04 WSKL02 WSWM02 WSWM04 (10)	WSBM02 WSBM04 WSBM06 WSHW02 WSHW04 WSKL02 WSMO02 WSWM02 (10)	WSBM02 WSMO02 (19)	WSMO02 (13)	WSBM02 WSHW04 WSKL02 (15)	WSBM02 (59)
MEAN	8.1	8.6	13.8	5.5	8.5	44.5

3.4.3 MAIN STEM

3.4.3.1 INFRASTRUCTURE

In Table 3-111, select infrastructure metrics have been presented in order to identify the reaches in the Large Tributary infrastructure assessment most impacted by certain types of infrastructure.

Table 3-111: Summary of Main Stem Infrastructure by Reach

Parameter	Main Stem	
	Max	Mean
Total Infrastructure	WSMS136 (23)	4.7
Priority Infrastructure	WSMS120 (2)	0.3
Culverts	WSMS112 WSMS120 WSMS124 WSMS136 (2)	0.7
Bridges	WSMS136 (5)	0.9
Outfalls	WSMS136 (12)	1.9
Channels	WSMS102 (3)	0.4
Dams	WSMS108 WSMS136 (2)	0.4
Manholes	WSMS120 (3)	0.2
Pipes	WSMS120 (1)	0.1
Outfalls >3 ft diameter	WSMS102 WSMS104 WSMS120 WSMS124 WSMS126 WSMS134 (1)	0.4
Outfall Area	WSMS136 (19.24 ft^2)	3.0 ft^2
Mean Outfall Area	WSMS102 (5.11)*	---
Single Outfall	WSMS120 (9 ft^2)	---
Segment Length	WSMS136 (7570 ft)	2394 ft
Culvert Length	WSMS124 (100 ft)	20.9 ft
Percent Culverted	WSMS124 (6 %)	---
Total Channel Length	WSMS136 (3590 ft)	248.9 ft
Percent Channelized	WSMS136 (16 %)	---

*** Excludes WSMS126 which has 1 outfall 3 ft diameter**

3.4.3.2 UNIFIED STREAM ASSESSMENT

The following table has been presented as a means of quickly assessing the performance of individual reaches within the Lower Wissahickon main stem USAM assessment. The reaches presented correspond to the extreme values among the dataset; however by comparing these values to the mean value for each respective metric, it is possible to quickly gauge the variability of conditions within the main stem of the Lower Wissahickon watershed.

Table 3-112: Summary of Main Stem USAM Results by Reach

Overall Stream Condition							
Parameter	**Instream Habitat**	**Vegetative Protection**		**Bank Erosion**		**Floodplain Connection**	**OSC Score**
		Left	**Right**	**Left**	**Right**		
MIN	WSMS120 (5)	WSMS102 WSMS108 WSMS110 WSMS120 WSMS128 (5)	WSMS106 WSMS112 WSMS116 (4)	WSMS102 WSMS106 WSMS128 (5)	WSMS112 (4)	WSMS130 (1)	WSMS120 (31)
MAX	WSMS114 WSMS122 WSMS126 WSMS128 WSMS134 (19)	WSMS126 (9)	WSMS104 WSMS132 (8)	WSMS112 WSMS126 WSMS130 WSMS132 WSMS134 (9)	WSMS124 WSMS126 WSMS132 (9)	WSMS112 (12)	WSMS126 (58)
MEAN	15.9	6.6	6.1	7.3	7.2	5.1	48.2

Overall Buffer Floodplain Condition						
Parameter	**Vegetated Buffer Width**		**Floodplain Vegetation**	**Floodplain Habitat**	**Floodplain Encroachment**	**OBF Score**
	Left	**Right**				
MIN	WSMS136 (2)	WSMS116 (7)	WSMS116 WSMS120 (13)	WSMS108 WSMS120 WSMS122 WSMS130-134 (4)	WSMS136 (3)	WSMS136 (33)
MAX	WSMS102-114 WSMS122-126 WSMS130-132 (10)	WSMS104-108 WSMS126 (10)	WSMS104 WSMS124 WSMS126 WSMS130 WSMS132 (17)	WSMS102 WSMS112 (8)	WSMS130 (19)	WSMS126 (62)
MEAN	9.2	9.1	15.6	5.4	14.6	53.9

3.5 RECOMMENDATIONS

Stream restoration is a general term that may be used to describe a broad spectrum of activities undertaken to correct problems affecting streams or improve stream habitat, structure and function. However, stream restoration and streambank reinforcement activities that do not take into account the stream's current morphological state and the tendency of streams to adjust to new hydrologic conditions may not be successful, and in some cases may be counterproductive. In order to be successful, stream restoration activities should:

1.) work with the stream's tendency to establish a dynamic equilibrium between land and water
2.) take into account new hydrologic conditions that accompany changes in land use, and
3.) seek establishment of a natural stream dimension, pattern, and profile. Stream corridors represent a micro-ecosystem within a watershed, consisting not only of the channel, but also of the adjacent floodplain and a transitional area where the floodplain ends and merges into an upland area. Stream restoration, therefore is the restoration of multiple micro-habitats that are a part of a larger watershed.

A comprehensive approach to watershed management and restoration is essential and should be planned and prioritized according to representative watershed indicators and identified issues. All information should be organized, maintained and be made easily accessible to residents. Components of an ideal watershed master plan should include information organized on a watershed basis for existing channel condition, impervious cover, sewer and storm drain infrastructure, drainage network, stormwater outfalls, stormwater problem locations, industrial sites, open space, and natural areas. The assessment of the Valley Green Run Watershed has provided some of these essential elements that can be used independently or built upon to identify and prioritize watershed indicators and issues. All strategies should complement existing regulations, management strategies, and community efforts.

Restoration strategies that would alleviate or minimize identified direct and future cumulative impacts to the Valley Green Run watershed are discussed in the following section. These strategies have been divided into three categories:

- ✓ Restoration Strategy Category I: Channel Stability & Infrastructure
- ✓ Restoration Strategy Category II: Habitat
- ✓ Restoration Strategy Category III: Land management.

3.5.1 RESTORATION STRATEGY CATEGORY I: CHANNEL STABILITY & INFRASTRUCTURE

3.5.1.1 BANK STABILIZATION

Many parameters that were evaluated throughout the Lower Wissahickon watershed may be applied as metrics to gauge the applicability of bank stabilization techniques for a given reach. Bank stabilization measures can vary, based on the severity of the erosion and whether it is localized or continues for some distance along a bank, from small plantings to the installation of boulder walls. Bank stabilization measures may consist of boulder bank and/or boulder "toe of slope" reinforcement in areas where the greatest erosive potential exists. Boulder structures may also be used in smaller channels when the stream is eroding and over-widening to the point where property is, or is expected, to be lost. Other more natural bank stabilization methods such as bioengineering, root wads, plantings and log and woody structures should be used in areas where the bankfull channel has not been severely overwidened and significant additional channel changes are not expected. These methods are best suited to small, local areas of bank erosion scattered throughout the smaller tributaries where discharges are the lowest. Bank stabilization can reduce erosion, sediment supply, tree fall, channel widening and migration.

3.5.1.2 BED STABILIZATION

Bed stabilization is recommended for those reaches that are currently degrading through incising or downcutting. Bed stabilization measures such as rock/log vanes with grade control, rock/log cross vanes, and using naturally occurring boulders and bedrock are examples of methods that could be used to stabilize channel beds. Rock/log vanes differ from cross vanes because they do not extend the entire width of the channel. However, both structures provide grade control while diverting flow away from the channel banks. Bed stabilization should be used to eliminate headcuts or knickpoints. Advantages of bed stabilization consist of bank protection through diverting flow and elimination of migrating bed scour through providing grade control. Bed stabilization techniques can also aid in re-establishing natural pool-riffle-run sequences that are often lacking in degraded reaches.

In general, bank and bed stabilization restoration potential should be evaluated together such that the maximum amount of stream improvement value may be obtained for the funds allotted for a particular project. This is also important because of the implicit relationship that one has with the other. For example, spacing and alignment of bed stabilization structures must also be coordinated with bank stabilization features so that the restoration design features complement one another and work with the stream's natural meander pattern rather than against it. It is also often necessary to secure stream-crossing structures such as rock and log vanes by trenching them into the streambanks.

3.5.1.3 REALIGNMENT & RELOCATION

Stream channel realignment and relocation are the most severe restoration measures involving the greatest amount of channel changes. These methods should be employed when it is more advantageous to realign the channel than it is to stabilize degrading, out-of-pattern sections. Channel realignment and relocation are commonly implemented for shorter portions of a channel rather than for extensive lengths of channel due to construction and maintenance costs, and the amount of disturbance that occurs to existing natural habitat. Stream channel realignment and relocation is best suited to consecutive severely degraded reaches where existing land uses are threatened.

3.5.1.4 INFRASTRUCTURE IMPACTS

Large structures or facilities within stream channels can interrupt natural flow patterns and alter the hydrology and hydraulics of the creek in which they are present. Anthropogenic alterations to the natural balance or progression towards the natural balance between land and water generally have adverse impacts on the channel. For example, some features, such as dams, can disrupt the natural movement of sediment and block upstream migration of stream biota. Other infrastructure features, such as stormwater outfalls or culverts, can create local erosion by causing stormwater shear forces to be directed at a small area or creating high velocity scour at constrictions. These local disturbances often serve as "knickpoints", from which additional destabilizing erosion, scour, and sediment transport problems may propagate.

3.5.1.4.1 STORMWATER OUTFALLS

126 outfalls greater than 12" in diameter were found in the Lower Wissahickon watershed. 28 of these outfalls were greater than three feet in diameter. Due to their size and density within the watershed and the degree to which they may cause local erosion, stormwater outfalls are considered one of the most important considerations in assessing stream reach stability. Outfalls often drain large areas of impervious surfaces and efficiently deliver large volumes of water to small streams. Streambank erosion and bed erosion (scour pools) were often observed at these outfalls, and in some cases, this local erosion served as a knickpoint, causing headcutting in an upstream direction. Because outfalls may be positioned to direct flow at banks from a disadvantageous angle, it may be necessary to armor the opposite bank or install energy dissipating structures where the outfall meets the stream. The presence of a large outfall or outfalls may also constrain the final pattern and profile of a stream restoration design.

3.5.1.4.2 CULVERTS

Culverts may have many of the same destabilizing influences as dams and stormwater outfalls and must also be considered in stream restoration design. In some cases, a large culvert may serve as a stable starting or end point for a stream restoration project, with the remainder of the restoration designed to mitigate the destabilization and sediment transport issues at the site.

3.5.1.4.3 DAM AND POND IMPACTS

There were 32 dams present within the Lower Wissahickon Watershed that provide little or no positive value to the hydraulic regime of the stream. Observations made during the various field investigations and infrastructure assessment suggested that most dams accrued large amounts of fine sediments upstream, and that reaches downstream of these structures are likely to have undergone a greater amount of channel degradation than those channels not influenced by dams. There are also a small number of ponds located in Lower Wissahickon watershed most of which are associated with golf courses, large estates and developments. Ponds often develop serious management problems, and are associated with algal blooms, overheating of impounded water and an overabundance of resident Canadian geese.

Despite these facts, their installation may also have created some beneficial habitat. Additional consideration must be given to the fact that any beneficial habitat may now rely on the existence of these dams, in which case removing dams to create a more natural channel may outweigh the benefits that resulted from its installation. Overall, dam and pond removal have been presented as possible channel stability restoration measures. It should be noted that careful evaluation of all environmental costs and benefits, specifically habitat and any potential historical significance associated with each structure must be taken into consideration.

3.5.1.4.4 REMEDIATION OF INFRASTRUCTURE IN POOR CONDITION

Products of the infrastructure assessment conducted during this study were observations and locations of infrastructure in poor condition. This classification was attributed to those dams, bridges and outfalls that exhibited the characteristics of being broken, exposed, or the potential of such issues based upon their proximity to the stream and ongoing bank erosion. Reach by reach summaries, statistics, and location maps of all points of infrastructure are documented in detail in Appendix D.

3.5.2 RESTORATION STRATEGY CATEGORY II: HABITAT

3.5.2.1 RIPARIAN BUFFER EXPANSION/IMPROVEMENT

Riparian buffer expansion and improvement can act as strategies which can significantly improve the habitat characteristics of the associated stream reaches. Several parameters were qualitatively and quantitatively evaluated along each reach which can be utilized in the prioritization of stream sections with respect to this strategy. Although priority reforestation areas consist of floodplains, steep slopes, and wetlands, smaller areas such as public right-of-ways, parks, schools, and neighborhoods also provide reforestation opportunities. Benefits of reforestation are numerous. Cooler temperatures, stream shading, rainfall interception, reduced runoff, reduced sediment load, reduced discharge velocities, increased groundwater recharge, increased species diversity and habitat, and improved air quality and aesthetics are all positive effects associated with a healthy riparian buffer.

3.5.2.2 INVASIVE SPECIES MANAGEMENT

Maintaining a healthy riparian plant community within the Lower Wissahickon Basin will retain biodiversity and support a healthy stream ecosystem. Invasive species provide little value to native animals that depend on native species for habitat and/or food. Because of this threat to the biodiversity of native communities, an invasive species management plan would assist natural succession within the riparian buffer through decreasing possible further impacts of invasive species. An invasive species management plan will require, at a minimum, a three-year commitment to ensure success. Planting plans for all restoration efforts should compliment the invasive species management plan by recommending appropriate native planting to supplement areas where invasive species have been eliminated. Although invasive species management priority areas are considered those that contain 80% or greater invasive species, invasive species management should also be implemented for all preliminary recommended channel restoration sites.

3.5.2.3 WETLAND CREATION

Land currently available for reforestation located adjacent to the channel is also ideal for wetland creation. Wetland creation adjacent to the channel is best suited to those areas where stream relocation and realignment are suitable. Because stream relocation and realignment typically involve large quantities of grading, replanting the disturbed areas can be customized to create specific habitats. Wetlands, a rich habitat that relies on saturated soils and vegetation adapted to these conditions could be created concurrently with channel relocation and realignment. Therefore, the best opportunities for wetland creation may be adjacent to those channels that are also suitable relocation /realignment sites.

Further investigation of all potential restoration and realignment sites should include the following: rainfall data collection and evaluation, runoff calculations, soils investigation, water budget, native species investigation, and groundwater monitoring. Ideally, groundwater levels for all potential wetland creation sites should be monitored to determine their suitability prior to design. Advantages of wetland creation are groundwater recharge, increased habitat, increased plant and animal species diversity, and improved water quality.

3.5.2.4 PRESERVATION OF EXISTING FORESTED AREAS

Existing forests are valuable habitat and should be protected. All of these areas throughout the watershed should be protected and managed, if necessary, to preserve the forested riparian buffer present surrounding all creeks within the watershed. Educational/informational signage, creating small parks or designated green space, and installing fences or prohibiting access in areas where the riparian area has been disturbed are additional strategies to help preserve existing forests.

3.5.3 RESTORATION STRATEGY CATEGORY III: LAND MANAGEMENT

3.5.3.1 REDUCE DIRECTLY CONNECTED IMPERVIOUS SURFACES

Stream channels within each watershed have responded to high density development and increased runoff through downcutting and over-widening in an attempt to accommodate higher flows. In addition to preserving land available for reforestation or to protect from becoming developed, the amount of existing impervious surfaces should be reduced. Examples of strategies to reduce the amount of existing impervious surfaces and/or decrease the severity of runoff include:

- ✓ Stormwater management basins – both wet/dry ponds have the ability to collect storm flow, hold water temporarily and release water to a stream at a constant rate. Disadvantages of basins are finding the available land to build them and the associated maintenance over many years. In areas where additional development is still possible, or re-development may occur, stormwater management ponds are a suitable method to reduce runoff. Planned species selection for vegetating the pond perimeter, banks, and edges may also help reduce nutrients delivered to streams. Similarly, in areas where adequate space is not available, grass swales can be used to increase infiltration while decreasing the velocity of runoff prior to delivering it to the creeks.

- ✓ Bioretention – bioretention facilities are similar to stormwater management ponds in their function, but differ since they are much better suited for small areas. Bioretention facilities can be installed next to parking lots, curbs, major roads, etc. to immediately catch runoff, filter sediment and allow rainwater to infiltrate back into the groundwater table.

- ✓ Parking Lot Island Installation and Plantings – parking lot islands can be installed and planted within large paved areas to create less contiguous impervious surfaces. Islands can be depressed to catch stormwater and planted to provide water quality benefits, shade and aesthetic value. Often, planted parking lot islands can serve dual purposes and provide water quality benefits if they are also bioretention facilities. At a minimum, efforts should aim to steady the existing percent impervious surfaces associated with parking lots. When and if the opportunity arises, unnecessarily paved and oversized parking lots could be converted to have smaller spaces and contain islands to create less contiguous paved surfaces. Parking lots and other paved right-of-ways should also be evaluated when adding or relocating utilities. To fully utilize existing paved surfaces instead of creating new impervious surfaces utilities could be located underneath existing pavement.

3.5.3.2 APPROPRIATE ROAD AND CULVERT MAINTENANCE

Often inappropriately sized culverts or poorly stabilized roads will impact a channel through eroding the bed and banks. Bed scour may cause a headcut or knickpoint that is capable of migrating upstream. A headcut or knickpoint will continue to scour the bed and deepen the channel as it moves upstream until it is inhibited by a natural bed formation or man-made structure resistant to erosion. Although the headcut or knickpoint may have stopped migrating, it is still present in the channel and if channel conditions change may begin to migrate again.

3.5.3.3 PUBLIC EDUCATION

Because watersheds are so diverse in their land use and ownership, a public educated in the ways and means of being a good steward to their watershed is perhaps one the best ways of addressing its restoration. Disturbances such as footbridges, landscaping, and mowing adjacent to the channel will continue so long as public education and awareness are not increased. Public education provides opportunities to relate the importance of stream habitat and stability and to influence and/or change the behavior of residents.

Public education begins with public involvement. One principal avenue for educating residents is through forming local watershed groups. Local watershed groups are most effective when strong, mutually beneficial relationships are established early between the volunteers and local government agencies. Planning agencies and volunteers could then communicate and work together to educate neighbors through activities such as stream clean-ups, re-vegetating stream banks, long-term monitoring, and publishing articles in the local newspaper(s), among many others. Additional opportunities for the community to participate in all aspects of the planning/development phase increases not only public education, but also recreation and habitat enhancement opportunities.

In November of 2005, the Wissahickon Watershed Partnership was formed, consisting of a consortium of proactive environmental groups, community groups, government agencies, businesses, residents and other watershed stakeholders interested in improving their watershed. The goals of the partnership initiative are to protect, enhance, and restore the beneficial uses of the waterways and riparian areas. The partnership seeks to achieve greater levels of environmental improvement by sharing information and resources.

More information about the Wissahickon Watershed Partnership can be found on the Philadelphia Water Department's website (http://www.phillyriverinfo.org/).

3.6 Completed and Proposed Projects

3.6.1 Cathedral Run

3.6.1.1 Completed Projects

In April of 2006, emergency repair work was completed 60 feet upstream of Forbidden Drive to protect a gas line crossing that was in danger of being exposed. Repairs consisted of the installation of a grouted native stone protection upstream and downstream of the pipe crossing as well as a grouted native stone weir downstream of the pipe crossing.

3.6.1.2 Proposed Projects

In the fall of 2010 PWD will begin construction of a stormwater wetland, designed by AKRF Inc., at the headwaters of Cathedral Run which is located near the intersection of Cathedral Road and Glenn Campbell Road. The wetland will be constructed within a forested depression currently owned by Fairmount Park. It will divert the majority of the flow from WSout760 (W-076-01), which currently discharges flow from a 48 inch storm sewer into Cathedral Run. The benefits will include reduced bank erosion and fine sediment deposition in the Cathedral Run stream channel as well as improved water quality.

3.6.2 Valley Green Run

3.6.2.1 Completed Projects

In 2008, stream bank and channel bed stabilization and were completed by Skelly and Loy. The project reach was a 350 foot stretch along Fairmount Park's Parking Area 9, which is adjacent to Valley Green Run. Upstream of the project reach Valley Green Run was culverted for 643 feet (WScul104), which contributed to bed scour and bank erosion in the project reach. Another contributing factor was the storm flow from WSout523 (W-076-10) which discharges storm flow from a 30 inch storm sewer. The stabilization work consisted of boulder revetments on the DSL adjacent to the parking lot, boulder stream bed armoring and boulder toe protection on the DSR bank.

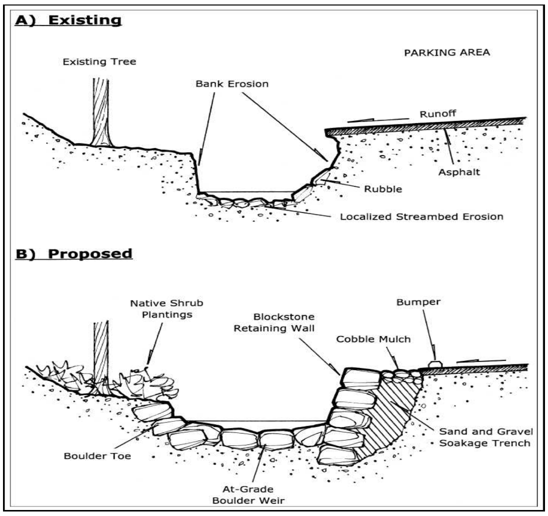


Figure 3-100: Bank erosion caused by parking lot runoff (left); schematic of restored condition (right).

Source: Skelly & Loy

3.6.3 GORGAS RUN

3.6.3.1 COMPLETED PROJECTS

In June of 2009 the Pennsylvania Department of Transportation (PENNDOT) repaired two gullies that formed beneath the Henry Avenue Bridge (WSbri246). The stormwater scuppers that drained the bridge were causing severe erosion due to the high potential energy created by the height differential between the scupper outlets and the hill slope beneath the bridge. Overland flow down the hill slope had also threatened the structural integrity of the FPC trial system abutting Gorgas Run. The two large gullies were stabilized with boulder step-pool structures and the "splash pads" beneath the scupper outlets were lined with geotextile fabric and armored with ballast stone. To further reduce the energy of stormflows, a trench and berm system was constructed to allow stormwater to be impounded before flowing into one of the two existing gullies.

3.6.3.2 CURRENT PROJECTS

PWD has contracted the design and engineering services of AKRF Inc. in order to complete a natural stream channel design and restoration framework for Gorgas Run. The primary objectives include infrastructure protection (both PWD and FPC infrastructure), bank stabilization, increased floodplain connection and improved ecological integrity. As with many of the small Lower Wissahickon tributaries, Gorgas Run has been severely impacted by stormwater. Preliminary concepts to mitigate the impacts of stormwater have considered the construction of a stormwater wetland and creation of an open channel system upstream of WSout566 (W-067-01).

3.6.4 BELL'S MILL RUN

3.6.4.1 CURRENT PROJECTS

PWD has contracted the design and engineering services of GTS Inc. to provide natural stream channel design concepts for the extent of Bell's Mill Run. Key project objectives and design elements address infrastructure protection (e.g. manholes and stormwater outfalls), bank erosion and channel incision. Elements of the design include potential channel realignment and outfall naturalization, both of which will be beneficial to the overall ecological and aesthetic integrity of Bell's Mill Run.

3.6.5 HARTWELL RUN

3.6.5.1 COMPLETED PROJECTS

In October of 2009 emergency repairs were completed on Hartwell Run at the stream crossing of the Wissahickon High Level Interceptor (WScul116). The concrete masonry encased pipe had succumbed to severe erosion which had exposed the interceptor. Frequent blockage of the three foot conveyance orifice by boulders, woody debris and fine sediment cause stream flow to overtop the culvert, which where blocked functioned as a dam. The combination of reduced flood flow conveyance, the steep slope of Hartwell Run cause severe bank erosion and plunge pool formation downstream of WScul116, as well as undermined a portion of the concrete-encase sanitary crossing (Figure 3-101).

The team of Skelly & Loy Environmental Consultants, WRT and Gebhart Construction Inc. completed repairs to the concrete encasement and stabilized the banks upstream and downstream of WScul116. Upstream of the structure, a step-terrace system was installed to reduce the energy of flood flows, which will alleviate the high shear stress in and around the conveyance orifice (Figure 3-101).

Figure 3-101: Upstream view of WScul116 pre-construction (left); Downstream view of WScul116 post-construction (right).

3.6.6 WISE'S MILL RUN

3.6.6.1 COMPLETED PROJECTS

In 2005 PWD's Waterways Restoration Team (WRT), following the natural stream channel design concepts of Skelly & Loy, constructed a boulder step-pool system on the lower reaches of Wise's Mill Run. The entire channel had experienced significant erosion and sediment deposition following two severe tropical storms in 2004. FPC stone masons also repaired a stone low-head dam which was damaged as a result of the storms. The boulder weir and step-pool system (Figure 3-102) dissipates much of the shear stress and concomitant erosion during high flows on the very steep stream thus dramatically increasing the stability of the downstream reaches of Wise's Mill Run.

Figure 3-102: View of boulder step-pool system looking upstream (left): scour pool at the base of the step-pool system (right).

3.6.6.2 CURRENT PROJECTS

AKRF Inc. is in the process of designing a stormwater wetland at the headwaters of the southern branch of reach WSWM06. The stormwater management facility would intercept flow from WSout572 (W-0776-13) which discharges flow from a 48 inch storm sewer draining 92 acres of residential development.

AKRF Inc. is also designing natural stream channel design concepts for five reaches on Wise's Mill Run. Three are located in reach WSWM02, one in WSWM04 and another on WSWM06. Restoration objectives include outfall modification (to dissipate energy), floodplain reconnection and regarding, riparian buffer enhancement bank stabilization and habitat enhancement (large woody debris jams).

3.6.7 KITCHEN'S LANE

3.6.7.1 COMPLETED PROJECTS

In the upstream-most reach of Kitchen's Lane (WSKL02), emergency repair work was completed in 2009 in a section of Fairmount Park known as Carpenter's Woods. Two outfalls, WSout513 and WSout514 (W-068-02), were severely undermined due to high velocity stormwater flows from Green Street. The erosion was so severe that the aprons for these outfalls were suspended up to five feet from their respective conveyance channels. Terraced boulder infiltration swales were installed to compensate for the vertical drop as well as reduce the energy of future storm flows. Cobble and boulder armoring was installed within the conveyance channels to reduce erosion and stabilize the banks of the conveyance channels. The emergency repair work was supplemented with shrub and tree plantings to further stabilize the site.

Figure 3-103: WSout513 conveyance channel during (left) and after (right) construction

Further downstream, gully repairs were completed by Friends of Wissahickon (FOW) in 2010. FOW Site 3 (Appendix E) was a gully that formed adjacent to a FPC trail on the steep eastern valley wall of Kitchen's Lane Run. FOW Site 4 (Appendix E) was a gully that formed along a "bench" on the western valley wall where it ultimately intersected and undermined a FPC trail at the downstream extent of the gully. The majority of the gully repair work has been completed at FOW Site 4 however the section in the immediate vicinity of the trail will be completed at a later date.

3.6.8 Monoshone Creek

3.6.8.1 Completed Projects

In the fall of 2005, PWD completed the construction of the City's first stormwater treatment wetland. The one acre wetland is designed to treat 70 million gallons of stormwater before an outlet structure discharges flow to Monoshone Creek. Besides water quality improvements, secondary benefits of the wetland include a reduction in high energy flows discharging to Monoshone Creek as well as the provision of habitat for a diverse assemblage of fish, amphibians, macroinvertebrates and birds.

In 2009, the Saylor Grove treatment wetland was dredged for the first time as part of the post-construction maintenance program. The wetland dredging had two main objectives- to expand the capacity of the wetland to store and treat stormwater and to redefine the wetland's low flow channels. Results of the post-dredging sediment composition analysis revealed that the vast majority of sediment removed consisted of sand (0.075mm – 4.75mm) and silt (0.005mm – 0.075mm). These results had implied that the wetland is in fact removing a large part of the suspended sediment load delivered from the Monoshone Creek watershed. If not for the wetland, the fine sediment component of stormwater would enter Monoshone Creek where it would have adverse implications for water quality (e.g. turbidity and total suspended sediment (TSS)) as well as instream habitat (e.g. stream bed embeddedness).

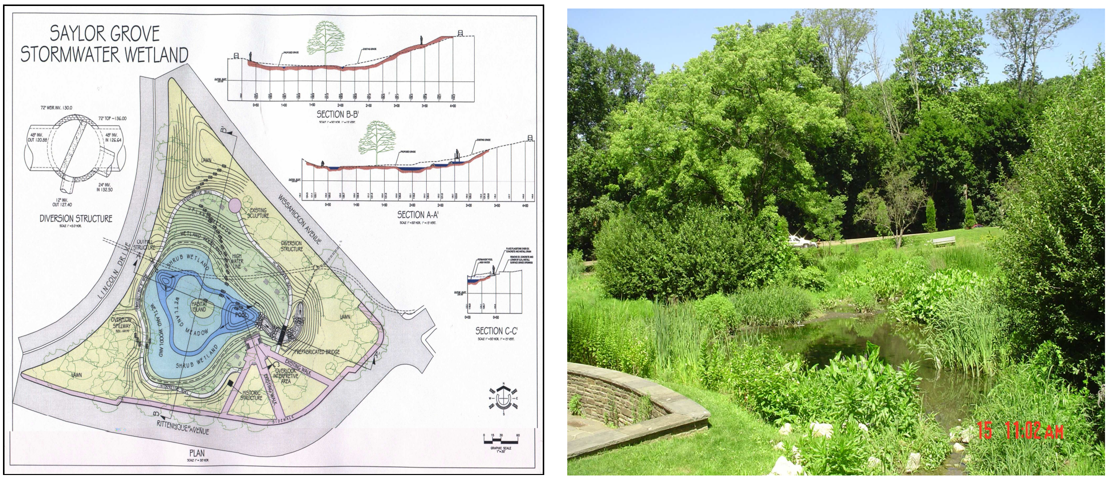


Figure 3-104: Plan view rendering of Saylor Grove Stormwater Wetland (left); fully vegetated view of Saylor Grove (right).

3.6.9 Wissahickon Main stem

3.6.9.1 Completed Projects

Directly across from the confluence of Rex Avenue Run and the main stem of Wissahickon Creek (WSconf161) on the DSR bank of the Lower Wissahickon reach WSMS110, a large 30 inch water main collapsed in December of 2008. Following immediate emergency repairs by PWD which required extensive excavation, the DSR bank was severely destabilized (Figure 3-105) and threatened to both undermine a stacked masonry wall which ran parallel to the bank as well as deliver excessive sediment loads to the downstream segments of the main stem Wissahickon via erosion.

In March of 2009 PWD contracted the environmental engineering services of Skelly and Loy, who designed and constructed 175 feet of staggered boulder bank stabilization. In addition, two log vanes and a log deflector were installed at the "toe" of the DSR bank (Figure 3-105). These features provide key instream habitat to fish and macroinvertebrates. Instream boulder clusters and log structures create "velocity shelters" as well as backwater areas which serve as vital habitat for fish, especially during high flows. The naturalized, staggered bank stabilization structure will be further stabilized as the live dogwood and willow stakes planted by PWD's Waterways Restoration Team, begin to fully mature.

Figure 3-105: DSR bank in reach WSMS110 following emergency repairs (left); DSR bank following bank stabilization and instream flow structure installation (right).

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