Tookany/Tacony-Frankford Creek Watershed Fluvial Geomorphologic Survey

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1 INTRODUCTION

1.1 PROJECT PURPOSE

The purpose of the Tookany/Tacony-Frankford Creek Watershed Fluvial Geomorphologic Survey report is to provide the City of Philadelphia Water Department documentation of the existing conditions within the watershed. Rosgen methodologies were used to measure channel geometry and stability parameters to determine stream classification. A comprehensive habitat survey and an infrastructure assessment were also completed for the watershed. Together, the measured geomorphologic channel survey, habitat survey, and infrastructure investigation will provide the City of Philadelphia the following:

- ✓ a baseline for evaluating effects of urbanization,
- ✓ a land use and/or planning tool,
- ✓ a rating method specific to the Tookany/Tacony-Frankford Creek Watershed,
- ✓ potential stream and habitat restoration sites, and
- ✓ appropriate potential restoration strategies.

1.2 PROJECT DESCRIPTION

The Tookany/Tacony-Frankford Creek Fluvial Geomorphologic Survey consisted of an assessment of approximately 27 miles of stream channel within the 33 square mile Watershed by members of the Philadelphia Water Department's Office of Watersheds (PWDOOW) in 2004. The assessment involved walking the entire length of the Tookany/Tacony-Frankford Creek, and 14 of its tributaries including creeks such as Baeder, Burholme, Jenkintown, Mill Run, and Rock to record specific information about the channel, surrounding habitat, and infrastructure located in or near the creeks. 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 impact the waterway. Both the measured and qualitative data were evaluated for correlations between the natural and urbanized environment.

1.3 PROJECT LOCATION

The Tookany/Tacony-Frankford Creek Watershed is located approximately half within the City of Philadelphia and half within Montgomery County (**Figure 1**). The portion within Montgomery County is further subdivided within four townships – Cheltenham (majority), Jenkintown, Abington, and Rockledge. The mainstem is approximately 14.5 miles in length – about 6.2 miles within the City (Tacony-Frankford Creek) and 8.3 miles in Montgomery County (Tookany Creek). All the tributaries included in this study are located in Montgomery County and vary in lengths from 0.3 miles (Creek D) to 2.6 miles (Jenkintown Creek). The Tookany/Tacony-Frankford Creek Watershed is to the East/Southeast of the

Wissahickon Watershed, to the Northeast of the Schuylkill Direct Watershed, and the West of the Pennypack Watershed.

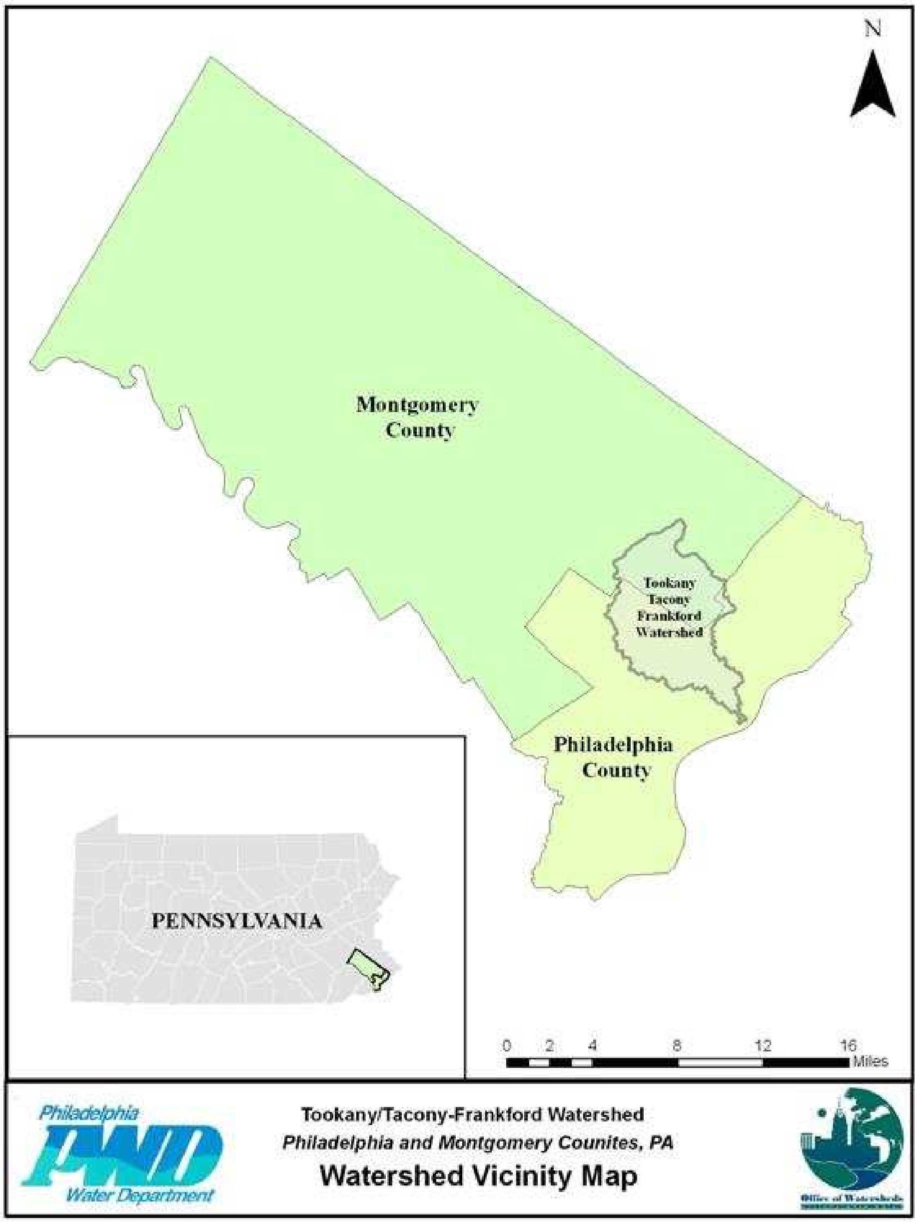


Figure 1- Location of Tookany/Tacony-Frankford Creek Watershed

2 MATERIALS AND METHODS

2.1 REACH DELINEATION AND CODING

Stream reach breaks were determined according to significant changes in channel geometry and/or surrounding natural environmental features. The degree of channel alteration was most often used to break reaches and consisted of the presence of utility crossings, outfalls, and road, railroad, and/or mass transit crossings. Changes in channel geometry were also used to break reaches and consisted of a change in stream channel classification, bank condition, and/or bed materials. Natural environmental features such as changes in riparian composition and riparian width, that generally corresponded to changes in land use, were also used to break reaches. Reaches generally did not exceed 2000 feet in length.

Reaches were named by a one or two letter code used to represent the name of the stream (**Table 1 and Figure 2**) followed by a one, two, or three digit number. The numbers assigned generally increased by two from upstream to downstream. For example, reaches on Burholme Creek were named B2, B4, B6, B8, and B10 going from the headwaters of Burholme Creek to its confluence with the mainstem of the Tookany Creek. This numbering scheme allowed for additional cross sections to be added in-between existing reaches, if necessary. In total, 102 cross-sections were surveyed for this study.

Tributaries	
Creek	**Creek Code**
Unknown Tributary A to Tookany Creek	A
Burholme Creek	B
Unknown Tributary C to Jenkintown Creek	C
Unknown Tributary D to Jenkintown Creek	D
East Branch to Jenkintown Creek	EJ
Unknown Tributary G to Tookany Creek	G
Rock Creek	H
Baeder Creek	I
Jenkintown Creek	J
West Branch Baeder Creek	K
Unknown Tributary L to Tookany Creek	L
Unknown Tributary M to Rock Creek	M
Mill Run	MR
Tookany/Tacony-Frankford Creek (Main Stem)	MS
Unknown Tributary N to Tookany Creek	N

Table 1 - Assessed Creeks and Representative Codes

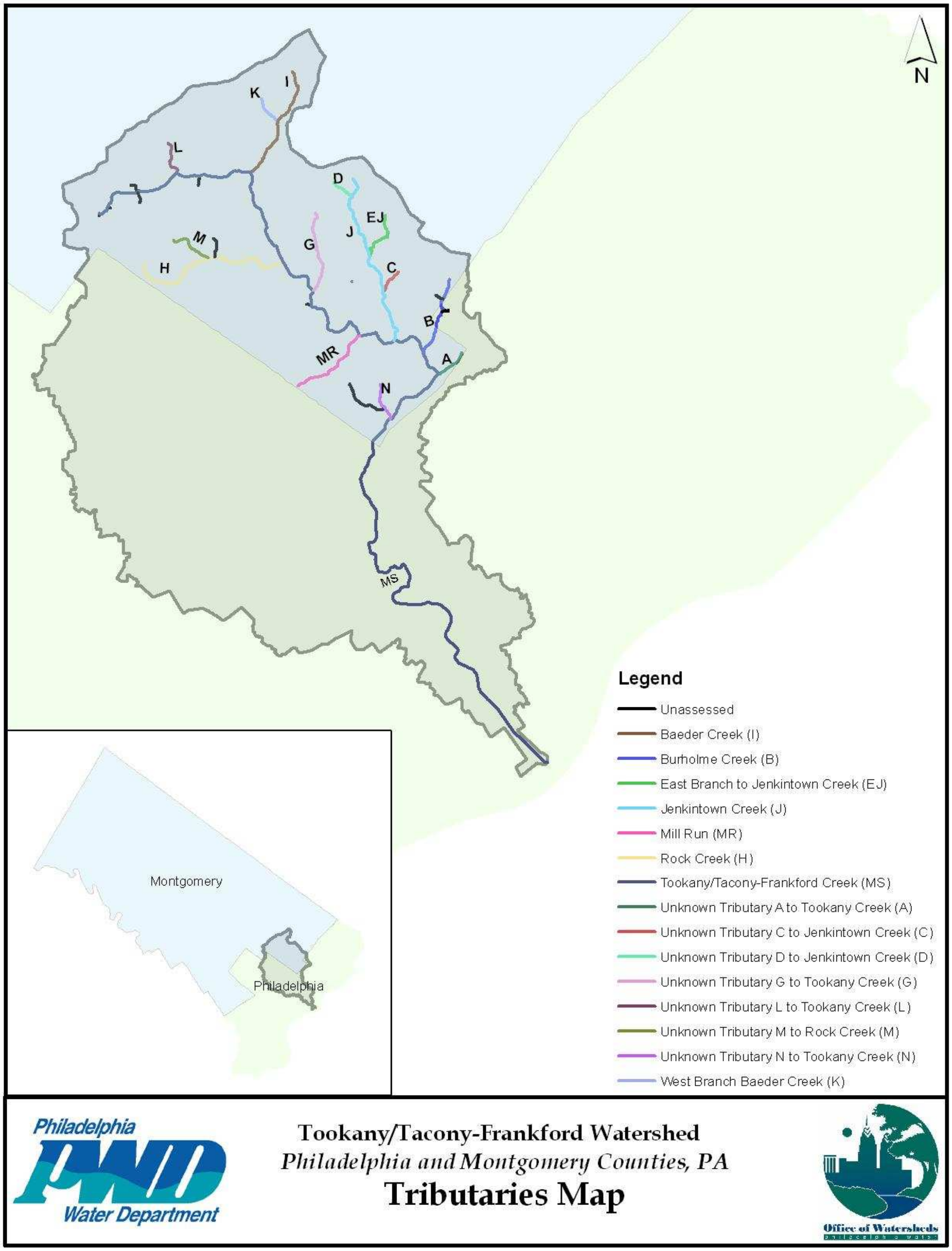


Figure 2- Tributaries of Tookany/Tacony-Frankford Watershed

The creeks and tributaries were combined in such a way to allow for subwatersheds to be analyzed in greater detail for the purposes of ranking and prioritization. This procedure created 7 subwatersheds, coded as BW, EJW, GW, HW, IW, JW, & MRW (**Table 2 and Figure 3**), all of which eventually contribute to the mainstem subwatershed which was subdivided into 9 individual sections (MS.1W – MS.9W).

Sub-watershed	Tributaries Contained (Creek Name)
Burholme Creek Sub-watershed (BW)	Burholme Creek (B)
East Branch Jenkintown Creek Sub-watershed (EJW)	East Branch to Jenkintown Creek (EJ)
Tributary G Sub-watershed (GW)	Unknown Tributary G to Tookany Creek (G)
Rock Creek Sub-watershed (HW)	Rock Creek (H), Unknown Tributary M to Rock Creek (M)
Baeder Creek Sub-watershed (IW)	Baeder Creek (I), West Branch Baeder Creek (K)
Jenkintown Creek Sub-watershed (JW)	Unknown Tributary C to Jenkintown Creek (C), Unknown Tributary D to Jenkintown Creek (D), Jenkintown Creek (J)
Mill Run Sub-watershed (MRW)	Mill Run (MR)
Mainstem Sub-watershed (MS.1W)	Tookany/Tacony-Frankford Creek (MS), Unknown Tributary L to Tookany Creek (L)
Mainstem Sub-watershed (MS.2W)	Tookany/Tacony-Frankford Creek (MS)
Mainstem. Sub-watershed (MS.3W)	Tookany/Tacony-Frankford Creek (MS)
Mainstem Sub-watershed (MS.4W)	Tookany/Tacony-Frankford Creek (MS)
Mainstem Sub-watershed (MS.5W)	Tookany/Tacony-Frankford Creek (MS)
Mainstem Sub-watershed (MS.6W)	Tookany/Tacony-Frankford Creek (MS), Unknown Tributary A to Tookany Creek (A)
Mainstem Sub-watershed (MS.7W)	Tookany/Tacony-Frankford Creek (MS), Unknown Tributary N to Tookany Creek (N)
Mainstem Sub-watershed (MS.8W)	Tookany/Tacony-Frankford Creek (MS)
Mainstem Sub-watershed (MS.9W)	Tookany/Tacony-Frankford Creek (MS)

Table 2- Defined Sub-watersheds

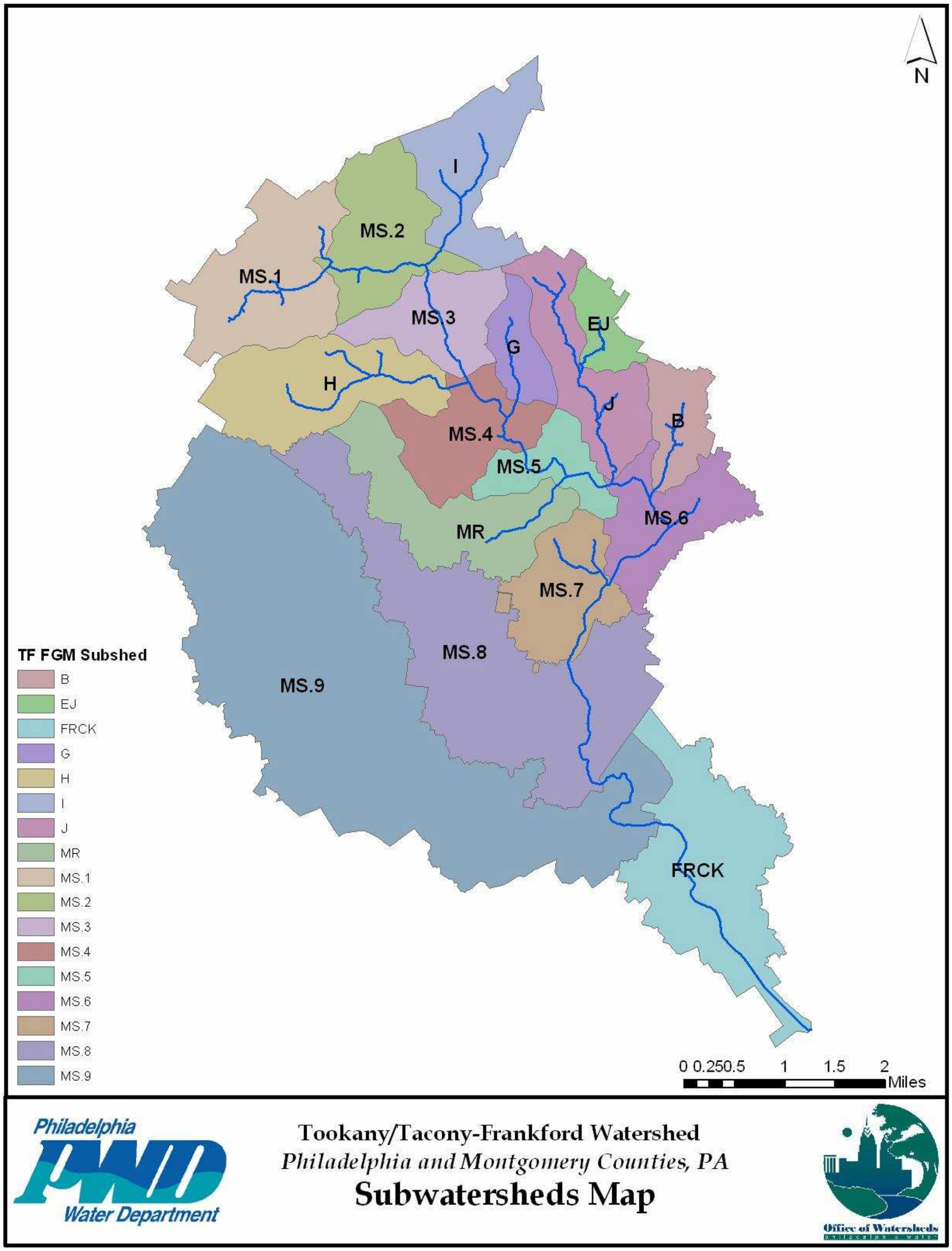


Figure 3- Tookany/Tacony-Frankford Watershed and Subwatersheds

2.2 CROSS SECTION SITE RATIONALES

Cross section locations were chosen according to multiple channel stability and geometry parameters that were representative of the entire reach. The appropriate location of cross sections 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 it satisfied the following criteria:

- ✓ Presence of bankfull indicators, or active floodplain,
- ✓ Representative of reach,
- ✓ No debris or obstructions such as rock, logs, outfalls, or in-stream structures, and
- ✓ No greater than 2000 feet from previous cross section.

Debris or obstructions such as rocks, logs, outfalls, or in-stream structures were avoided since they would influence bankfull indicators and yield a false bankfull width. In some cases, reaches were so strongly influenced, degraded and/or altered that there were no cross over 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, and
- ✓ No greater than 2000 feet from previous cross section.

Generally, reach lengths were no greater than 2000 feet long 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 the hydraulic and hydrologic model would be reliable. Frankford Creek has been artificially straightened and channelized from Castor Avenue to the confluence with the Delaware River and no cross sections were located in this channelized segment of the creek.

Cross section locations were monumented on the downstream right and downstream left sides with 2' long, and either 1/2" or 5/8" wide rebar that was installed flush with the ground, when possible. At some sites where substrate consisted of large rocks, or tree roots or concrete debris were encountered, rebar could not be installed flush with the ground. After making sure 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.

2.3 STREAM SURVEY

The stream survey consisted of Philadelphia Water Department field crews performing a field reconnaissance of the Tookany/Tacony-Frankford Creek Watershed. Approximately 27 miles of stream channel were surveyed on the mainstem of Tookany/Tacony-Frankford Creek, and the majority of its contributing tributaries. The field reconnaissance included walking the entire length of stream, choosing and marking cross section locations, and making general observations of the surrounding watershed. All initial field observations and cross section locations were noted on a large scale field maps. The field reconnaissance was completed during the months of December, 2003 and January, 2004.

2.4 MEASURED STREAM SURVEY AND CROSS SECTION PARAMETERS

Based on results of the stream survey/field reconnaissance and following additional planning and base map preparation, the measured reach portion of the stream survey was completed. The measured reach stream survey consisted of collecting data for various channel morphology, disturbance, stability, and habitat parameters. Specific channel and habitat parameters included the following:

Channel Morphology

- Stream Bed Materials
- Sinuosity
- Water Surface Slope
- Bankfull Width
- Bankfull Depth
- 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

Channel Habitat Characteristics

- Riparian Width
- Riparian Composition
- Canopy Cover
- Bed Materials
- Sediment Supply
- Sinuosity
- Woody Debris
- Attachment Sites

The measured reach stream survey also consisted of surveying channel cross sections at each location previously chosen during the field reconnaissance. 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).** Field data sheets were used to record all data collected in the field. **Appendix B** contains a summary of the results of the surveyed cross sections and local longitudinal profiles. Cross section locations are shown on **Figure 4** below:

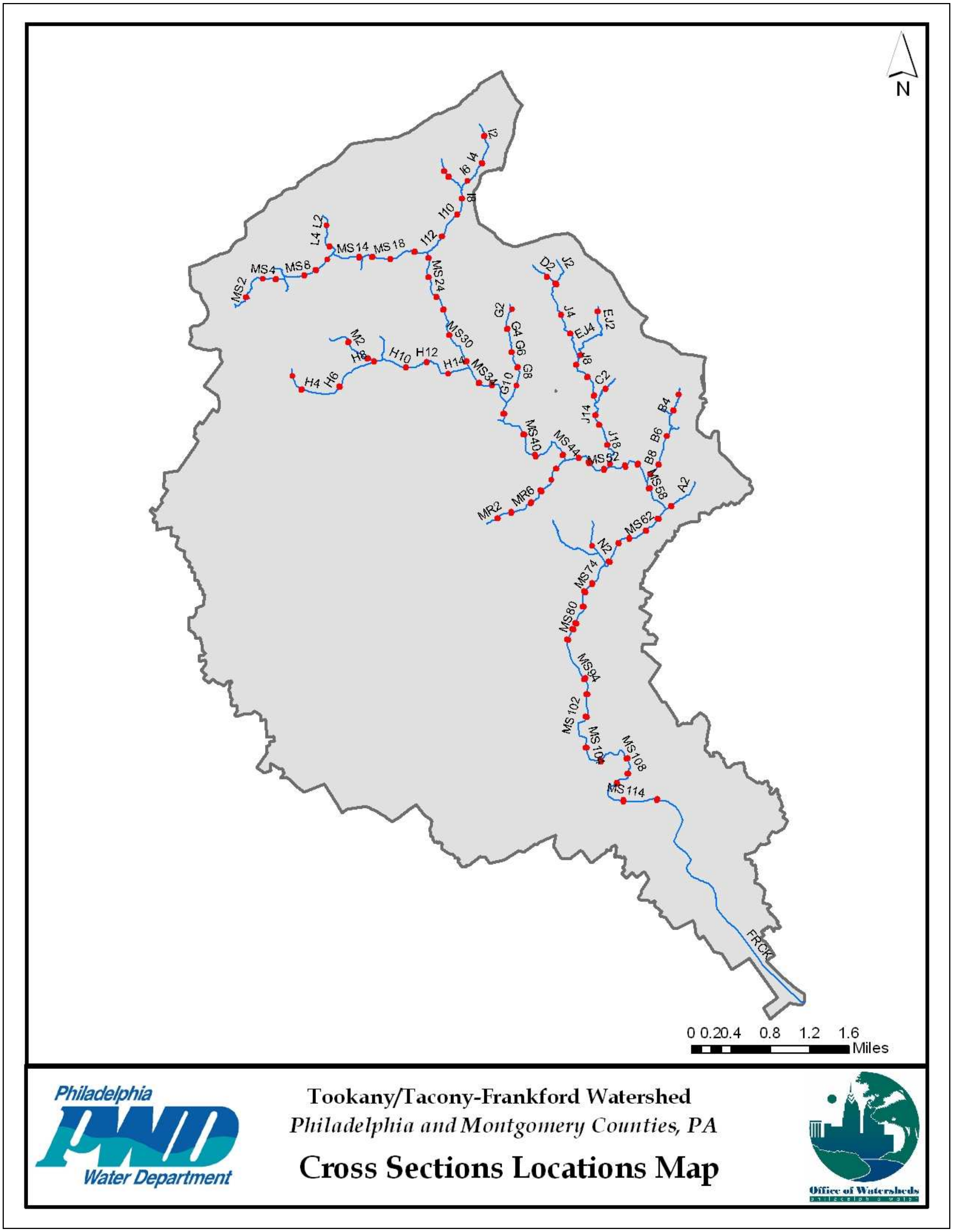


Figure 4 -Cross-Section Locations in Tookany/Tacony-Frankford Watershed

2.4.1 CROSS SECTION SURVEY PROCEDURES

Each stream cross section was measured by extending a 100 foot measuring tape across the channel. Where possible, measuring tapes were extended a minimum of twice the bankfull width for each cross section and sometimes extended the entire valley width due to the estimated floodprone 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/Depth
- Entrenchment ratio
- Shear Stress
- Velocity
- Water Surface/Channel slope
- Sinuosity
- Median particle size (D_{50})
- Bankfull Discharge

2.4.2 PROFILE SURVEY PROCEDURES

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. For example:

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

In instances where there was no cross section present either upstream or downstream from the reach of interest, the following procedure was utilized:

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

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. A 300 foot measuring tape was extended, upstream to downstream, in the channel thalweg. At a minimum, profiles began 100 feet upstream of the measured cross section and extended 100 feet downstream of the cross section. Therefore, profiles were a minimum of 200 feet long. 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 to calculate a local slope for each cross section that is shown on each cross section graph in **Appendix C**.

2.5 CALIBRATING BANKFULL ELEVATION & DISCHARGE

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. All preliminary bankfull discharge values were compared and evaluated based on merit and strength of correlations in order to determine the most appropriate discharge. The strongest correlations between discharges were generally considered the most reliable bankfull calibration. All preliminary bankfull discharges are presented and discussed within Section 4.1 Bankfull Calibration Results.

"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."
Dunne and Leopold (1978)

2.5.1 FIELD CROSS SECTIONS

In an ideal channel, the bankfull elevation is at the top of the bank and is the point where the stream begins to overflow into the floodplain. Bankfull flows have the ability to transport sediment, shape the channel and eventually change the planform of the channel. The recurrence interval of a bankfull event is between every 1 to 2 years. Because these events occur so frequently they form features in the channel that indicate the bankfull elevation. Bankfull indicators consist of tops of point bars, changes in vegetation, and changes in bank slope. Bankfull indicators are often more difficult to identify, or not present at all, in impacted or disturbed urban streams, but are still essential to determining a bankfull elevation and discharge.

PWD personnel identified bankfull elevations in the field at varied locations as part of the Tookany/Tacony-Frankford Creek Watershed FGM study. As a result of channel disequilibrium, bankfull indicators were not easily identified. Bankfull elevation at the individual cross-sections were derived from all available indications including depositional features, changes in bank angle, vegetation, scour lines and storm debris lines. Depositional features were the primary indicator used in the final determination of bankfull elevation. Bankfull discharge was estimated by solving the Manning 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 visual reconnaissance, best professional judgment and literature references Chow (1959), Barnes (1967) and Aldridge and Garrett (1973, Table 1).

2.5.2 REGRESSION EQUATIONS

A three part regression equation consisting of modeling results and regional curves was developed to aid in the calibration of the field identified bankfull discharges. The curve generated consisted of a combination of three separate regression equations all relating drainage area to bankfull discharge.

For drainage areas of less than 1.5 mi^2, the USEPA's Stormwater Management Model (SWMM) Runoff Block was used to determine peak discharges corresponding to return periods of 1-year, 1.5-year, and 2-year rainfall events. Using linear regression, the following relationship was developed:

Qbf = 301.5DA + 10.729

where Qbf is the bankfull discharge in cubic feet per second (cfs) and DA is the drainage area in square miles, as seen in **Figure 5**.

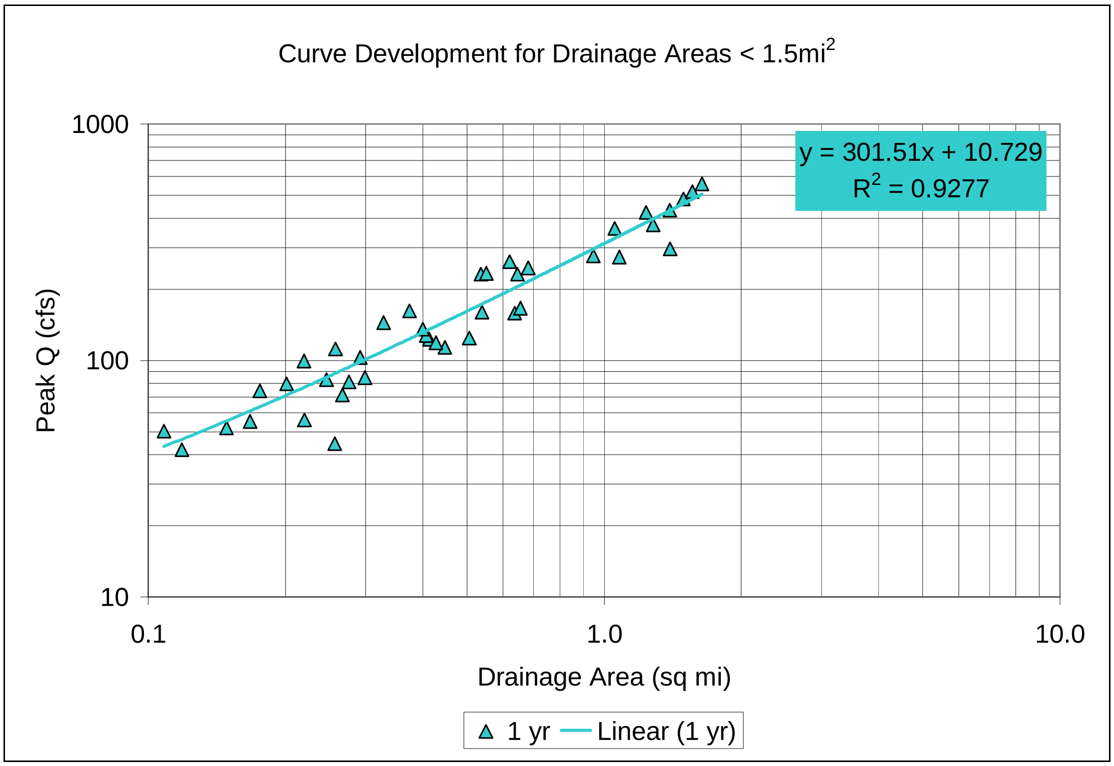


Figure 5 – Linear Regression for Drainage Areas <1.5mi^2 based on SWMM Runoff Results for 1st Order Streams of the TTF Watershed

The second part of the calibration regression was generated using a bankfull regional regression from the Baltimore County Regional Curve (Baltimore County Department of Environmental Protection and Resource Management, 1999).

The Baltimore Curve was considered suitable based on the following two criteria: 1) The geologic province and land use patterns of the watershed used to develop the relationships were similar and 2) It was developed based on data for watershed sizes inclusive of those of Tookany/Tacony-Frankford Creek study locations.

The Baltimore County regression relationship was developed for urban drainages (>20% impervious area) in the Piedmont physiographic province, similar to the Tookany/Tacony-Frankford Creek Watershed. Based on five urban gauges, Baltimore County developed the following regression relationships:

$\log Qbf = 0.5601(\log DA) + 2.4351$
where Qbf is the bankfull discharge in cubic feet per second (cfs) and DA is the drainage area in square miles.

This regression relationship was used to develop the portion of the three part calibration regression for drainage areas from 1.5 mi^2 to $20mi^2$.

The third part of the calibration regression was generated using values provided by the Pennsylvania Department of Environmental Protection for 1.2 year storm discharges for two watersheds adjacent to the TTF Watershed. Both discharges used were obtained at locations where the drainage area was greater then $40mi^2$. The regression equation of:

$Qbf = 43.253(DA)+445.015$
where Qbf is the bankfull discharge in cubic feet per second (cfs) and DA is the drainage area in square miles.

All parts of the combination regression required land use and drainage area information for the entire Tookany/Tacony-Frankford Creek Watershed. Land use information was obtained using a 2000 land use/land cover GIS file from the Delaware Valley Regional Planning Commission (DVRPC).

Along with this three-part regression relationship, drainage area parameters such as impervious percentage, total outfall area, presence of channels/dams/culverts, and reach slopes were used to calibrate the bankfull discharges documented in this report (**Appendix C**).

2.5.3 STREAM GAUGE STATION DATA

Stream gauge station data was used to generate flood frequency graphs showing the 1- and 2-year recurrence discharges for two locations on the Tookany/Tacony-Frankford Creek mainstem (USGS Gauge No. 01467086 and 01467087). Recurrence discharges were compared with field bankfull discharges to determine whether field indicators yielded discharges within a reasonable range. Because land use has not changed significantly since the stream flow gauges were operated, gauge station data was considered applicable to calibrating bankfull discharge for the Tookany/Tacony-Frankford Creek Watershed.

2.6 INFRASTRUCTURE ASSESSMENT METHODS

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, photos were taken and documented, along with important notes which included the GPS point number and any other miscellaneous characteristics.

2.6.1 OUTFALL

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

Figure 6 - Example of an outfall collected during infrastructure assessment

2.6.2 BRIDGES

A bridge is a structure that spans a stream over which a road or walkway passes. The data collected for each bridge included the height, width and depth of the bridge opening, the construction material (metal, concrete, wood, stone, etc.), and structural condition (good, fair, or poor).

Figure 7 - Examples of bridges collected during infrastructure assessment

2.6.3 MANHOLES

A manhole is the covered opening that allows access to a sewer. Data was collected for manholes either located within the creek or close proximity to the creek within the banks. The data collected for each manhole included the diameter of the manhole, the construction material (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), presence and description of odor, and submergence amount.

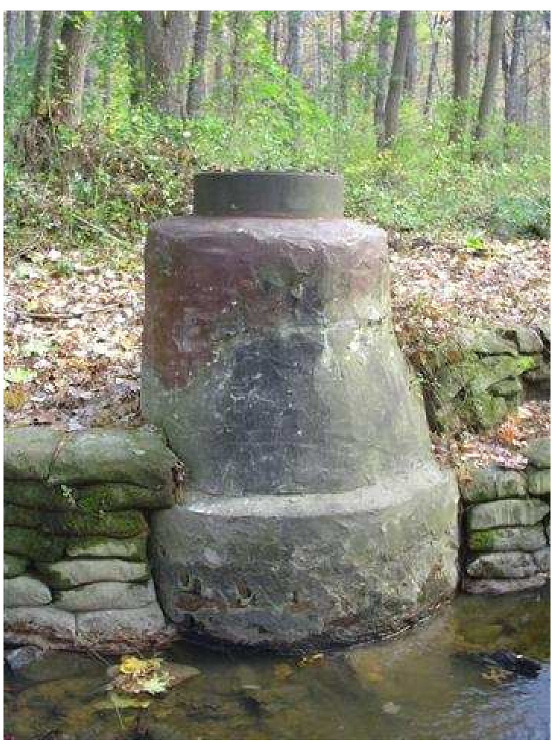


Figure 8 - Example of a manhole collected during infrastructure assessment

2.6.4 CULVERTS

A culvert is a conduit which carries the stream under a roadway, sidewalk, building, or miscellaneous structure. The data collected for each culvert included the physical dimensions, construction material (stone, concrete, brick, etc.), structural condition (good, fair, or poor), presence and quality of dry weather flow, and bank location (left or right).

Figure 9 - Examples of culverts collected during infrastructure assessment

2.6.5 DAMS

A dam is an obstruction that impedes the stream flow. Data was only collected for manmade dams that were constructed of either concrete or stone. The data collected for each dam included the physical dimensions, construction material, structural condition (good, fair, or poor), bank location (left, right, or across the creek), and submergence amount.

Figure 10 - Examples of dams collected during infrastructure assessment

2.6.6 CHANNELS

A channel is a straightening and reinforcement of stream bed and/or banks with manmade materials such as concrete. Channels can be on one or both banks, as well as on the bottom of the stream bed. The data collected for each channel included physical dimensions, structural condition (good, fair, or poor), the portion of stream that was channelized (left bank, right bank or bottom), and construction material (stone or concrete).

Figure 11 - Examples of channels collected during infrastructure assessment

2.6.7 CONFLUENCES

A confluence is the junction where two streams meet. The data collected for each Confluence included the larger stem bank location looking downstream (left or right) and width of the stream entering the larger stem.

Figure 12 - Example of a confluence collected during infrastructure assessment

2.6.8 PIPES

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

Figure 13 - Example of a pipe collected during infrastructure assessment

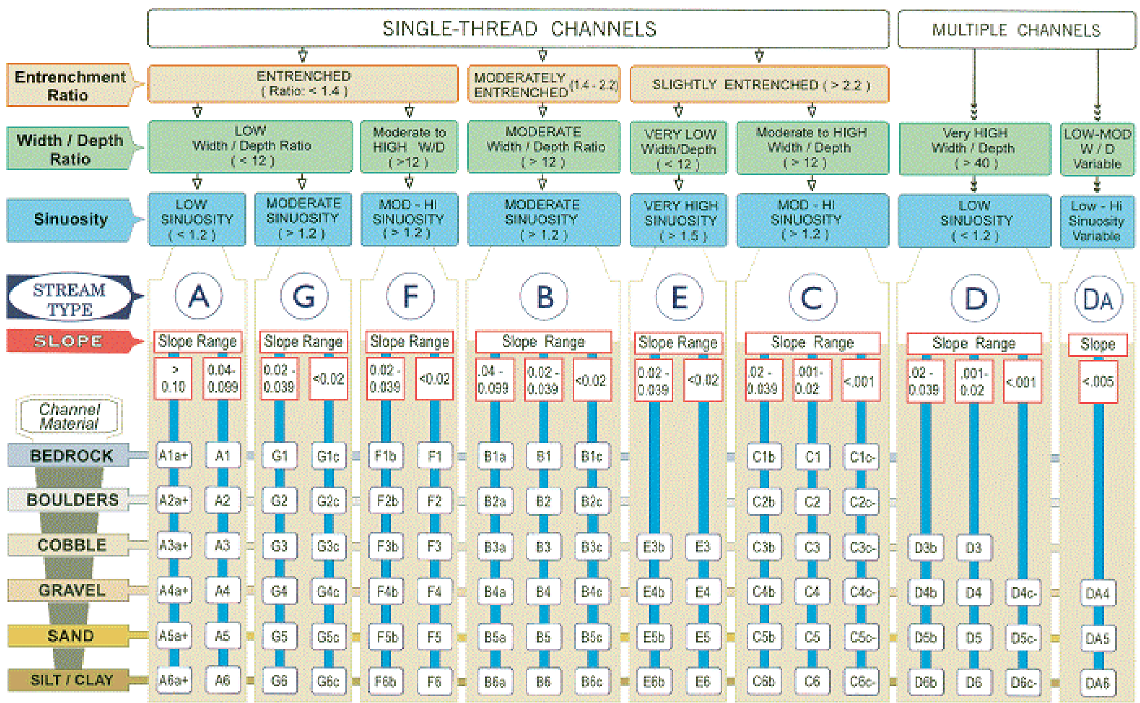
2.7 STREAM CLASSIFICATION

Physical channel conditions were assessed using the procedures and methodologies for fluvial geomorphologic analysis as outlined in "A Classification of Natural Rivers" (Rosgen, 1994). As part of the field reconnaissance, the Rosgen classification system was used to categorize the stream channel into major, natural channel types. These channel types are determined on the basis of existing morphological features of the stream channel and valley. Key parameters and channel types used in the Rosgen classification system are presented in **Figure 14**.

Each major channel type identified in the field was further classified based upon the median particle size of the bed material. The median particle size (D_{50}) of the bed material at each cross section was estimated in the field and average Manning's 'n' values were used in the calculations. Average Manning's 'n' values were based upon several references: Chow (1959), Barnes (1967) and Aldridge and Garrett (1973, Table 1).

Field measurements taken at the cross section were then compared with the parameters in the Rosgen classification system to determine channel type. It should be noted that the stream is actively adjusting, as evidenced by eroding banks and meander migration. Identification of the bankfull elevation is extremely difficult in altered reaches and reaches undergoing adjustments like those present in the Tookany/Tacony-Frankford Creek and its tributaries. In such cases, stream morphology can be expected to deviate from the Rosgen channel types, because the Rosgen classification system generally applies to channels that are in a state of "dynamic equilibrium". Additionally, for stream sections that have been highly modified such as through the placement of concrete riprap, lining with concrete (channelization), or piping (culverting), channel morphology often does not coincide with a single Rosgen channel type.

When stream reaches exhibited features of multiple channel types, the current or principal channel type was determined according to the channel type which was most closely resembled by the Entrenchment Ratio, Width to Depth Ratio, and Sinuosity for that cross-section. This was done by adjusting the parameter with the smaller percent difference between the given threshold values and thereby adjusting the classification by altering the path through the Rosgen Stream Classification Flowchart (**Figure 14 - Rosgen Stream Classification System**). Resulting reach characterizations can be referenced in **Appendix C**.



KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the "*continuum of physical variables*" within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

Figure 14 - Rosgen Stream Classification System

2.7.1 VARIATIONS FROM THE ROSGEN CLASSIFICATION SYSTEM

The original form of the Rosgen Classification System defines the flood-prone depth to be a function of the bankfull depth as follows:

$$D_{FP} = 2 \times D_{BF}$$

This relationship is based on field measurements collected at hundreds of cross sections. D_{FP}/D_{BF} ratios ranged between 1.3 and 2.7, with the average value equal to 2.0. However, Rosgen concedes that this ratio is also a function of the total width of the flood prone area. To the extent that this ratio is typically used in Level II Rosgen Stream Classifications, its application does not create any troubling issues.

However, in order to produce a more robust study, a drainage area to flow relationship was developed for the bankfull condition. The addition of a flow component allowed for the calculation of expected flow conditions at the flood prone stage. Unfortunately, in calculating the flow (Q_{FP}) at the flood-prone stage, the flow balance from reach to reach often resulted in decreasing flows. This effect was observed in the mainstem of the Tookany/Tacony-Frankford Creek, one example of which is between cross-sections MS2, MS4, and MS6 (**Figure 15**). The figure illustrates that the bankfull depths and widths are comparable. When the D_{FP} formula is applied, the cross-sectional area, and therefore the changes in Q_{FP} between each cross- section results in a large increase from MS2 to MS4. This is followed by a large decrease from MS4 to MS6. Clearly these changes in the flow regime do not concur with direct relationship of flow and drainage area. While the regional curve predicts increasing flow with increasing drainage area, **Figure 15** serves as a contradiction. In this case, the large change in the entrenchment ratio of MS4 in comparison to MS2 and MS6 causes the drastic effect on Q_{FP}. This example was a common problem throughout the analysis of the reaches surveyed in the Tookany/Tacony-Frankford Creek Watershed, and therefore the impetus for the development of this method.

In order to resolve the apparent conflict between the Rosgen Stream Classification Method and the $Q/A_{Drainage}$ rating curve, some alteration was necessary. Upon further inspection, the D_{FP}/D_{BF} ratio was found to be the cause. While Rosgen suggests the use of the constant value 2.0, this value represents an average of actual field values ranging from 1.3 to 2.7. Considering the fact that this study surveyed 102 cross sections, it would make sense for this value to have some variation. Because the D_{FP}/D_{BF} ratio considers only the height dimension of each cross-section, severe changes in entrenchment allow for the flow profile of the stream to fall out of balance with its drainage area. Furthermore, it is expected that the stream conditions experienced by Rosgen in rural, more pristine watersheds would not be altered by anthropogenic improvement and development to the degree present in urban watersheds such as the Tookany/Tacony-Frankford.

To address the disagreement between Q_{FP} and the $Q/A_{Drainage}$ rating curve, further consultation of Rosgen revealed that the use of an alternate dimensionless variable would provide a viable solution. Dunne and Leopold established that the two dimensionless ratios, D/D_{BF} and Q/Q_{BF}, are related as illustrated in **Figure 16**. Therefore, rather than choosing D/D_{BF} as the ratio upon which the flood-prone area is based, Q/Q_{BF} can be utilized instead. The use of Q, rather than D, allows for the flow balance to hold and remain consistent with Rosgen considering that Depth = f(Q, channel geometry).

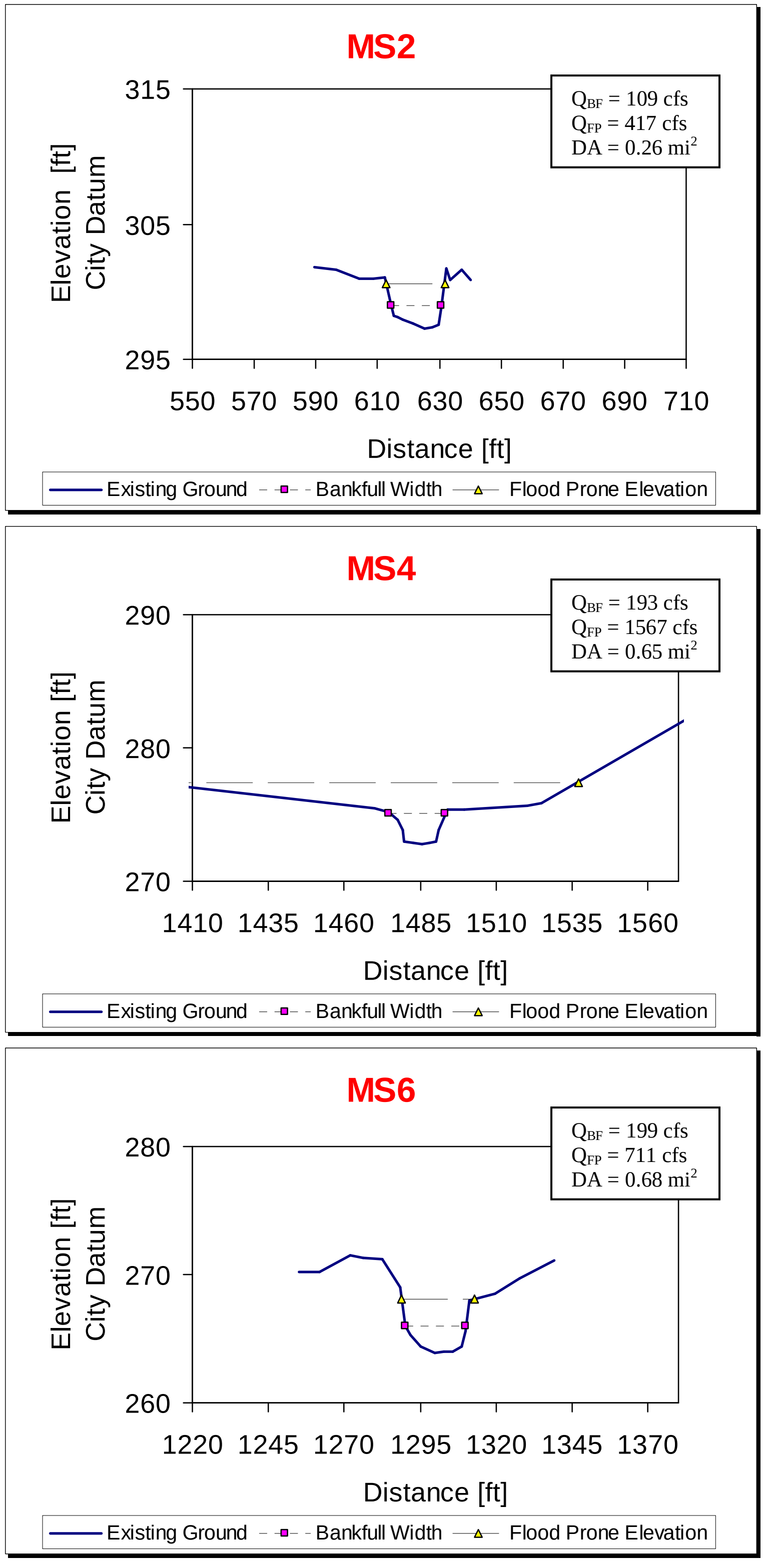


Figure 15 - Cross-Sections MS2, MS4, & MS6

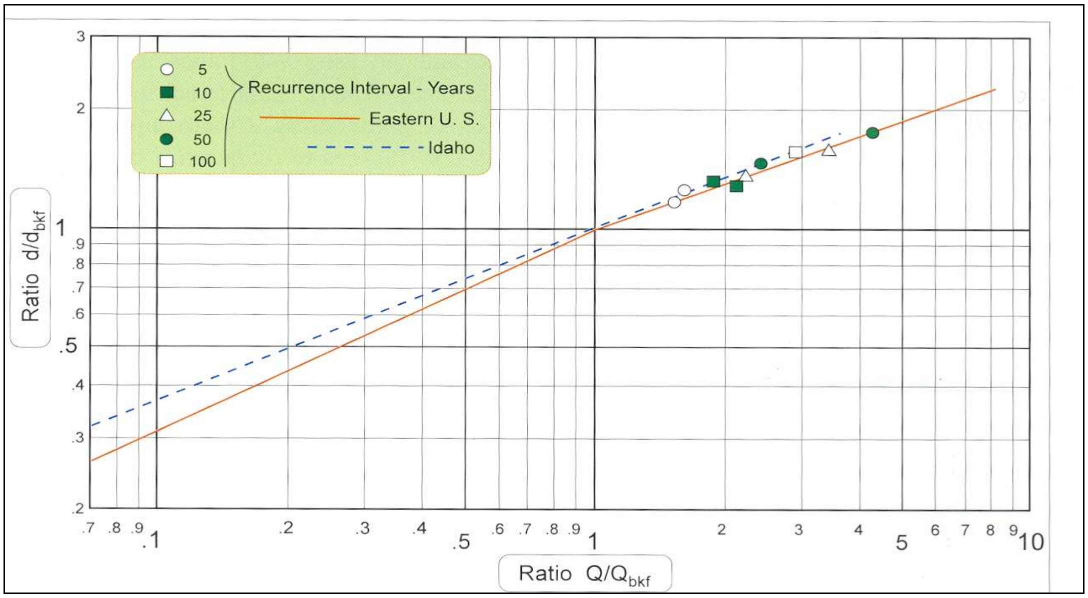


Figure 16- Dimensionless rating curve for two regions, eastern US & Idaho

To establish a Q/Q_{BF} consistent with flow experienced in the Tookany/Tacony-Frankford Watershed, available flow data was consulted. Along the Tacony/Frankford Creek, USGS has historically and/or currently manages 6 flow gauges (**Table 3**). Of the 6 stations, 4 stations are located on the mainstem of the Tookany/Tacony-Frankford Creek, while the other 2 stations are located along tributaries to the mainstem.

To determine an appropriate Q/Q_{BF}, the peak annual discharges for length of the dataset at each station were used to calculate flow at several return periods (1, 1.2, 5, 10, 25, 50 year). The data from USGS Gauge Stations 01467083, 01467084, and 01467085 were excluded because their periods of record were less than 10 years. The remaining stations were included in the flood frequency analysis.

USGS Gauge #	Location	Years of Operation	# of Data Pts
1467083	Tacony Creek at Jenkintown, PA	1973-1978	5
1467084	Rock Creek above Curtis. Arboretum near Philadelphia , PA	1971-1978	7
1467085	Jenkintown Creek At Elkins Park, PA	1973-1978	7
1467086	Tacony Creek at County Line, Philadelphia, PA	1965-1988	23
1467087	Frankford Creek at Castor Ave, Philadelphia, PA	1982-present	22
1467089	Frankford Creek at Torresdale Ave, Philadelphia, PA	1965-1982	17

Table 3 - USGS Gauge Stations in the Tacony/Frankford Watershed

The return period for Q_{BF} was deemed to be the 1.2-year flow, referencing Rosgen's approximation of the return period of the bankfull condition in urban watersheds. The return period for Q_{FP} was assigned the 50-year flow, as referenced in Rosgen's "A Classification of Natural Rivers" (1994). Q_{50} and $Q_{1.2}$ were approximated using multiple, commonly accepted distributions and plotting-position formulas in hydrological flood frequency analysis. The average of all $Q_{50}/Q_{1.2}$ results was used to determine an appropriate Q/Q_{BF} ratio with no particular formula receiving any bias (**Table 4**).

$Q_{50}/Q_{1.2}$				
Distributions	**1467087**	**1467086**	**1467089**	**Average**
Log-Pearson Type III Distribution	2.51	3.23	2.2	2.65
Normal Distribution	2.8	3.09	2.1	2.66
Extreme-Value Type I Distribution	3.01	3.32	2.24	2.86
Log-Normal Distribution	3.59	4.03	2.52	3.38
Gamma/Pearson Type III Distribution	2.77	3.07	1.72	2.52
Plotting Position Formulas	**1467087**	**1467086**	**1467089**	**Average**
Weibull	3.03	3.25	2.59	2.96
Beard	2.86	3.03	2.4	2.76
m/n	2.78	3.18	2.55	2.84
Cunnane	2.6	2.94	2.33	2.62
General	2.6	2.88	2.27	2.58
		$Q_{50}/Q_{1.2\ AVG}$	2.78	~ 3.00

Table 4- $Q_{50}/Q_{1.2}$ Ratios from Hydrological Frequency Analysis

The average $Q_{50}/Q_{1.2}$ was 2.78 and was rounded up to 3.00 to allow for errors in each distribution/formula. Using this ratio, the maximum depth of the flood-prone area was calculated. Of the 102 cross sections to which this methodology was applied, the average D_{FP}/D_{BF} was 1.78 with a standard deviation of 0.144. Overall, the D_{FP}/D_{BF} ranged from 1.47 to 2.54, which is within the 1.3 to 2.7 range that Rosgen cited when comparing the 50-year flow to the observed bankfull flow.

This slight modification proved to be reasonable given the great variation in stream type that occurs over the stream length assessed within this study. While addressing the contradiction that occurred as a result of the strict interpretation of Rosgen's definition of floodprone area, this method was applied while still agreeing with the definition's supporting data.

2.8 STREAM REACH RANKINGS

Field data was divided into two categories depending on whether it related to habitat or channel stability. Numerical values assigned to each channel stability parameter were established according to field surveyed existing channel geometry. Existing geometry determined the Rosgen channel type, which provided the basis for assigning ranking values to other stability parameters. Other background information such as soils, geology, topography, valley type and land use were also evaluated to determine stability and habitat parameter ranking values. Habitat parameters were assigned ranking values based on qualitative data collected during the field survey.

Final reach scores were determined by adding the total stability and habitat reach scores. The maximum, or worst, stability score attainable by any reach is 100, while the maximum habitat score is 55.

2.8.1 STABILITY PARAMETERS RANKING VALUES

To score the stability of each reach, a combination of both quantitative and qualitative parameters were used. Length of culverts and channels were considered important because these sections tend to accelerate flow, thereby having greater impacts on non-hardened portions of the streams. Other important quantitative parameters include outfall area, number of infrastructure points, entrenchment ratio, and shear stress. The remaining qualitative parameters such as Reach Bed Stability and Bank Erosion were assigned values based upon observations made during field inspections. Each of these parameters was assigned scores with the lowest scores assigned to the condition deemed ideal as given in **Table 5**.

Determination of Stability Parameter Ranking Values

S1

Outfall Area (ft^2)	Ranking Value
0	0
0.1 to 5.0	1
5.0 to 10.0	2
10.1 to 15.0	4
15.1 to 20.0	6
20.1 to 30.0	10
30.1 to 40.0	12
40.1 to 50.0	14
50.1 to 60.0	16
60.1 to 80.0	18
80.1 to 100.0	20
100.1 to 120.0	21
120.1 to 140.0	22
140.1 to 160.0	23
160.1 to 180.0	24
>180.1	25

S2

Culverts (% Culverted)	Ranking Value
0	0
0.1 - 5.0	3
5.1 to 10.0	6
10.1 to 15.0	9
15.1 to 20.0	12
21.0 to 40.0	15
40.1 to 60.0	18
>60	20

S3

Channels (% Channelized)	Ranking Value
0	0
0.1 - 5.0	2
5.1 to 10.0	4
10.1 to 15.0	6
15.1 to 20.0	8
21.0 to 40.0	10
40.1 to 60.0	12
>60	15

S4

Number of Infrastructure Pts	Ranking Value
0	0
1 to 5	1
6 to 10	2
11 to 15	3
16 to 20	4
>20	5

S5

Shear Stress	Possible Size Range of Material Moved (?)	Ranking Value
<0.01	0.1-2	1
<0.02	0.2-5	2
<0.2	1-10	3
<1	10-50	3
<2	20-500	7
<10	50-1000	10

S6

Channel Type		Ranking Value
C		0
E		0
B		2
G		3
F		5
D		5

S7

Reach Bed Stability		Ranking Value
Aggrading		4
Degrading		5
Indeterminate		3
Stable		0

S8

Bed Materials	D50 (mm)	Ranking Value
Silt and Clay	2<	5
Sand	<2 through 12	5
Gravel	12 through 96	3
Cobble	96 through 512	2
Boulder	512 through 4096	1
Bedrock	> 4096	0

S9

Bank Erosion	(?) Value	Ranking Value
Low	10-19.5	1
Moderate	20-29.5	3
High	30-39.5	5

S10

Entrenchment Ratio	Ratio Value	Ranking Value
Entrenched	1-1.4	5
Moderately Entrenched	1.41-2.2	3
Slightly Entrenched	>2.2	1

Table 5 -Determination of Stability Parameter Ranking Values

Outfall Area (ft^2)
Outfall area was weighted the greatest of all channel stability parameters. Sixteen (16) possible ranking values were assigned with a minimum ranking value of 0 for reaches that had no outfall contributions, and a maximum value of 25 for reaches where the outfall area contribution was greater than 180 square feet.

Culverts (% Culverted)
Culverts are conduits that pass flow under a road or a railroad. Culvertization was assigned one of the highest rankings in the channel stability parameters. Reaches were assigned a ranking value based on the percent of stream culverted within that reach. Eight (8) possible ranking values were assigned, with reaches that were greater than 60% culverted receiving a ranking value of 20. The ranking value assigned decreased with decreasing percent culvertization with a minimum ranking value of zero for those reaches with no culverts.

Channels (% Channelized)
Stream channels were considered channelized when they have been straightened and lined with manmade materials such as concrete, brick or stone. The natural geometry is absent and has been replaced with an artificial watercourse. Reaches were assigned a ranking value based on the percent of channelization within that reach, with eight possible ranking values. Reaches that were greater than 60% channelized received a ranking value of 15. The ranking value assigned decreased with decreasing percent channelization with a minimum ranking value of zero for those reaches with no channelization. Each bank was assessed separately when determining the percent channelization of the stream.

Infrastructure Points
Infrastructure, such as, manholes, pipes, dams, and bridges, was considered a very influential parameter on the channel geometry. Reaches were assigned a ranking value from 0 to 5 based on the number of infrastructure points within the reach, which ranged from no infrastructure points to greater than 20 infrastructure points.

Shear Stress
Shear stress can be defined as the amount of force exerted on the wetted perimeter of a channel by moving water. It is not uniform along the wetted perimeter, but varies according to the channel shape, bank materials and their ability to resist erosion. The bankfull wetted perimeter, cross sectional area, bankfull slope, and hydraulic radius were calculated based upon the surveyed cross section geometry and then used to calculate the shear stress for each cross section using the following equation:

Shear Stress = $T = \gamma RS$, where
T = shear stress (lbs/ft^2)
γ = density of water (lbs/ft^3)
R = hydraulic radius (cross sectional area/wetted perimeter) (ft^2/ft)
S = channel slope (ft/ft)

Shear stress values calculated for all cross sections are shown on the cross section graphs within **Appendix C**.

Shear stress was assigned a ranking value from 1 to 10 from a range of 6 possible categories, with the lowest ranking value being assigned to the reaches with a shear stress of less than 0.01 and the highest ranking value of 10 being assigned to reaches with a shear stress greater than 10.

Channel Type

Channel type was assigned a ranking value according to stability and the amount of deviation from baseline conditions. A total of 6 Rosgen channel types were included in the channel type parameter: C, E, B, G, F, and D. C and E Rosgen channel types were assigned the lowest ranking value of 0, B and G channel types were intermediates with assigned ranking values of 2 and 3 respectively, while F and D channel types were considered the least stable, and were assigned the highest ranking value of 5.

Reach Bed Stability

Reach bed stability was determined based on whether the streambed was actively degrading, aggrading or stable. Degrading beds exhibited evidence of active erosion and/or downcutting, while aggrading reaches contained depositional features. The highest reach bed stability ranking value of 5 was assigned to degrading reaches, while aggrading reaches were assigned a ranking value of 4. Although a channel that is aggrading is becoming more stable, a moderately high ranking value was assigned because changes to channel geometry and/or planform are considered unstable. In reaches where channel changes were not evident, reach bed stability was "indeterminate" and a ranking value of 3 was assigned. Only stable reaches were assigned the lowest ranking value of zero, which are those reaches that displayed characteristics of an established, unchanging bank geometry.

Bed Materials

Existing bed materials were assigned a stability parameter value according to size and how easily they can be eroded from the bed or banks. Sand and silt/clay were assigned the highest ranking value of 5 while values for more coarse materials increased by an increment of one. Boulders and bedrock were assigned the lowest values since they are not easily eroded.

Bank Erosion

Bank erosion was rated as low, moderate, or high based on field observations. High bank erosion, or actively eroding banks, generally steep or vertical, was assigned a ranking value of 5. Channel banks that were generally less than 4 feet tall, stabilized with vegetation and not actively eroding were rated as low and assigned a ranking value of 1. Bank erosion did not include a zero ranking value.

Entrenchment Ratio

The entrenchment ratio is the ratio of the width of the flood-prone area to the surface width of the bankfull channel. Three possible ranking values were assigned, with a minimum ranking value of 1 for reaches that were slightly entrenched, a ranking value of 3 for reaches that were moderately entrenched and a maximum value of 5 for reaches that were considered completely entrenched.

2.8.2 HABITAT PARAMETERS RANKING VALUES

Ranking values were assigned to habitat parameter data based on ideal conditions. For example, riparian width values consisted of '<10 feet', '10-25 feet', '25-100 feet', and '>100 feet'. The ideal value of '>100 feet' was then assigned the lowest ranking value (0) and the least ideal condition of '<10 feet' was assigned the highest ranking value (5). Therefore, each habitat field data parameter was assigned a ranking value based on the ideal condition for that parameter (**Table 6**).

Determination of Habitat Parameter Ranking Values

H1

Riparian Width	Ranking Value DSL	Ranking Value DSR
<10 feet	5	5
10-25 feet	3	3
25-100 feet	1	1
>100 feet	0	0

H2

Riparian Composition	Ranking Value DSL	Ranking Value DSR
Paved/Bare Ground	5	5
Yards/Lawn/Pasture	4	4
Vines/Herbaceous/Shrubs	3	3
Modified/Mixed/Broken Forest	1	1
Natural Forest (Multi-Tiered)	0	0

H3

Canopy Cover	Ranking Value DSL	Ranking Value DSR
0-20%	5	5
21-40%	4	4
41-60%	3	3
61-80%	1	1
81-100%	0	0

H4

Bed Materials	D50 (mm)	Ranking Value
Silt and Clay	<2	5
Sand	<2 through 12	4
Gravel	12 through 96	2
Cobble	96 through 512	0
Boulder	512 through 4096	1
Bedrock	> 4096	5

H5

Sediment Supply		Ranking Value
Low		1
Moderate		3
High		5

H6

Sinuosity	Ratio	Ranking Value
Low	1-1.2	5
Moderate	1.2-1.4	3
High	>1.4	0

H7

Woody Debris		Ranking Value
Absent		5
Few		3
Moderate		1
Frequent		0

H8

Attachment Sites		Ranking Value
<25% Exposed		0
25-75% Exposed		3
>75% Exposed		5

Table 6 - Determination of Habitat Parameter Ranking Values

Riparian Width
Reaches were assigned individual ranking values for the downstream right and left riparian widths. Values ranged from zero for a forested riparian equal or greater than 100 feet wide and increase to a ranking value of 5 for those reaches having a riparian width less than 10 feet wide.

Riparian Composition
There were five categories of riparian composition, with a minimum ranking value of zero assigned to riparian banks with a natural, multi-tiered forest and a maximum ranking value of 5 assigned to riparian areas with bare or paved ground. Riparian composition was analyzed independently for the left and right banks.

Canopy Cover
Canopy cover was ranked according to the percent canopy directly above the channel throughout the reach. Canopy cover was divided into five categories ranging from the lowest of 0-20% to the highest, or ideal category, of 81-100%. The most ideal category was assigned a zero ranking value while all others decrease by an increment of 1 as they worsened.

Bed Materials
Existing bed materials were assigned a habitat parameter value according to size that was intended to reflect the relative stability and suitability of substrate particles for colonization by stream flora and fauna. Silt/clay and bedrock were assigned the highest ranking value of 5. The ranking values decreased with material size from 4 for sand down to 1 for boulders.

Sediment Supply
Sediment supply was categorized as low, moderate or high. Ranking values began at 1 for the ideal condition, or low sediment supply, increased to 3 for moderate sediment supply, and again increased to 5 for high sediment supply. Sediment supply was considered high when severe bank erosion was occurring and there was deposition occurring within the channel.

Sinuosity
Sinuosity was defined as the ratio of stream length to valley length. Reaches were assigned values of 5, 3, or 0 for high, moderate, and low sinuosities respectively.

Woody Debris
Woody debris, such as fallen trees and branches, are beneficial to streams because they provide habitat for fish and other aquatic organisms. Although woody debris can negatively impact the stability of a channel, for the purpose of assigning ranking values to this habitat parameter, the ideal condition was assigned to those reaches in which stable woody debris was encountered frequently. There were four categories of woody debris: absent, few, moderate, and frequent. Reaches in which woody debris was encountered frequently were assigned a zero ranking value and those containing no woody debris were assigned a ranking value of 5.

Attachment Sites

Attachment sites were assessed by determining the percent of the channel bottom that was exposed or not covered by baseflow. Channel substrate not covered by baseflow is unsuitable habitat for aquatic microorganisms and macroinvertebrates. Therefore, reaches that had 75% or more of the channel substrate exposed were assigned the worst ranking value of 5, reaches that had between 25% and 75% of channel substrate exposed were assigned a ranking value of 3 and reaches having 25% or less substrate exposed were assigned the ideal ranking value of zero.

2.9 SUBWATERSHED RANKING VALUES

Subwatershed reach rankings allowed for characteristics to be analyzed over more continuous stretches of stream. Individual tributaries and mainstem reaches were combined in a geographically logical fashion and considered a subwatershed. Individual reach rankings within each subwatershed were used to calculate a weighted average. In some cases where the subwatershed reaches were considerably longer in comparison to others, the subwatershed reaches were divided into multiple sections, such as the case in the mainstem. In the weighting procedure, no subwatershed's stream reach length was longer than 3.25 miles. The segmentation procedure resulted in 16 subwatersheds (**Table 7** and **Figure 3)**.

Sub-watershed	Reaches	Total Reach Length (mi)
Burholme Creek Sub-watershed (BW)	B2, B4, B6, B8, B10	1.10
East Branch Jenkintown Creek Sub-watershed (EJW)	EJ2, EJ4	0.75
Tributary G Sub-watershed (GW)	G2, G4, G6, G8, G10	1.10
Rock Creek Sub-watershed (HW)	H2, H4, H6, M2, M4, H8, H10, H12, H14	2.82
Baeder Creek Sub-watershed (IW)	I2, I4, I6, K2, K4, I8, I10, I12	1.99
Jenkintown Creek Sub-watershed (JW)	J2, D2, D4, J4, J6, J8, J10, J12, C2, J14, J16, J18, J20	3.25
Mill Run Sub-watershed (MRW)	MR2, MR4, MR6, MR8, MR10, MR12	1.12
Tookany/Tacony-Frankford Creek Sub-watershed (MS.1W)	MS2, MS4, MS6, MS8, MS10, MS12, L2, L4	1.91
Tookany/Tacony-Frankford Creek Sub-watershed (MS.2W)	MS14, MS16, MS18, MS20, MS22	1.08
Tookany/Tacony-Frankford Creek Sub-watershed (MS.3W)	MS24, MS26, MS28, MS30, MS32	1.23
Tookany/Tacony-Frankford Creek Sub-watershed (MS.4W)	MS34, MS36, MS38, MS40	1.18
Tookany/Tacony-Frankford Creek Sub-watershed (MS.5W)	MS42, MS44, MS46, MS48, MS50, MS52	1.22
Tookany/Tacony-Frankford Creek Sub-watershed (MS.6W)	MS54, MS56, MS58, A2, MS60, MS62, MS64, MS70, MS72	2.28
Tookany/Tacony-Frankford Creek Sub-watershed (MS.7W)	N2, MS74, MS76, MS78, MS80, MS86, MS88	1.55
Tookany/Tacony-Frankford Creek Sub-watershed (MS.8W)	MS94, MS100, MS102, MS104, MS106	1.48
Tookany/Tacony-Frankford Creek Sub-watershed (MS.9W)	MS108, MS110, MS112, MS114, MS120	1.30

Table 7– Subwatershed Reach Identification

2.10 SUBWATERSHED PERCENT (%) IMPERVIOUSNESS

The impervious analysis was performed differently for the areas inside and outside the city.

For areas inside the city, a City Planning impervious GIS layer was used. The drainage area tributary to the cross section was intersected with the impervious layer. The areas coded as natural (Code 9999) were summed as pervious, and the remaining areas were summed and considered impervious. The sum of impervious land area was divided by total subshed area in order to estimate percent imperviousness.

For areas outside the city, such a GIS layer was not available. However, these areas did have land use data for each parcel. The land use and the Census population by blocks were intersected with the cross section sheds. From this data, a population density relationship for imperviousness was developed. This relationship was used to estimate the impervious area of the residential areas only. All other land uses had a set imperviousness value based on predetermined values as seen in **Table 8**. Once the % imperviousness value for all the land uses was calculated, a weighted area approach was utilized to estimate the % imperviousness for the entire contributing area for each reach.

Land Use Type	% Impervious
Agriculture	5%
Cemetery	5%
Commercial	80%
Golf Course	5%
Industrial	65%
Recreation	80%
Residential	5%
Transportation	90%
Urban Open	60%
Vacant	20%
Water	95%
Wooded	5%

Table 8– % Imperviousness Estimates by Land Use Type

3 EXISTING CONDITIONS

In total, 102 cross-sections were surveyed on about 27 miles of mainstem Tookany/Tacony-Frankford Creek, and its 14 major contributing tributaries (**Table 9**). The average length represented by each cross-section was 1394 feet.

Creek	Creek Code	Total Cross Sections	Total Linear Feet Assessed	Average Reach Length	Total Miles Assessed
Burholme Creek Sub-watershed (BW)		**5**	**6923**	**1385**	**1.31**
Burholme Creek	B	5	6923	1385	1.31
East Branch Jenkintown Creek Sub-watershed (EJW)		**2**	**3956**	**1978**	**0.75**
East Branch to Jenkintown Creek	EJ	2	3956	1978	0.75
Tributary G Sub-watershed (GW)		**5**	**5808**	**1162**	**1.10**
Unknown Tributary G to Tookany Creek	G	5	5808	1162	1.10
Rock Creek Sub-watershed (HW)		**9**	**16262**	**1807**	**3.08**
Rock Creek	H	7	13203	1886	2.50
Unknown Tributary M to Rock Creek	M	2	3059	1530	0.58
Baeder Creek Sub-watershed (IW)		**8**	**10500**	**1313**	**1.99**
Baeder Creek	I	6	8506	1418	1.61
West Branch Baeder Creek	K	2	1994	997	0.38
Jenkintown Creek Sub-watershed (JW)		**13**	**17173**	**1321**	**3.25**
Unknown Tributary C to Jenkintown Creek	C	1	1848	1848	0.35
Unknown Tributary D to Jenkintown Creek	D	2	1727	863	0.33
Jenkintown Creek	J	10	13599	1360	2.58
Mill Run Sub-watershed (MRW)		**6**	**5912**	**985**	**1.12**
Mill Run	MR	6	5912	985	1.12
Tookany/Tacony-Frankford Creek Sub-watershed (MS.1W)		**8**	**12121**	**1515**	**2.30**
Tookany/Tacony-Frankford Creek	MS	6	9475	1579	1.79
Unknown Tributary L to Tookany Creek	L	2	2646	1323	0.50
Tookany/Tacony-Frankford Creek Sub-watershed (MS.2W)		**5**	**6376**	**1275**	**1.21**
Tookany/Tacony-Frankford Creek	MS	5	6376	1275	1.21
Tookany/Tacony-Frankford Creek Sub-watershed (MS.3W)		**5**	**6474**	**1295**	**1.23**
Tookany/Tacony-Frankford Creek	MS	5	6474	1295	1.23
Tookany/Tacony-Frankford Creek Sub-watershed (MS.4W)		**4**	**6539**	**1635**	**1.24**
Tookany/Tacony-Frankford Creek	MS	4	6539	1635	1.24
Tookany/Tacony-Frankford Creek Sub-watershed (MS.5W)		**6**	**6445**	**1074**	**1.22**
Tookany/Tacony-Frankford Creek	MS	6	6445	1074	1.22
Tookany/Tacony-Frankford Creek Sub-watershed (MS.6W)		**9**	**12030**	**1337**	**2.28**
Tookany/Tacony-Frankford Creek	MS	8	9695	1212	1.84
Unknown Tributary A to Tookany Creek	A	1	2335	2335	0.44
Tookany/Tacony-Frankford Creek Sub-watershed (MS.7W)		**7**	**11776**	**1682**	**2.23**
Tookany/Tacony-Frankford Creek	MS	6	5452	909	1.03
Unknown Tributary N to Tookany Creek	N	1	6324	6324	1.20
Tookany/Tacony-Frankford Creek Sub-watershed (MS.8W)		**5**	**7800**	**1560**	**1.48**
Tookany/Tacony-Frankford Creek	MS	5	7800	1560	1.48
Tookany/Tacony-Frankford Creek Sub-watershed (MS.9W)		**5**	**6876**	**1375**	**1.30**
Tookany/Tacony-Frankford Creek	MS	5	6876	1375	1.30

Table 9- Total Stream Length Assessed

A land use GIS analysis was performed using DVRPC's land use data from 2000. The analysis was performed by categorizing land use of each subshed attributable to individual cross-sections. The percentage of each subshed's land area represented by each land use category was determined. Various land uses were grouped into 9 major categories: (1) Residential, (2) Roads & Parking, (3) Commercial/Manufacturing/Utilities, (4) Recreation, (5) Wooded, (6) Agriculture, (7) Cemetery, (8) Vacant and (9) Water. A land use categorization was performed for each creek and subwatershed (**Table 10**). The analysis showed that the Tookany-Tacony-Frankford Watershed is largely residential and commercial, with these land use types comprising over 75% of the watershed.

Creek	Creek Code	Total Cross Sections	Residential %	Roads & Parking %	Commercial/ Manufacturing/ Utilities %	Recreation %	Wooded %	Agriculture %	Cemetery %	Vacant %	Water %
Burholme Creek Sub-watershed (BW)		**5**	**41%**	**4%**	**12%**	**10%**	**9%**	**1%**	**23%**	**0%**	**0%**
Burholme Creek	B	5	41%	4%	12%	10%	9%	1%	23%	0%	0%
East Branch Jenkintown Creek Sub-watershed (EJW)		**2**	**36%**	**2%**	**13%**	**9%**	**25%**	**10%**	**6%**	**1%**	**0%**
East Branch to Jenkintown Creek	EJ	2	36%	2%	13%	9%	25%	10%	6%	1%	0%
Tributary G Sub-watershed (GW)		**5**	**63%**	**8%**	**7%**	**13%**	**6%**	**0%**	**3%**	**0%**	**0%**
Unknown Tributary G to Tookany Creek	G	5	63%	8%	7%	13%	6%	0%	3%	0%	0%
Rock Creek Sub-watershed (HW)		**9**	**52%**	**9%**	**9%**	**13%**	**12%**	**0%**	**5%**	**0%**	**0%**
Rock Creek	H	7	50%	8%	10%	12%	13%	0%	7%	0%	0%
Unknown Tributary M to Rock Creek	M	2	58%	11%	5%	16%	10%	0%	0%	0%	0%
Baeder Creek Sub-watershed (IW)		**8**	**63%**	**6%**	**14%**	**6%**	**10%**	**0%**	**0%**	**2%**	**0%**
Baeder Creek	I	6	67%	6%	15%	4%	8%	0%	0%	0%	0%
West Branch Baeder Creek	K	2	47%	7%	8%	13%	18%	0%	0%	8%	0%
Jenkintown Creek Sub-watershed (JW)		**13**	**63%**	**4%**	**5%**	**3%**	**17%**	**0%**	**7%**	**0%**	**1%**
Unknown Tributary C to Jenkintown Creek	C	1	56%	6%	0%	1%	10%	0%	26%	0%	0%
Unknown Tributary D to Jenkintown Creek	D	2	56%	2%	0%	0%	12%	0%	31%	0%	0%
Jenkintown Creek	J	10	65%	3%	7%	3%	19%	0%	1%	0%	1%
Mill Run Sub-watershed (MRW)		**6**	**76%**	**5%**	**7%**	**3%**	**2%**	**0%**	**6%**	**0%**	**0%**
Mill Run	MR	6	76%	5%	7%	3%	2%	0%	6%	0%	0%
Mainstem Sub-watershed (MS.1W)		**8**	**57%**	**5%**	**14%**	**3%**	**2%**	**0%**	**9%**	**9%**	**0%**
Tookany/Tacony-Frankford Creek	MS	6	54%	6%	10%	3%	2%	0%	13%	12%	0%
Unknown Tributary L to Tookany Creek	L	2	65%	2%	24%	3%	3%	0%	0%	1%	1%
Mainstem Sub-watershed (MS.2W)		**5**	**75%**	**6%**	**13%**	**3%**	**4%**	**0%**	**0%**	**0%**	**0%**
Tookany/Tacony-Frankford Creek	MS	5	75%	6%	13%	3%	4%	0%	0%	0%	0%
Mainstem Sub-watershed (MS.3W)		**5**	**65%**	**11%**	**11%**	**3%**	**4%**	**0%**	**0%**	**6%**	**0%**
Tookany/Tacony-Frankford Creek	MS	5	65%	11%	11%	3%	4%	0%	0%	6%	0%
Mainstem Sub-watershed (MS.4W)		**4**	**64%**	**4%**	**22%**	**5%**	**2%**	**0%**	**0%**	**1%**	**0%**
Tookany/Tacony-Frankford Creek	MS	4	64%	4%	22%	5%	2%	0%	0%	1%	0%
Mainstem Sub-watershed (MS.5W)		**6**	**60%**	**1%**	**3%**	**26%**	**9%**	**0%**	**0%**	**0%**	**2%**
Tookany/Tacony-Frankford Creek	MS	6	60%	1%	3%	26%	9%	0%	0%	0%	2%
Mainstem Sub-watershed (MS.6W)		**9**	**63%**	**2%**	**11%**	**14%**	**9%**	**0%**	**0%**	**0%**	**1%**
Tookany/Tacony-Frankford Creek	MS	8	60%	1%	5%	19%	13%	0%	0%	0%	2%
Unknown Tributary A to Tookany Creek	A	1	70%	3%	22%	4%	2%	0%	0%	0%	0%
Mainstem Sub-watershed (MS.7W)		**7**	**63%**	**3%**	**3%**	**15%**	**12%**	**0%**	**0%**	**1%**	**3%**
Tookany/Tacony-Frankford Creek	MS	6	65%	3%	2%	12%	12%	0%	0%	1%	3%
Unknown Tributary N to Tookany Creek	N	1	52%	1%	5%	27%	11%	0%	0%	4%	0%
Mainstem Sub-watershed (MS.8W)		**5**	**66%**	**8%**	**18%**	**6%**	**1%**	**0%**	**1%**	**0%**	**0%**
Tookany/Tacony-Frankford Creek	MS	5	66%	8%	18%	6%	1%	0%	1%	0%	0%
Mainstem Sub-watershed (MS.9W)		**5**	**59%**	**4%**	**20%**	**9%**	**3%**	**0%**	**4%**	**0%**	**0%**
Tookany/Tacony-Frankford Creek	MS	5	59%	4%	20%	9%	3%	0%	4%	0%	0%
			61.4 %	**5.4 %**	**14.6%**	**7.9 %**	**5.4 %**	**0.2 %**	**3.6 %**	**1.2%**	**0.4 %**

Table 10– Land Use in the Tookany/Tacony-Frankford Watershed

3.1 MAINSTEM AND TRIBUTARY WATERSHED CHARACTERISTICS

3.1.1 TOOKANY/TACONY-FRANKFORD CREEK (MAINSTEM) SUBWATERSHED

The Tookany/Tacony-Frankford Creek Subwatershed contains the Tookany/Tacony-Frankford Creek mainstem, Tributary L, Tributary A and Tributary N.

Mainstem

The assessed length of the mainstem is 12.3 miles and represents the bulk of this study. It begins near the intersection of Morgan Lane & Azalea Lane, Cheltenham, PA and ends at the Juniata Park Golf Course, north of Castor Ave. and Wingohocking Sts., Philadelphia, PA. Its name changes several times as it moves thorough the watershed beginning as the Tookany Creek, and then becoming the Tacony Creek, and finally becoming the Frankford Creek before it empties into the Delaware River. Its watershed is 21.3 mi^2, lying in both Philadelphia and Montgomery Counties and in the municipalities of the City of Philadelphia, Cheltenham Township, Abington Township, Springfield Township, and Jenkintown Borough. The land area of the watershed is 49% impervious. The watershed is mostly residential with almost 62% of the land occupied by housing. The 2nd largest land use is devoted to commercial, manufacturing, and utility infrastructure, accounting for just over 16%. The remaining land in the watershed is parceled out between roads and parking (5.4%), recreational facilities (8.1%), cemetery (2.8%), and wooded areas (3.5%). The assessed section of the mainstem was divided into 50 reaches with an average reach length equal to 1,303 ft.

Tributary L

The assessed length of "L" Tributary is 0.5 miles beginning northeast of Radcliff Rd. and Glenside Ave., Cheltenham, PA. and ending east off Harrison Ave., between Springhouse Ln. and Waverly Rd., Cheltenham, PA. It enters the mainstem between cross sections MS12 and MS14. Its watershed is 0.54 mi^2, lying in Montgomery County and in the municipalities of Abington Township and Cheltenham Township. The land area of the watershed is 23% impervious. The watershed is mostly residential with 64.9% of the land occupied by housing. The 2nd largest land use is devoted to commercial, manufacturing, and utility infrastructure accounting for 24.5%. The remaining land in the watershed is parceled out between roads and parking (1.9%), recreational facilities (3.4%), wooded area (3.5%), vacant land (0.9%), and water (1.0%). The assessed section of "L" Tributary was divided into 2 reaches of 1,132 ft and 1,514 ft respectively.

Tributary A

The assessed length of "A" Tributary is 0.44 miles beginning northwest of Hasbrook Ave., between Jefferson and Beecher Aves., Cheltenham, PA. and ending just south of Tookany Creek Parkway and Ryers Ave., Cheltenham, PA. It enters the mainstem between cross sections MS58 and MS60. Its watershed is 0.41 mi^2, lying in both Philadelphia and Montgomery Counties and in the municipalities of the City of Philadelphia and Cheltenham Township. The land area of the watershed is 53% impervious. The watershed is mostly residential with over 70% of the land occupied by housing. The 2nd largest land use is devoted to commercial, manufacturing, and utility infrastructure, accounting for just over 22%. The remaining land in the watershed is parceled out between roads, parking, recreational facilities, and wooded areas. The comparatively short length (2,335 ft) of "A" Tributary and rather uniform features allowed for 1 reach to suffice in classifying the stream's stability and habitat characteristics.

Tributary N

The assessed length of "N" Tributary is 1.2 miles beginning just southwest of Pleasant Hill Rd. and Front St., Cheltenham, PA and ending northeast of Tookany Creek Parkway and Johns Rd., Cheltenham, PA. It enters the mainstem between MS72 and MS74. Its watershed is 0.18 mi^2 lying in Montgomery County and in the municipality of Cheltenham Township. The land area of the watershed is 18% impervious. The watershed is mostly residential with more than 52% of the land occupied by housing. The 2nd largest land use is devoted to recreational facilities, accounting for just over 27%. The remaining land in the watershed is parceled out between roads and parking (0.6%), commercial, manufacturing, and utility infrastructure (5.2%), vacant land (3.9%), and wooded areas (11.0%). The assessed section of Unknown Tributary N included 1 reach with a reach length of 6,324 ft.

3.1.2 BURHOLME CREEK SUBWATERSHED

The Burholme Creek Subwatershed contains only Burholme Creek.

The assessed length of the Burholme Creek (B) is 1.3 miles beginning due east of Church Rd. and Chandler St., Rockledge, PA. and ending southwest of Laurel Ave. and Myrtle Ave., Cheltenham, PA.. It enters the mainstem between cross sections MS56 and MS58. Its watershed is 0.65 mi^2, lying in both Philadelphia and Montgomery Counties and in the municipalities of the City of Philadelphia, Cheltenham Township, Abington Township, and Rockledge Borough. The land area of the watershed is 17% impervious. The watershed is rather diverse in its land uses. The largest land uses are residential (41.3%) and cemetery (22.5%), with parts of both Lawnview and Montefiore Cemeteries contained herein. The remaining land in the watershed is designated as commercial/manufacturing/utility (12.1%), recreation (9.6%), wooded (9.2%), roads, parking (4.1%), and agriculture (1.3%). The assessed section of Burholme Creek was divided into 5 reaches with an average reach length equal to 1,385 ft.

3.1.3 TRIBUTARY G SUBWATERSHED

The Tributary G Subwatershed contains only Tributary G to Tookany Creek.

The assessed length of "G" Tributary is 1.1 miles beginning east of Old York Rd. and Wyncote Rd., Abington, PA. and ending northwest of Church Rd. and Brookside Rd., Cheltenham, PA. Its watershed is 0.54 mi^2, lying in Montgomery County and in the municipalities of Cheltenham Township, Abington Township, and Jenkintown Borough. The land area of the watershed is 23% impervious. The watershed is highly residential with housing accounting for more than 63% of the land use. The remaining land uses are cemetery (2.6%), commercial/manufacturing/utility (7.4%), recreation (13.4%), wooded (6.1%), and roads and parking (7.5%). The assessed section of "G" Tributary was divided into 5 reaches with an average reach length equal to 1,162 ft.

3.1.4 ROCK CREEK SUBWATERSHED

The Rock Creek Subwatershed contains Rock Creek and Tributary M to Rock Creek.

Rock Creek

The assessed length of the Rock Creek is 2.5 miles beginning northwest of Cheltenham Ave. and Mt. Pleasant Ave., Cheltenham, PA. and ending east of Ivy Ln. and Chelten Hills Dr., Cheltenham, PA. It enters the mainstem between MS32 and MS34. Its watershed is 1.41 mi^2, lying in both Philadelphia and Montgomery Counties and in the municipalities of the City of Philadelphia, Cheltenham Township, and Springfield Township. The land area of the watershed is 34% impervious. The watershed is rather diverse in its land uses. The largest land use is residential (49.9%). The remaining land area in the watershed is designated as commercial/manufacturing/utility (9.5%), recreation (12.2%), wooded area (12.9%), roads, parking (8.3%), cemetery (7.0%), and water (0.1%). The assessed section of the Burholme Creek was divided into 7 reaches with an average reach length equal to 1,886 ft.

Tributary M

The assessed length of "M" Tributary is 0.58 miles beginning at north of Rices Mill Rd. and Salisbury Rd., Cheltenham, PA. and ending south of Rock Creek Dr. and Lorimer Ave., Cheltenham, PA. It enters Rock Creek between H6 and H8. Its watershed is 0.4 mi^2, lying in Montgomery County and in the municipality of Cheltenham Township. The land area of the watershed is 20% impervious. The watershed is rather diverse in its land uses. The largest land use is residential (58.3%). The remaining land area in the watershed is designated as commercial/manufacturing/utility (4.9%), recreation (16.1%), wooded area (9.6%), and roads and parking (11.1%). The assessed section of "M" Tributary was divided into 2 reaches of 1,770 ft and 1,289 ft respectively.

3.1.5 BAEDER CREEK SUBWATERSHED

The Baeder Creek Subwatershed contains Baeder Creek (I) and West Branch Baeder Creek (K).

Baeder Creek

The assessed length of the Baeder Creek is 1.6 miles beginning southwest of Jericho Rd. and Susquehanna Rd., Abington, PA and ending at southwest of Mt. Carmel and Highland Aves., Abington, PA. It enters the mainstem between MS20 and MS22. Its watershed is 1.1 mi^2, lying in Montgomery County and in the municipalities of the Abington Township and Jenkintown Borough. The land area of the watershed is 26% impervious. The watershed is mostly residential with 2/3 of the land occupied by housing. The 2nd largest land use is devoted to commercial, manufacturing, and utility infrastructure, accounting for just over 15%. The remaining land in the watershed is parceled out between roads and parking (5.7%), recreational facilities (4.2%), wooded areas (8.0%), and vacant land (0.1%). The assessed section of the Baeder Creek was divided into 6 reaches with an average reach length equal to 1,418 ft.

West Branch Baeder Creek

The assessed length of the West Branch Baeder Creek is 0.38 miles beginning north of Charles St. and Ghost Rd., Abington, PA and ending east of Pleasant and Highland Aves., Abington, PA, where it confluences with Baeder Creek between I6 and I8. Its watershed is 0.3 mi^2 lying in Montgomery County and in the municipality of Abington Township. The land area of the watershed is 21% impervious. The watershed is rather diverse in its land uses. The largest land use is residential (46.7%). The remaining land area in the watershed is designated as commercial/manufacturing/utility (7.7%), recreation (12.5%), wooded area (18.5%), roads and parking (6.7%), and vacant land (7.8). The assessed section of the West Branch Baeder Creek was divided into 2 reaches of 829 ft and 1,166 ft respectively.

3.1.6 JENKINTOWN CREEK SUBWATERSHED

The Jenkintown Creek Subwatershed contains an Unknown Tributary (C) to Jenkintown Creek, an Unknown Tributary (D) to Jenkintown Creek, and Jenkintown Creek (J).

Jenkintown Creek

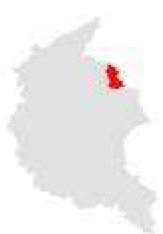
The assessed length of the Jenkintown Creek is 2.6 miles beginning just south of Meetinghouse Rd. and Red Rambler Rd., Abington, PA and ending southwest of Tookany Creek Parkway and Jenkintown Rd., Cheltenham, PA., where it enters the mainstem between MS52 and MS54. Its watershed is 1.0 mi^2, lying in Montgomery County and in the municipalities of the Abington Township and Cheltenham Township. The land area of the watershed is

22% impervious. The watershed is mostly residential with 65.1% of the land occupied by housing. The 2nd largest land use is devoted to wooded area accounting for just over 19.2%. The remaining land in the watershed is parceled out between roads and parking (3.3%), recreational facilities (3.1%), commercial, manufacturing, and utility infrastructure (7.0%), cemetery (1.2%), water (0.9%), and vacant land (0.2%). The assessed section of the Jenkintown Creek was divided into 10 reaches with an average reach length equal to 1,360 ft.

Tributary C
The assessed length of "C" Tributary is 0.35 miles beginning west of Valley Glen Rd. and Glenmoore Ave., Abington, PA and ending southwest of Valley Glen Rd. and Township Line Rd. Cheltenham, PA., where it enters the Jenkintown Creek between J12 and J14. Its watershed is 0.167 mi^2, lying entirely in Montgomery County in the municipality of Abington Township. The land area of the watershed is 22% impervious. The watershed is mostly residential with 56% of the land occupied by housing. The 2nd largest land use is devoted to portions of St. Mary's, Lawnview, and Montefiore Cemeteries, accounting for just under 26%. The remaining land in the watershed is divided between roads, and parking (6.4%), wooded areas (10.2%), and recreational area (1.4%). The comparatively short length (1,848 ft) and rather uniform features allowed for 1 reach to suffice in classifying the stream's physical characteristics.

Tributary D
The assessed length of "D" Tributary is 0.33 miles beginning ¼ mile west of Meethinghouse Rd. and Fairacres Rd., Abington, PA and ending ¼ mile west of Foxchase Rd. and Pondview Rd., Abington, PA., where it enters the Jenkintown Creek between J2 and J4. Its watershed is 0.13 mi^2, lying entirely in Montgomery County and in the municipalities of Abington Township and Jenkintown Borough. The land area of the watershed is 14% impervious. The watershed is mostly residential with 56% of the land occupied by housing. The 2nd largest land use is devoted to Abington Friends Cemetery, accounting for just over 31%. The remaining land in the watershed is divided between roads and parking (1.5%) and wooded areas (11.9%). The short length of "D" Tributary (1,727 ft) allowed for 2 reaches to suffice in classifying the stream's physical characteristics. The reach lengths were 1,341 ft and 386 ft respectively.

3.1.7 EAST JENKINTOWN CREEK SUBWATERSHED



The East Jenkintown Creek Subwatershed contains only the East Branch of Jenkintown Creek.

The assessed length of the East Branch of the Jenkintown Creek is 0.75 miles beginning at Forrest Ave. just below Foxchase Rd., Abington, PA and ending southwest of Dogwood Ln. and Pinewood Dr., Abington, PA. Its watershed is 0.45 mi^2, lying entirely in Montgomery County and in the municipality of Abington Township. The land area of the watershed is 10% impervious. The watershed is rather diverse in its land uses. The largest land uses are residential (36.0%) and wooded area (24.8%). The remaining land in the watershed is designated as commercial/manufacturing/utility (12.6%), recreation (8.6%), agriculture (9.9%), cemetery

(5.8%), roads and parking (1.5%), and vacant land (0.8%). The assessed section of the East Branch was divided into 2 reaches of 1,963 ft and 1,993 ft respectively.

3.1.8 MILL RUN SUBWATERSHED

The Mill Run Subwatershed contains only Mill Run.

The assessed length of Mill Run (MR) is 1.1 miles beginning southwest of Coventry Ave. and Valley Rd., Cheltenham, PA and ending northeast of Mulberry Ln. and Ashbourne Rd., Cheltenham, PA., where it enters the mainstem between MS44 and MS46. Its watershed is 1.6 mi^2, lying in both Philadelphia and Montgomery Counties and in the municipalities of the City of Philadelphia and Cheltenham Township. The land area of the watershed is 45% impervious. The watershed is highly residential with almost 76% of the land occupied by housing. The 2nd largest land use is devoted to commercial, manufacturing, and utility infrastructure, accounting for just over 7%. The remaining land in the watershed is parceled out between roads and parking (5.2%), recreational facilities (2.9%), cemetery (6.4%), and wooded areas (2.3%). The assessed section of Mill Run was divided into 6 reaches with an average reach length equal to 985 ft.

4 RESULTS

4.1 BANKFULL CALIBRATION RESULTS

Principal bankfull indicators for the Tookany/Tacony-Frankford Creek mainstem consisted of watermarks, cobble and gravel bars, and undercut banks. Identifying bankfull indicators was most difficult in headwater segments, due to the widespread extent of channelization and streambank stabilization structures installed by private homeowners/landowners. Dominant bankfull indicators used throughout the mid-section of Tookany/Tacony-Frankford consisted of the back of gravel/cobble bars when there was evidence that the bar was actively forming, and the top of gravel/cobble bars when there was evidence that the bar had completed forming. Progressing downstream, bankfull indicators consisted of undercut trees and watermarks on large debris within the channel.

As stated previously in section 2.5.2, field-identified bankfull elevations and corresponding discharges were calibrated using a regression relationship based on modeling results and regional curves, as well as analyses of drainage area characteristics like impervious percentages, slopes, outfall areas, and potential impacts of dams and channels. Bankfull discharges for each cross section location are listed in **Appendix C – Measured Reach Cross Section Graphs**.

4.2 INFRASTRUCTURE INVESTIGATION

In addition to qualitative data collection and cross section measurements, other channel characteristics were observed throughout the Tookany/Tacony-Frankford watershed that influence channel stability. Dominant influences on channel stability throughout the watershed, aside from land use, consisted of utility infrastructure, bridges, culverts, and dams.

4.2.1 UTILITY STRUCTURES (MANHOLES, OUTFALLS, PIPES)

A total of 445 utility structures were observed to be present throughout the Tookany/Tacony-Frankford Watershed, either within the channel or within close vicinity of the channel. This figure includes 114 Manholes, 291 Outfalls, and 40 Pipes. The principal utilities present consisted of sanitary and storm sewer infrastructure. Manholes, various pipes, and outfalls associated with these systems were located within and/or along the channel banks. Overall, most systems were observed in good or fair condition, but a small number of these features were considered an immediate concern to water quality. Those that were considered a concern to water quality consisted of outfalls with discolored dry-weather discharge, exposed sewer pipes, and manholes that were found to be in poor condition. Outfalls, manholes, and exposed sewer pipes in poor condition have been depicted in **Figure 20** - **Priority Infrastructure Sites by Subwatershed** within Section 5 of this report. It should be noted that the presence of any utility associated structures was considered an immediate concern to channel stability and also water quality as it relates to increased sediment supply. **Appendix D** contains summary sheets documenting infrastructure results and visual depictions of locations within the stream reach.

4.2.2 DAMS

A total of 47 dams were found to be present within the Tookany/Tacony-Frankford Creek Watershed. Possible historical uses consist of irrigation, power generation for the milling industry, and/or water supply. Of the 47 identified dams, zero appeared to have been constructed to provide any flood storage. It is likely that each of theses dams is impacting the channel downstream to some degree. Potential adverse impacts of these dams consist of:

- ✓ impacting or eliminating fish species,
- ✓ decreasing baseflow,
- ✓ excessive aggradation (deposition of fine sediments) upstream of the dam,
- ✓ changes to the sediment supply regime downstream of the dams,
- ✓ changing and/or potentially eliminating aquatic habitat,
- ✓ changing channel geometry, and
- ✓ influencing the riparian vegetation.

Beside the sediment accumulation issues behind the dams, the impacts of the existing dams in the Tookany/Tacony-Frankford Creek Watershed are difficult to assess without knowing, or having data for conditions that existed prior to their installation. However, future impacts may be monitored over time to gain additional insight regarding how to manage the existing dams and minimize any future impacts to the channels downstream.

4.2.3 CHANNELS

There are 168 channelized portions of varying lengths in the Tookany/Tacony-Frankford Creek Watershed. In general, these structures were put in place to stabilize banks as residential and commercial development began to encroach upon the riparian areas of the Creek. Channelized sections of creek can be harmful to both the habitat and the stability of the stream. Channelized streams disrupt the riffle-pool sequencing needed to support aquatic organisms. This has the effect of reducing habitat diversity which in turn reduces ecological diversity within the creek environment. Accompanying channelization of streams is also the removal of woody debris and overhanging vegetation that are present in streams with natural riparian areas. These habitat features are generally supportive of high densities of aquatic macroinvertebrates and other stream life. Channelized sections may also create downstream impacts by increasing velocities such that bank and bed erosion occurs in the more natural stream areas.

4.2.4 CULVERTS

The Tookany/Tacony-Frankford Creek Watershed contains 107 culverted sections of varying lengths. These sections can have similar, if not more severe impacts on the health of the stream as channelization. Because culverts completely enclose the stream, they in addition to increasing flow velocity, provide absolutely no supporting habitat for native species.

4.2.5 BRIDGES

Within the Tookany/Tacony-Frankford Creek Watershed, there are 32 bridges that contact the stream at some point. Bridges are important because they may significantly influence the hydraulic efficiency of the stream if portions of the bridge structure intrude into the bankfull or floodprone channel. The changes in the velocity distribution can impact channel geometry by causing scour in the vicinity of the structure. In addition, bridge abutments can cause the channel to significantly widen due to these changes in the flow regime. As a result, such structures are extremely important to consider when evaluating a stream.

4.3 STREAM REACH RANKINGS

Stream reach ranking was determined by combining channel stability and habitat ranking values for each reach. Usually this ranking, the worst ranked reach was G4, which had a total score of 97/155 (stability score of 60/100 and a habitat score of 37/55). The best ranked reach was MS78, which had a total score of 39/155 (stability score of 16/100 and a habitat score of 23/55). **Table 11** and **Figure 17** provide the total stability and habitat ranking values for each reach. All habitat and stability parameter values assigned to each reach can be referenced in **Appendix E – Reach Ranking Spreadsheets**.

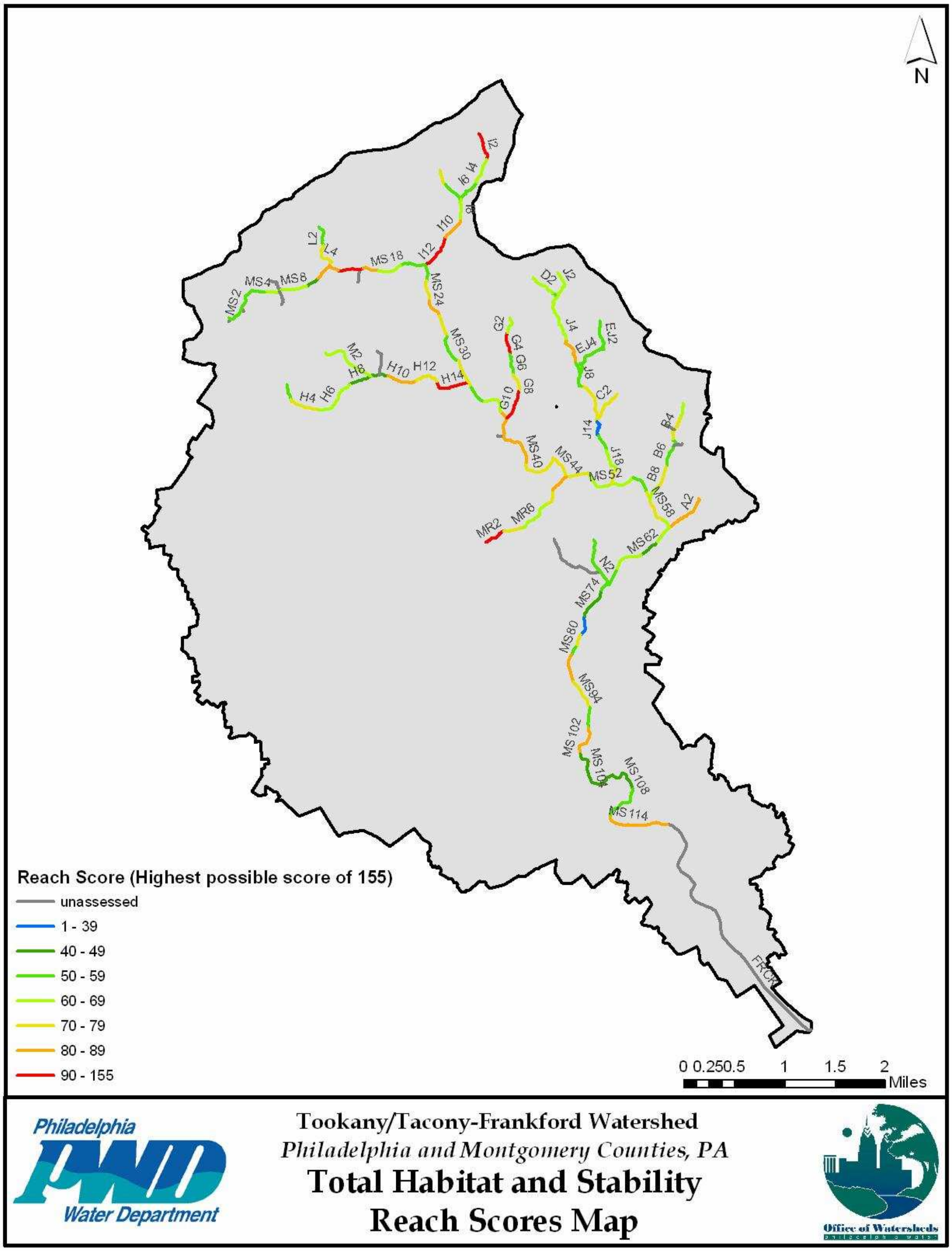


Figure 17 - Total Stream Reach Rankings

Reach	Total Stability Reach Score	Total Habitat Reach Score	Total Stability and Channel Reach Score (Worst to Best)
G4	60	37	97
MR2	62	33	95
H14	53	42	95
I2	59	34	93
MS14	60	32	92
G10	53	38	91
I12	58	32	90
MS120	61	28	89
J6	54	35	89
MR12	44	44	88
I10	44	44	88
H10	54	32	86
MS102	62	23	85
MS16	48	36	84
MS40	46	37	83
MS114	50	33	83
A2	52	31	83
MS26	48	35	83
MS88	53	30	83
MS38	42	40	82
MS12	44	37	81
B8	38	41	79
J10	47	31	78
MS44	37	40	77
G8	44	33	77
MS94	48	28	76
MR4	41	35	76
H12	39	37	76
MS32	46	30	76
MS46	32	43	75
MS24	40	35	75
L4	47	27	74
MR10	42	32	74
MS80	27	45	72
J12	43	29	72
J20	36	35	71
K2	42	29	71
MS28	39	32	71
MS42	35	35	70
C2	32	38	70
MS58	40	30	70
B4	33	37	70
H4	38	32	70
B2	34	35	69
MR6	38	31	69
MS36	34	35	69
MS50	36	32	68
G2	27	41	68
MS64	30	38	68
MS18	37	30	67
MS52	31	36	67

Reach	Total Stability Reach Score	Total Habitat Reach Score	Total Stability and Channel Reach Score (Worst to Best)
H6	43	24	67
MS8	31	35	66
MS70	31	35	66
I4	29	37	66
J4	31	35	66
MS48	28	37	65
I8	41	24	65
J18	33	31	64
M2	33	30	63
MS60	36	27	63
MS6	38	25	63
MR8	32	30	62
B10	36	25	61
M4	34	27	61
MS54	30	31	61
J2	36	24	60
D2	32	28	60
MS30	39	20	59
MS72	20	39	59
N2	20	39	59
MS110	31	27	58
MS112	27	31	58
K4	27	29	56
MS86	23	33	56
G6	28	28	56
B6	37	18	55
L2	19	36	55
MS100	28	26	54
MS34	30	24	54
EJ2	31	22	53
MS22	14	39	53
MS56	29	24	53
MS20	13	39	52
MS4	34	18	52
H2	32	19	51
D4	35	16	51
EJ4	36	15	51
I6	34	17	51
J8	24	26	50
J16	24	26	50
MS2	34	16	50
MS74	26	23	49
MS108	21	28	49
MS104	29	19	48
MS76	26	22	48
H8	25	22	47
MS10	23	23	46
MS62	26	19	45
MS106	19	24	43
J14	21	18	39
MS78	16	23	39

Table 11 - Total Stream Reach Rankings

4.4 SUBWATERSHED RANKINGS

When analyzing the habitat and stability reach rankings over a subwatershed scale (**Table 12** and **Figure 18**), Tributary 'G' was determined to be the unhealthiest subwatershed based upon the ranking scheme utilized in this study. This was a result of having 2 of its reaches (G4, G10) in the top 6 list of worst reaches, and 3 of its reaches (G4, G10, G8) in the top 25 list of worst reaches. Another interesting result was the variability of the various mainstem subwatersheds within this analysis. Overall, the majority of the upper subwatersheds of the mainstem (MS.2, MS.3, MS.4, and MS.5) placed in the unhealthier half of the distribution based on this analysis. However, MS.1 was ranked third best among all subwatersheds. In contrast, the lower mainstem subwatersheds were generally considered healthier. Further analysis shows this was due in large part to presence of positive habitat characteristics surrounding the mainstem of Tacony Creek in the City of Philadelphia, where most of the adjoining land is owned and managed by the Fairmount Park Commission.

Subwatershed - Subwatershed Code			Habitat	Stability	Total
Tributary G Sub-watershed	-	GW	36	44	80
Mill Run Sub-watershed	-	MRW	34	44	78
Tookany/Tacony-Frankford Creek Sub-watershed MS.4	-	MS.4W	35	39	75
Baeder Creek Sub-watershed	-	IW	31	43	74
Tookany/Tacony-Frankford Creek Sub-watershed MS.3	-	MS.3W	30	42	72
Tookany/Tacony-Frankford Creek Sub-watershed MS.5	-	MS.5W	37	34	72
Tookany/Tacony-Frankford Creek Sub-watershed MS.2	-	MS.2W	35	35	70
Tookany/Tacony-Frankford Creek Sub-watershed MS.9	-	MS.9W	30	39	69
Rock Creek Sub-watershed	-	HW	30	39	69
Burholme Creek Sub-watershed	-	BW	30	36	66
Tookany/Tacony-Frankford Creek Sub-watershed MS.6	-	MS.6W	30	35	66
Jenkintown Creek Sub-watershed	-	JW	30	35	64
Tookany/Tacony-Frankford Creek Sub-watershed MS.8	-	MS.8W	24	38	62
Tookany/Tacony-Frankford Creek Sub-watershed MS.1	-	MS.1W	27	35	62
Tookany/Tacony-Frankford Creek Sub-watershed MS.7	-	MS.7W	32	28	60
East Branch Jenkintown Creek Sub-watershed	-	EJW	34	18	52

Table 12 - Average Area-weighted Subwatershed Rankings

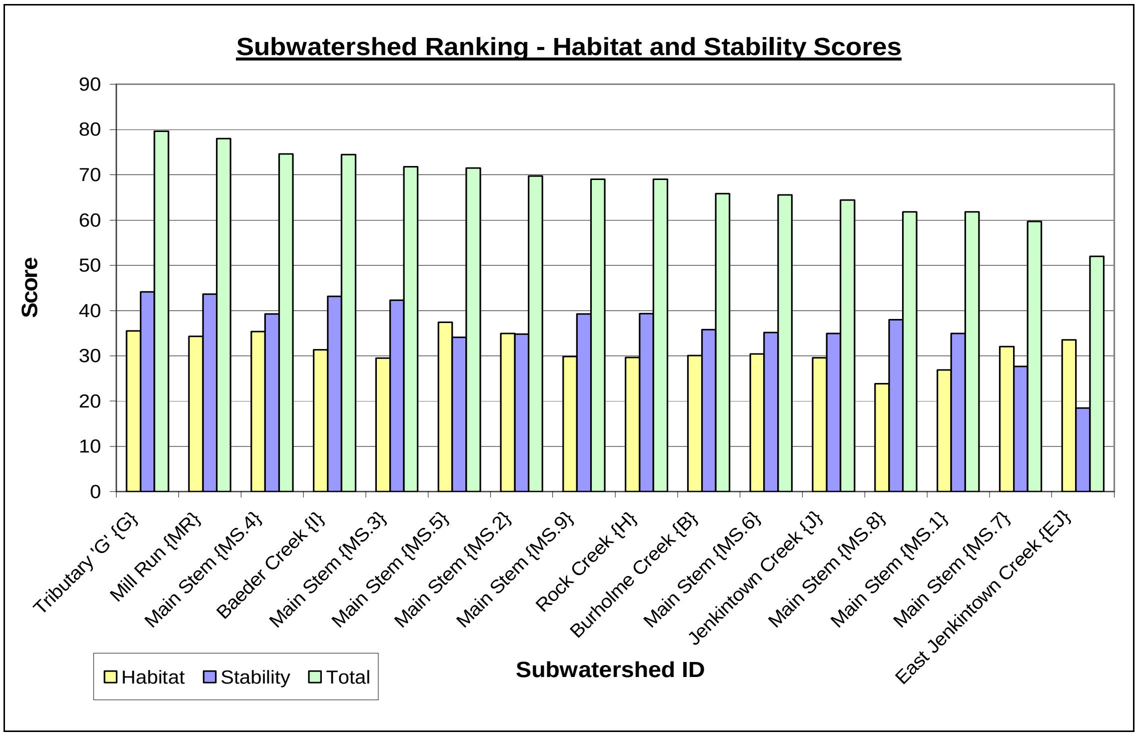


Figure 18– Subwatershed Habitat and Stability Score

4.5 SUBWATERSHED PERCENT IMPERVIOUSNESS

The Subwatershed Percent Imperviousness values (**Table 13**) were determined by area-weighting the Percent Imperviousness values for the areas that directly contributed to the reaches contained within each subwatershed.

Sub-watershed	Sub-watershed Code	Total Area (mi^2)	Impervious Area (mi^2)	% Imperviousness
Mainstem Sub-watershed MS.8	MS.8W	4.43	2.94	66%
Mainstem Sub-watershed MS.9	MS.9W	9.25	5.35	58%
Mill Run Sub-watershed	MRW	1.64	0.74	45%
Mainstem Sub-watershed MS.7	MS.7W	1.22	0.5	41%
Mainstem Sub-watershed MS.6	MS.6W	1.25	0.45	36%
Rock Creek Sub-watershed	HW	1.81	0.56	31%
Mainstem Sub-watershed MS.2	MS.2W	1.45	0.43	30%
Mainstem Sub-watershed MS.3	MS.3W	1.06	0.27	25%
Baeder Creek Sub-watershed	IW	1.38	0.34	25%
Tributary G Sub-watershed	GW	0.54	0.12	23%
Mainstem Sub-watershed MS.4	MS.4W	1.2	0.27	22%
Jenkintown Creek Sub-watershed	JW	1.31	0.28	21%
Mainstem Sub-watershed MS.5	MS.5W	0.7	0.15	21%
Mainstem Sub-watershed MS.1	MS.1W	1.91	0.36	19%
Burholme Creek Sub-watershed	BW	0.66	0.11	17%
East Branch Jenkintown Creek Sub-watershed	EJW	0.45	0.04	10%

Table 13– Subwatershed % Imperviousness

As expected, the more urbanized areas within the City of Philadelphia which contribute to the Tookany/Tacony-Frankford Creek had the greatest relative amount of impervious surfaces (**Figure 19**). MS.7, MS.8, and MS.9 are subwatersheds that are almost entirely within the City limits, with MS.6 including areas both inside and outside the City limits. The sub-watersheds within the City of Philadelphia contrasted with the sub-watersheds in the surrounding suburbs, as percent imperviousness values inside the City were generally much greater than in the suburbs.

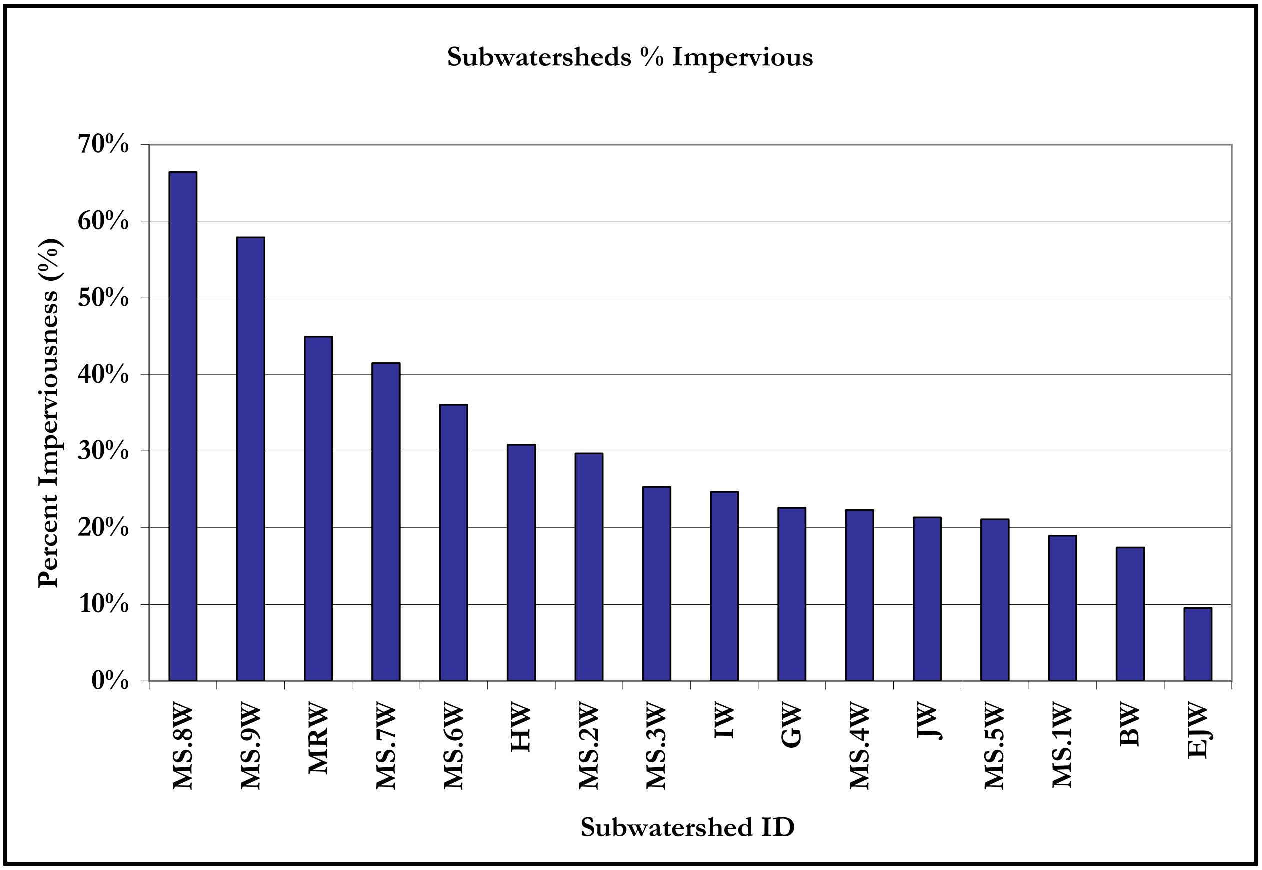


Figure 19– Subwatershed % Imperviousness

4.6 GIS LAYER CREATION

During the progression of this study and development of this report, multiple GIS shapefiles were created to aid in the further analysis. These shapefiles were created and edited in ArcGIS 9.x. **Appendix F** contains the metadata for all shapefiles used in the generation of statistics and graphics and metadata for the shapefiles created to display the findings of the study.

5 RECOMMENDATIONS AND CONCLUSION

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 key 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 subwatershed 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 Tookany/Tacony-Frankford Watershed and adjoining stream corridors 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 Tookany/Tacony-Frankford 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.

5.1 RESTORATION STRATEGY CATEGORY I: CHANNEL STABILITY & INFRASTRUCTURE

5.1.1 BANK STABILIZATION

Many parameters that were evaluated throughout the Tookany/Tacony-Frankford 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 overwidening 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.

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.

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. In general, potential realignment and relocation projects may be appropriate for segments of stream that have poor bank and bed parameter scores over consecutive reaches.

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.

5.1.5 CSO / STORMWATER OUTFALLS

Two-hundred and ninety (290) outfalls greater than 12" in diameter were found in Tookany/Tacony-Frankford watershed. Thirty-seven (37) of these outfalls were greater than 3 feet in diameter. Due to their size and density within the watershed and the degree to which they may cause local erosion, stormwater outfalls were considered one of the most important features in ranking 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.

5.1.6 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.

5.1.7 DAM AND POND IMPACTS

There are 47 dams present within the Tookany/Tacony-Frankford Creek that provide little or no positive value to the hydraulic regime of the stream. These dams are run-of-the-river dams that do not provide any significant flood storage. 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 Tookany/Tacony-Frankford watershed, most of which are associated with golf courses, large estates and developments. Ponds often develop serious management problems, with algal blooms, solar heating of stream water and overabundant resident Canadian geese.

Despite this fact, the installation of these structures may 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.

5.1.8 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 manholes, pipes, and outfalls that exhibited the characteristics of being broken, exposed, or the potential of such based upon their proximity to the stream and ongoing bank erosion. In total, 82 points of infrastructure were identified that had some issue that caused it to be classified as in poor condition. The locations of these points can be found on **Figure 20**, which highlights their subwatershed locations.

Reach by reach summaries, statistics, and location maps of all points of infrastructure are documented in detail in **Appendix D**.

5.1.9 DEBRIS REMOVAL

Debris, or trash, was most abundant in Tookany/Tacony-Frankford Creek within the City of Philadelphia, although it was also present within the outlying stream reaches to a certain degree as well. Manual removal and installing trash racks are methods that could be implemented to decrease debris in the channels. Should removal be feasible, benefits include reestablishing natural flow patterns, decreasing nutrient levels, improved water quality, and improved habitat for macroinvertebrate and aquatic vegetation species. It should be noted that accumulation of coarse woody material is often beneficial for the aquatic habitat that it provides, and it may be difficult to achieve a balance between habitat and stability-related debris removal in an urban watershed.

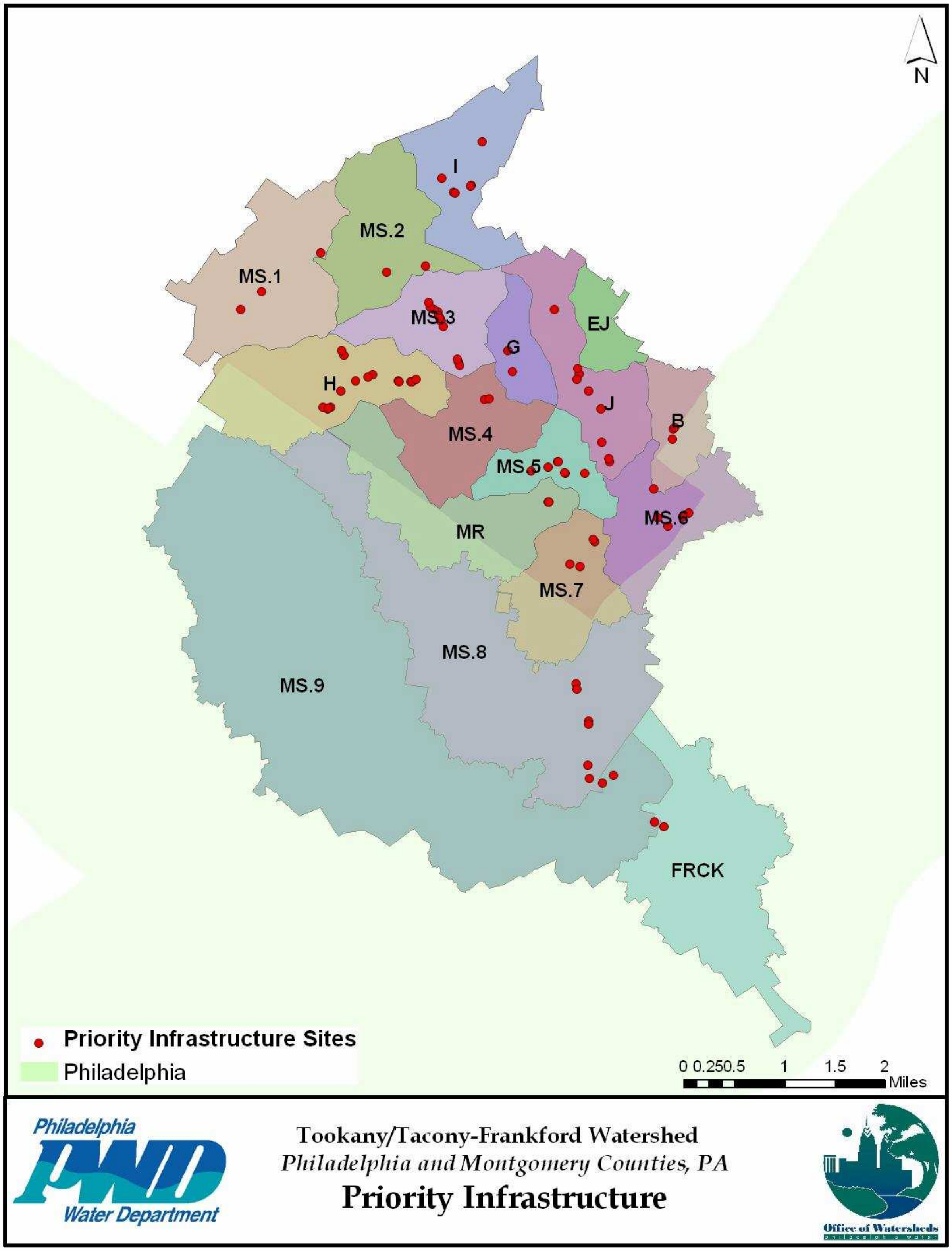


Figure 20 - Priority Infrastructure Sites by Subwatershed

5.2 RESTORATION STRATEGY CATEGORY II: HABITAT

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.

5.2.2 INVASIVE SPECIES MANAGEMENT

Maintaining a healthy riparian plant community along the Tookany/Tacony-Frankford Creek 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. Although a detailed invasive species assessment was not completed for the Tookany/Tacony-Frankford Watershed, Japanese knotweed (*Polygonum cuspidatum*) is the one prevalent invasive species that was observed during the field reconnaissance. In many areas, knotweed, due to its aggressive nature, has already out-competed native vegetation. The Fairmount Park System Natural Lands Restoration Master Plan, completed in 1999, provides a detailed description of invasive species within the Park, known locations and invasive species control measures. The 2004 McNair invasive control study, focusing partly in the Tookany/Tacony-Frankford Watershed, is another valuable reference for invasive species management.

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.

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 are 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.

In April, 2006, A.D. Marble & Company, an environmental and engineering consulting firm, prepared a report documenting a watershed assessment for the Tookany/Tacony-Frankford Watershed. This assessment was completed as part of the Philadelphia Water Department's (PWD) Southeast Regional Wetland Inventory and Water Quality Improvement Initiative (PWD 2002). The assessment includes the entire Tookany/Tacony-Frankford Watershed, in Montgomery and Philadelphia Counties. The primary purposes of the assessment were to assess existing wetlands, evaluate select stormwater outfalls, and identify potential wetland creation sites throughout the Tookany/Tacony-Frankford watershed. When evaluating the potential for creating and enhancing wetlands, the products of this Initiative should be referenced.

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 small amount of 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 has been disturbed are additional strategies to help preserve existing forests.

5.3 RESTORATION STRATEGY CATEGORY III: LAND MANAGEMENT

5.3.1 REDUCE IMPERVIOUS SURFACES

Stream channels within each subshed have responded to high density development and increased runoff through downcutting and overwidening in an attempt to accommodate higher flows. Since there is little 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. These facilities are well suited to the Tookany/Tacony-Frankford Watershed because the majority of the watershed is already developed, especially within and immediately bordering the City of Philadelphia. Available space is limited and the size and shape of bioretention facilities are extremely adaptable.

- ✓ 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.

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.

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 fountains, 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, revegetating 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 2000, the Tookany/Tacony-Frankford 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 Watershed Partnership can be found on the Philadelphia Water Department's website (http://www.phillyriverinfo.org/).

5.4 CONCLUSION

This study was successful in developing a vast dataset for the Tookany/Tacony-Frankford Creek Watershed that was previously unavailable. The study covered approximately 27 miles of stream that drains 33 square miles of surrounding area. The study divided the 27 miles of the Tookany/Tacony-Frankford Creek and its tributaries into 102 reaches with an average length of 1400 feet.

Within each of the 102 reaches, a modified Level II Rosgen Stream Classification was performed to obtain assessment data. Each cross section was selected to represent the overall stability and habitat characteristics present at that particular stretch of stream. Ten (10) stability parameters and eight (8) habitat parameters were measured and/or observed at each of these cross-sections, along with other supporting intermediate parameters such as slope, stream velocity, flow, etc.

In addition to performing the requisite Level II Rosgen analysis, a reach ranking protocol was developed to gauge stream stability and habitat. These parameters were weighted to develop a stability score with a maximum value of 100 and a habitat score with a maximum value of 55. The stability and habitat scores were added with a maximum attainable score of 155. This metric was developed to assign high score values to unhealthy stream reaches and low score values to those stream reaches which consist of comparatively healthy stream characteristics. The top 5 worst ranking reaches as seen in **Table 14** were:

Reach ID	Total Reach Score
G4	97
MR2	95
H14	95
I2	93
MS14	92

Table 14 - Worst Ranked Reaches

Overall, these reaches were dominated by culverts and/or channelized portions over large percentages of its length. In addition, the presence of other infrastructure such as outfalls, low sinuosity, poor habitat characteristics, and bank and bed erosion within these reaches negatively impacted their scores. When evaluated over a subwatershed scale, Tributary "G" ranked worst with a weighted total reach score of 80.

Although this study has produced a metric by which the 102 reaches of the Tookany/Tacony-Frankford Creek delineated can be ranked, it is also recognized that there are an infinite number of methods in which this could have been achieved. In the particular scheme utilized in this study, bias was assigned to the presence of infrastructure such as culverts, channels, and outfalls. These modifications to the natural channel not only impact the precise area where they are located, but also have extremely significant impacts throughout the stream. Culverts, channels, and outfalls contribute high velocity flows that possess high erosive potential to more natural stream bank and bed materials. These conditions cause incising and down-cutting destabilizing the channel and increasing sediment loading to the stream.

In an effort to point toward specific projects, that can directed at remedying problems in stream reaches in poor condition, a collection of restoration strategies was compiled. Projects under the major headings of Channel Stability, Habitat, and Land Management can be initiated to best address issues affecting the health of the Tookany/Tacony-Frankford Creek and its tributaries. However, it is important to note that each of these specific restoration strategies should not be prioritized based upon the total reach ranking scores. The total reach ranking scores were designed to provide a holistic view of each individual reach.

Taken as a whole, the purpose of this study has been achieved. Through the collection of Fluvial GeoMorphologic, survey, stream stability, habitat, and infrastructure data, the tools have been developed to further the goals of our partners in restoring the Tookany/Tacony-Frankford Watershed.

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7 Relevant Reports

NLREEP Tookany/Tacony-Frankford Master Plan

Philadelphia Water Department's (PWD) Southeast Regional Wetland Inventory and Water Quality Improvement Initiative

Tookany/Tacony-Frankford Comprehensive Characterization Report

8 APPENDIX