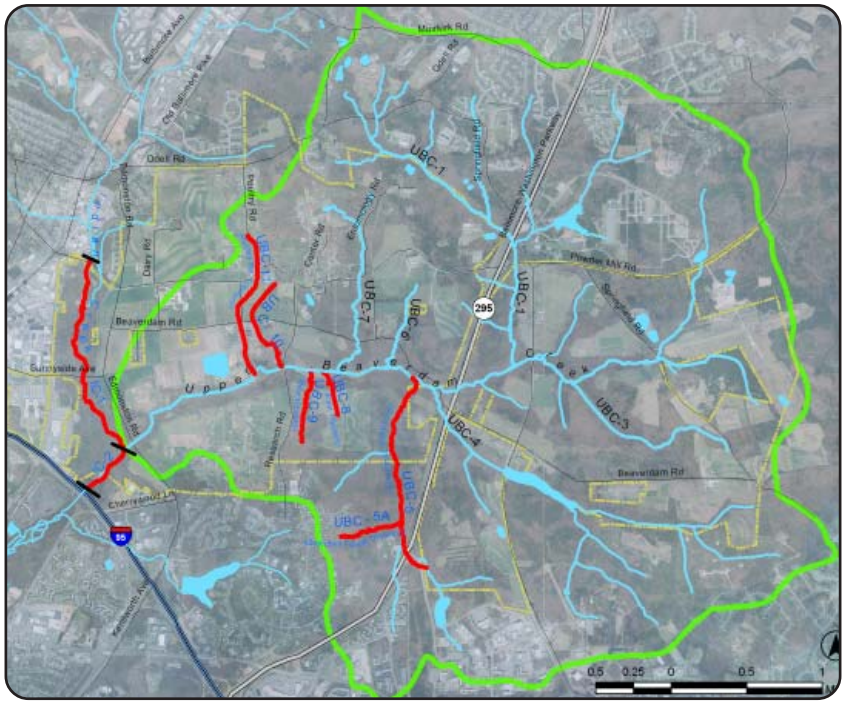
Technical Memorandum

Anacostia Tributary Streambank Erosion Study

Phase II-A

Upper Beaverdam and Indian Creek Subwatersheds



Prepared for:
Maryland Department of the Environment

Prepared by:
Department of Environmental Programs
Metropolitan Washington Council of Governments

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Prepared for:
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Executive Summary

In partnership with the U.S. Department of Agriculture's Beltsville Agricultural Research Center (BARC) and with funding support from the Maryland Department of the Environment (MDE), the Metropolitan Washington Council of Governments (COG) through its Anacostia Watershed Restoration Program was contracted for Phase II-A in July 2005 to: 1) evaluate current general streambank erosion conditions in the BARC portion of the Upper Beaverdam Creek and Indian Creek subwatersheds, 2) perform limited mainstem and tributary streambank soil chemistry characterization analyses and 3) develop representative permanent channel cross-sections for the surveyed portions of Upper Beaverdam Creek and Indian Creek. The survey described herein consisted of three parts:

- Employment of COG's Rapid Stream Assessment Technique (RSAT) to evaluate a total of 5.2 stream miles;
- Streambank soil texture and chemistry characterization (upper, middle and lower bank portions) for six representative tributary stream areas and three Indian Creek mainstem areas, respectively; and
- The establishment of 21 permanent, geo-referenced channel cross-sections;

With the exception of UBC- 8 (East Tributary) and UBC-11 (Poultry Road Tributary) this baseline study confirmed that the 3.3-mile-long Upper Beaverdam Creek tributary streambank network is actively eroding. In addition, the 1.9 mile of Indian Creek streambank network below Powder Mill Road also exhibits active erosion conditions.

Additional major findings of the survey are described in the following sections.

1. Streambank Erosion

Upper Beaverdam Creek Tributary System

Mean streambank stability for the UBC-5 (Goddard Tributary) UBC-5A (Greenbelt Forest Tributary), UBC-8 (East Tributary), UBC-9 (West Tributary) and UBC-11 (Poultry Road Tributary) (i.e., 68.0, 59.8, 92.1, 62.2, and 79.9 percent, respectively) were rated as being fair to excellent. RSAT Upper Beaverdam Creek tributary streambank erosion results and totals are as follows: 2,590.5 linear feet of severe bank erosion (<7.5 percent of the total length), 3,574.8 linear feet of moderate/ severe streambank erosion (10.3 percent of the total length) and 9,909.9 linear feet of moderate erosion (28.7 percent of the total length). It should be noted that more than 87 percent of the Goddard tributary streambank network generally fell between the moderate to severe categories. Stream channel survey results revealed that only UBC-8 (East Tributary) mean streambank heights fell within the expected or reference condition bank height range of one to two feet. However, mean bank heights for UBC-9 and UBC-11 were generally 1 to 2 feet higher than the expected or reference condition. For the UBC-5 and UBC-5A surveyed stream segments, mean bank heights were generally 2 feet or higher than the expected or reference condition. Results for UBC-5 (Goddard Tributary) strongly suggest that moderate to severe channel downcutting has taken place.

Indian Creek

Mean streambank stability for IC-1, Powder Mill Road to Upper Beaverdam Creek confluence and IC-2, Upper Beaverdam Creek confluence 0.7 miles downstream were 68.2 (fair range) and 75.3 (good range) percent, respectively. RSAT Indian Creek streambank network erosion results and totals are as follows: 142.3 linear feet of severe streambank erosion (0.7 percent of the total length), 1,374.1

linear feet of moderate/severe erosion (6.8 percent of the total length) and 7,255.6 linear feet of moderate streambank erosion (35.9 percent of the total length). It should be noted that the severe streambank erosion condition were observed upstream of the Upper Beaverdam Creek confluence and (5.5 percent of the total stream length). Stream channel survey results further revealed that IC-1 and IC-2 mean streambank heights fell within the expected or reference condition bank height ranges of two-three feet and three-four feet, respectively.

2. Stream Channel Cross-Sections

Upper Beaverdam Creek Tributary System

Cross-sectional analysis results revealed that the mean cross-sectional area of the Upper Beaverdam Creek tributaries are as follows: UBC-5 = 68.67 ft^2, UBC-5A = 25.94 ft^2, UBC-8 = 10.93 ft^2, UBC-9 = 41.71 ft^2 and UBC-11 = 47.96 ft^2. With the exception of UBC-8 (East Tributary), tributary channel widths and bank heights were all (for their respective drainage areas) generally wider and higher than the expected or reference condition. Specifically, mean tributary streambank heights were on the order of one to 2.5 feet higher than the expected or reference bank height ranges (i.e., 1-2 feet). Notably, the highly entrenched UBC-5 (Goddard Tributary) and UBC-9 (West Tributary) exhibited mean bank heights which were approximately 2.5 feet higher than expected bank height range.

Indian Creek

Indian Creek stream mean cross-sectional area results are as follows: IC-1 (Powder Mill Road to Upper Beaverdam Creek confluence) = 88.48 ft^2, and IC-2 (Upper Beaverdam Creek confluence to 0.7 miles downstream) = 136.97 ft^2. Both IC-1 and IC-2 fell within the expected or reference condition bank height range of three to four feet.

3. Streambank Riparian Habitat Conditions

Upper Beaverdam Creek Tributary System

Riparian habitat conditions (Table 6) for the UBC-5 (Goddard Tributary), UBC-5A (Greenbelt Forest Tributary), UBC-8 (East Tributary), UBC-9 (West Tributary) and UBC-11 (Poultry Road Tributary) surveyed reaches were rated as being good to excellent. Stream canopy coverage was rated as being in the good (i.e., 60-79 percent) to excellent (i.e., >= 80 percent) range. In addition, the forest riparian buffer zones were generally very wide (i.e., ~ 200 feet) and comprised of hardwood forest for UBC-5, and UBC-5A . However, the riparian buffer zones along UBC-8, UBC-9 and UBC-11 were generally narrower than 200 feet. It should be noted that the existing agricultural-related landuse (i.e., crop fields, cattle pastures, etc.) surround the UBC-8, UBC-9 and UBC-11 riparian buffer zones.

Indian Creek

Riparian habitat condition ratings for Indian Creek RSAT system were rated as being good. Generally, stream canopy coverage percentages ranged from 61.9 to 69.2 falling into the good category. In addition, the forest riparian buffer zones were typically wide (i.e., ~ 200 feet) and comprised of hardwood forest.

4. Streambank Soil Texture and Chemistry

Upper Beaverdam Creek Tributary System

Select mainstem streambank soil chemistry results (reported as a range in mg/kg dry weight, unless otherwise noted) are as follows: 1) nitrate-nitrogen = 0.8-5.6, 2) total phosphorus = 175.86-

696.40, 3) organic matter = 1.1-1.9 percent, 4) arsenic = 1.46-6.79, 5) chromium = 10.57-22.83, 6) copper = 6.35-15.58, 7) lead = 8.88-33.91, 8) zinc = 22.22-72.12 and 9) total PCB's = present in trace amounts (i.e., < 0.07 mg/kg) at all six streambank soil chemistry sampling sites.

Indian Creek

Select tributary streambank soil chemistry results (reported as a range in mg/kg dry weight, unless otherwise noted) are as follows: 1) nitrate-nitrogen = 1.3-26.6, 2) total phosphorus = 228.05-381.94, 3) organic matter = 2.1-3.5 percent, 4) arsenic = 2.15-4.58, 5) chromium = 65.97-521.95, 6) copper = 9.36-19.92, 7) lead = 34.57-177.03, 8) zinc = 55.85-167.42 and 9) total PCB's = present in trace amounts (i.e., < 0.07 mg/kg) at all three streambank soil chemistry sampling sites. It should be noted that mean Maryland soil metal background concentrations (mg/kg dry weight) for the above-listed metals are as follows: arsenic = 3.8, chromium = 47.9 copper = 20.0, lead = 22.0 and zinc = 39.0 (U.S. EPA, 2003). Therefore, the soil chemistry results for Indian Creek strongly suggest anthropogenic-related metals contamination/enrichment.

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1.0 Introduction

1.1 Project Background

Streambank erosion is widely recognized as a major source of sediment and various other contaminants in fluvial systems. Recent studies (Simon and Collison, 2002) have shown that more than one-half of the total amount of sediment eroded from stream channels in the southeastern United States originates from streambanks. In addition to sediment, bank erosion is suspected of delivering large quantities of contaminants (e.g., phosphorus and nitrates) to downstream receiving bodies of water such as the Anacostia River and Chesapeake Bay.

For well over 200 years, excessive erosion and subsequent sediment deposition have been a major Anacostia River problem. Because the Anacostia River functions in many ways like a tidal lake, it is a very efficient sediment trap. It has been estimated that approximately 85 percent of the incoming sediment load remains trapped within the river (Scatena, 1987). In addition to adversely impacting navigation, reducing water clarity, degrading aquatic habitat and associated biota, sediment serves as a binding site for a broad range of urban pollutants and toxicants. These include: petroleum hydrocarbons (PAH's), polychlorinated biphenyls (PCB's), pesticides, herbicides, nutrients, metals and bacteria. Sediment-related stream quality degradation in the Anacostia tributary system has been equally devastating. Related impacts include: impairment of pool and riffle habitat through deposition of finer grained sediments such as sand and silt; accelerated streambank and streambed erosion during stormflows; and high suspended solids loads which impair the biological community by obscuring the water for sight feeders and irritating exposed gills.

In an effort to both document the magnitude of current streambank erosion problems and their potential contribution of nutrients and other pollutants of interest to the Anacostia River, the Metropolitan Washington Council of Governments (COG) completed a comprehensive, multi-year streambank erosion assessment of the Maryland portion of the Anacostia tributary system. In 2004, COG completed Phase I assessment of 13.6 open stream miles in the Upper Beaverdam Creek (UBC) subwatershed. In Phase II and II-A COG completed an assessment of 3.3 additional UBC tributary miles as well as, 1.9 miles of the Indian Creek mainstem portion located downstream of Powder Mill Road (Figure 1).

Under Phase II-A, the following tasks were performed: 1) evaluation of current streambank erosion conditions, 2) documentation of stream channel cross-sectional areas, 3) evaluation of riparian forest conditions, and 4) analysis of streambank soil chemical and physical properties. The study represents the start of systematically analyzing both the overall stability of the Anacostia tributary system, as well as the potential contribution of streambank erosion to both local and downstream water quality and physical aquatic habitat problems. It is expected that the data generated from the study will be of value to Maryland Department of Environments in its preparation of Anacostia TMDL's, as well as to the US Army Corps of Engineers in its preparation of the Comprehensive Anacostia Watershed Restoration Plan, and BARC, AWRC and AWTA members and their various sediment and toxics monitoring, modeling and restoration initiatives. A brief description of the study area and each task follows.

1.2 Upper Beaverdam Creek and Indian Creek Subwatersheds

Upper Beaverdam and Indian Creek are free-flowing, MDE Use I tributaries of the Northeast Branch of the Anacostia River (Figure 1). Both subwatersheds are located within Prince George's County, Maryland, and are wholly contained within the Coastal Plain physiographic province. Upper Beaverdam Creek has a drainage areas of 14.1 square miles and is a part of the larger Indian Creek subwatershed that drains 29.2 square miles. Land uses in the two subwatersheds include forest, agricultural lands (including both pasture and row crop), former sand and gravel quarries, garden apartments, single family residential, industrial, institutional and commercial areas and various government building complexes. The majority of the Upper Beaverdam Creek and the surveyed portion of

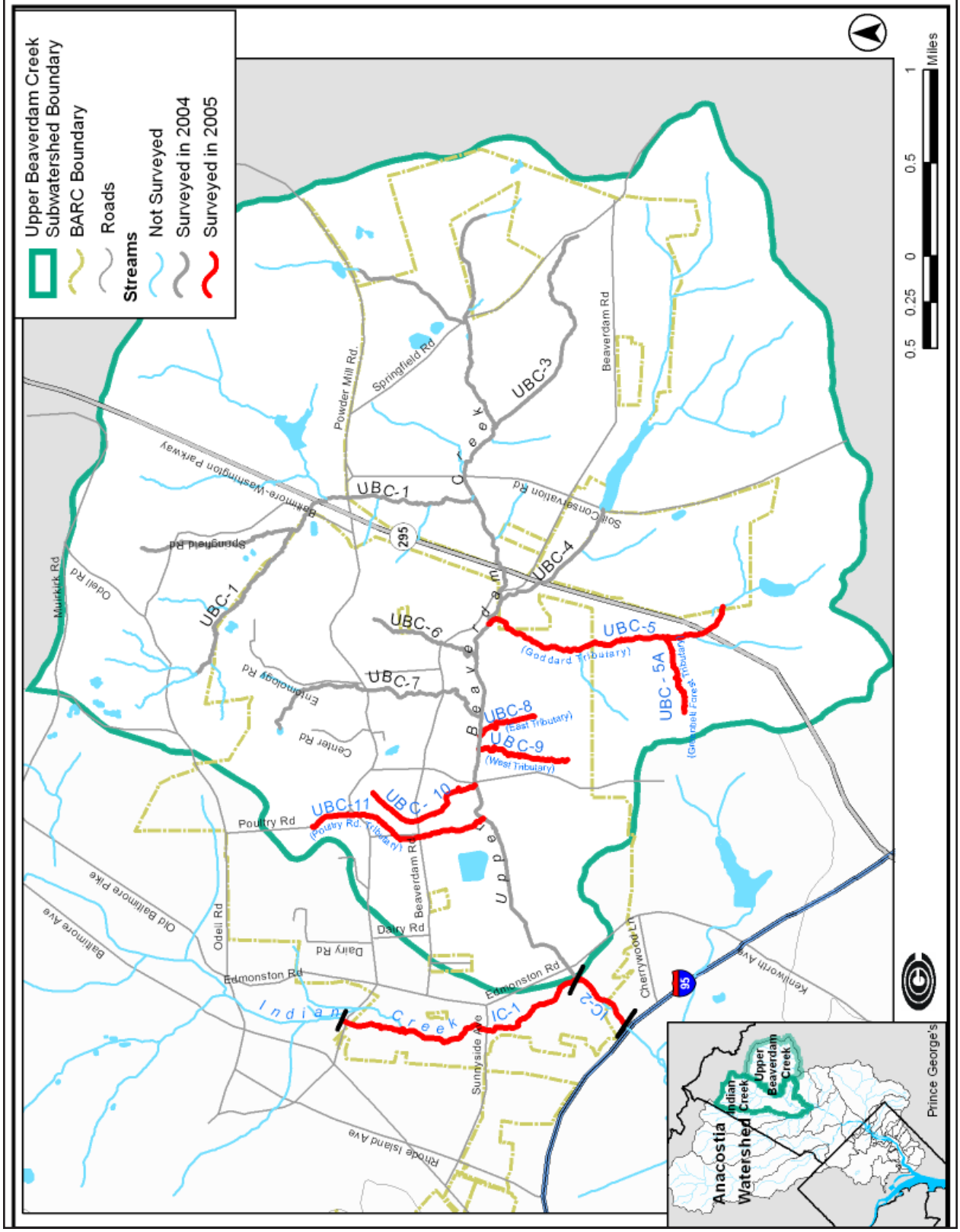


Figure 1: Upper Beaverdam Creek COG Study Area

Indian Creek subwatersheds is owned by the U.S. Department of Agriculture and is operated as the Beltsville Agricultural Research Center (BARC). BARC is a long-time AWRC affiliate and has an excellent working relationship with both the AWRC and COG. Among the 14 major Anacostia subwatersheds, Upper Beaverdam Creek boasts the highest percent forest cover. High nutrient, suspended sediment and high stream turbidity levels continue to plague streams in both subwatersheds. Not surprisingly, casual field surveys conducted by COG staff of the two subject stream systems revealed locally moderate to severe erosion problems associated with uncontrolled stormwater runoff.

2.0 Study Design/Methods

2.1 Upper Beaverdam Creek and Indian Creek Study Area

Under Phase II-A, COG staff completed the modified RSAT field survey for five Upper Beaverdam Creek (UBC) tributaries and a portion Indian Creek for a total of 5.2 miles of open stream channel. As part of this survey, a total of 46 stream transects (spaced on average 400 to 500 feet apart) were established for the Rapid Stream Assessment Technique (RSAT) evaluation portion of the study. The five tributary segments included the UBC-5 (Goddard Tributary), UBC-5A (Greenbelt Forest Tributary), UBC-8 (East Tributary) , UBC-9 (West Tributary), and UBC-11 (Poultry Road Tributary). General Upper Beaverdam Creek tributary background information and RSAT stream transect locations are presented in Table 1 and Figure 2, respectively. For exact locations of transect locations, the reader is referred to Appendix A where latitude/longitude coordinates captured by a Trimble GEO-XT handheld GPS receiver have been included. Field data results tables are included as Appendix B. Under Phase I, II and II-A, COG has surveyed 16.9 miles that includes the mainstem and tributary open stream channels in the Upper Beaverdam Creek as well as, 1.9 miles of the Indian Creek mainstem within the BARC property.

2.2 RSAT Survey

The Rapid Stream Assessment Technique (RSAT) was developed by COG in 1992 to provide a simple, rapid reconnaissance-level assessment of stream quality conditions. The RSAT survey includes six standard evaluation categories (i.e., 1) Bank Stability, 2) Channel Scouring/Sediment Deposition, 3) Physical Instream Habitat, 4) Water Quality, 5) Riparian Habitat Condition and 6) Biological Indicators). For this study a modified RSAT survey has been employed that included only two of the six standard RSAT survey evaluation categories; 1) Streambank Stability Conditions, and 2) Riparian Habitat Condition. In addition, as part of the study both the creation of a photo library and GIS Mapping tasks were involved. A brief overview of the types of field measurements and observations made for the preceding RSAT evaluation categories follow.

1. Streambank Stability

One of the primary assessments of channel stability is overall bank stability, which is evaluated through both a visual estimation of the percentage of bank that is stable along each transect surveyed (expressed as a percentage) and a generalized approximation of the degree of erosion between transects (categorized verbally as stable, slight, slight/moderate, moderate, moderate/severe, or severe). Additional observations factored into the bank stability evaluation include the stability of stream bend areas and the number of recent, large tree falls per stream mile. The relative erodibility of the soil material comprising the bottom one-third of the bank (the area most susceptible to erosion) is also considered.[1] Another factor considered

[1] Relative erodibility describes the erosion potential and is classified as low, moderate or high. Low potential denotes predominantly clay-textured soils, bedrock, saprolite and rip-rap; moderate potential characterizes non-silt or non-clay dominant soil textures; and high potential describes predominantly silt-textured soils.

Table 1: Upper Beaverdam Creek - General Study Area Information

RSAT Stream Segment	Drainage Area (mi^2)	Stream Order[1]	Surveyed Stream Length		Stream Gradient	No. of RSAT Transects
			Feet	Miles		
Tributaries to Upper Beaverdam Creek						
1. UBC-5 (Goddard Tributary)	1.8	2	6,451	1.2	0.37%	12
2. UBC-5A (Greenbelt Forest Tributary)	0.1	1	2,540	0.5	0.78%	3
3. UBC-8 (East Tributary)	0.1	1	1,779	0.3	1.91%	3
4. UBC-9 (West Tributary)	0.2	1	2,429	0.5	1.15%	4
5. UBC-11 (Poultry Rd. Tributary)	0.4	1	4,086	0.8	0.88%	8
Subtotal	- -	- -	17,286	3.3	- -	30
Indian Creek Mainstem						
1. IC-1 (Powder Mill Road to UBC Confluence)	10.3	3	8,198	1.6	0.34%	13
2. IC-2 (UBC Confluence to 0.7mi Downstream)	24.3	4	1,894	0.4	0.32%	3
Subtotal	- -	- -	10,092	1.9	- -	16
Total	**- -**	**- -**	**27,378**	**5.2**	**- -**	**46**

[1] Stream order determination was made using 200 foot scale maps.

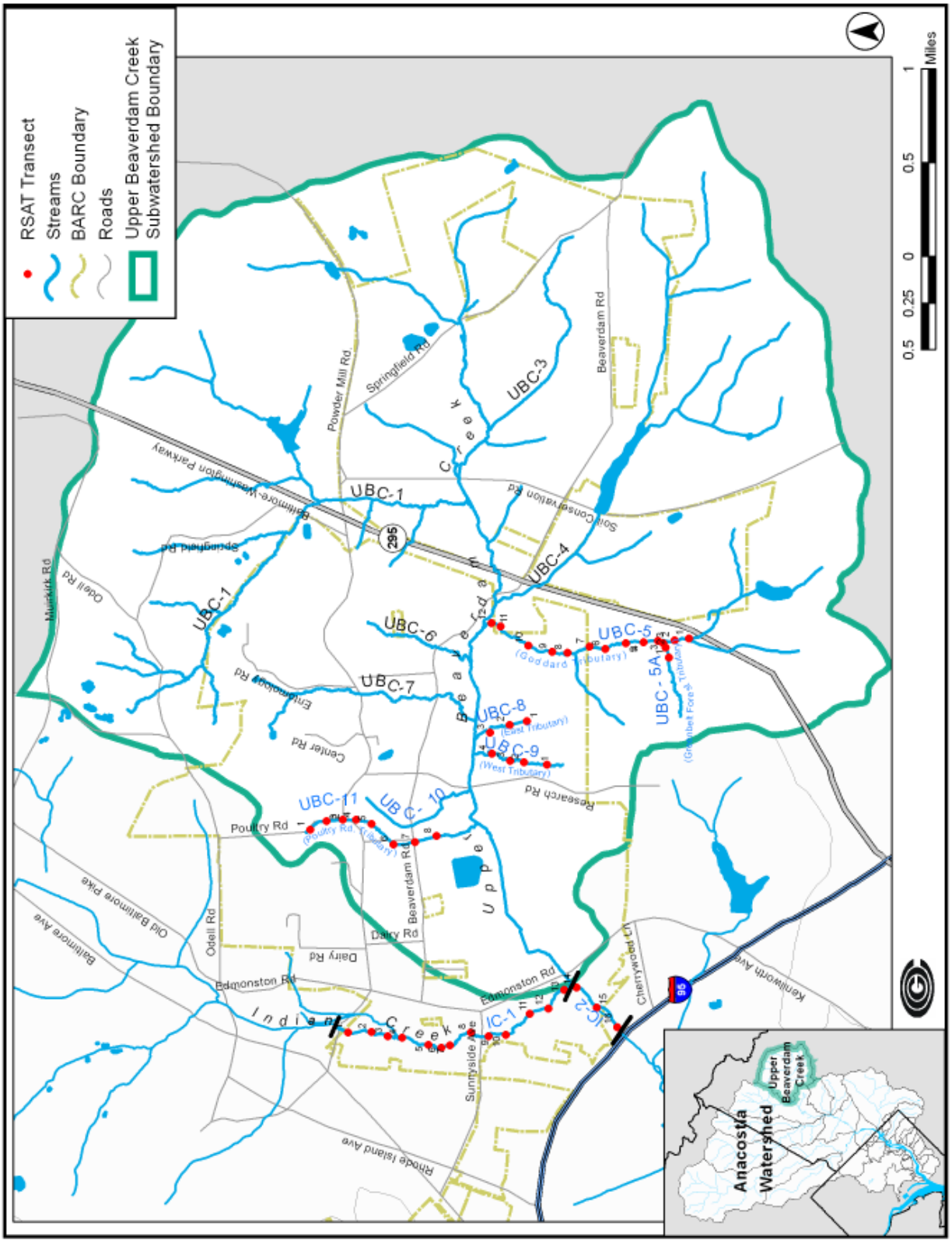


Figure 2: Upper Beaverdam Cree Tributary System - RSAT Transect Station Locations

in assessing channel stability is the degree of channel downcutting, which is evaluated by a set of indicators that includes bank heights, exposed utility lines and nick points.[2]

2. Riparian Habitat

The quality of riparian habitat is evaluated based on: 1) the width of the vegetated buffer zone on the left and right banks and the type of vegetation (a forested buffer rating highest) and 2) the percent canopy coverage (i.e., shading) over the stream.

3. Photo Library

Representative photographs were taken at each RSAT transect and at each permanent cross-section location, as well as of any notable features (including fish barriers, nick points, debris jams, etc.). The resulting photo library is a useful tool for observing high quality areas of the stream system, as well as areas of concern where additional actions may be considered. These photos have been catalogued using the geo-referenced RSAT data points, and have been included with this report as a CD-ROM. Appendix C summarizes both photo stream segment and transect locations.

4. GIS Mapping

To accurately document streambank channel conditions, COG staff employed the Trimble GEO-XT GPS receiver to register and georeference linear stream channel reaches that depicted the following streambank erosion condition: stable, slight, slight/moderate, moderate, moderate/severe and severe. Furthermore, the Trimble receiver was used to verify/correct (field truthing) the Upper Beaverdam Creek and Indian Creek existing digital stream channel network layer. The stream layer field truthing was conducted during the early spring 'leaf off' period. In addition, point data were also acquired for the following stream features; nick points, debris jams, fish blockages, utility line crossings, and other sites of interests. Such stream-related information were then transferred to ArcGIS platform for analysis and cartography.

2.3 Streambank Soil Collection

As part of the streambank soil sediment chemistry assessment, COG staff collected soil samples from nine RSAT representative locations (Figure 3) within the Upper Beaverdam Creek subwatershed survey area (Note: the reader is referred to Appendix D for exact coordinate locations).

Under this task, COG staff used a stainless steel soil probe to collect the vertical streambank soil profile samples (i.e., from the upper, middle and lower portions of the streambank) for laboratory analysis. The Pennsylvania State University Soils Laboratory analyzed the samples for the following pollutants of interest: phosphorus, nitrates, arsenic, chlordane and PCB's. The laboratory also analyzed for the following metals - cadmium, chromium, copper, lead, molybdenum, nickel, selenium, and zinc. In addition, they performed both percent organic content and soil textural composition analyses (i.e., percent sand, silt and clay).

2.4 Permanent Channel Cross-Sections

As part of the channel morphology characterization portion of the study, COG staff established permanent channel cross-section stations at an approximately 1,600 foot interval (i.e., every fourth RSAT transect) along the Upper Beaverdam Creek tributaries and Indian Creek mainstem open channels. At each permanent cross-section, COG staff employed a LEICA Total Station (TCR110) to measure elevational differ-

[2] Mean bank heights of one to two feet for small first and second-order Coastal Plain streams and two to three feet for third-order streams approximate reference conditions. Sewer lines are typically laid three to four feet below the bottom of the streambed; therefore, their exposure offers insight into the depth of downcutting that has occurred. A nick point is an erosional feature in the streambed, marked by an abrupt drop in elevation, which is caused by stream headcutting.

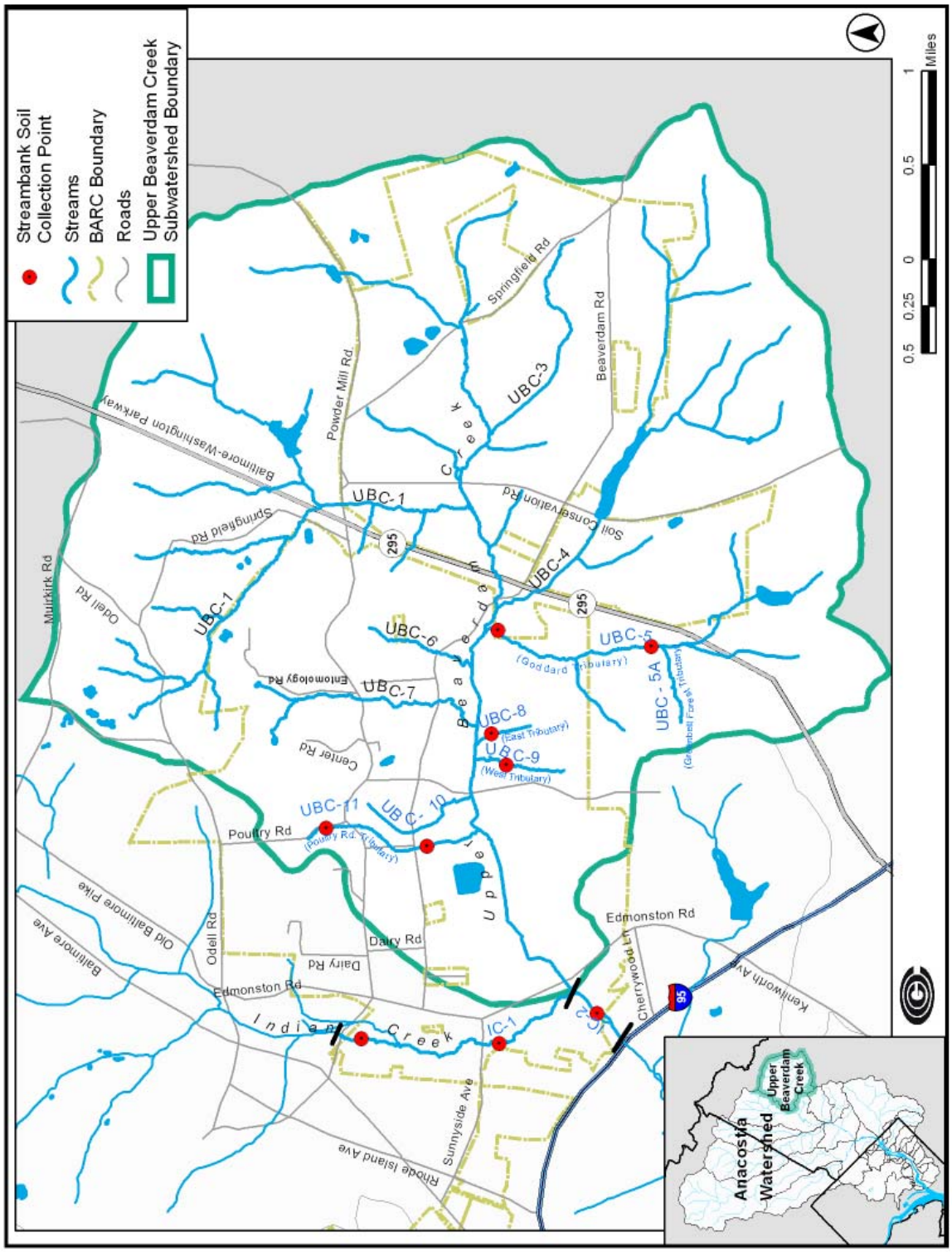


Figure 3: Upper Beaverdam Creek Tributary System- Streambank Soil Collection Locations

ences at one-foot intervals across the stream channel. It should be noted that for consistency purposes, the LEICA total station was always positioned on the left streambank, looking downstream. Furthermore, COG staff acquired cross-section location point data using the Trimble GEO-XT handheld GPS receiver. For complete permanent channel cross-section illustrations and locations, the reader is referred to Appendix E.

3.0 Results

3.1 Upper Beaverdam Creek

3.1.1 Stream Channel Erosion

Background

Under the RSAT system, the following channel morphology-related data were collected at each riffle transect: top channel width, bottom channel width, average right and left bank height, general right and left bank material type and right and left bank stability. In addition, between each transect station, COG staff noted and recorded both the general level of bank stability in the channel network and the presence of recent tree falls, exposed utility lines, perched road culverts or other tell-tale signs of lateral stream channel erosion and degradation. Bank stability conditions between transect stations were visually rated and placed into one of the following six categories:

1) Stable - Over 90 percent of bank network is stable, with no signs of major lateral bank erosion problems present;

2) Slight - 81 to 90 percent of bank network is stable and signs of major lateral bank erosion problems are rarely observed;

3) Slight/Moderate - 71 to 80 percent of bank network is stable and signs of major lateral bank erosion problems are uncommon to common;

4) Moderate – 61 to 70 percent of bank network is stable and signs of lateral bank erosion problems are common;

5) Moderate/Severe – 50 to 60 percent of bank network is stable and signs of lateral bank erosion problems are very common;

6) Severe – Less than 50 percent of bank network is stable and major portions of banks are unraveling.

The preceding information was digitized, in the field, into an Upper Beaverdam Creek GIS-based database using a Trimble Geo-XT handheld GPS receiver and mapping unit. Additional bank condition information was logged on field survey forms and subsequently entered into a Microsoft Excel spread-sheet database for further analysis. Photographs were taken to document stream channel erosion conditions.

Upper Beaverdam Creek Tributaries

Streambank stability results are summarized in Table 2 and Figure 4. Also, representative photographs depicting bank conditions for the mainstem areas are shown in Figures 5 through 22. Mean streambank stability for the UBC-5 (Goddard Tributary) UBC-5A (Greenbelt Forest Tributary), UBC-8 (East Tributary), UBC-9 (West Tributary) and UBC-11 (Poultry Road Tributary) (i.e., 68.0, 59.8, 92.1, 62.2, and 79.9 percent, respectively) were rated as being fair to excellent.

RSAT Upper Beaverdam Creek tributary streambank erosion results and totals are as follows: 2,590.5 linear feet of severe bank erosion (<7.5 percent of the total length), 3,574.8 linear feet of moderate/severe streambank erosion (10.3 percent of the total length) and 9,909.9 linear feet of moderate erosion (28.7 percent of the total length). It should be noted that more than 87 percent of the

Goddard Tributary streambank network generally fell between the moderate to severe categories.

RSAT streambank soil relative erodibility potential results for the Upper Beaverdam Creek tributary system (Figure 23) indicated that the bank materials present are, in order of dominance, moderate (i.e., generally loam-textured soils), low (i.e., generally clay-textured soils) and high (i.e., generally sand/silt-textured soils) erodible potential soil types, respectively.

Table 2: Summary: Upper Beaverdam Creek - Tributary Streambank Erosion Condition[1]

RSAT Stream Segment	Surveyed Stream Length (mi.)	Surveyed Streambank Network[2] Length (ft.)	Streambank Network Erosion Lengths (Feet)			No. of Recent Tree Falls[3]		No. of Erosional Log Jams	Mean Bank Stability[4] (%)
			Severe (LF)	Moderate/ Severe (LF)	Moderate (LF)	No.	No./ mi.		
Tributaries to Upper Beaverdam Creek									
1. UBC-5 (Goddard Tributary)	1.2	12,901.6	1,444.8	2,894.1	6,920.8	3	2.5	2	68.0
2. UBC-5A (Greenbelt Forest Tributary)	0.5	5,080.3	231.3	254.8	1,054.6	1	2.1	0	59.8
3. UBC-8 (East Tributary)	0.3	3,558.9	0.0	0.0	0.0	3	8.9	0	92.1
4. UBC-9 (West Tributary)	0.5	4,857.8	914.5	425.8	1,747.8	0	0.0	0	62.2
5. UBC-11 (Poultry Rd. Tributary)	0.8	8,172.4	0.0	0.0	186.6	0	0.0	0	79.9
Total	**3.3**	**34,571.1**	**2,590.5**	**3,574.8**	**9,909.9**	**7**			

[1] Moderate – 61 to 70 percent of bank network is stable and signs of lateral bank erosion problems are common; Moderate/Severe – 50 to 60 percent of bank network is stable and signs of lateral bank erosion problems are very common; Severe – Less than 50 percent of bank network is stable and major portions of banks are unraveling.

[2] Length to include both the left and right bank distances (e.g., twice the length of the Surveyed Stream Length)

[3] Tree fall interpretation: 0-1/mi. = Excellent, 2-3/mi. = Good, 4-5/mi = Fair, ≥6/mi. = Poor.

[4] Mean bank stability interpretation: >80% = Excellent, 71-80% = Good, 50-70% = Fair, <50% = Poor.

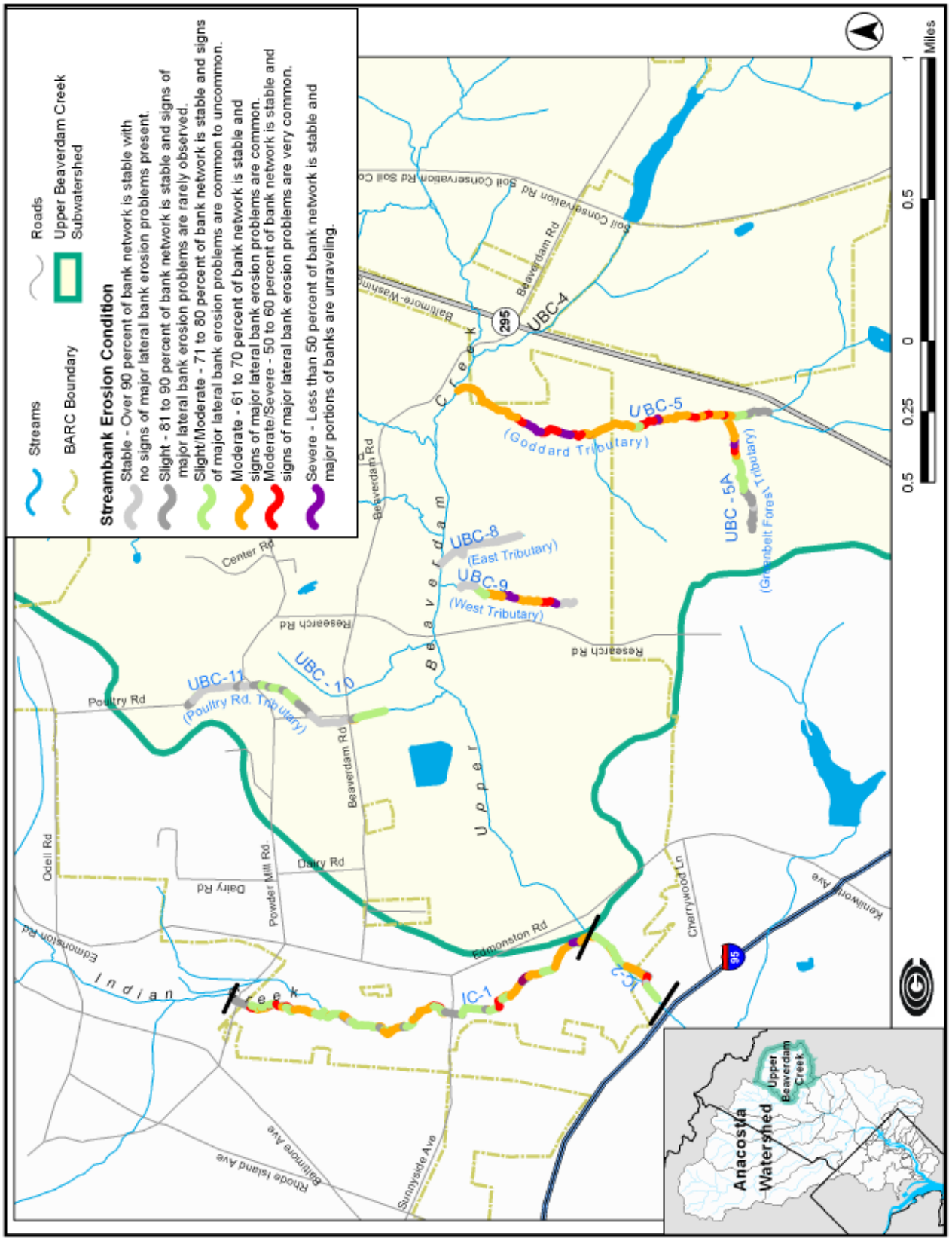


Figure 4: Summary: Upper Beaverdam Creek Tributary System Streambank Erosion Condition

UBC-5A (Greenbelt Forest Tributary)

Figure 9: Location - Approx. 640 Feet Upstream of Goddard Tributary Confluence (Near X-1): Severe Streambank Erosion

Figure 10: Location - Approx. 240 Feet Upstream of Goddard Tributary Confluence (X-2): Moderate Streambank Erosion

Figure 11: Location - Approx. 150 Feet Upstream of Goddard Tributary Confluence (Near X-3): Moderate\Severe Streambank Erosion

Figure 12: Location - Approx. 100 Feet Upstream of Goddard Tributary Confluence (X-3): Moderate Streambank Erosion

Location - Approx. 1,600 Feet Upstream of UBC Mainstem Confluence (X-1): Stable Streambank

UBC-8 (East Tributary)

Figure 13:

Figure 14: Location - Approx. 500 Feet Upstream of of UBC Mainstem Confluence (X-3): Stable Streambank

Figure 15: Location - Approx. 2,100 Feet Upstream of of UBC Mainstem Confluence (X-1): Severe Streambank Erosion

UBC-9 (West Tributary)

Figure 16: Location - Approx. 1,500 Feet Upstream of of UBC Mainstem Confluence (X-2): Moderate Streambank Erosion

Figure 17: Location - Approx. 1,000 Feet Upstream of of UBC Mainstem Confluence (X-3): Moderate Streambank Erosion

UBC-9 (West Tributary) Cont'd

Figure 18: Location - Approx. 500 Feet Upstream of of UBC Mainstem Confluence (X-4): Stable Streambank

UBC-11 (Poultry Road Tributary)

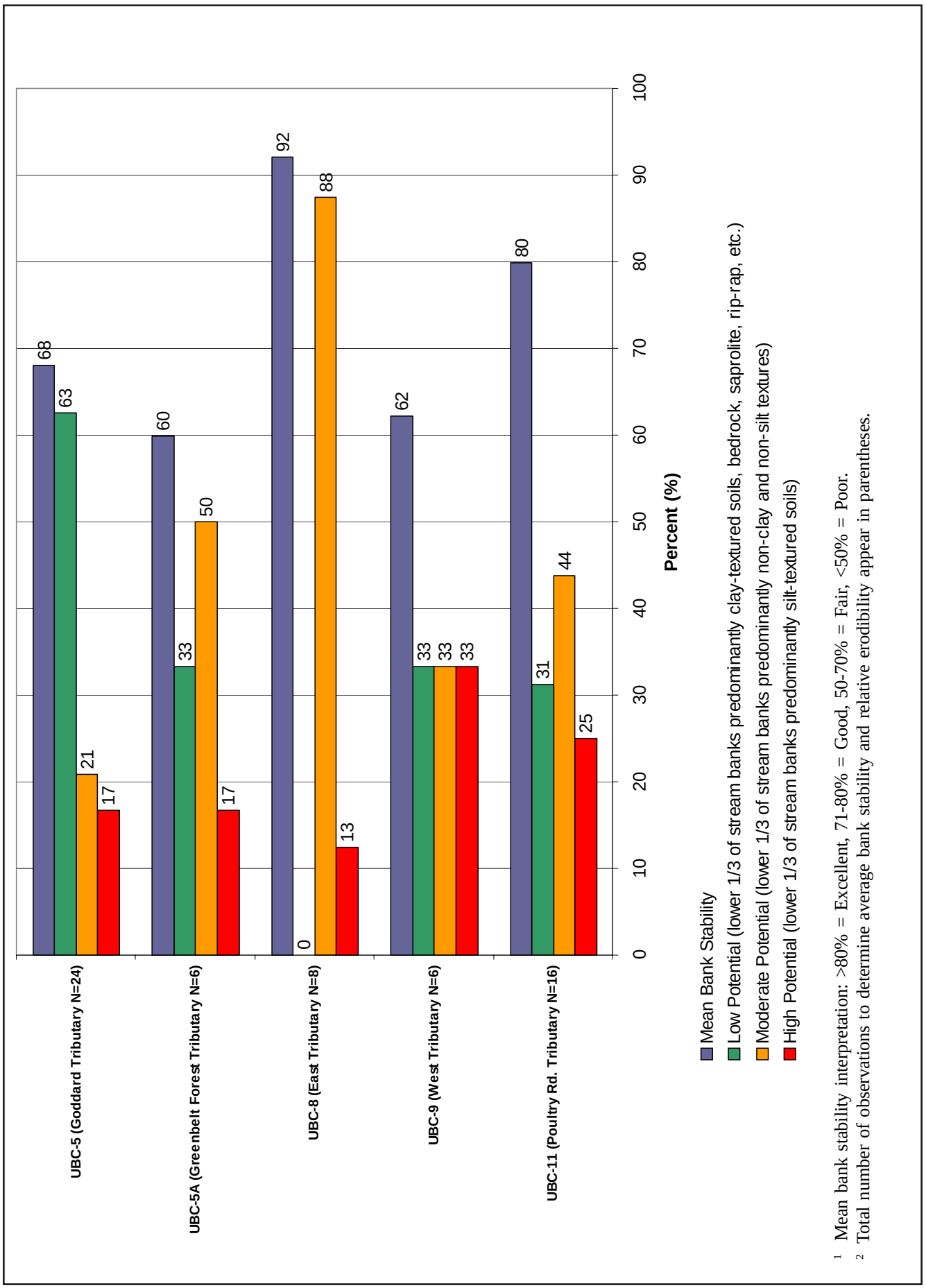
Figure 19: Location - Approx. 1,200 Feet Upstream of Powder Mill Road (X-1): Slight Streambank Erosion

Figure 20: Location - Approx. 500 Feet Upstream of Powder Mill Road (Near X-3): Slight Streambank Erosion

Figure 21: Location - Approx. 650 Feet Downstream of Powder Mill Road (X-5): Slight Streambank Erosion

Figure 22: Location - Approx. 15 Feet Downstream of Beaverdam Road (X-7): Slight/Moderate Streambank Erosion

Figure 23: Upper Beaverdam Creek Tributary System Mean Streambank Stability[1] and Relative Erodibility[2] (%)



[1] Mean bank stability interpretation: >80% = Excellent, 71-80% = Good, 50-70% = Fair, <50% = Poor.

[2] Total number of observations to determine average bank stability and relative erodibility appear in parentheses.

Indian Creek

Streambank stability results are summarized in Table 3 and Figure 24. Also, representative photographs depicting bank conditions for the tributary areas are presented in Figures 25 through 32. Mean streambank stability for IC-1 (Powder Mill Road to Upper Beaverdam Creek confluence) and IC-2 (Upper Beaverdam Creek confluence to 0.7 miles downstream) (i.e., 68.2 and 75.3 percent, respectively) were rated as being fair to good.

RSAT Indian Creek streambank network erosion results and totals are as follows: 142.3 linear feet of severe streambank erosion (0.7 percent of the total length), 1,374.1 linear feet of moderate/ severe erosion (6.8 percent of the total length) and 7,255.6 linear feet of moderate streambank erosion (35.9 percent of the total length). It should be noted that the severe streambank erosion condition were observed upstream of the Upper Beaverdam Creek confluence and (5.5 percent of the total stream length).

RSAT streambank soil relative erodibility results for the surveyed portion of the Indian Creek mainstem (Figure 33) revealed that the bank material present are, in order of dominance, moderate (i.e., generally loam-textured soils), high (i.e., generally sand/silt-textured soils) and low (i.e., generally clay-textured soils).

Table 3: Summary: Indian Creek - Mainstem Streambank Erosion Condition[1]

RSAT Stream Segment	Surveyed Stream Length (mi.)	Surveyed Streambank Network[2] Length (ft.)	Streambank Network Erosion Conditions			No. of Recent Tree Falls[3]		No. of Erosional Log Jams	Mean Bank Stability[4] (%)
			Severe	Moderate/ Severe	Moderate				
			(LF)	(LF)	(LF)	No.	No./mi.		
Indian Creek Mainstem									
1. IC-1 (Powder Mill Road to UBC Confluence)	1.6	16,396.0	142.3	1,105.3	6,578.3	23	14.8	3	68.2
2. IC-2 (UBC Confluence to 0.7mi Downstream)	0.4	3,789.0	0.0	268.8	677.3	3	8.4	0	75.3
Total	**1.9**	**20,184.9**	**142.3**	**1,374.1**	**7,255.6**	**26**			

[1] Moderate – 61 to 70 percent of bank network is stable and signs of lateral bank erosion problems are common; Moderate/Severe – 50 to 60 percent of bank network is stable and signs of lateral bank erosion problems are very common; Severe – Less than 50 percent of bank network is stable and major portions of banks are unraveling.

[2] Length to include both the left and right bank distances (e.g., twice the length of the Surveyed Stream Length)

[3] Tree fall interpretation: 0-1/mi. = Excellent, 2-3/mi. = Good, 4-5/mi = Fair, ≥6/mi. = Poor.

[4] Mean bank stability interpretation: >80% = Excellent, 71-80% = Good, 50-70% = Fair, <50% = Poor.

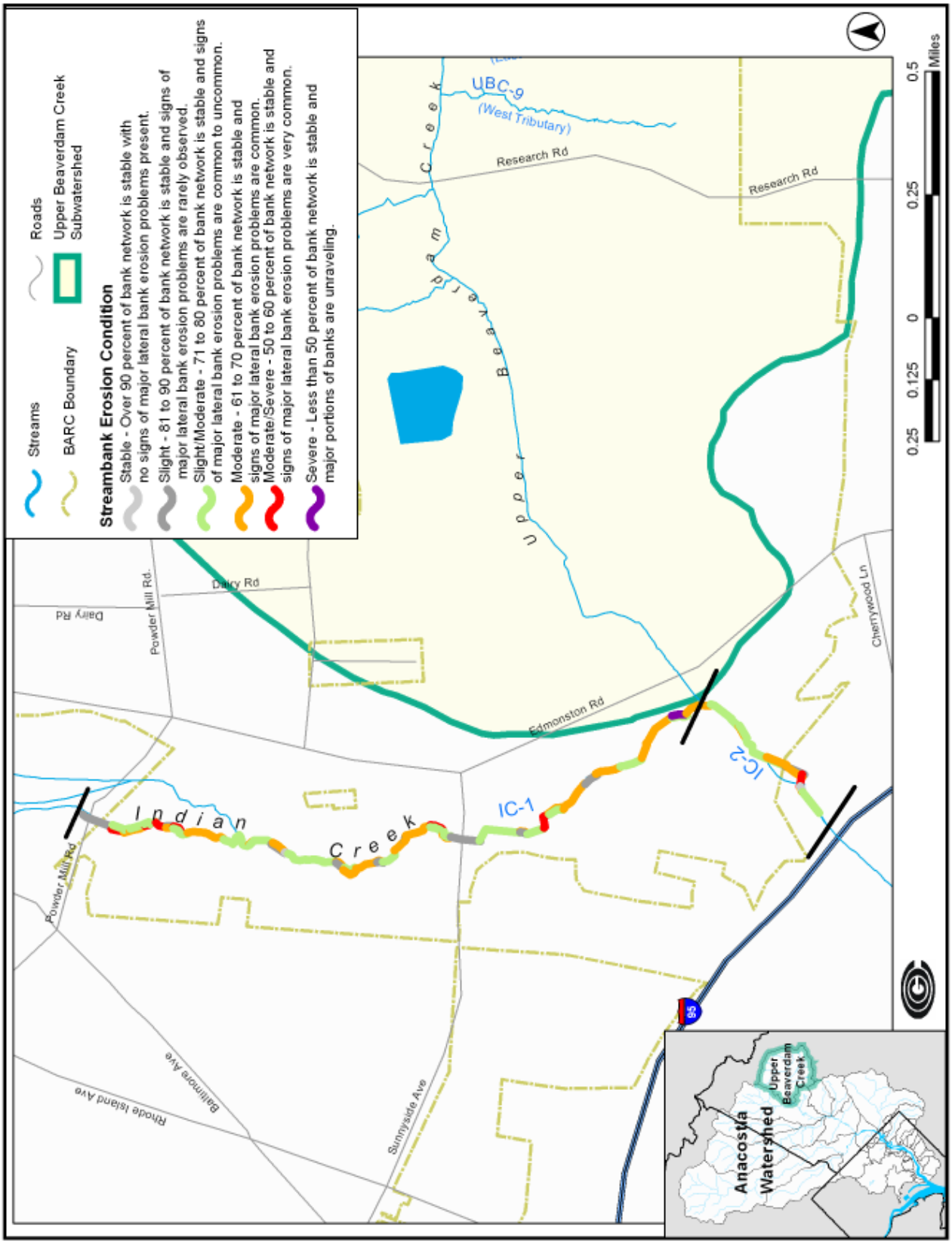


Figure 24: Location - Summary: Indian Creek Mainstem Streambank Erosion Condition

<u>Indian Creek (Powder Mill Road to UBC Confluence)</u>

Figure 25: Location - Approx. 400 Feet Downstream of Powder Mill Road (Near X-1): Severe Streambank Erosion

Figure 26: Location - Approx. 1,000 Feet Downstream of Powder Mill Road (X-2): Severe Streambank Erosion (Left Bank)

Figure 27: Location - Approx. 2,500 Feet Downstream of Powder Mill Road (X-5): Slight/Moderate Streambank Erosion

Figure 28: Location - Approx. 3,870 Feet Downstream of Powder Mill Road (X-8): Moderate/Severe Streambank Erosion

Figure 29: Location - Approx. 710 Feet Downstream of Sunnyside Avenue (X-10): Slight/Moderate Streambank Erosion

Indian Creek (Powder Mill Road to UBC Confluence) Cont'd

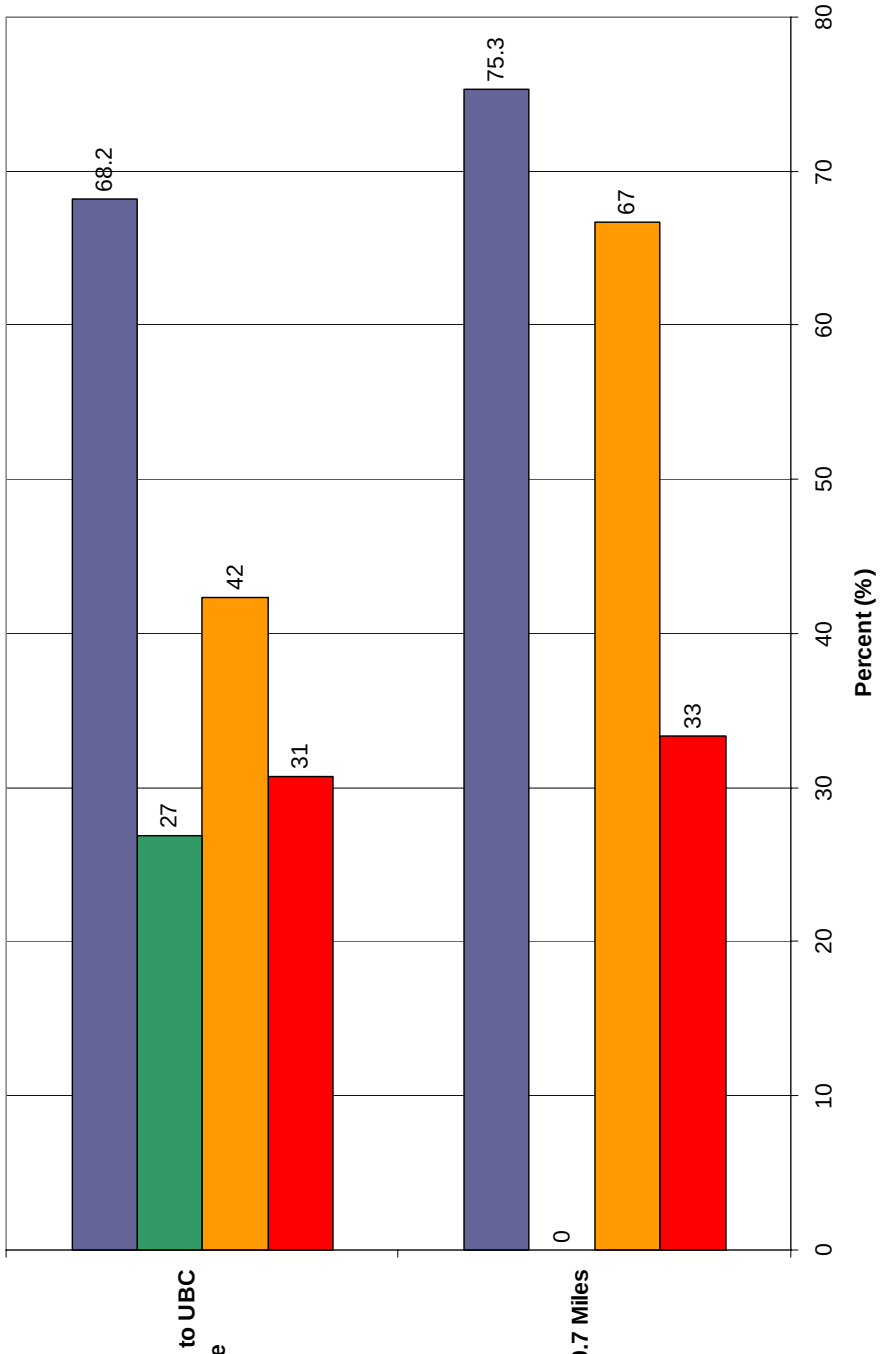
Figure 30: Location - Approx. 2,900 Feet Downstream of Powder Mill Road (X-13): Severe Streambank Erosion

Figure 31: Location - Approx. 1,300 Feet Downstream of UBC Confluence (Near X-15): Moderate/Severe Streambank Erosion

Indian Creek (UBC Confluence to 0.7mi Downstream)

Figure 32: Location - Approx. 2,000 Feet Downstream of UBC Confluence (X-16): Slight/Moderate Streambank Erosion

Figure 33: Indian Creek Mean Streambank Stability[1] and Relative Erodibility[2] (%)



[1] Mean bank stability interpretation: >80% = Excellent, 71-80% = Good, 50-70% = Fair, <50% = Poor.

[2] Total number of observations to determine average bank stability and relative erodibility appear in parentheses.

UBC-5 (Goddard Tributary)

Figure 5: Location - Approx. 365 Feet Downstream of Baltimore/ Washington Parkway (X-1): Slight/Moderate Streambank Erosion

Figure 6: Location - Approx. 1,270 feet Downstream of Baltimore/ Washington Parkway (X-3): Moderate Streambank Erosion

Figure 7: Location - Approx. 3,850 feet Downstream of Baltimore/ Washington Parkway (X-8): Moderate/Severe Streambank Erosion

Figure 8: Location - Approx. 100 Feet Downstream of Baltimore/ Washington Parkway (X-9): Moderate/Severe Streambank Erosion

3.1.2 Stream Channel Downcutting

Upper Beaverdam Creek Tributaries

Stream channel downcutting results (Table 4) revealed that only UBC-8 (East Tributary) mean streambank heights fell within the expected or reference condition bank height range of one to two feet. Otherwise, mean bank heights for UBC-9 and UBC-11 were generally 1 to 2 feet higher than the expected or reference condition. For the UBC-5 and UBC-5A surveyed stream reaches, mean bank heights were generally 2 feet or higher than the expected or reference condition. Such conditions for UBC-5 (Goddard Tributary) results strongly suggest moderate to severe channel downcutting.

Table 4: Summary: Upper Beaverdam Creek Tributaries - Stream Channel Downcutting

RSAT Stream Segment	Drainage Area (mi^2)	Surveyed Stream Segment Length (mi.)	Mean Bank Height Right[1] (ft)	Mean Bank Height Left[2] (ft)	Mean Bank Height L and R (ft)	Expected Bank Height Range (ft)	Number of Nick Points	Number of Exposed Utility Lines Within Stream Channel
Tributaries to Upper Beaverdam Creek								
1. UBC-5 (Goddard Tributary)	1.8	1.2	4.5	4.4	4.5	1-2	0	0
2. UBC-5A (Greenbelt Forest Tributary)	0.1	0.5	3.9	4.0	4.0	1-2	1	0
3. UBC-8 (East Tributary)	0.1	0.3	2.1	2.0	2.1	1-2	0	0
4. UBC-9 (West Tributary)	0.2	0.5	4.2	4.7	4.5	1-2	0	0
5. UBC-11 (Poultry Rd. Tributary)	0.4	0.8	3.3	4.3	3.8	1-2	0	2
Total		**3.3**					**1**	**2**

Indian Creek

Stream channel downcutting results (Table 5) revealed that IC-1 and IC-2 mean streambank heights fell within the drainage area-based expected or reference condition bank height ranges of two-three feet and three-four feet, respectively.

Table 5: Summary: Indian Creek - Mainstem Stream Channel Downcutting

RSAT Stream Segment	Dranage Area (mi^2)	Approx. Stream Segment Length (mi.)	Mean Bank Height Right[1] (ft)	Mean Bank Height Left[2] (ft)	Mean Bank Height L and R (ft)	Expected Bank Height Range (ft)	Number of Nick Points	Number of Exposed Utility Lines Within Stream Channel
Indian Creek Mainstem								
1. IC-1 (Powder Mill Road to UBC Confluence)	10.3	1.6	3.0	3.1	3.1	3-4	0	0
2. IC-2 (UBC Confluence to 0.7mi Downstream)	24.3	0.4	3.7	3.4	3.6	3-4	0	0
Total		**2.0**					**0**	**0**

[1] Right bank looking downstream.
[2] Left bank looking downstream.

3.1.3 Stream Channel Cross-sections

Upper Beaverdam Creek Tributary

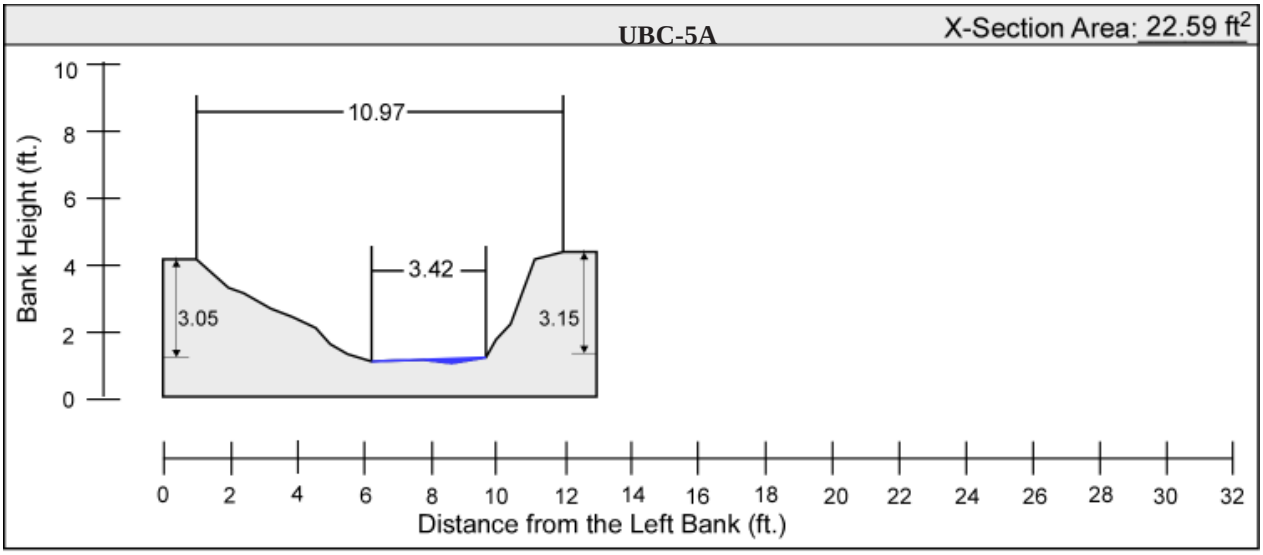
Cross-sectional analysis results revealed that the mean cross-sectional area of the Upper Beaverdam Creek tributaries are as follows: UBC-5 = 68.67 ft^2, UBC-5A = 25.94 ft^2, UBC-8 = 10.93 ft^2, UBC-9 = 41.71 ft^2 and UBC-11 = 47.96 ft^2. With the exception of UBC-8 (East Tributary), tributary channel widths and bank heights were all (for their respective drainage areas) generally wider and higher than their expected or reference condition. Specifically, mean tributary streambank heights were on the order of one to 2.5 feet higher than the expected or reference bank height ranges (i.e., 1-2 feet). Notably, the highly entrenched UBC-5 (Goddard Tributary) and UBC-9 (West Tributary) exhibited mean bank heights which were approximately 2.5 feet or higher than expected bank height range. Figures 34 through 37 illustrate selected mainstem cross-sections.

Indian Creek

Indian Creek stream mean cross-sectional area results are as follows: IC-1 (Powder Mill Road to Upper Beaverdam Creek confluence) = 88.48 ft^2, and IC-2 (Upper Beaverdam Creek confluence 0.7 miles downstream) = 136.97 ft^2. Both IC-1 and IC-2 fell within the expected or referenced condition bank height range of three to four feet. Figure 38 illustrates a representative mainstem cross-section located within the IC-1 surveyed segment.

Figure 34: Representative Cross Section and Photograph for (Greenbelt Forest Tributary) to UBC-5[1]

Location: Approximately 260 feet above Goddard tributary confluence[2]

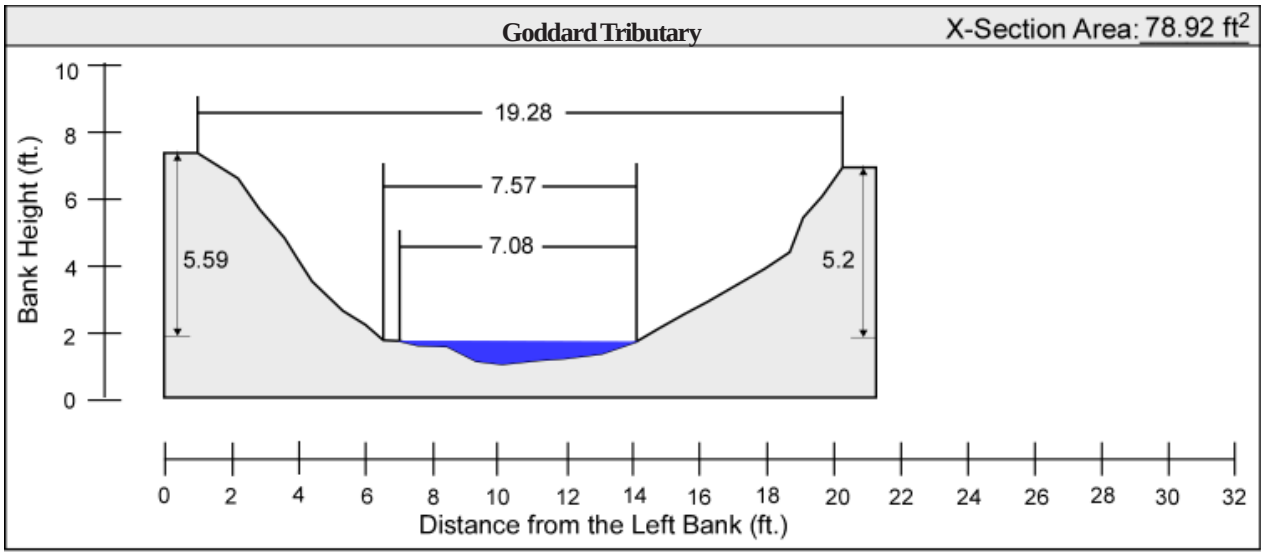


[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

[2] Photograph orientation is looking downstream (i.e., the left bank is on the left side).

Figure 35: Representative Cross Section and Photograph UBC-5[1]

Location: Approximately 2,280 feet above Upper Beaverdam Creek Mainstem Confluence[2]

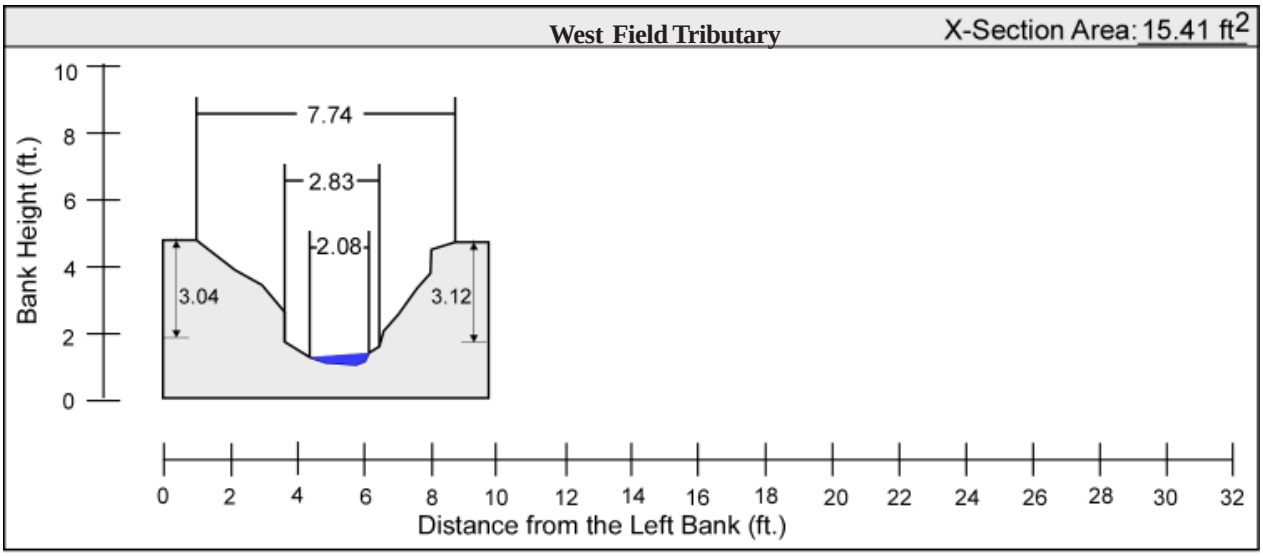


[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

[2] Photograph orientation is looking downstream (i.e., the left bank is on the left side).

Figure 36: Representative Cross Section and Photograph for UBC-9[1]

Location: Approximately 2,360 feet above Upper Beaverdam Creek Mainstem Confluence[2]

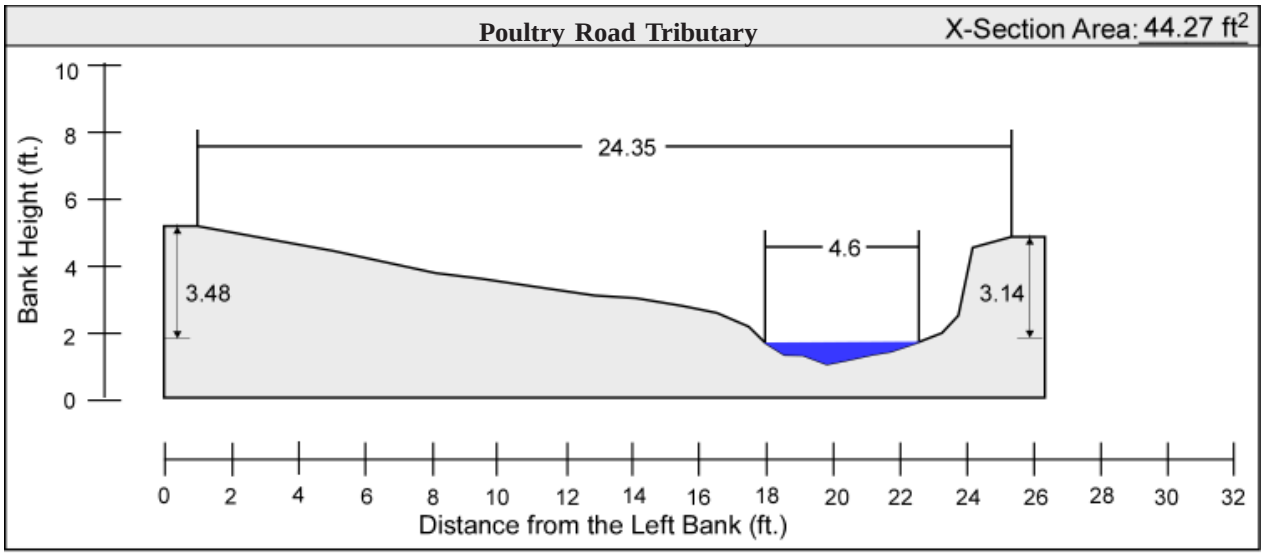


[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

[2] Photograph orientation is looking downstream (i.e., the left bank is on the left side).

Figure 37: Representative Cross Section and Photograph for UBC-11[1]

Location: Approximately 1,900 feet above Upper Beaverdam Creek Mainstem Confluence[2]

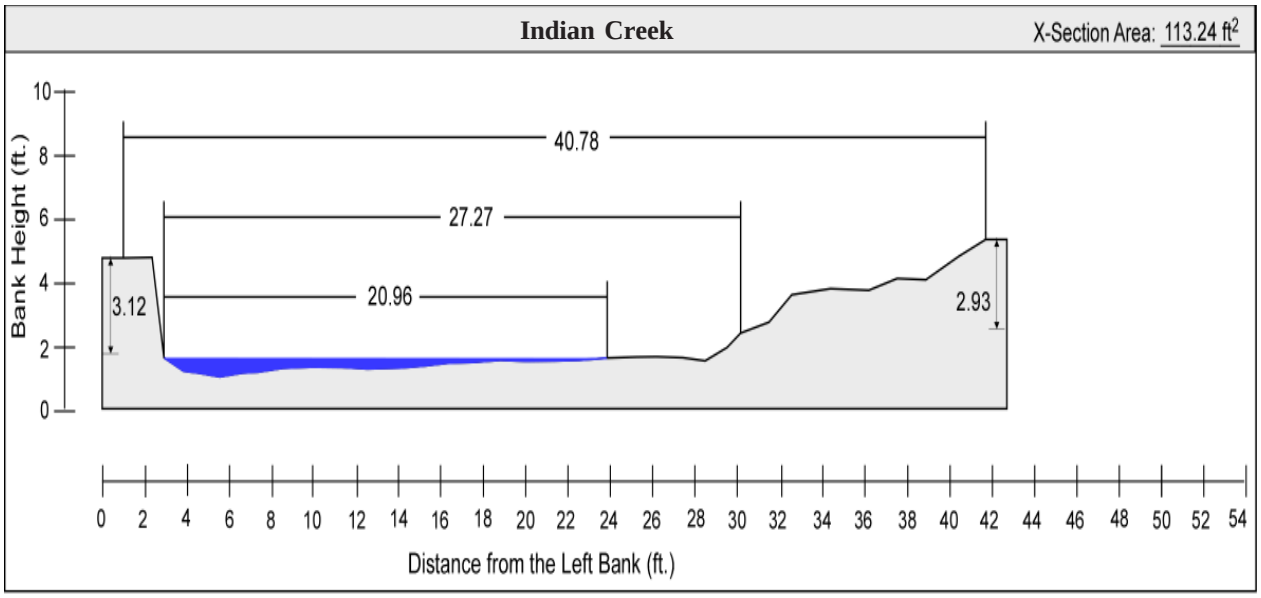


[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

[2] Photograph orientation is looking upstream (i.e., the left bank is on the right side).

Figure 38: Representative Cross Section and Photograph for IC-1 (Powder Mill Road to UBC Confluence)[1]

Location: Approximately 400 feet above confluence with Upper Beaverdam Creek Mainstem [2]



[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

[2] Photograph orientation is looking upstream (i.e., the left bank is on the right side).

3.1.4 Riparian Habitat Conditions

Upper Beaverdam Creek Tributary System

Riparian habitat conditions (Table 6) for the UBC-5 (Goddard Tributary) UBC-5A (Greenbelt Forest Tributary), UBC-8 (East Tributary), UBC-9 (West Tributary) and UBC-11 (Poultry Road Tributary) surveyed segments were rated as being good to excellent. Stream canopy coverage was rated as being in the good (i.e., 60-79 percent) to excellent (i.e., >= 80 percent) range. In addition, the forest riparian buffer zones were generally very wide (i.e., ~ 200 feet) and comprised of hard-wood forest for UBC-5, and UBC-5A (Figures 39 and 40). However, the riparian buffer zones along UBC-8, UBC-9 and UBC-11 (Figure 41) were generally narrower than 200 feet. It should be noted that the existing agricultural-related landuse (i.e., crop fields, cattle pastures, etc.) surround the UBC-8, UBC-9 and UBC-11 riparian buffer zones.

Table 6: Summary: Upper Beaverdam Creek - Tributary Riparian Habitat Condition

RSAT Stream Segment	Approx. Stream Segment Length (mi.)	Number of Observations	Mean Buffer Width Right (ft)	Mean Buffer Width Left (ft)	Mean Canopy Coverage (%)[1]	Riparian Habitat Condition Verbal Ranking
Tributaries to Upper Beaverdam Creek						
1. UBC-5 (Goddard Tributary)	1.2	12	187	194	85.5	Excellent
2. UBC-5A (Greenbelt Forest Tributary)	0.5	3	200	200	95.0	Excellent
3. UBC-8 (East Tributary)	0.3	4	101	12	67.5	Good
4. UBC-9 (West Tributary)	0.5	3	133	92	66.7	Good
5. UBC-11 (Poultry Rd. Tributary)	0.8	8	179	105	67.7	Good
Total	**3.3**	**30**	**--**	**--**	**--**	**--**

Figure 39: Location - Goddard Tributary Mainstem - Downstream of Baltimore/Washington Parkway: Excellent Stream Canopy Coverage

[1] Mean canopy coverage interpretation: ≥ 80% = Excellent, 60-79% = Good, 50-59% = Fair, <50% = Poor.

Figure 40: Location - Greenbelt Forest Tributary Upstream of Goddard Tributary Confluence: Excellent Stream Canopy Coverage

Figure 41: Location - Poultry Road Tributary Downstream of Powder Mill Road: Poor Stream Canopy Coverage

Indian Creek

Riparian habitat condition ratings (Table 7) for Indian Creek RSAT system were rated as being good. Generally, stream canopy coverage percentages ranged from 61.9 to 69.2, falling into the good category. In addition, the forest riparian buffer zones were typically wide (i.e., ~ 200 feet) and comprised of hardwood forest. Figures 42 through 43 depict representative riparian habitat conditions for select Indian Creek RSAT stream areas.

Table 7: Summary: Indian Creek - Mainstem Riparian Habitat Condition

RSAT Stream Segment	Approx. Stream Segment Length (mi.)	Number of Observations	Mean Buffer Width Right (ft)	Mean Buffer Width Left (ft)	Mean Canopy Coverage (%) [1]	Riparian Habitat Condition Verbal Ranking
Indian Creek Mainstem						
1. IC-1 (Powder Mill Road to UBC Confluence)	1.6	36	200	177	61.9	Good
2. IC-2 (UBC Confluence to 0.7mi Downstream)	0.4	6	200	200	69.2	Good
Total	**2.0**	**42**	**--**	**--**	**--**	**--**

Figure 42: Location - Indian Creek Downstream of Powder Mill Road (X-3): Fair Stream Canopy Coverage

[1] Mean canopy coverage interpretation: ≥ 80% = Excellent, 60-79% = Good, 50-59% = Fair, <50% = Poor.

Figure 43: Location - Indian Creek Downstream of Powder Mill Road (X-6) : Excellent Stream Canopy Coverage

Figure 44: Location - Indian Creek Downstream of Powder Mill Road (X-14): Excellent Stream Canopy Coverage

3.3 Streambank Soil Texture and Chemistry Analysis

3.3.1 Streambank Soil Texture

As shown in Table 8, soil texture results revealed that the UBC tributary and Indian Creek bank materials at the nine selected sampling sites are predominantly loam-based soils (i.e., loam, sandy loam, clay loam and sandy clay loam).

3.3.2 Streambank Soil Chemistry Analysis

Upper Beaverdam Creek Tributary System

Table 9 summarizes the UBC tributary streambank soil chemistry analysis results. Select main-stem streambank soil chemistry results (reported as a range in mg/kg dry weight, unless otherwise noted) are as follows: 1) nitrate-nitrogen = 0.8-5.6, 2) total phosphorus = 175.86-696.40, 3) organic matter = 1.1-1.9 percent, 4) arsenic = 1.46-6.79, 5) chromium = 10.57-22.83, 6) copper = 6.35-15.58, 7) lead = 8.88-33.91, 8) zinc = 22.22-72.12 and 9) total PCB's = present in trace amounts (i.e., < 0.07 mg/kg) at all six streambank soil chemistry sampling sites.

Indian Creek

Table 10 summarizes the Indian Creek streambank soil chemistry analysis results. Select tributary streambank soil chemistry results (reported as a range in mg/kg dry weight, unless otherwise noted) are as follows: 1) nitrate-nitrogen = 1.3-26.6, 2) total phosphorus = 228.05-381.94, 3) organic matter = 2.1-3.5 percent, 4) arsenic = 2.15-4.58, 5) chromium = 65.97-521.95, 6) copper = 9.36-19.92, 7) lead = 34.57-177.03, 8) zinc = 55.85-167.42 and 9) total PCB's = present in trace amounts (i.e., < 0.07 mg/kg) at all three streambank soil chemistry sampling sites. It should be noted that mean Maryland soil metal background concentrations (mg/kg dry weight) for the above-listed metals are as follows: arsenic = 3.8, chromium = 47.9, copper = 20.0, lead = 22.0 and zinc = 39.0 (U.S. EPA, 2003). Therefore, the soil chemistry results for Indian Creek strongly suggest anthropogenic-related metals contamination/enrichment.

Table 8: Upper Beaverdam Creek - Tributary Streambank Soil Particle Size[1, 2]

Sampling Site	% Sand	% Silt	% Clay	Soil Texture Class
Tributaries to Beaverdam Creek				
UBC-5 (Goddard Tributary)				
~ 800' above Northway Road	56.5	25.6	17.9	Sandy Loam
~ 550' below Beaverdam Road	41.5	35.4	23.1	Loam
UBC-8 (East Tributary)				
~700' above confluence to Mainstem	65.9	18.3	15.8	Sandy Loam
UBC-9 (West Tributary)				
~ 1000' above confluence with Mainstem	47.3	30.9	21.7	Loam
UBC-11 (Poultry Road Tributary)				
~ 700' above Powder Mill Road	33.8	30.3	35.9	Clay Loam
~ 400' below Beaverdam Road	67.6	19.2	13.2	Sandy Loam

Sampling Site	% Sand	% Silt	% Clay	Soil Texture Class
Indian Creek Mainstem				
1. IC-1 (Powder Mill Road to UBC Confluence)				
~ 600' below Powder Mill Road	41.3	36.6	22.1	Loam
~ 550' below Sunnyside Avenue	37.1	29.5	33.4	Clay Loam
2. IC-2 (UBC Confluence to 0.7mi Downstream)				
~ 800' below Confluence with UBC	46.6	25.8	27.6	Sandy Clay Loam

[1] COG staff used a stainless steel soil probe to collect the vertical streambank soil profile samples (i.e., from the upper, middle and lower portions of the streambank) from represenative erosional and depositional stream areas.
[2] Particle size analysis performed by Agricultural Analytical Services Laboratory, Pennsylvania State University.

Table 9: Summary: Upper Beaverdam Creek Tributary Soil Chemistry Results[1]

Parameters	Unit	Detection Limit	UBC-5		UBC-8	UBC-9	UBC-11	
			Goddard Tributary, Upper (~800' above Northway Road)	**Goddard Tributary, Lower** (~550' below Beaverdam Road)	**East Tributary** (~700' above confluence to Mainstem)	**West Tributary** (~1000' above confluence to Mainstem)	**Poultry Road Tributary, Upper** (~700' above Powder Mill Road)	**Poultry Road Tributary, Lower** (~400' below Beaverdam Road)
1. pH	--	--	5.6	4.8	5.7	4.5	5.2	5.8
2. Total Nitrogen	%	--	0.09	0.08	0.08	0.10	0.10	0.09
3. Nitrate Nitrogen	mg/kg	1	5.6	1.5	1.1	0.8	1.0	1.9
3. Total Carbon	%	--	1.22	1.04	1.02	1.03	1.12	1.07
4. Total Phosphorus	mg/kg	0.06	234.03	185.47	246.60	175.86	696.40	302.85
5. Organic Matter	%	--	1.8	1.7	1.5	1.7	1.9	1.1
6. Cation Exchange Capacity	meq/100g	--	5.8	7.0	5.2	8.1	11.8	6.3
Metals[2]								
7. Arsenic	mg/kg	0.5	3.34	2.32	1.46	1.37	6.79	3.04
8. Cadmium	mg/kg	0.004	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
9. Chromium	mg/kg	0.005	14.19	12.76	13.58	10.57	22.83	12.69
10. Copper	mg/kg	0.002	10.17	8.30	7.98	6.35	13.77	15.58
11. Lead	mg/kg	0.025	15.86	8.88	18.72	8.92	33.91	21.98
12. Molybdenum	mg/kg	0.005	2.47	1.58	<1.00	<1.00	1.18	<1.00
13. Nickel	mg/kg	0.01	14.10	17.42	15.98	7.15	21.50	15.36
14. Selenium	mg/kg	0.3	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
15. Zinc	mg/kg	0.004	44.88	41.35	46.60	22.22	72.12	58.16
16. Total PCB's[3]	mg/kg	--	<0.06	<0.06	<0.05	<0.06	<0.07	<0.06

[1] Mainstem soil analysis samples were collected on April 28, 2006. Chemical analysis performed by Agricultural Analytical Services Laboratory, Pennsylvania State University.

[2] EPA mean reported soil metal background concentrations (mg/kg dry weight) for Maryland are as follows; Arsenic = 3.8, Cadmium = not reported; Chromium = 47.9, Copper = 20; Lead = 22, Nickel = 13, Selenium = 0.2, and Zinc = 39 (2003, USEPA).

[3] PCB results indicate the maximum possible value detectable by analyzer.

Table 10: Indian Creek Streambank Soil Chemistry Results[1]

Parameters	Unit	Detection Limit	IC-1		IC-2
			~600' below Powder Mill Road	~550' below Sunnyside Road	~800' below Confluence with UBC
1. pH	--	--	5.4	5.2	5.6
2. Total Nitrogen	%	--	0.09	0.10	0.17
3. Nitrate Nitrogen	mg/kg	1	26.6	1.3	2
4. Total Carbon	%	--	1.78	1.40	2.44
5. Total Phosphorus	mg/kg	0.06	281.42	228.05	381.94
6. Organic Matter	%	--	2.1	2.1	3.5
7. Cation Exchange Capacity	meq/100g	--	7.6	9.5	8.8
Metals[2]					
8. Arsenic	mg/kg	0.5	4.58	2.15	4.48
9. Cadmium	mg/kg	0.004	<0.50	<0.50	0.70
10. Chromium	mg/kg	0.005	521.95	65.97	402.68
11. Copper	mg/kg	0.002	16.48	9.36	19.92
12. Lead	mg/kg	0.025	177.03	34.57	147.87
13. Molybdenum	mg/kg	0.005	1.40	<1.00	1.97
14. Nickel	mg/kg	0.01	10.54	9.63	15.43
15. Selenium	mg/kg	0.3	1.47	0.67	0.77
16. Zinc	mg/kg	0.004	167.42	55.85	125.50
17. Total PCB's[3]	mg/kg	--	<0.06	<0.06	<0.07

[1] Mainstem soil analysis samples were collected on April 28, 2006. Chemical analysis performed by Agricultural Analytical Services Laboratory, Pennsylvania State University.

[2] EPA mean reported soil metal background concentrations (mg/kg dry weight) for Maryland are as follows; Arsenic = 3.8, Cadmium = not reported; Chromium = 47.9, Copper = 20; Lead = 22, Nickel = 13, Selenium = 0.2, and Zinc = 39 (2003, USEPA).

[3] PCB results indicate the maximum possible value detectable by analyzer.

4.0 Study Recommendations

1) In keeping with Phase I study recommendations, because of the inaccurate nature of current GIS stream channel network data layers for both the Upper Beaverdam Creek and Indian Creek subwatersheds (i.e., Prince George's County, BARC, USGS, COG and others), it is recommended that future subwatershed studies (as the first order of business) include a field-generated stream channel mapping task. Furthermore, the study should build upon the Anacostia 'area of interest' (i.e., nick points, debris jams, fish barriers, stormdrain outfalls, utility line stream crossings, etc.) database. Note: In performing its RSAT survey it was necessary for COG staff to again create (via the employment of a sub-one-meter GPS unit) a new data layer for all stream areas surveyed.

2) Conduct additional and similar RSAT-type surveys for both the UBC-5 (Goddard Tributary) portion within NASA's Goddard Space Flight Center, as well the mainstem of Indian Creek upstream of Powder Mill Road.

3) As part of a larger BARC, facility-wide stormwater management planning effort, it is recommended that potential stormwater retrofitting focus first on those tributary area catchments exhibiting significant amounts of 'moderate' streambank erosion levels or higher (i.e., UBC-5, Goddard Tributary. In addition, large uncontrolled on-site and off-site impervious surfaces (such as large building areas, parking lots and major roadways) which generate significant amounts of stormwater runoff should be similarly evaluated. In COG staff's opinion, BARC's Animal Husbandry, Poultry Management and aerobic manure digester complexes, the National Park Service's Baltimore Washington Parkway, NASA's Goddard Space Flight Center, City of Greenbelt, the Beltsville Industrial Park (from Muirkirk Road downstream to Powder Mill Road), the Beltsville Industrial Center (from Powder Mill Road downstream to Sunnyside Avenue) and the Washington Metro Area Transit Authority's Green Line Maintenance Yard are all additional candidate retrofit areas that are currently contributing large volumes of stormwater runoff and associated pollutants to both the Upper Beaverdam Creek and Indian Creek systems.

UBC-11 - 24 inch CMP stormdrain outfall

4) Based on both the level of current streambank erosion and degree of channel downcutting, Rosgen-based stream channel restoration studies should be initiated for the following tributaries: UBC-5 (Goddard Tributary), UBC-11 (Poultry Road Tributary), IC-1 (Indian Creek below Powder Mill Road) and IC-2 (from the confluence of UBC to 0.7 miles downstream).

5) The bottom portion of the 24 inch corrugated metal storm drain pipe located upstream of Powder Mill Road within UBC-11 (Poultry Road tributary) is corroded and should be replaced, by BARC, as soon as possible.

6) The ductile iron utility pipe, (UBC-11, Poultry Road Tributary) located upstream of Powder Mill Road is currently being supported by two columns of cinder blocks. It is strongly recommended that a more permanent poured-in-place, concrete pier, replacement support system be installed by BARC as soon as possible.

UBC-11 - Ductile Iron Utility Line Supported by Two Cinder Block Columns

7) The high total phosphorus, lead and zinc streambank soil chemistry levels (696.4 mg/kg, 33.91 mg/kg, and 72.12 mg/kg, respectively) observed at UBC-11 (Poultry Road Tributary) suggest localized contamination, and warrant further and immediate investigation.

8) The high metal (arsenic, chromium, copper, lead, nickel, selenium and zinc) streambank levels observed at all Indian Creek soil survey collection sites strongly suggest anthropogenic-related metals contamination/enrichment. At a minimum, MDE and PGDER (with BARC involvement) should: 1) perform a comprehensive source tracking study to identify source(s) of these metal contaminants and 2) develop an appropriate remediation plan.

9) Given their ecological significance, a comprehensive Upper Beaverdam Creek and Indian Creek subwatershed riparian corridor analysis (which at a minimum examines buffer widths and vegetation types) should be a high BARC priority.

10) As a companion piece to the successful November 2005 Upper Beaverdam Creek Stream Cleanup event, BARC should consider a similar event for its section of Indian Creek below Powder Mill Road. Potential cleanup partners include COG, MDSHA, Citizen to Conserve and Restore Indian Creek (CCRIC), Beaverdam Creek Watershed Watch Group (BCWWG) and others.

11) Results from this study should be integrated into both BARC's stormwater management and Facility-Wide Baseline Ecological Risk Assessment initiatives, as well as into broader Anacostia water quality monitoring, modeling and TMDL development efforts. In addition, a joint meeting between MDE, BARC, COG and other interested stakeholders to go over study findings and coordinate next steps is recommended.

12) In future years, if at all possible, similar RSAT surveys for the BARC mainstem portions of Little Paint Branch and Paint Branch should be performed.

5.0 Literature Cited

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Appendix

Table 1 - Upper Beaverdam Creek Tributary System - Corresponding Latitude and Longitude Coordinates for RSAT Transects

Transect Number	Latitude	Longitude
Tributaries to Upper Beaverdam Creek		
1. UBC-5 (Goddard Tributary)		
1	39.00676	-76.86361
2	39.00789	-76.86378
3	39.00916	-76.86382
4	39.01027	-76.86397
5	39.01167	-76.86406
6	39.01324	-76.86464
7	39.01446	-76.86437
8	39.01618	-76.86500
9	39.01737	-76.86491
10	39.01922	-76.86429
11	39.02137	-76.86238
12	39.02205	-76.86206
2. UBC-5A (Greenbelt Forest Tributary)		
1	39.00834	-76.86552
2	39.00858	-76.86452
3	39.00877	-76.86406
3. UBC-8 (East Tributary)		
1	39.01933	-76.87178
2	39.02066	-76.87215
3	39.02217	-76.87293
4. UBC-9 (West Tributary)		
1	39.01778	-76.87610
2	39.01956	-76.87588
3	39.02064	-76.87572
4	39.02204	-76.87499
5. UBC-11 (Poultry Rd. Tributary)		
1	39.03612	-76.88251
2	39.03484	-76.88169
3	39.03254	-76.88156
4	39.03136	-76.88196
5	39.02966	-76.88400
6	39.02799	-76.88377
7	39.02632	-76.88318
8	39.03358	-76.88156

Table 2 - Indian Creek - Corresponding Latitude and Longitude Coordinates for RSAT Transects

Transect Number	Latitude	Longitude
Indian Creek Mainstem		
1. IC-1 (Powder Mill Road to UBC Confluence)		
1	39.03320	-76.90265
2	39.03138	-76.90262
3	39.03013	-76.90302
4	39.02903	-76.90318
5	39.02698	-76.90392
6	39.02600	-76.90416
7	39.02533	-76.90397
8	39.02367	-76.90266
9	39.02232	-76.90307
10	39.02098	-76.90293
11	39.01912	-76.90083
12	39.01769	-76.90029
13	39.01648	-76.89848
2. IC-2 (UBC Confluence to 0.7mi Downstream)		
14	39.01552	-76.89820
15	39.01394	-76.90021
16	39.01235	-76.90215

Table 1. Upper Beaverdam Creek Tributary System RSAT Field Data

Stream:	UBC-5 (Goddard Tributary)											Survey Date:			9/20/2005
Transect Number	Top Channel Width (ft)	Bottom Channel Width (ft)	Wetted Perimeter	Mean Bank Height R	Mean Bank Height L	Mean Bank Stability R&L (%)	Bank Material Type R	Bank Material Type L	Substrate Material Comp.	Riparian Veg. Type R	Riparian Veg. Type L	Buffer Width R	Buffer Width L	Max. Pool Depth	Pool Habitat Quality
x-1	19.5	10.3	6.4	4.1	3.4	74.0	SL/CL	SL/CL	G,S,C	F	F	48	200	12.0	V. Good
x-2	18.8	9.7	3.5	3.1	3.3	72.5	CL/SL	SL/S	S	F	F	200	200	0.0	Poor
x-3	16.1	8.5	3.7	6.1	5.7	64.0	CL	CL	CL,S	F	F	200	200	12.0	Good
x-4	20.8	9.3	8.0	4.8	5.4	64.0	CL	CL	S,G	F	F	200	200	36.0	Good
x-5	21.5	14.7	4.4	3.9	3.7	65.5	SL/S	S/SL	S,G,C,R	F	F	200	200	10.0	Fair
x-6	23.6	10.2	3.1	3.9	4.5	67.0	SL/S	S/CL	CL	F	F	200	200	30.0	Fair
x-7	16.8	7.1	7.0	3.8	2.9	66.0	CL	CL	CL	F	F	200	200	12.0	Fair
x-8	13.3	6.1	2.3	3.4	3.8	62.0	S/CL	S/CL	CL	F	F	200	200	24.0	V. Good
x-9	19.3	7.6	4.7	6.8	5.6	58.5	S/CL	SL/CL	CL	F	F	200	200	36.0	V. Good
x-10	24.1	17.9	4.6	5.6	6.3	69.0	SL/CL	S/SL	S,G,C,R	F	F	200	200	24.0	V. Good
x-11	29.0	14.3	5.4	4.1	4.3	76.0	S/CL	SL/S	S	F	F	200	130	16.0	Good
x-12	23.7	9.7	3.2	3.9	3.7	78.0	SL	S/SL	S,G,C,R	F	F	200	200	0.0	Poor
Average	**20.5**	**10.5**	**4.7**	**4.5**	**4.4**	**68.0**						**187.3**	**194.2**	**17.7**	

[1]Bank material type abbreviations: cl = clay, s = sand, sl = silt, l = loam
[2]Substrate material abbreviations: c = cobble, s = sand, sl = silt, g = gravel, r = rubble
[3]Riparian vegetation type abbreviations: f = forest, g = grass
[4]Pool habitat quality interpretation: poor = <10" deep, dominated by sandy substrate and with no overhead cover; fair = 10-12" deep, dominated by sandy substrate with few coarse materials and little overhead cover; good = up to 18" deep, with coarse material substrate and adequate overhead cover; very good = up to 24" deep, dominated by coarse material substrate and with optimum overhead cover; excellent = up to 36" deep, dominated by coarse material substrate and with optimum overhead cover.

Table 1. Upper Beaverdam Creek Tributary System RSAT Field Data Cont'd.

Stream:	UBC-5A (Greenbelt Forest Tributary)											Survey Date:	
Transect Number	Top Channel Width (ft)	Bottom Channel Width (ft)	Wetted Perimeter	Mean Bank Height R	Mean Bank Height L	Mean Bank Stability R&L (%)	Bank Material Type R	Bank Material Type L	Substrate Material Comp.	Riparian Veg. Type R	Riparian Veg. Type L	Buffer Width R	Buffer Width L
x-1	9.9	3.2	1.5	3.3	3.2	71.5	SL/S	SL/S	S,G,C,R	F	F	200	200
x-2	11.0	3.6	1.7	3.5	3.6	75.0	SL/S	S/SL	G,S	F	F	200	200
x-3	7.1	4.7	1.6	5.1	5.0	33.0	CL	CL	CL	F	F	200	200
Average	**9.3**	**3.8**	**1.6**	**3.9**	**4.0**	**59.8**						**200.0**	**200.0**

Stream:	UBC-8 (East Tributary)											Survey Date:			9/6/2005
Transect Number	Top Channel Width (ft)	Bottom Channel Width (ft)	Wetted Perimeter	Mean Bank Height R	Mean Bank Height L	Mean Bank Stability R&L (%)	Bank Material Type R	Bank Material Type L	Substrate Material Comp.	Riparian Veg. Type R	Riparian Veg. Type L	Buffer Width R	Buffer Width L	Max. Pool Depth	Pool Habitat Quality
x-1	7.0	3.5	1.0	3.8	4.0	55.0	S/CL	S/CL	CL	F	F	200	200	0.0	Poor
x-2	21.1	5.0	0.3	4.6	6.3	64.0	SL/S	SL/S	S,G,C	F	F	200	35	0.0	Poor
x-3	13.6	6.3	0.0	4.1	3.8	67.5	S/SL	S/SL	S,G	F	F	0	40	0.0	Poor
Average	**13.9**	**4.9**	**0.4**	**4.2**	**4.7**	**62.2**						**133.3**	**91.7**	**0.0**	
	41.70937														

[1]Bank material type abbreviations: cl = clay, s = sand, sl = silt, l = loam
[2]Substrate material abbreviations: c = cobble, s = sand, sl = silt, g = gravel, r = rubble
[3]Riparian vegetation type abbreviations: f = forest, g = grass
[4]Pool habitat quality interpretation: poor = <10" deep, dominated by sandy substrate and with no overhead cover; fair = 10-12" deep, dominated by sandy substrate with few coarse materials and little overhead cover; good = up to 18" deep, with coarse material substrate and adequate overhead cover; very good = up to 24" deep, dominated by coarse material substrate and with optimum overhead cover; excellent = up to 36" deep, dominated by coarse material substrate and with optimum overhead cover.

Table 1. Upper Beaverdam Creek Tributary System RSAT Field Data Cont'd.

Stream: UBC-9 (East Tributary)												Survey Date:			9/6/2005
Transect Number	Top Channel Width (ft)	Bottom Channel Width (ft)	Wetted Perimeter	Mean Bank Height R	Mean Bank Height L	Mean Bank Stability R&L (%)	Bank Material Type R	Bank Material Type L	Substrate Material Comp.	Riparian Veg. Type R	Riparian Veg. Type L	Buffer Width R	Buffer Width L	Max. Pool Depth	Pool Habitat Quality
x-1	13.0	2.9	1.7	5.5	5.5	90.0	SL/S	SL/S	S,G,C	F	F	75	30	0	Poor
x-2	2.9	2.0	0.0	0.8	0.7	95.0	SL/S	SL/S	S	F	F	22	17	0	Poor
x-3	5.2	3.6	0.0	0.7	0.5	95.0	SL/S	SL/S	S,G,C,R	F	F	106	200	0	Poor
x-4	7.4	5.1	0.0	1.5	1.4	88.5	S	SL	S,G,C,R	F	F	200	200	0	Poor

Stream: UBC-11 (Poultry Rd. Tributary)												Survey Date:			9/20/2005
Transect Number	Top Channel Width (ft)	Bottom Channel Width (ft)	Wetted Perimeter	Mean Bank Height R	Mean Bank Height L	Mean Bank Stability R&L (%)	Bank Material Type R	Bank Material Type L	Substrate Material Comp.	Riparian Veg. Type R	Riparian Veg. Type L	Buffer Width R	Buffer Width L	Max. Pool Depth	Pool Habitat Quality
x-1	11.6	3.4	2.9	2.1	3.5	76.5	L/CL	CL	C,G,S	F/G	F/G	32	39	0.0	Good
x-2	28.1	8.2	5.3	4.4	5.4	88.5	L/CL	SL/S	C,G,S	F/G	F/G	200	15	12.0	V. Good
x-3	29.3	7.4	3.3	3.3	7.6	78.0	SL/S	L/CL	G,S,C	F/G	F/G	200	20	13.0	V. Good
x-4	19.5	8.4	3.9	5.2	4.3	78.5	SL/S	SL/S	G,C,S	F/G	F	200	108	10.0	Good
x-5	16.6	7.7	3.3	3.7	3.7	83.5	SL/S	SL	G,C,S	F/G	F/G	200	200	28.0	Excellent
x-6	11.2	1.0	0.7	1.0	2.5	90.0	SL	SL	G,C,S	G	G	200	200	0.0	Poor
x-7	24.4	4.6	2.5	3.1	3.5	69.5	CL	SL/S	CL	F/G	F/G	200	60	18.0	Good
x-8	17.6	5.3	2.2	3.2	3.7	75.0	SL/S	SL	G,S,C	F/G	F/G	200	200	0.0	Poor
Average	**19.8**	**5.8**	**3.0**	**3.3**	**4.3**	**79.9**						**179.0**	**105.3**	**10.1**	

[1]Bank material type abbreviations: cl = clay, s = sand, sl = silt, l = loam

[2]Substrate material abbreviations: c = cobble, s = sand, sl = silt, g = gravel, r = rubble

[3]Riparian vegetation type abbreviations: f = forest, g = grass

[4]Pool habitat quality interpretation: poor = <10" deep, dominated by sandy substrate and with no overhead cover; fair = 10-12" deep, dominated by sandy substrate with few coarse materials and little overhead cover; good = up to 18" deep, with coarse material substrate and adequate overhead cover; very good = up to 24" deep, dominated by coarse material substrate and with optimum overhead cover; excellent = up to 36" deep, dominated by coarse material substrate and with optimum overhead cover.

Table 2. Indian Creek RSAT Field Data

Stream:	Indian Creek											Survey Date:		8/16/05, 8/18/05	
Transect Number	Top Channel Width (ft)	Bottom Channel Width (ft)	Wetted Perimeter	Mean Bank Height R	Mean Bank Height L	Mean Bank Stability R&L (%)	Bank Material Type R	Bank Material Type L	Substrate Material Comp.	Riparian Veg. Type R	Riparian Veg. Type L	Buffer Width R	Buffer Width L	Max. Pool Depth	Pool Habitat Quality
1. IC-1 (Powder Mill Road to UBC Confluence)															
x-1	43.9	28.6	19.6	5.5	5.4	57.5	SL/CL	S/L	C,G,R,S,B	F	F	200	200	28.0	Fair
x-2	33.1	18.0	8.6	4.4	3.8	60.0	SL/S	S/CL	G,C,S,R	F	F	200	200	28.0	V. Good
x-3	24.2	17.2	16.1	4.2	4.0	63.0	SL/CL	S/SL	G,S,C	F/sh	F	200	200	32.0	V. Good
x-4	33.5	28.8	8.4	2.9	2.4	62.5	SL/S	S	G,S,C	F	F	200	200	30.0	Excellent
x-5	32.1	28.6	28.6	2.7	2.1	69.0	SL/L	SL/L	G,S,C	F	F	200	200	30.0	Good
x-6	36.6	30.6	26.2	2.4	2.3	66.5	S/SL	S/SL	G,S	F	F	200	200	36.0	Excellent
x-7	24.7	22.3	15.1	2.4	2.5	76.5	S/SL	CL/SL	G,S	F	F	200	200	18.0	Fair
x-8	35.3	28.3	15.5	2.2	3.0	72.0	S/SL	CL/SL	G,C,S	F	F	200	200	26.0	Excellent
x-9	27.3	20.1	18.9	2.5	2.4	77.5	SL/CL	S/SL	S,G	F	F	200	200	24.0	Good
x-10	27.1	19.7	19.2	3.6	3.4	71.0	SL/CL	SL/S	G,S	F	F	200	200	24.0	Good
x-11	31.0	27.6	14.3	2.3	2.4	76.0	S/SL	SL/CL	S,G	F	F	200	200	26.0	Excellent
x-12	38.7	30.1	21.0	2.6	2.8	72.0	S/L	SL/L	S,G	F	F	200	0	26.0	Good
x-13	32.8	30.6	8.0	1.8	3.6	62.5	S/SL	S/CL	S,G	F	F	200	100	18.0	Fair
Average	**32.3**	**25.4**	**16.9**	**3.0**	**3.1**	**68.2**						**200.0**	**176.9**	**26.6**	
2. IC-2 (UBC Confluence to 0.7mi Downstream)															
x-14	40.8	36.0	25.3	3.9	3.4	68.5	S/SL	CL/SL	S,G	F	F	200	200	26.0	Fair
x-15	33.3	32.6	11.0	3.3	3.1	72.5	SL/S	S/L	G,S,C	F	F	200	200	32.0	V. Good
x-16	50.8	37.4	37.3	3.9	3.8	85.0	SL	SL/S	S,G,C,R	F	F	200	200	26.0	Good
Average	**41.6**	**35.3**	**24.5**	**3.7**	**3.4**	**75.3**						**200.0**	**200.0**	**28.0**	

[1]Bank material type abbreviations: cl = clay, s = sand, sl = silt, l = loam
[2]Substrate material abbreviations: c = cobble, s = sand, sl = silt, g = gravel, r = rubble
[3]Riparian vegetation type abbreviations: f = forest, g = grass
[4]Pool habitat quality interpretation: poor = <10" deep, dominated by sandy substrate and with no overhead cover; fair = 10-12" deep, dominated by sandy substrate with few coarse materials and little overhead cover; good = up to 18" deep, with coarse material substrate and adequate overhead cover; very good = up to 24" deep, dominated by coarse material substrate and with optimum overhead cover; excellent = up to 36" deep, dominated by coarse material substrate and with optimum overhead cover.

Table 1 - Upper Beaverdam Creek Tributary System - Photo Library Index

Upper Beaverdam Creek Photo Library		
RSAT Stream Segment	**Transect #**	**File Path**
UBC-5 (Goddard Tributary)	Fish Blockage	UBC-5\P9070022.JPG
UBC-5 (Goddard Tributary)	Fish Blockage	UBC-5\P9070023.JPG
UBC-5 (Goddard Tributary)	x-1	UBC-5\P9070024.JPG
UBC-5 (Goddard Tributary)	x-1	UBC-5\P9070025.JPG
UBC-5 (Goddard Tributary)	x-2	UBC-5\P9070026.JPG
UBC-5 (Goddard Tributary)	x-2	UBC-5\P9070027.JPG
UBC-5 (Goddard Tributary)	x-3	UBC-5\P9070028.JPG
UBC-5 (Goddard Tributary)	x-3	UBC-5\P9070029.JPG
UBC-5 (Goddard Tributary)	x-4	UBC-5\P9070030.JPG
UBC-5 (Goddard Tributary)	x-5	UBC-5\P9070031.JPG
UBC-5 (Goddard Tributary)	x-5	UBC-5\P9070032.JPG
UBC-5 (Goddard Tributary)	x-6	UBC-5\P9070033.JPG
UBC-5 (Goddard Tributary)	x-6	UBC-5\P9070034.JPG
UBC-5 (Goddard Tributary)	x-7	UBC-5\P9070035.JPG
UBC-5 (Goddard Tributary)	x-7	UBC-5\P9070036.JPG
UBC-5 (Goddard Tributary)	Moderate-Severe Erosion	UBC-5\P9070037.JPG
UBC-5 (Goddard Tributary)	x-8	UBC-5\P9070038.JPG
UBC-5 (Goddard Tributary)	x-8	UBC-5\P9070039.JPG
UBC-5 (Goddard Tributary)	x-8	UBC-5\P9070040.JPG
UBC-5 (Goddard Tributary)	Moderate-Severe Erosion	UBC-5\P9070041.JPG
UBC-5 (Goddard Tributary)	x-9	UBC-5\P9070042.JPG
UBC-5 (Goddard Tributary)	x-9	UBC-5\P9070043.JPG
UBC-5 (Goddard Tributary)	x-10	UBC-5\P9070044.JPG
UBC-5A (Greenbelt Forest Tributary)	Dry Channel	UBC-5A\907001
UBC-5A (Greenbelt Forest Tributary)	Dry Channel	UBC-5A\907002
UBC-5A (Greenbelt Forest Tributary)	Dry Channel	UBC-5A\907003
UBC-5A (Greenbelt Forest Tributary)	Slight Erosion	UBC-5A\907004
UBC-5A (Greenbelt Forest Tributary)	Dry Channel	UBC-5A\907005
UBC-5A (Greenbelt Forest Tributary)	Dry Channel	UBC-5A\907006
UBC-5A (Greenbelt Forest Tributary)	Dry Channel	UBC-5A\907007
UBC-5A (Greenbelt Forest Tributary)	Nick Point	UBC-5A\907008
UBC-5A (Greenbelt Forest Tributary)	x-1	UBC-5A\907009
UBC-5A (Greenbelt Forest Tributary)	x-1	UBC-5A\9070010
UBC-5A (Greenbelt Forest Tributary)	x-1	UBC-5A\9070011
UBC-5A (Greenbelt Forest Tributary)	Box Turtle	UBC-5A\9070012
UBC-5A (Greenbelt Forest Tributary)	28" Nick Point	UBC-5A\9070013
UBC-5A (Greenbelt Forest Tributary)	28" Nick Point	UBC-5A\9070014
UBC-5A (Greenbelt Forest Tributary)	28" Nick Point	UBC-5A\9070015
UBC-5A (Greenbelt Forest Tributary)	x-2	UBC-5A\9070016
UBC-5A (Greenbelt Forest Tributary)	x-2	UBC-5A\9070017
UBC-5A (Greenbelt Forest Tributary)	x-2	UBC-5A\9070018
UBC-5A (Greenbelt Forest Tributary)	x-2	UBC-5A\9070019
UBC-5A (Greenbelt Forest Tributary)	x-3	UBC-5A\9070020
UBC-5A (Greenbelt Forest Tributary)	x-3	UBC-5A\9070021

Table 1 - Upper Beaverdam Creek Tributary System - Photo Library Index Cont'd.

Upper Beaverdam Creek Photo Library		
RSAT Stream Segment	**Transect #**	**File Path**
UBC-8 (East Tributary)	x-1	UBC-8\P9060058
UBC-8 (East Tributary)	x-1	UBC-8\P9060059
UBC-8 (East Tributary)	x-1	UBC-8\P9060060
UBC-8 (East Tributary)	Severe Erosion	UBC-8\P9060061
UBC-8 (East Tributary)	Notched Weir	UBC-8\P9060062
UBC-8 (East Tributary)	x-2	UBC-8\P9060063
UBC-8 (East Tributary)	x-2	UBC-8\P9060064
UBC-8 (East Tributary)	x-3	UBC-8\P9060065
UBC-8 (East Tributary)	x-3	UBC-8\P9060066
UBC-8 (East Tributary)	x-4	UBC-8\P9060067
UBC-8 (East Tributary)	x-4	UBC-8\P9060068
UBC-9 (West Tributary)	x-3	UBC-9\P9060052
UBC-9 (West Tributary)	x-3	UBC-9\P9060053
UBC-9 (West Tributary)	x-2	UBC-9\P9060054
UBC-9 (West Tributary)	x-2	UBC-9\P9060055
UBC-9 (West Tributary)	x-1	UBC-9\P9060056
UBC-9 (West Tributary)	x-1	UBC-9\P9060057
UBC-11 (Poultry Rd. Tributary)	x-1	UBC-11\P9230058
UBC-11 (Poultry Rd. Tributary)	x-1	UBC-11\P9230059
UBC-11 (Poultry Rd. Tributary)	8" CIP + 24" CMP(rusted out)	UBC-11\P9230060
UBC-11 (Poultry Rd. Tributary)	8" CIP + 24" CMP(rusted out)	UBC-11\P9230061
UBC-11 (Poultry Rd. Tributary)	24"PVC	UBC-11\P9230062
UBC-11 (Poultry Rd. Tributary)	x-2	UBC-11\P9230063
UBC-11 (Poultry Rd. Tributary)	Outfall	UBC-11\P9230064
UBC-11 (Poultry Rd. Tributary)	x-3	UBC-11\P9230065
UBC-11 (Poultry Rd. Tributary)	x-3	UBC-11\P9230066
UBC-11 (Poultry Rd. Tributary)	Pipe	UBC-11\P9230067
UBC-11 (Poultry Rd. Tributary)	x-5	UBC-11\P9230068
UBC-11 (Poultry Rd. Tributary)	x-6	UBC-11\P9230069
UBC-11 (Poultry Rd. Tributary)	x-7	UBC-11\P9230070

Table 2 - Indian Creek - Photo Library Index

Indian Creek Photo Library		
RSAT Stream Segment	**Transect #**	**File Path**
IC-1 (Powder Mill Road to UBC Confluence)	x-1	IC-1\P8160037_IC-1U
IC-1 (Powder Mill Road to UBC Confluence)	x-1	IC-1\P8160038_IC-1D
IC-1 (Powder Mill Road to UBC Confluence)	Severe Erosion	IC-1\P8160039_SEV_EROSION1
IC-1 (Powder Mill Road to UBC Confluence)	Severe Erosion	IC-1\P8160040_SEVERE_EROSION2
IC-1 (Powder Mill Road to UBC Confluence)	Severe Erosion	IC-1\P8160041_SEVERE_EROSION3
IC-1 (Powder Mill Road to UBC Confluence)	Debris Dam	IC-1\P8160042DEBRIS
IC-1 (Powder Mill Road to UBC Confluence)	Marker	IC-1\P8160044_MARKER
IC-1 (Powder Mill Road to UBC Confluence)	x-2	IC-1\P8160045_IC-2D
IC-1 (Powder Mill Road to UBC Confluence)	x-2	IC-1\P8160046_IC-2U
IC-1 (Powder Mill Road to UBC Confluence)	x-3	IC-1\P8160047_IC3D
IC-1 (Powder Mill Road to UBC Confluence)	x-3	IC-1\P8160048_IC-3U
IC-1 (Powder Mill Road to UBC Confluence)	Debris Dam	IC-1\P8160049DEBRIS
IC-1 (Powder Mill Road to UBC Confluence)	x-4	IC-1\P8160050_IC-4D
IC-1 (Powder Mill Road to UBC Confluence)	x-4	IC-1\P8160051_IC-4U
IC-1 (Powder Mill Road to UBC Confluence)	Debris Dam	IC-1\P8160052_DEBRIS
IC-1 (Powder Mill Road to UBC Confluence)	Debris Dam	IC-1\P8160053_DEBRIS
IC-1 (Powder Mill Road to UBC Confluence)	x-5	IC-1\P8160054_IC-5D
IC-1 (Powder Mill Road to UBC Confluence)	x-5	IC-1\P8160055_IC-5U
IC-1 (Powder Mill Road to UBC Confluence)	Debris Dam	IC-1\P8180058
IC-1 (Powder Mill Road to UBC Confluence)	x-6	IC-1\P8180059_IC_6D
IC-1 (Powder Mill Road to UBC Confluence)	x-6	IC-1\P8180060_IC_6U
IC-1 (Powder Mill Road to UBC Confluence)	trash	IC-1\P8180061IC_TRASH
IC-1 (Powder Mill Road to UBC Confluence)	x-7	IC-1\P8180056_IC_7U
IC-1 (Powder Mill Road to UBC Confluence)	x-7	IC-1\P8180057_IC_7D
IC-1 (Powder Mill Road to UBC Confluence)	x-8	IC-1\P8180054_IC_8D
IC-1 (Powder Mill Road to UBC Confluence)	x-8	IC-1\P8180055_IC_8U
IC-1 (Powder Mill Road to UBC Confluence)	x-9	IC-1\P8180051_IC_9U
IC-1 (Powder Mill Road to UBC Confluence)	x-9	IC-1\P8180052_IC_9U
IC-1 (Powder Mill Road to UBC Confluence)	x-9	IC-1\P8180053_IC_9D
IC-1 (Powder Mill Road to UBC Confluence)	x-10	IC-1\P8180049_IC_10U
IC-1 (Powder Mill Road to UBC Confluence)	x-10	IC-1\P8180050_IC_10D
IC-1 (Powder Mill Road to UBC Confluence)	x-11	IC-1\P8180046_IC_11D
IC-1 (Powder Mill Road to UBC Confluence)	x-11	IC-1\P8180048_IC_11D
IC-1 (Powder Mill Road to UBC Confluence)	x-12	IC-1\P8180044_IC_12U
IC-1 (Powder Mill Road to UBC Confluence)	x-12	IC-1\P8180045_IC_12D
IC-1 (Powder Mill Road to UBC Confluence)	x-13	IC-1\P8180043_IC_13U

Table 2 - Indian Creek - Photo Library Index Cont'd.

Indian Creek Photo Library		
RSAT Stream Segment	**Transect #**	**File Path**
IC-2 (UBC Confluence to 0.7mi Downstream)	x-14	IC-1\P8180039_IC-14
IC-2 (UBC Confluence to 0.7mi Downstream)	x-14	IC-1\P8180040_IC-14
IC-2 (UBC Confluence to 0.7mi Downstream)	x-15	IC-2\P9060040_IC15_U
IC-2 (UBC Confluence to 0.7mi Downstream)	x-15	IC-2\P9060041_IC15_D
IC-2 (UBC Confluence to 0.7mi Downstream)	Tree Falls	IC-2\P9060042_IC_tree_falls
IC-2 (UBC Confluence to 0.7mi Downstream)	Moderate Erosion	IC-2\P9060043_IC
IC-2 (UBC Confluence to 0.7mi Downstream)	Moderate Erosion	IC-2\P9060044_IC
IC-2 (UBC Confluence to 0.7mi Downstream)	Moderate Erosion	IC-2\P9060045_IC
IC-2 (UBC Confluence to 0.7mi Downstream)	Moderate Erosion	IC-2\P9060046_IC_mod
IC-2 (UBC Confluence to 0.7mi Downstream)	x-16	IC-2\P9060047_IC16_SAV
IC-2 (UBC Confluence to 0.7mi Downstream)	x-16	IC-2\P9060048_IC16_SAV
IC-2 (UBC Confluence to 0.7mi Downstream)	x-16	IC-2\P9060049_IC16_SAV
IC-2 (UBC Confluence to 0.7mi Downstream)	x-16	IC-2\P9060050_IC16_D
IC-2 (UBC Confluence to 0.7mi Downstream)	x-16	IC-2\P9060051_IC16_U

Table 1 - Upper Beaverdam Creek Tributary System and Indian Creek - Corresponding Latitude and Longitude Coordinates for Streambank Soil Collection Sites

Sampling Site	Latitude	Longitude
Tributaries to Beaverdam Creek		
1. UBC-5 (Goddard Tributary)		
~ 800' above Northway Road	39.00972	-76.86382
~ 550' below Beaverdam Road	39.02162	-76.86219
2. UBC-8 (East Tributary)		
~700' above confluence to Mainstem	39.02213	-76.87240
3. UBC-9 (West Tributary)		
~ 1000' above confluence with Mainstem	39.02097	-76.87550
4. UBC-11 (Poultry Road Tributary)		
~ 700' above Powder Mill Road	39.03499	-76.88171
~ 400' below Beaverdam Road	39.02715	-76.88347
Indian Creek Mainstem		
1. IC-1 (Powder Mill Road to UBC Confluence)		
~ 600' below Powder Mill Road	39.03227	-76.90251
~ 550' below Sunnyside Avenue	39.02156	-76.90301
2. IC-2 (UBC Confluence to 0.7mi Downstream)		
~ 800' below Confluence with UBC	39.01395	-76.90004

Table 1 - Upper Beaverdam Creek Tributary System and Indian Creek Mainstem - Corresponding Latitude and Longitude Coordinates for Permanent Cross Sections

Permanent X-Station ID Number	Latitude	Longitude
Upper Beaverdam Creek Tributaries		
1. UBC-5 (Goddard Tributary)		
1	39.00790	-76.86378
2	39.01030	-76.86404
3	39.01450	-76.86446
4	39.01740	-76.86490
5	39.02150	-76.86249
UBC-5A (Greenbelt Forest Tributary)		
6	39.00860	-76.86451
2. UBC-8 (East Tributary)		
7	39.01940	-76.87180
8	39.02210	-76.87295
3. UBC-9 (West Tributary)		
9	39.01780	-76.87611
10	39.02200	-76.87503
4. UBC-10		
11	39.02820	-76.88211
12	39.02610	-76.88061
5. UBC-11 (Poultry Rd. Tributary)		
13	39.03610	-76.88248
14	39.03250	-76.88149
15	39.02800	-76.88368
16	39.02330	-76.88199
Indian Creek		
6. Mainstem BARC Property Portion Only		
17	39.03320	-76.90253
18	39.02700	-76.90383
19	39.02230	-76.90307
20	39.01650	-76.89834
21	39.01235	-76.90215

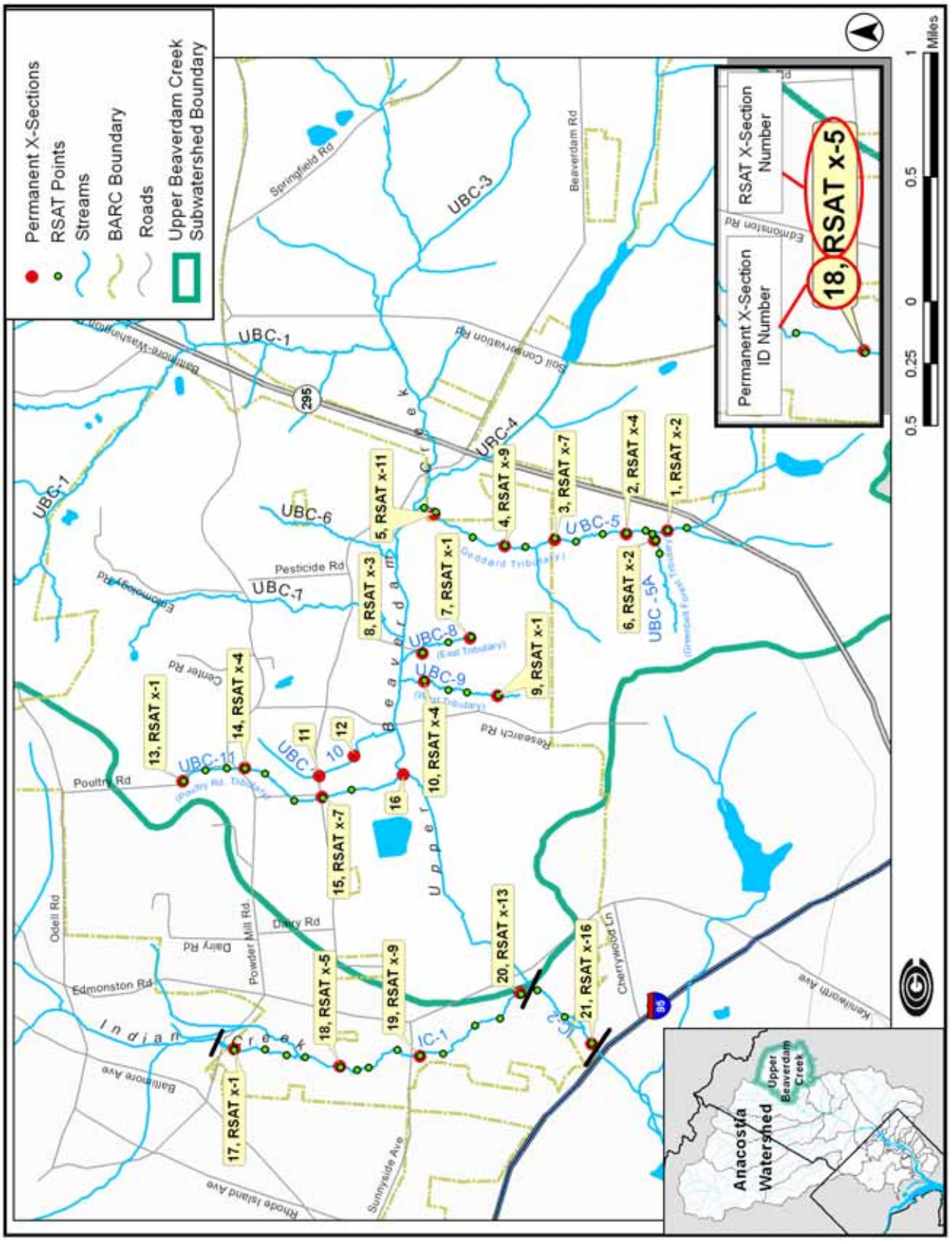
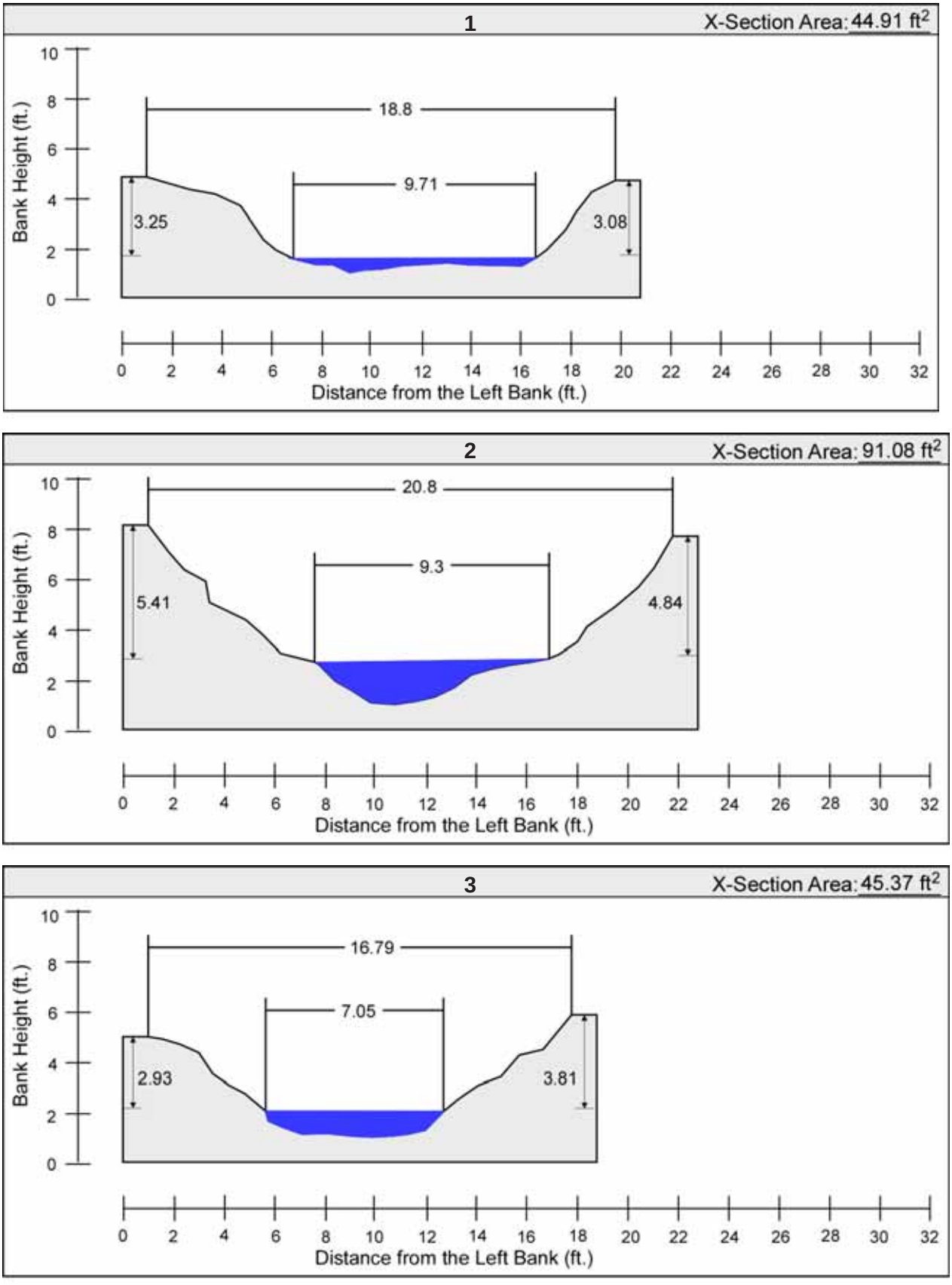


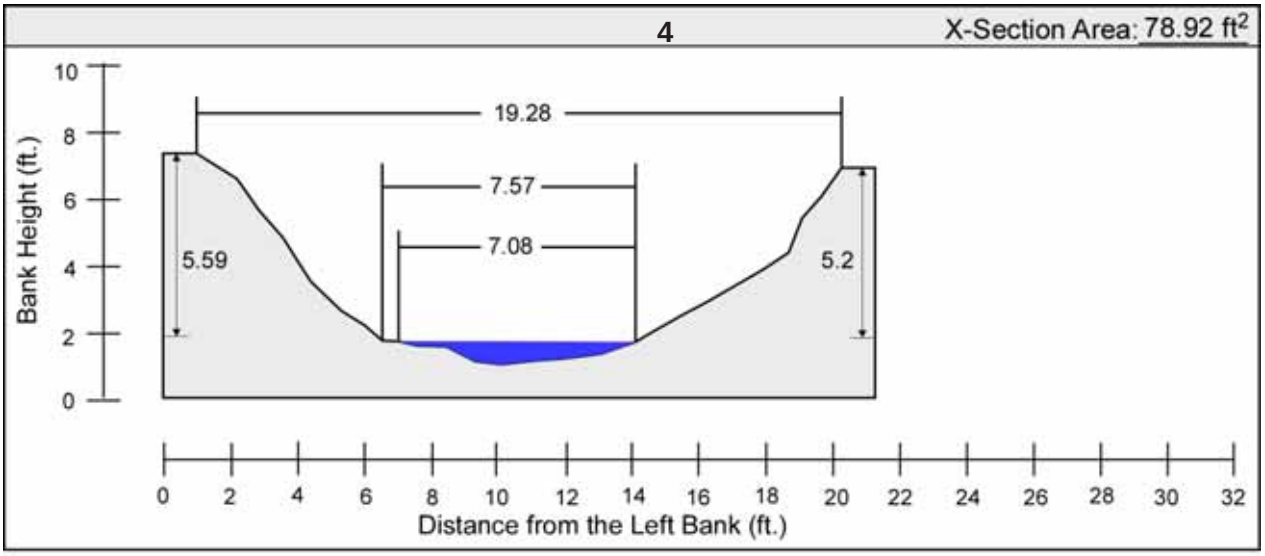
Figure 1. Upper Beaverdam Creek and Indian Creek - Map of Permanent Channel Cross Sections and RSAT Station Points

Figure 2. Permanent Channel Cross Sections for UBC-5 (Goddard Tributary)[1]



[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

Figure 2. Continued[1]



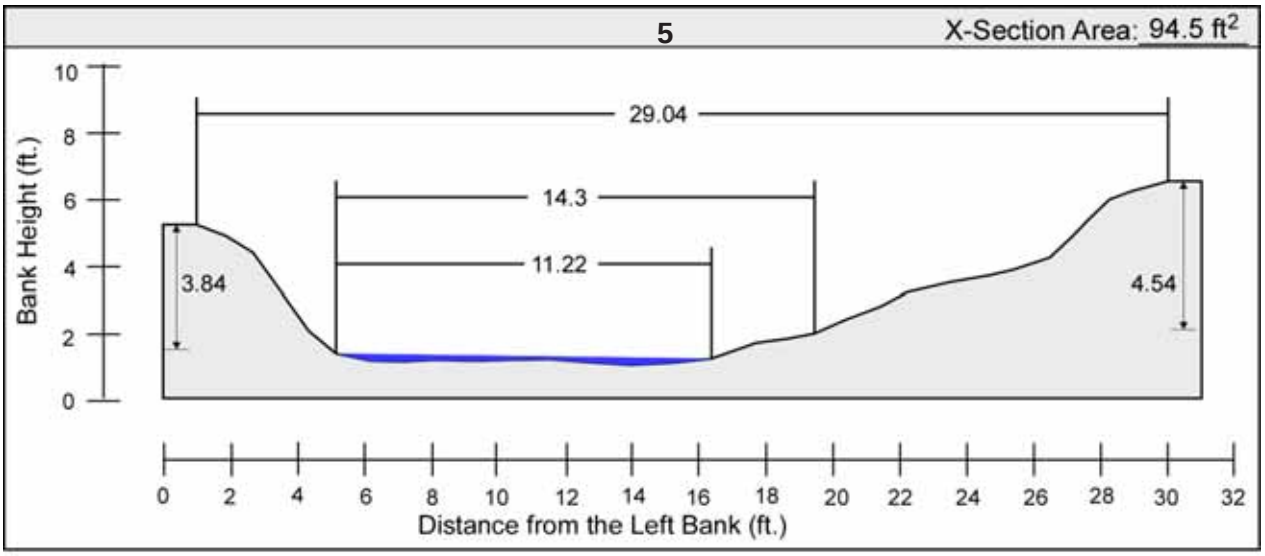
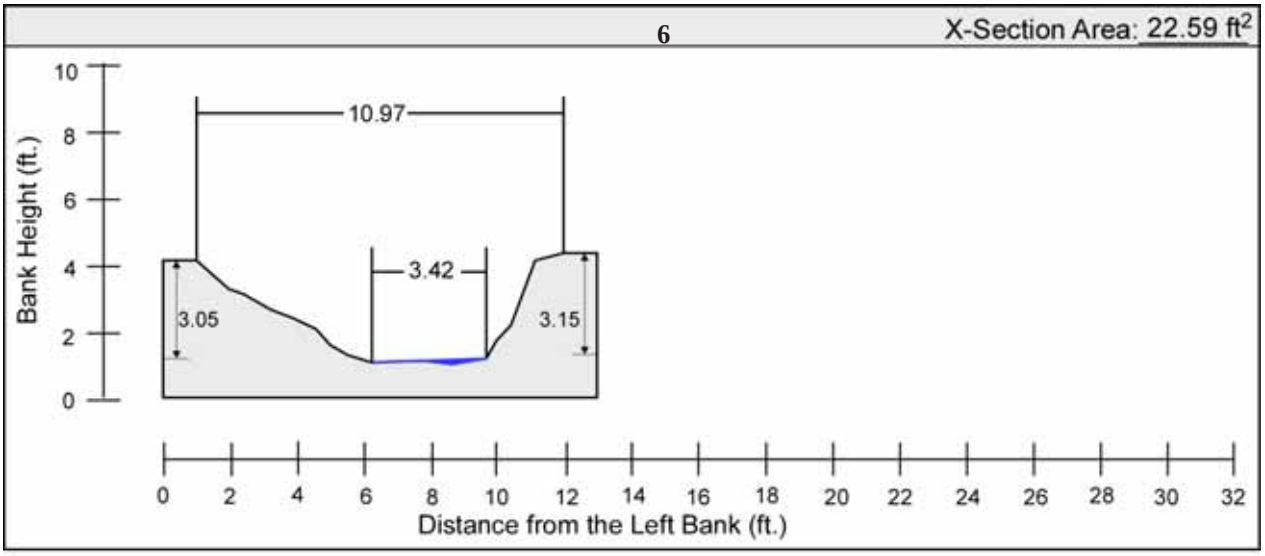


Figure 3. Permanent Channel Cross Sections for UBC-5A Greenbelt Forest Tributary[1]



[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

Figure 4. Permanent Channel Cross Sections for UBC-8 (East Tributary) [1]

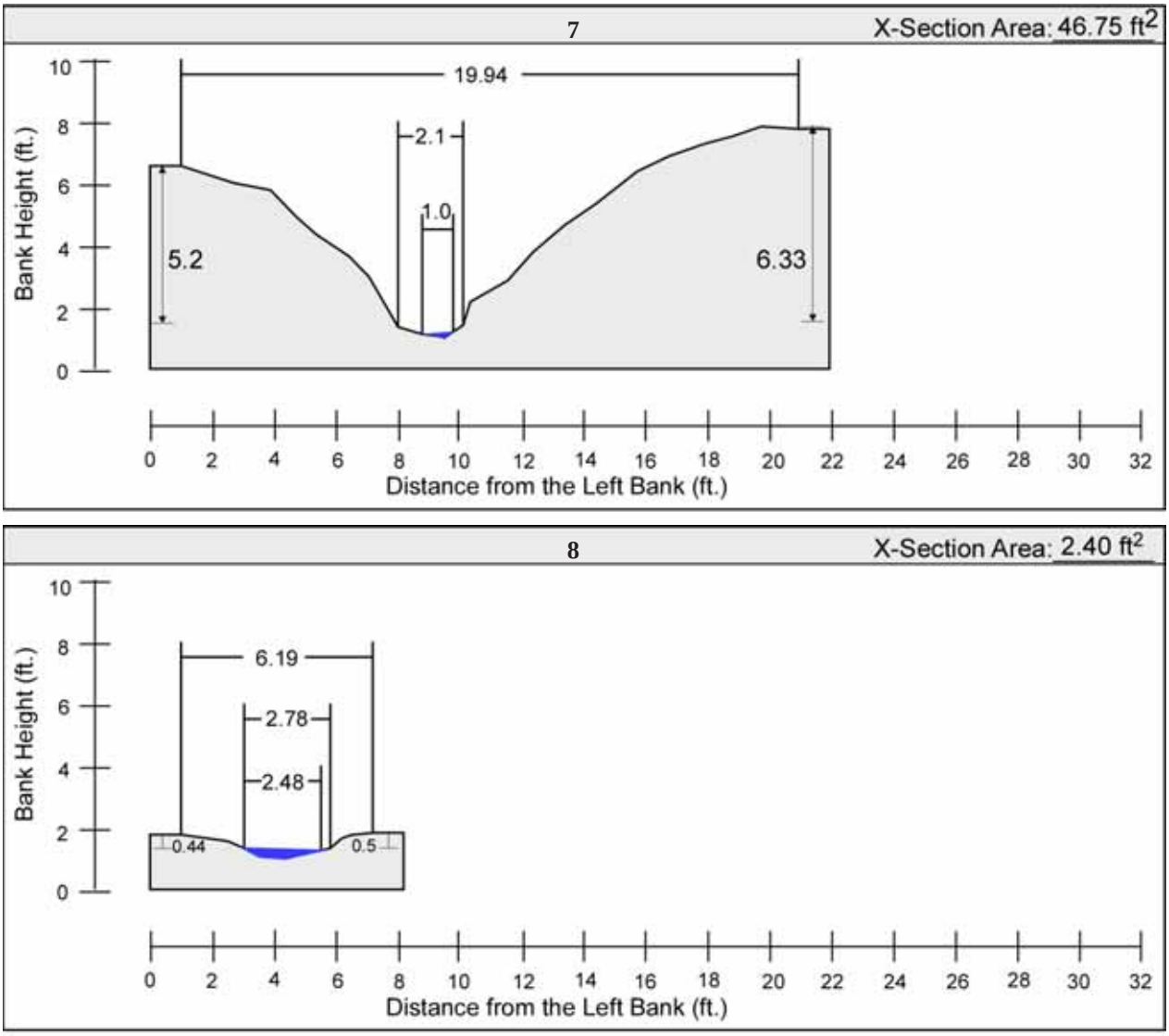
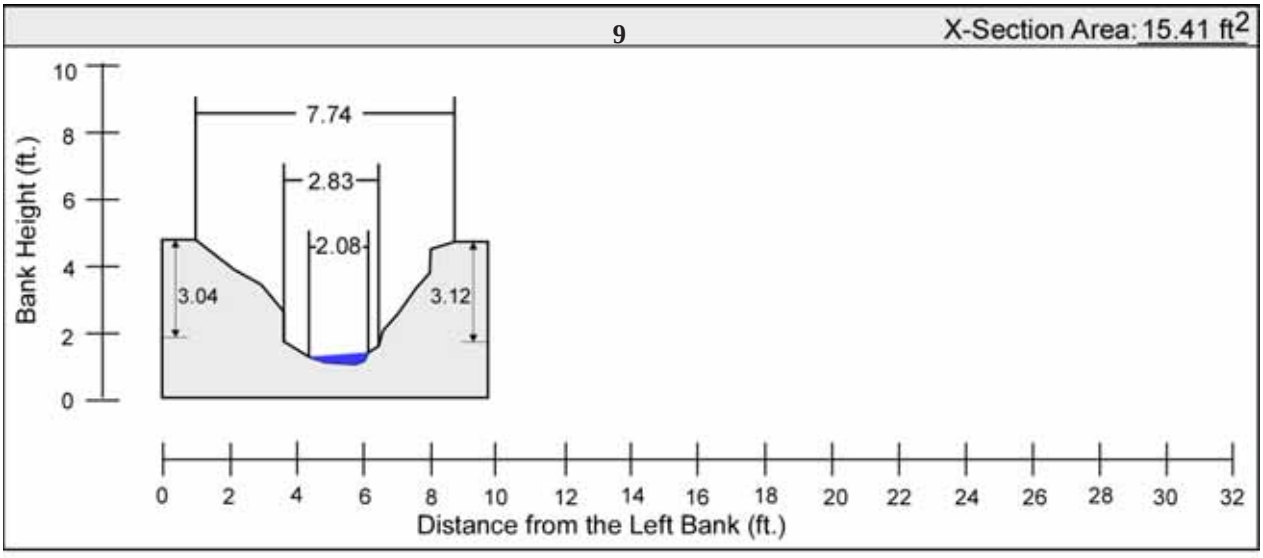


Figure 5. Permanent Channel Cross Sections for UBC-9 (West Tributary) [1]



[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

Figure 5. Continued[1]

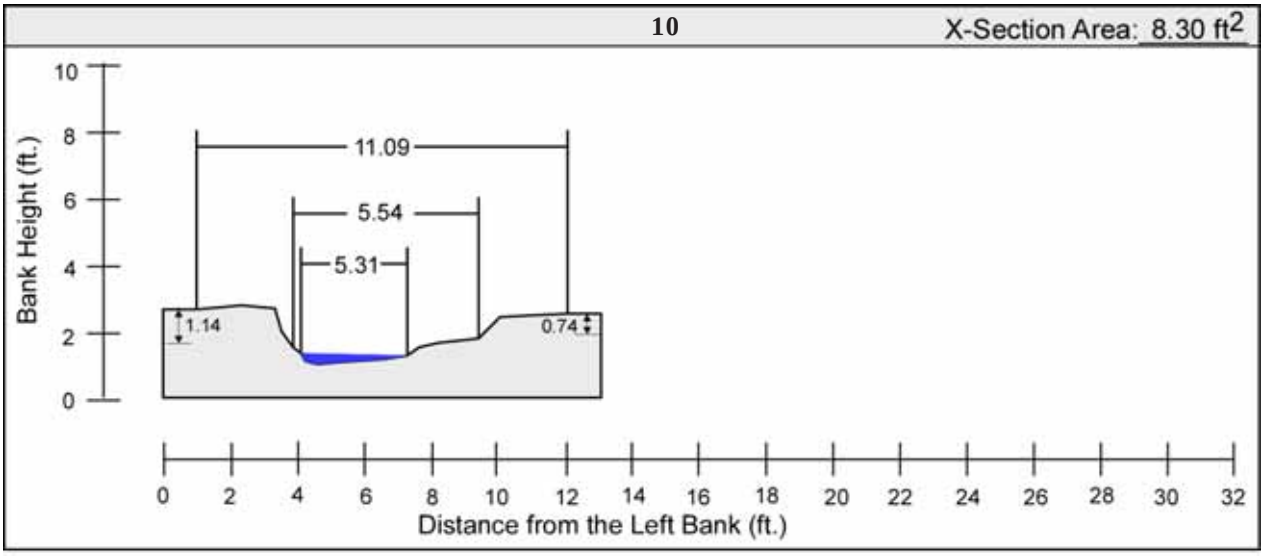
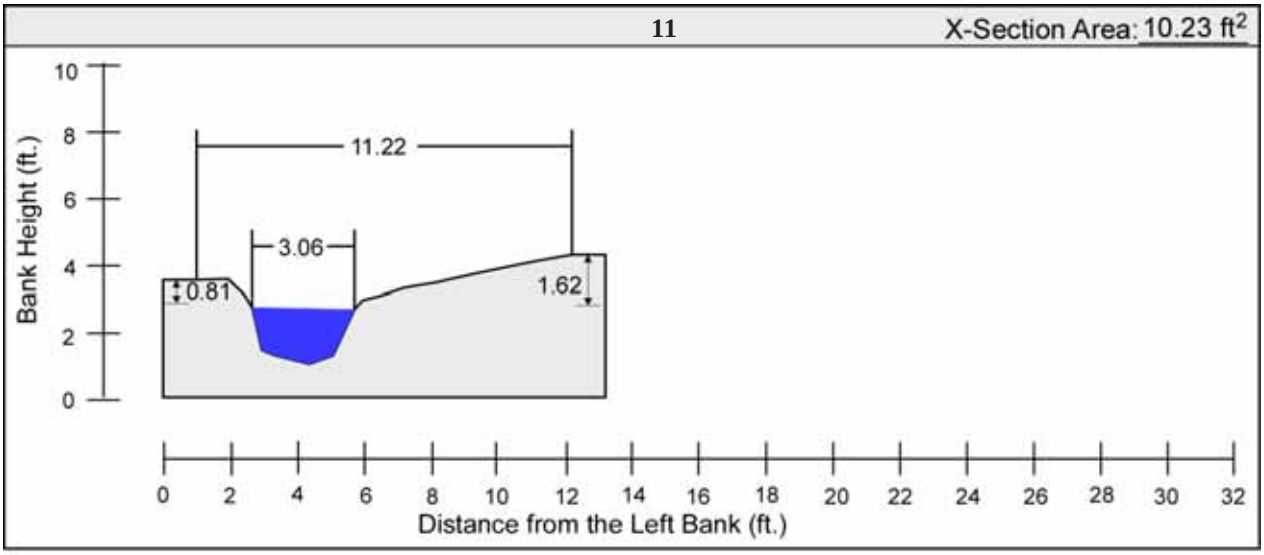
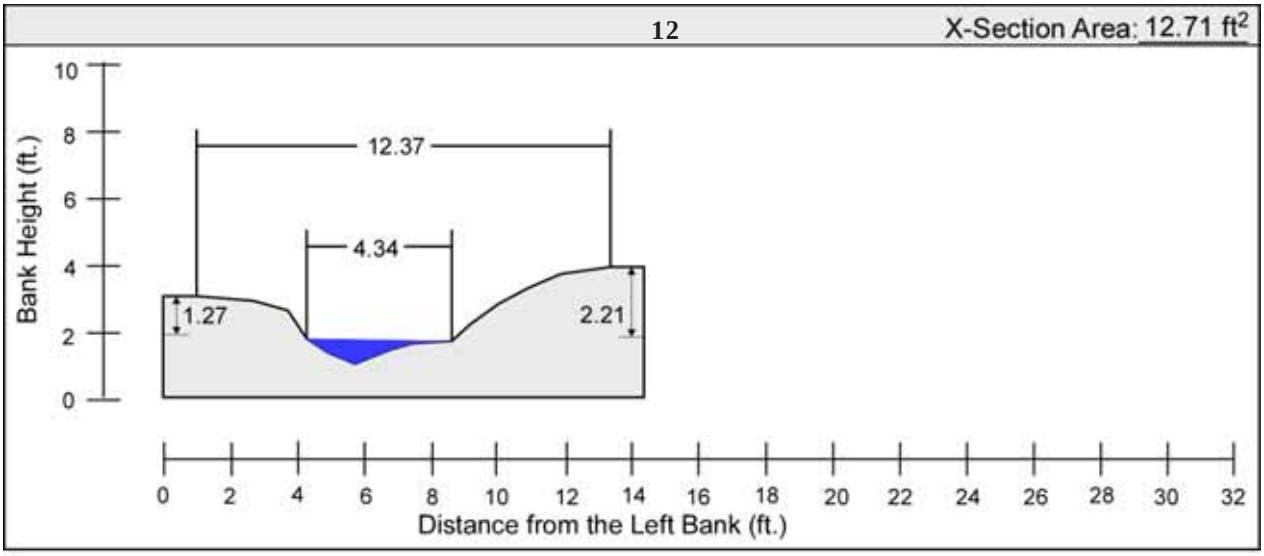


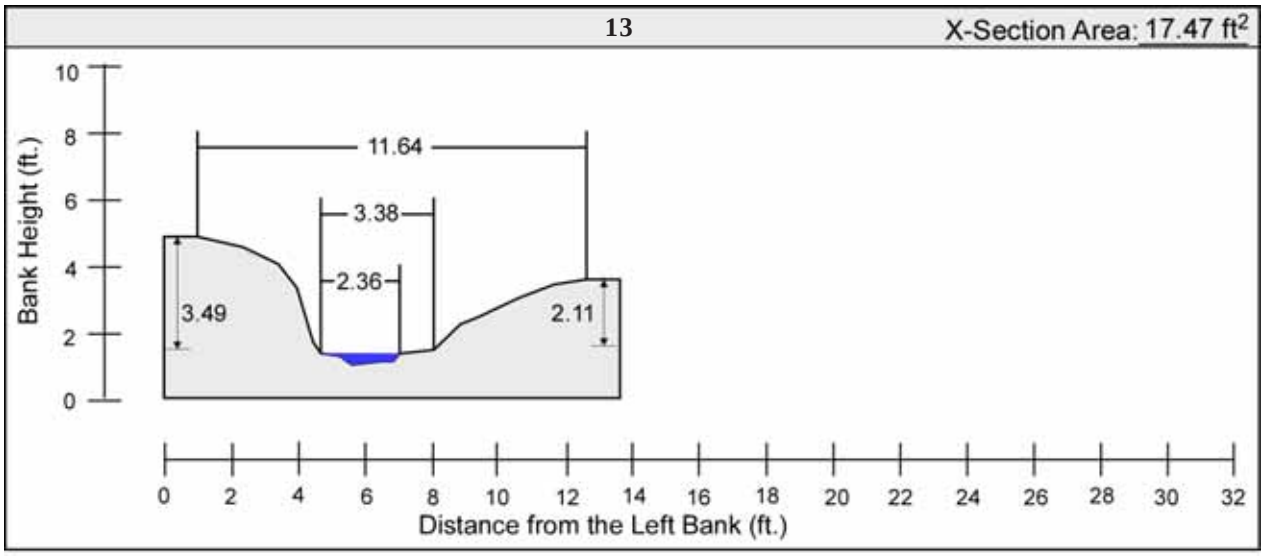
Figure 6. Permanent Channel Cross Sections for UBC-10[1]

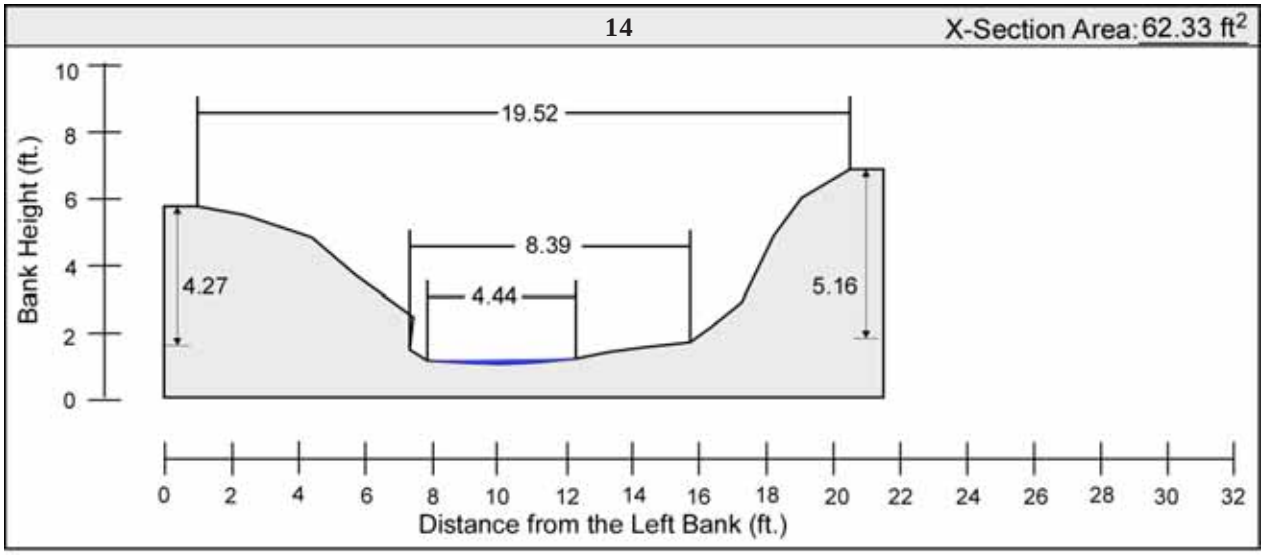


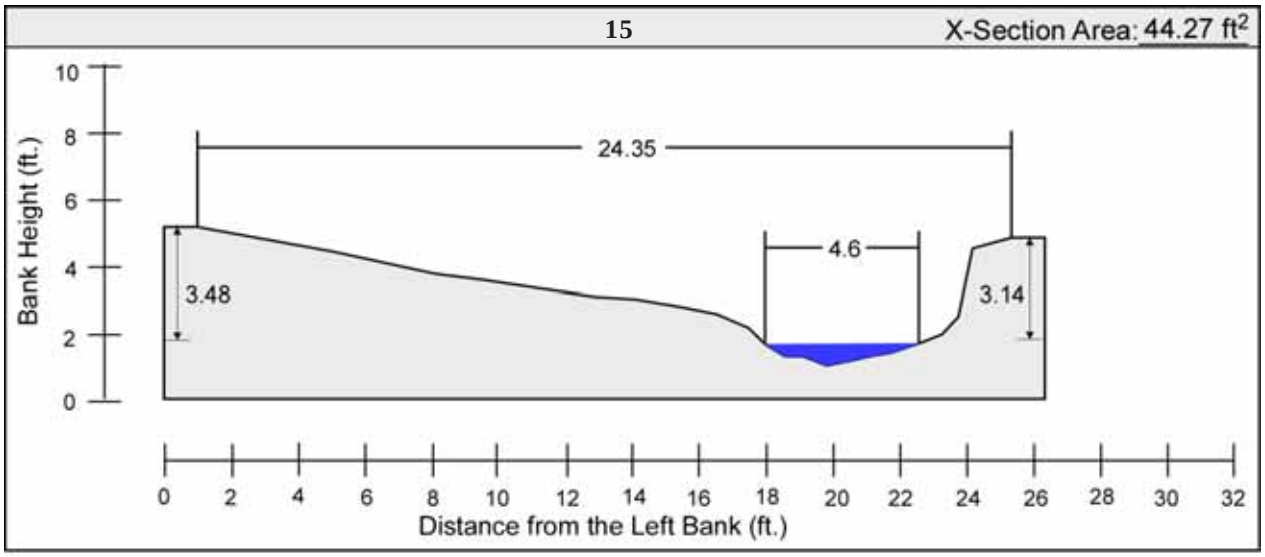


[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

Figure 7. Permanent Channel Cross Sections for UBC-11 (Poultry Rd. Tributary)[1]

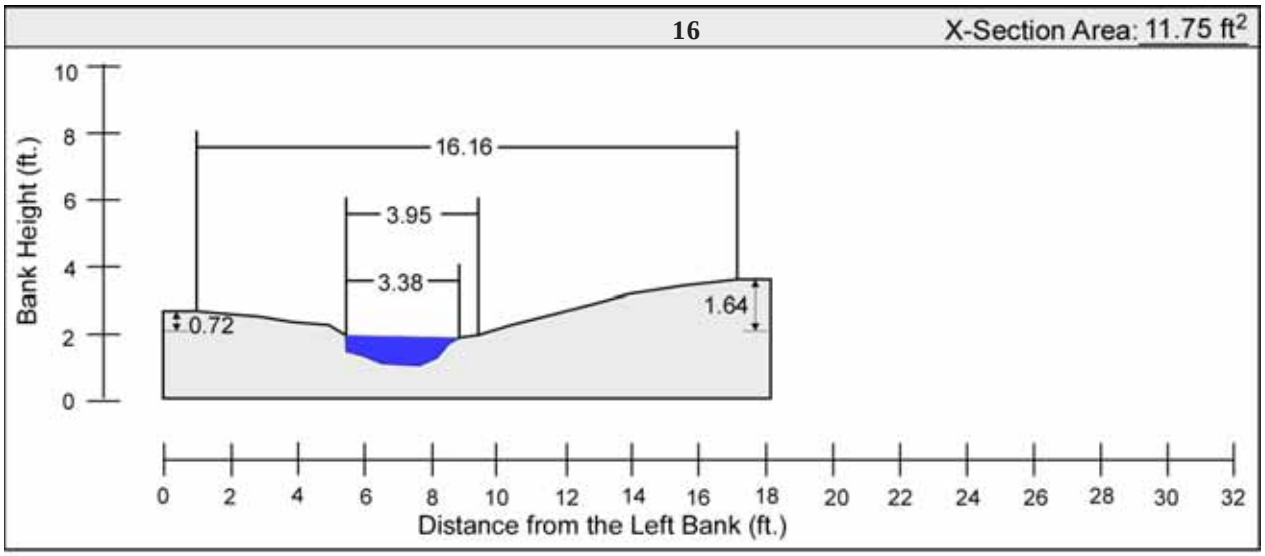






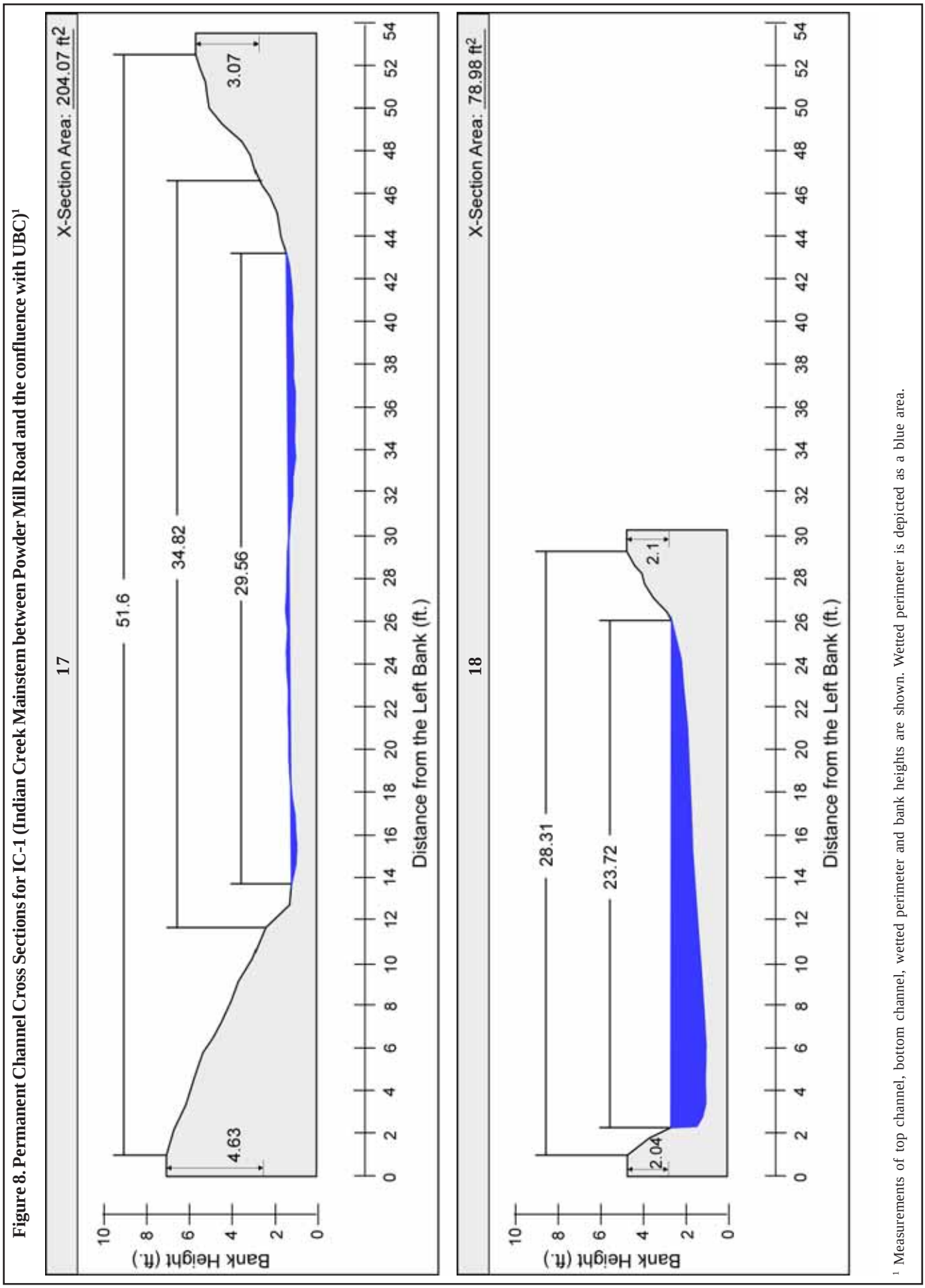
[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

Figure 7. Continued[1]



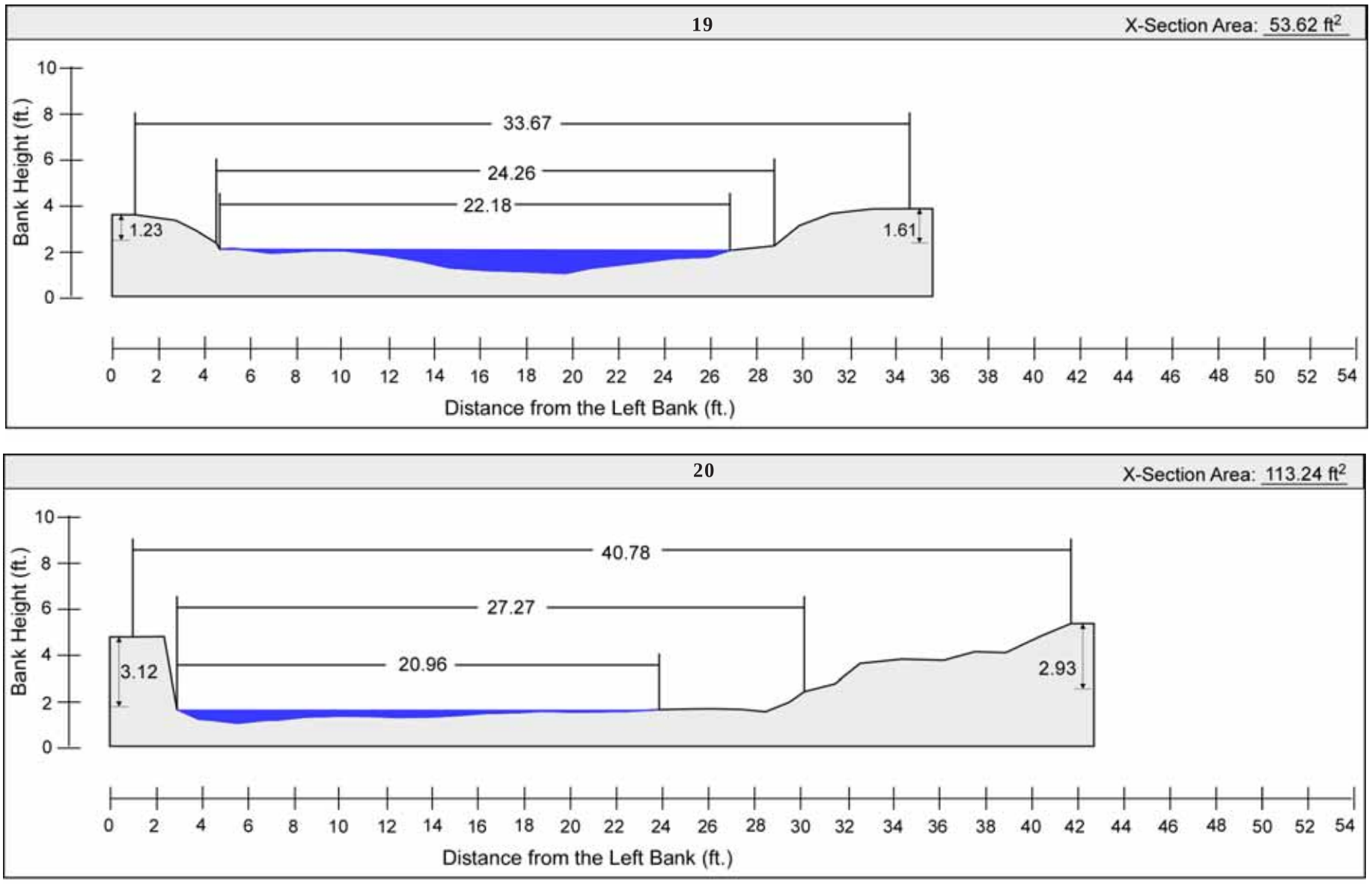
[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

Figure 8. Permanent Channel Cross Sections for IC-1 (Indian Creek Mainstem between Powder Mill Road and the confluence with UBC)[1]



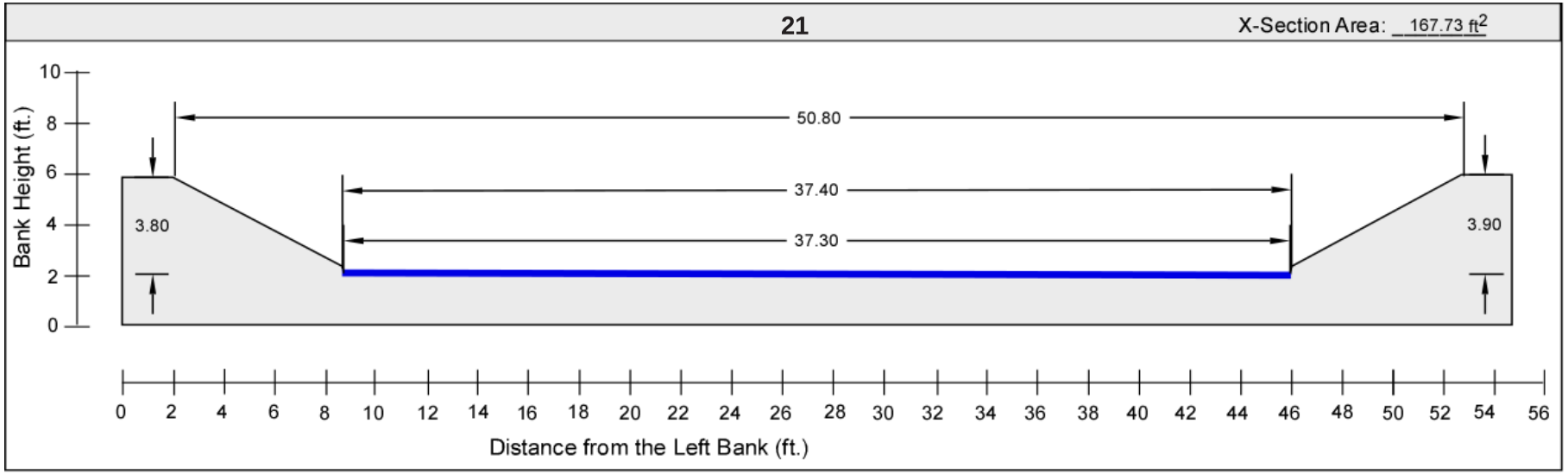
[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

Figure 8. Continued[1]



[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

Figure 9. Permanent Channel Cross Sections for IC-2 (Indian Creek Mainstem between UBC confluence and the beltway)[1]



[1] Measurements of top channel, bottom channel, wetted perimeter and bank heights are shown. Wetted perimeter is depicted as a blue area.

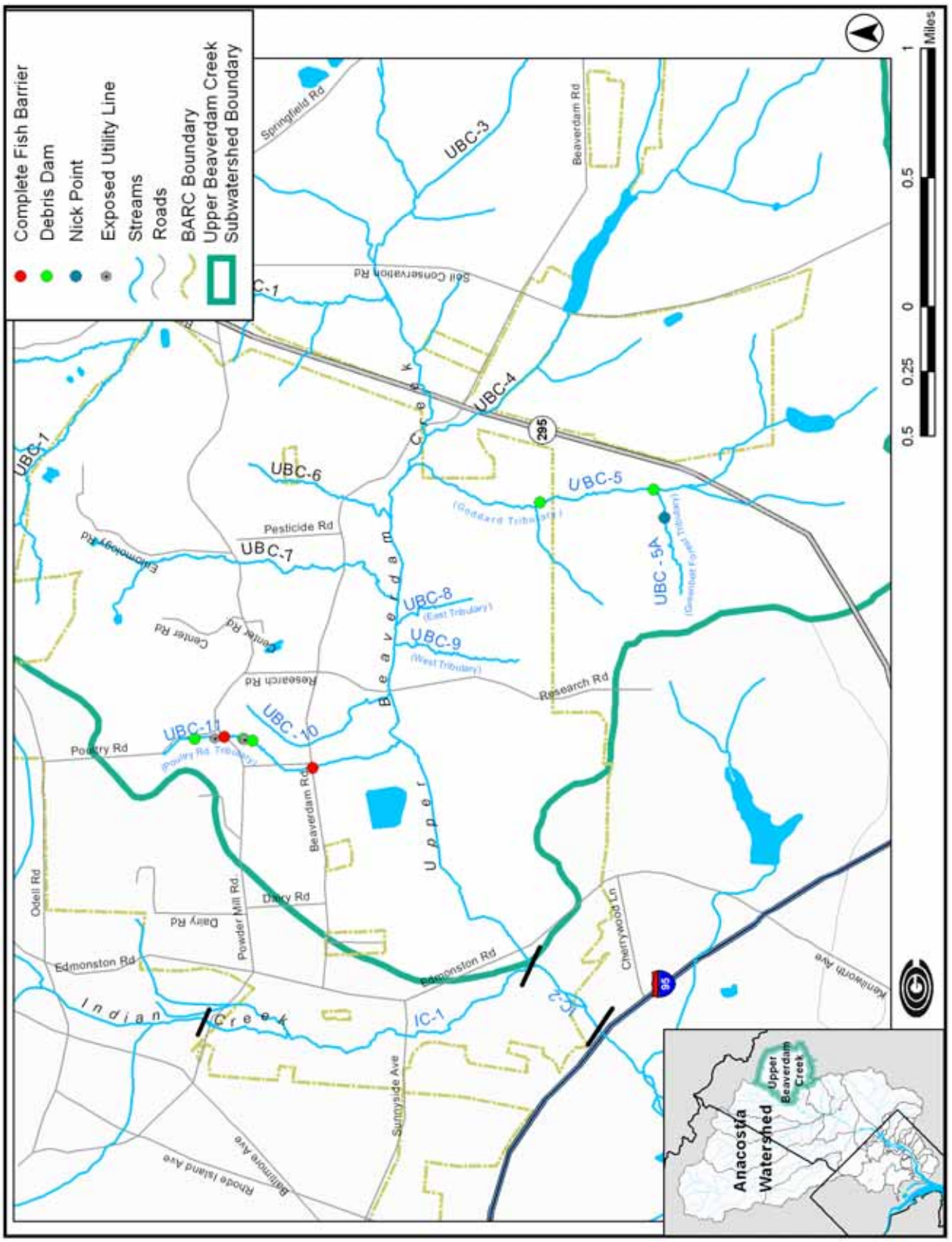


Figure 1. Upper Beaverdam Creek Tributary System and Indian Creek - Map of Debris Dams, Nick Points, Fish Barriers and Exposed Utility Lines

Table 1. Upper Beaverdam Creek Tributary System and Indian Creek - Corresponding Latitude and Longitude Coordinates for Debris Dams, Nick Points, Fish Barriers and Exposed Utility Lines

Feature	Latitude	Longitude
Upper Beaverdam Creek Tributaries		
1. UBC-5 (Goddard Tributary)		
debris dam	39.00895	-76.86384
debris dam	39.01533	-76.86475
fish barrier, complete	39.00659	-76.86366
UBC-5A (Greenbelt Forest Tributary)		
nick point	39.00834	-76.86586
nick point	39.00794	-76.86838
nick point	39.00837	-76.86584
nick point	39.00748	-76.86964
2. UBC-8 (East Tributary) NONE		
3. UBC-9 (West Tributary)		
fish barrier, partial	39.01943	-76.87588
nick point	39.01784	-76.87606
4. UBC-10		
Dry Channel - Not Surveyed		
5. UBC-11 (Poultry Road Tributary)		
debris dam	39.03467	-76.88169
pipe	39.03354	-76.88167
pipe	39.03187	-76.88177
debris dam	39.03143	-76.88185
fish barrier, complete	39.03303	-76.88156
debris dam	39.03194	-76.88171
fish barrier, complete	39.02807	-76.88379
fish barrier, partial	39.03643	-76.88272
Indian Creek		
6. Mainstem BARC Property Portion Only		
debris dam	39.03256	-76.90270
debris dam	39.03184	-76.90246
debris dam	39.03156	-76.90263
debris dam	39.03115	-76.90278
debris dam	39.02918	-76.90334
debris dam	39.02849	-76.90330
debris dam	39.02504	-76.90394
debris dam	39.02561	-76.90401
debris dam	39.01340	-76.90041
debris dam	39.01339	-76.90044