APPENDICES

1999 Baseline Study

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX A

SITE SELECTION FOR THE STREAM PROTECTION STRATEGY

A.1 Criteria for site selection

Sites were established on streams that were second order or greater with a unique drainage area between two and five square miles (stream order designations were based upon USGS 7.5 minute topographic quadrangles (1:24,000 scale)). An individual site consists of a 100-meter stream reach that is representative of conditions in the surrounding watershed. Reach boundaries were marked and their field location determined using a global positioning system (GPS) (see Appendix F). Where possible, efforts were made to avoid private property.

Suitable sites also met the following criteria:

- No major inputs, such as tributaries
- Must be 100 meters up or downstream of any road crossing or pond input, when possible
- For Piedmont/Triassic areas – must contain at least one riffle
- Suitable for use with backpack electrofisher(s) (depth and width)
- Must be shallow enough to use a kick net to sample benthic macroinvertebrates
- Must have flow throughout an average year
- If on private property, landowner permission must be given
- Must be representative of local stream conditions

A.2 Criteria for reference site selection

For each physiographic province, reference sites were chosen that either best reflect historic conditions or represent the highest quality conditions still available. These sites were assessed using the same protocols as the non-reference sites. Ultimate rankings and prioritization of systems within Fairfax County were based on their relative level of correspondence to the standard or “benchmark” characteristics of the reference streams.

Desirable characteristics of a reference site are:

- Low population density/land use
- Low imperviousness
- Extensive riparian buffer with maturing vegetation community
- No channel alterations
- Natural or low levels of sediment loading
- Presence of surrounding natural ecosystem
- Natural appearance, color, and odor

- Stable banks
- Healthy aquatic benthic macroinvertebrate and fish communities/ecosystems

Nine streams in Prince William Forest Park in Prince William County, Virginia, were used as reference sites for second-, third-, and fourth-order systems in the Piedmont and Triassic Basin physiographic provinces. The Quantico Creek watershed lies almost entirely within the Park's boundaries, which is almost completely forested and only minimally disturbed.

Other potential reference sites in both Maryland and Virginia were assessed during the course of the study. Due to difficulties encountered while attempting to locate suitable reference sites in the Coastal Plain physiographic province, Kane Creek was chosen as a reference stream based on the use of the least impaired sites approach (Karr *et al*. 1986).

APPENDIX B

BENTHIC MACROINVERTEBRATE PROTOCOLS

Benthic macroinvertebrate communities are a major component of any healthy stream system. They are an important link in any aquatic food web, forming the core diet of many stream fishes. These organisms are also useful indicators of water quality, due to their varying tolerances to chemical, nutrient, and sediment pollution.

B.1 RBP High- and Low-gradient field Sampling Methods

Two separate techniques were employed to evaluate the benthic macroinvertebrate communities of Fairfax County. A modified version of EPA's Rapid Bioassessment Protocol (RBP) for benthic sampling in high-gradient streams was used to collect samples from the Triassic Basin and Piedmont provinces (Barbour, *et al*, 1999). Sites within the Coastal Plain province were sampled using the "Twenty Jab" method. This technique was designed by the Mid-Atlantic Coastal Streams Workgroup (MACS) specifically for low-gradient streams (US EPA, 1997), and adopted for use in the EPA's RBP for benthic macroinvertebrate sampling in low-gradient areas. Samples collected in the field were preserved with 10% (by volume of sample jar) formalin solution (17% formaldehyde).

Genus-level classification of all macroinvertebrates samples was performed using selected taxonomic keys (Pennak 1989, Peckarsky 1990, Merritt and Cummins 1996). However, time constraints prevented the more detailed examinations required to identify taxa such as aquatic worms (Oligochaeta) and midge larvae (Chironomidae) to this level. In such cases, higher-tier classifications were considered sufficient.

The Quality Assurance and Quality Control (QA/QC) methodology defined by the RBP protocols was followed. The QA/QC procedure is designed to ensure that the data collected complies with the *Goals and Objectives* set forth in the Introduction chapter of the main report. Specific QA/QC procedures are outlined in separate sections where applicable.

B.2 Laboratory identification and analysis

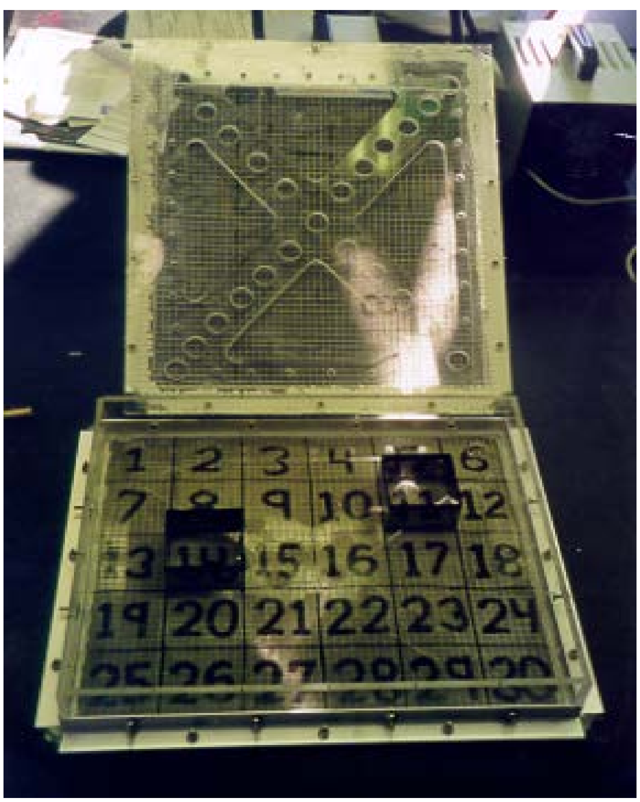
The following laboratory equipment was used to identify, record and catalog the benthic macroinvertebrate samples:

- benthic sample
- 8-inch diameter sieve with 500 micron mesh sorting grid, (30 squares) with 500 micron mesh (Figure B1)

- polyethylene wash tray, dissecting microscope,
- fiber-optic light source
- temporary formalin storage jar; funnel
- 95% ethanol
- scintillation vials
- 9-unit laboratory counter with grand total counter
- extra-fine/jewelers forceps
- chain-of-custody form and QA/QC log in sheets (Figures B2 & B3)
- benthic macroinvertebrate laboratory benchsheets (Figures B4 & B5)

Formalin-preserved field samples were later transferred to a 95% denatured ethanol solution to reduce the exposure to dangerous formaldehyde vapors during the sub-sampling, sorting, and identification processes. Universal precaution techniques, including the use of goggles and gloves, were utilized by all staff members while working in the laboratory. All work involving volatile chemicals and preservatives was conducted under a fume hood. All staff members were informed about chemical safety and hazards of chemicals associated with sampling techniques. In accordance with OSHA, Material Safety Data Sheets (MSDS) were and are posted and readily available in the laboratory. All hazardous chemicals were disposed of in accordance with applicable state and local guidelines.

Figure B1: View of top and bottom of sub-sampler built by SPS staff.



Upon arrival in the lab, field samples were logged in (figure B2). Invertebrate collections were developed by spreading each respective sample over the surface of a 30 x 36 cm (500 micron) mesh sorting grid sub-sampler (Caton, 1991) (Figure B1). A sub-sample of individuals was picked from a randomly selected square subdivision marked on the grid's surface (30 total squares). A tally of specimens continued until a minimum of 200 were obtained; all organisms were picked and counted from the square containing the 200th, allowing for a total of greater than two hundred individuals. The 200+ specimens for each site were then transferred to a scintillation vial, preserved with 95% ethanol, and labeled with the following information:

- Site code
- Date collected
- Sorted by
- Total number of organisms in the sample (chironomids, oligochaetes, others)
- QA/QC information (where applicable)

In compliance with QA/QC protocols, after laboratory processing was completed for a given sample, all sieves, pans, trays, etc., that had come in contact with the sample were rinsed thoroughly, examined carefully, and picked free of organisms or debris. Organisms found were added to the sample residue. Additionally, 10% of picked samples (randomly selected) were re-tallied to ensure numerical consistency.

Once all site samples were sub-sampled, sorted, and labeled, taxonomic identifications were then made to the genus level. The representatives in each respective taxonomic grouping were enumerated and recorded on the macroinvertebrate data bench sheet (figures B4 & B5) and on the sample identification log-in sheet (figure B3). All individuals from the sub-sample were then returned to the 95% ethanol solution and archived. To ensure conformity with QA/QC protocols, these additional steps were taken:

- Ten percent of the already processed and identified samples were randomly selected and rechecked for taxonomic and numerical consistency (Figure B3).
- A voucher collection of all samples and sub-samples was maintained. These specimens were properly labeled, preserved, and stored in the laboratory for future reference.
- A reference collection of each identified taxon was also maintained and verified by a second taxonomist.

Because of the time and labor requirements of precise identification of oligochaetes (aquatic worms) and chironomid (midge) larvae, these two groups were not identified down to the genus level. Oligochaetes were identified at the class level, and chironomids were identified at the family level. Tolerance values for both of these invertebrate groups both fall within a narrow range of values. Oligochaetes by and large fall primarily into the moderately tolerant (5) to tolerant (10) range, with only a very small subsection of species being slightly intolerant (<5). The tolerance value of 8 was used for all identified aquatic worms. The four sub-families of chironomidae found in this province are all moderately tolerant, with tolerance values ranging from 5 to 7. Therefore, the average tolerance value of 6 was assigned to all midges for use in the IBI metrics.

Figure B2: Laboratory log-in sheet for macroinvertebrate samples

Benthic Macroinvertebrate Sample Log-in Sheet

Site Code	Stream Name	Date collect	# jars	Preservation	Date received by	Date of completion: sorting	Date of completion: identification	Initials: sorter	Initials: identifier	QA/QC Site?

Figure B3: Macroinvertebrate QA/QC sample identification log-in data sheet

QA/QC Sample Log In Sheet for Identification

			Identification			QA/QC	QA/QC Identification		
Sample	Site Code	# of Jars	Date	Initials	n = ?	Site?	Date	Initials	n = ?
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									

Figure B4: Benthic macroinvertebrate sample identification data sheet (front).

Site Code____________

Benthic Macroinvertebrate Laboratory Bench Sheet

(front)

Agency: Stormwater Management Branch
Project: Stream Protection Strategy Study

Sorting start date:	**Identification start date:**
Sorting finish date:	**Identification finish date:**
Stream Name:	**Collector:**
Stream Order:	**Processor:**
Drainage basin:	**Taxonomist:**

Subsample Target: 200 Organisms
QC Sample? Y N QC Site? Y N

Number sorted:	
Number ID'ed:	

Organisms			**#**	**L.S.**	**T.I.**
Order	**Family**	**Genus**			
Oligochaeta					
Hirudinea					
Isopoda					
Amphipoda					
Decapoda					
Ephemeroptera					
Plecoptera					
Odonata					
		Subtotal:			

L.S. = Life Stage (i.e. adults, pupae, or larvae/immatures)
T.I. = Taxonomist's Initials

Figure B5: Benthic macroinvertebrate sample identification data sheet (back).

Site Code ______________

Benthic Macroinvertebrate Laboratory Bench Sheet

(back)

Organisms			#	L.S.	T.I.
Order	**Family**	**Genus**			
Trichoptera					
Hemiptera					
Megaloptera					
Coleoptera					
Diptera					
Gastropoda					
Pelecypoda					
Other					
		Grand Total:			

L.S. = Life Stage (i.e. adults, pupae, or larvae/immatures)
T.I. = Taxonomist's Initials

B.3 Development of a Benthic Macroinvertebrate Index of Biotic Integrity (IBI)

The response of a given biological community to environmental degradation can provide a useful measure of overall system health. Such responses, often evident as changes in community structure and composition, can highlight single-source environmental stressors, or the cumulative impact of multiple stressors. Potential measures of relative tolerance and intolerance will be identified from within the various subcategories (i.e., genus, species, functional group) of the macroinvertebrate communities.

These attributes, or “metrics,” were used to construct the foundation of an Index of Biotic Integrity (IBI) for ranking each study site. The IBI has two distinct components; (1) a set of criteria which transforms the metric values into scores that can then be used in the aggregate and (2) narrative “integrity” classes (*excellent, good, fair, poor and very poor*) which reflect relative correspondence to the numeric rating of the “reference” condition. Examples are shown in Table B1.

Table B1: Classification ratings used on total IBI scores.

IBI SCORE	SPS RATING	DESCRIPTION
80 to 100	Excellent	Equivalent to reference conditions; High biodiversity and balanced community
60 to 80	Good	Slightly degraded site with intolerant species decreasing in numbers
40 to 60	Fair	Marked decrease in intolerant species; shift to an unbalanced community
20 to 40	Poor	Intolerant species rare or absent, decreased diversity
0 to 20	Very Poor	Degraded site dominated by a small number of tolerant species

For the benthic macroinvertebrates, IBIs were created separately for the Piedmont/Triassic basin areas and the Coastal Plain area. An IBI was created for the Coastal Plain province using metrics taken from the Mid-Atlantic Integrated Assessment (MAIA) data report (Table B1), *Assessment Framework for Mid-Atlantic Coastal Plain Streams Using Benthic Macroinvertebrates* (Maxted et al. 1999). For the Piedmont-Triassic area the Index of MacroBenthic Integrity (IMBI) (Jones 2000, personal communication) was used (Table B2) since it provided regionally tested metrics and multi-year data for the same reference sites which were used in the SPS study.

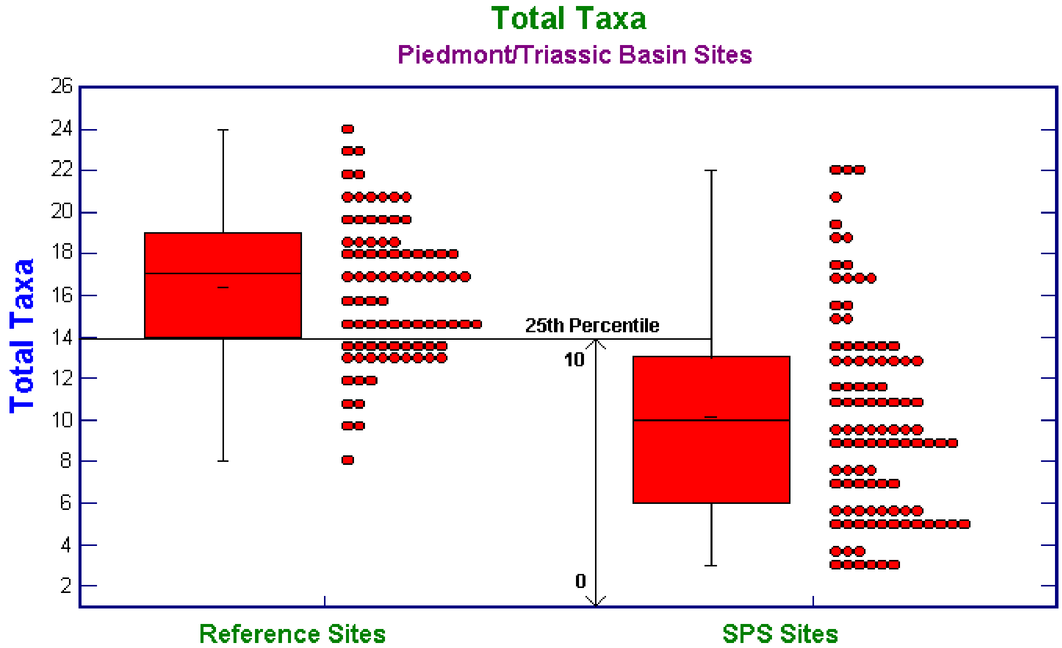
Table B2: Metrics used for the Coastal Plain sites. (Based on Maxted et al. 1999.)

COASTAL PLAIN IBI METRICS	
METRIC	**DESCRIPTION**
1. Taxa Richness	Number of different taxa at a site
2. EPT Taxa	Number of Mayfly, Stonefly and Caddisfly taxa at a site
3. Percent Ephemeroptera	Percent of sample that was in the order Ephemeroptera
4. Hilsenhoff Biotic Index	Hilsenhoff Biotic Index - general tolerance/intolerance of the sample
5. Percent Clingers	Percent of individuals whose habitat type is clingers

Table B3: IMBI metric descriptions (Jones 2000).

PIEDMONT AND TRIASSIC BASIN IMBI METRICS	
METRICS	**DESCRIPTIONS**
1. Taxa Richness	Number of different taxa at a site
2. EPT richness	Number of Mayfly, Stonefly and Caddisfly taxa at a site
3. Percent EPT	Percent of sample that are Mayfly, Stonefly and Caddisfly excluding the tolerant Net-Spinning Caddisflies (Hydropsychidae)
4. Percent Trichoptera w/o Hydropsychidae	Percent of sample that are Caddisflies excluding the tolerant Net-Spinning Caddisflies (Hydropsychidae)
5. Percent Coleoptera	Percent of sample that are beetles
6. Family Biotic Index	General tolerance/intolerance of the sample
7. Percent Dominance	Percent of the most abundant taxa
8. Percent Clingers + Percent Plecoptera	Percent of individuals whose habitat type is clingers plus percent of sample that are stoneflies but are not clingers
9. Percent Shredders	Percent of individuals that uses shredding as its primary functional feeding group
10. Percent Predators	Percent of individuals that uses predation as its primary functional feeding group

Figure B6: Box and Whisker Plot of Total Taxa for the Piedmont/Triassic Basin.



Example 1: For metric values that decrease with increasing disturbance (Total Taxa, EPT Richness, % EPT w/o Hydropsychidae, % Trichoptera w/o Hydropsychidae, % Coleoptera, % Clingers plus % Plecoptera, % Clingers, % Shredders, % Ephemeroptera and % Predators).

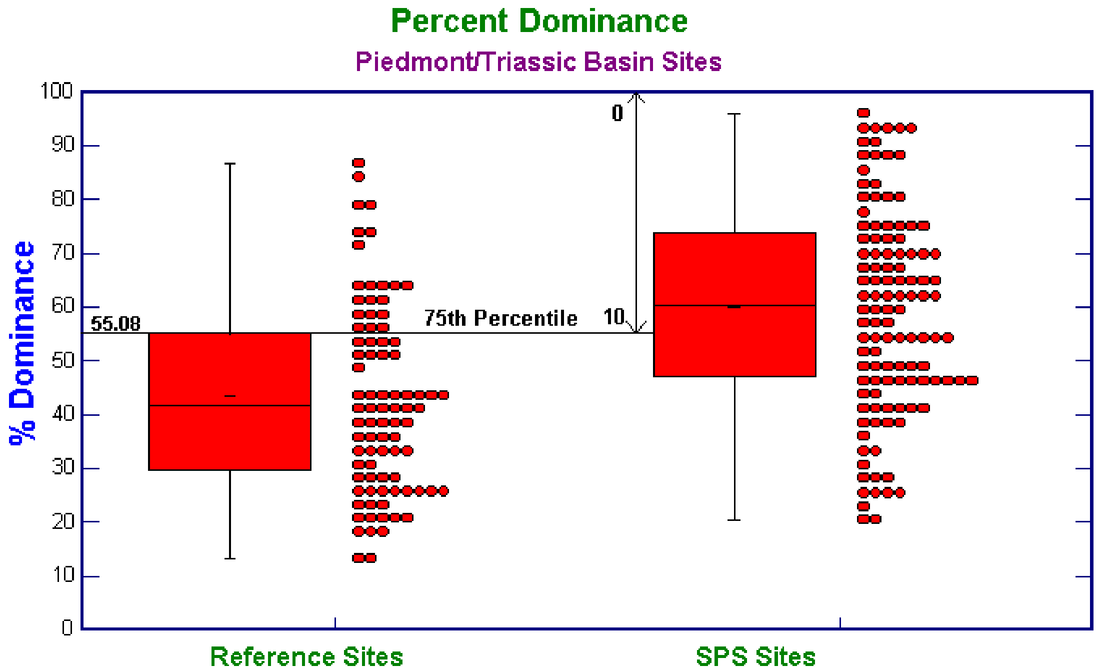
Table B4: Metric value conversions for Example 1.

Site Values	Converted Values	Final Value
7	5	5
10	7.14	7.14
22	15.71	10
13	9.29	9.29
8	5.71	5.71
5	3.57	3.57
4	2.86	2.86
14	10.00	10
6	4.29	4.29
3	2.14	2.14
17	12.14	10

The data for total taxa from the Piedmont and Triassic Basin reference areas and the SPS total taxa data were plotted against each other using a box and whisker plot. The 25th percentile from the reference data was then designated as the "reference condition" value. Therefore, any value above that mark was considered equivalent to reference conditions. The 25th percentile value of the reference data was, then divided by 10 to obtain the conversion factor. In this example (Figure B6) the conversion factor would be 14 (the 25th percentile of the reference conditions) divided by 10 (the upper limit of the 10-point scale), which is 1.4. All the SPS site values for total taxa were then divided by the conversion factor to convert them to the final 0 to 10 scale (Table B4). If the resulting value was more than 10, it was rectified to 10. The resulting values were summed to give each site a rating between 0 – 100. Each site was given a qualitative ranking based on its final rating (Table B3).

These steps were also performed for the Coastal Plain SPS site data. Unlike the Piedmont and Triassic Basin sites however, for which spatially and temporally broad reference information was available, the Coastal Plain sites were only compared to Kane Creek. The metric scores for the Kane Creek site were used in lieu of the 25th percentile of aggregate reference data for inversely-correlated metrics (Total Taxa, EPT Richness, % Ephemeroptera and % Clingers).

Figure B7: Box and Whisker Plot of % Dominance for the Piedmont/Triassic basin.



Example 2: For metric values that increase with increasing disturbance (i.e. FBI, HBI and Percent Dominance).

The data for percent dominance from the Piedmont/Triassic basin reference areas and the SPS data were plotted against each other using a box and whisker plot. In this case, the 75th percentile from the reference data was designated as the "reference condition" value. The difference between these metrics and those from example 1 is that the best value obtainable is 0 for the metric instead of 100, and the 75th percentile of the reference data, rather than the 25th, is the 10 value on the 0 to 10 scale. In this example (Figure B7), 100% dominance is the 0 value and 55.08 is the 10 value. In order to obtain the conversion factor, the

Table B5: Metric value conversions for Example 2.

SPS Site Value	100 - SPS site	Converted Value	Final Value
59.38	40.62	9.04	9.04
49.03	50.97	11.35	10
94.44	5.56	1.24	1.24
88.79	11.21	2.50	2.50
82.14	17.86	3.98	3.98
58.74	41.26	9.19	9.19
90.70	9.30	2.07	2.07
95.83	4.17	0.93	0.93
76.87	23.13	5.15	5.15
95.88	4.12	0.92	0.92
50.72	49.28	10.97	10
49.63	50.37	11.21	10

75th percentile value for the reference condition was subtracted from its upper limits. This value was then divided into 10 to arrive at the conversion factor. So in this example, the 75th percentile (55.08) is subtracted from the upper limit of this metric (100) to give 44.92. The final step to obtain the conversion factor is to divide 10 by 44.92, which yields 0.22262. Individual values from the SPS sites for percent dominance were then taken and subtracted from 100. Each value was then multiplied by the conversion factor to give the 0 to 10 value for that site (Table B5). If the value exceeded 10, the site was given a value of 10. This procedure was also followed for the coastal plain SPS sites using the coastal plain reference data. The converted values for each site were then summed to form a 0 to 100 scale. Since the coastal plain IBI consisted of only 5 metrics, the summed total was doubled to give it a 0 to 100 range (Table B3). The final IBI score for all the sites were then used to help create the Andrew's Curves in the countywide stream rankings (Appendix H).

These steps were also performed for the Coastal Plain SPS site data. Unlike the Piedmont and Triassic Basin sites however, for which spatially and temporally broad reference information was available, the Coastal Plain sites were only compared to Kane Creek. The metric scores for the Kane Creek site were used in lieu of the 75th percentile of aggregate reference data for the one directly correlated metric (Hilsenhoff Biotic Index).

B.4 Tolerance Values, Functional Feeding Groups and Habitat Classification for Benthic Macroinvertebrates

In order to assess benthic macroinvertebrate community health using the IBI, qualification of family- and genus-specific community traits is necessary (i.e. total taxa, percent ephemeroptera). The following tables list the tolerance values, functional feeding groups and habitat classification for the benthic macroinvertebrates identified in the SPS study. Since the benthic macroinvertebrates were sampled from two distinct physiographic provinces (Coastal Plain vs Piedmont/Triassic Basin), separate values for each community trait were used depending on which province they were sampled from. For the Coastal Plain IBI, both tolerance values and habitat classification (Table B6) were based on genus-level identifications. The Piedmont and Triassic Basin IBI contains metrics which require functional feeding group (FFG) and habitat guilds designations (Table B7) for genus-level taxonomic resolution, while the metric based on the tolerance values (FBI) required only family-level identifications (Table B8).

Table B6: Tolerance values (TV) and habitat designations for Coastal Plain sites taken from Assessment Framework for Mid-Atlantic Coastal Plain Streams Using Benthic Macroinvertebrates (Maxted et al. 1999). Abbreviations for habitat are as follows: **BU** - Burrower, **CG** - Clinger, **CL** - Climber, **SK** - Skater, **SP** - Sprawler, and **SW** - Swimmer.

Class	Order	Family	Genus	TV	Habitat
Arachnida	Acari	Aturidae	Brachypoda		
		Hydrachnidae	Hydrachna		
			Hygrobates		
			Atractides		
		Lebertiidae	Lebertia		
		Limnesiidae	Limnesia		
		Mideopsidae	Mideopsis		
		Sperchonidae	Sperchon		
		Torrenticolidae	Torrenticola		
		Unionicolidae	Neumania		
Bivalvia	Pelecypoda	Corbiculidae	Corbicula	4	
		Sphaeriidae	Unidentified	8	
			Pisidium	8	
			Sphaerium	8	
Crustacea	Amphipoda	Crangonyctidae	Crangonyx	4	
		Gammaridae	Gammarus	6	
	Decapoda	Cambaridae	Unidentified	6	
			Cambarus	6	
	Isopoda	Asellidae	Caecidotea	6	
Gastropoda	Limnophila	Ancylidae	Unidentified		
			Ferrissia	7	
		Lymnaidae	Fossaria	6	
			Pseudosuccinea	6	
		Physidae	Unidentified		
			Physella		
		Planorbidae	Unidentified	6	
			Gyraulus	7	
			Helisoma	7	
			Menetus	6	
			Planorbella	6	
	Mesogastropoda	Hydrobiidae	Amnicola	8	
		Valvatidae	Valvata		
		Viviparidae	Viviparus		
Hirudinea	Pharyngobdellida	Erpobdellidae	Mooreobdella		
	Rhynchobdellida	Glossiphoniidae	Helobdella		
		Piscicolidae	Myzobdella		
Hydrozoa	Hydroida	Hydridae	Hydra	3	
Insecta	Coleoptera	Dryopidae	Helichus	5	CG
		Dytiscidae	Agabus	5	SW
			Liodessus		CL
			Oreodytes		CL
			Potamonectes		CL
		Elmidae	Ancyronyx	2	CG
			Dubiraphia	6	CG
			Macronychus	2	CG
			Microcylloepus	2	CG

Table B6 (cont.): Tolerance values (TV) and habitat designations for Coastal Plain sites taken from Assessment Framework for Mid-Atlantic Coastal Plain Streams Using Benthic Macroinvertebrates (Maxted et al. 1999). Abbreviations for habitat are as follows: **BU** - Burrower, **CG** - Clinger, **CL** - Climber, **SK** - Skater, **SP** - Sprawler, and **SW** – Swimmer.

Class	Order	Family	Genus	TV	Habitat
			Optioservus	4	CG
			Oulimnius		CG
			Promoresia	2	CG
			Stenelmis	5	CG
		Hydrophilidae	Berosus		SW
			Paracymus		BU
		Limnichidae	Unidentified		CG
		Psephenidae	Ectopria	5	CG
			Psephenus		CG
		Salpingidae	Unidentified		
		Staphylinidae	Psephidonus		CG
	Collembola	Isotomidae	Agrenia		SP
			Isotomurus		SP
		Poduridae	Podura		
	Diptera	Ceratopogonidae	Alluaudomyia		
			Bezzia	6	BU
			Ceratopogon	6	
			Culicoides	10	BU
			Dasyhelea		SP
			Leptoconops		
			Mallochohelea		
			Probezzia	6	BU
		Chironomidae	Unidentified	6	BU
		Culicidae	Culex	8	SW
		Dolichopodidae	Unidentified		
		Empidae	Unidentified		SP
		Empididae	Chelifera	6	SP
			Clinocera	6	CG
			Hemerodromia	6	SP
		Psychodidae	Unidentified		
		Simuliidae	Prosimulium	4	CG
			Simulium	6	CG
		Stratiomyiidae	Odontomyia	7	SP
			Stratiomys		SP
		Tabanidae	Unidentified		
			Chrysops	7	SP
		Tipulidae	Unidentified	3	BU
			Antocha	3	BU
			Brachypremna	3	BU
			Dicranota	3	BU
			Hexatoma	2	BU
			Leptotarsus	3	BU

Table B6 (cont.): Tolerance values (TV) and habitat designations for Coastal Plain sites taken from Assessment Framework for Mid-Atlantic Coastal Plain Streams Using Benthic Macroinvertebrates (Maxted et al. 1999). Abbreviations for habitat are as follows: **BU** - Burrower, **CG** - Clinger, **CL** - Climber, **SK** - Skater, **SP** - Sprawler, and **SW** – Swimmer.

Class	Order	Family	Genus	TV	Habitat
			Rhabdomastix	3	BU
			Tipula	4	BU
	Ephemeroptera	Ameletidae	Ameletus		
		Baetidae	Acentrella	4	SW
			Baetis	6	SW
			Fallceon	4	SW
			Paracloeodes	4	SW
		Caenidae	Caenis	7	SP
		Ephemerellidae	Attenella		CG
			Ephemerella	2	CG
			Eurylophella	4	CG
			Serratella	2	CG
			Timpanoga		CG
		Heptageniidae	Unidentified	4	CG
			Epeorus	4	CG
			Stenacron	4	CG
			Stenonema	3	CG
		Isonychiidae	Isonychia	2	SW
		Leptophlebiidae	Habrophlebia		
			Habrophlebiodes		
			Paraleptophlebia	1	SW
	Hemiptera	Velliidae	Microvelia	6	SK
	Lepidoptera	Noctuidae	Archanara		
		Pyralidae	Acentria		
			Crambus		
			Petrophila		CG
		Tortricidae	Archips		
			Bactra		
	Megaloptera	Corydalidae	Corydalus	5	CG
			Nigronia	2	CG
		Sialidae	Sialis	4	BU
	Odonata	Aeshnidae	Unidentified	3	CL
			Boyeria	2	CL
		Calopterygidae	Calopteryx	6	CL
			Hetaerina	5	CL
		Coenagrionidae	Argia	6	CG
			Enallagma	8	CL
			Ischnura	9	CL
		Cordulegastridae	Cordulegaster	3	BU
		Corduliidae	Unidentified	5	SP
		Gomphidae	Unidentified	1	BU
			Dromogomphus		BU

<u>Table B6 (cont.):</u> Tolerance values (TV) and habitat designations for Coastal Plain sites taken from Assessment Framework for Mid-Atlantic Coastal Plain Streams Using Benthic Macroinvertebrates (Maxted et al. 1999). Abbreviations for habitat are as follows: **BU** - Burrower, **CG** - Clinger, **CL** - Climber, **SK** - Skater, **SP** - Sprawler, and **SW** – Swimmer.

Class	Order	Family	Genus	TV	Habitat
			Gomphus	5	BU
			Lanthus	1	BU
			Stylogomphus	1	BU
			Stylurus	1	SP
		Libellulidae	Unidentified	9	SP
	Plecoptera	Chloroperlidae	Unidentified		CG
			Haploperla		CG
			Sweltsa		CG
		Leuctridae	Leuctra	0	CG
			Zealeuctra		
		Nemouridae	Amphinemura	3	SP
			Nemoura		SP
			Podmosta		
			Prostoia		SP
			Shipsa		SP
		Perlidae	Acroneuria	0	CG
			Perlesta	1	CG
			Perlinella	1	CG
		Perlodidae	Unidentified	2	CG
			Diploperla	2	CG
			Diura	2	CG
			Isoperla	2	CG
		Taeniopterygidae	Strophopteryx	3	SP
			Taeniopteryx	2	SP
	Trichoptera	Brachycentridae	Micrasema	2	CG
		Calamoceratidae	Ansiocentropus	2	SP
		Glossosomatidae	Agapetus		CG
		Hydropsychidae	Unidentified	4	CG
			Ceratopsyche	4	CG
			Cheumatopsyche	5	CG
			Diplectrona	0	CG
			Hydropsyche	4	CG
		Hydroptilidae	Unidentified		CG
			Agraylea	5	CL
			Hydroptila	6	CG
			Ochrotrichia		CG
			Stactobiella		CG
		Lepidostomatidae	Lepidostoma	1	CL
		Leptoceridae	Ceraclea	3	SP
			Oecetis	8	CG
		Limnephilidae	Apatania	4	CL
			Chyrandra	4	CL

Table B6 (cont.): Tolerance values (TV) and habitat designations for Coastal Plain sites taken from Assessment Framework for Mid-Atlantic Coastal Plain Streams Using Benthic Macroinvertebrates (Maxted et al. 1999). Abbreviations for habitat are as follows: **BU** - Burrower, **CG** - Clinger, **CL** - Climber, **SK** - Skater, **SP** - Sprawler, and **SW** – Swimmer.

Class	Order	Family	Genus	TV	Habitat
			Lenarchus	4	CL
			Pycnopsyche	4	SP
		Philopotamidae	Chimarra	4	CG
			Dolophilodes	3	CG
			Wormaldia	3	CG
		Polycentropodidae	Cyrnellus		CG
			Neureclipsis	7	CG
			Nyctiophylax	5	CG
			Phylocentropus		CG
			Polycentropus	6	CG
		Psychomyiidae	Lype	2	CG
		Rhyacophilidae	Rhyacophila		CG
		Uenoidae	Neophylax		CG
Nematomorpha			Unidentified		
Oligochaeta			Unidentified	8	
Turbellaria			Unidentified		
	Macrostomida	Macrostomidae	Macrostomum		
	Tricladida	Planariidae	Unidentified		
			Cura		
			Hymanella		
			Phagocata		

Table B7: Functional Feeding Groups (FFG) and Habitat values for Piedmont and Triassic Basin (Merrit and Cummings, 1996). Abbreviations for Habitat are as follows: **BU** - Burrower, **CG** - Clinger, **CL** - Climber, **SK** - Skater, **SP** - Sprawler, and **SW** - Swimmer.

Class	Order	Family	Genus	FFG	Habitat
Arachnida	Acari	Aturidae	Brachypoda	Predator	
		Hydrachnidae	Atractides	Predator	
			Hydrachna	Predator	
			Hygrobates	Predator	
		Lebertiidae	Lebertia	Predator	
		Limnesiidae	Limnesia	Predator	
		Mideopsidae	Mideopsis	Predator	
		Sperchonidae	Sperchon	Predator	
		Torrenticolidae	Torrenticola	Predator	
		Unionicolidae	Neumania	Predator	
Bivalvia	Pelecypoda	Corbiculidae	Corbicula	Filterer	
		Sphaeriidae	Unidentified	Filterer	
			Pisidium	Filterer	
			Sphaerium	Collector	
Crustacea	Amphipoda	Crangonyctidae	Crangonyx	Collector	
		Gammaridae	Gammarus	Omnivore	
	Decapoda	Cambaridae	Cambarus		
			Unidentified	Collector	
	Isopoda	Asellidae	Caecidotea	Collector	
Gastropoda	Limnophila	Ancylidae	Unidentified	Scraper	
			Ferrissia	Scraper	
		Lymnaidae	Fossaria		
			Pseudosuccinea	Scraper	
		Physidae	Unidentified	Scraper	
			Physella	Scraper	
		Planorbidae	Unidentified	Scraper	
			Gyraulus	Scraper	
			Helisoma		
			Menetus		
			Planorbella	Scraper	
	Mesogastropoda	Hydrobiidae	Amnicola		
		Valvatidae	Valvata	Scraper	
		Viviparidae	Viviparus	Scraper	
Hirudinea	Pharyngobdellida	Erpobdellidae	Mooreobdella	Predator	
	Rhynchobdellida	Glossiphoniidae	Helobdella	Predator	
		Piscicolidae	Myzobdella		
Hydrozoa	Hydroida	Hydridae	Hydra	Predator	CG
Insecta	Coleoptera	Dryopidae	Agabus	Predator	SW
			Helichus	Shredder	CG
			Liodessus	Predator	CL
			Oreodytes	Predator	CL
			Potamonectes	Predator	CL
		Elmidae	Unidentified	Collector	CG

Table B7 (cont.): Functional Feeding Groups (FFG) and Habitat values for Piedmont and Triassic Basin (Merrit and Cummings. 1996). Abbreviations for Habitat are as follows: **BU** - Burrower, **CG** - Clinger, **CL** - Climber, **SK** - Skater, **SP** - Sprawler, and **SW** - Swimmer.

Class	Order	Family	Genus	FFG	Habitat
			Ancyronyx	Collector	CG
			Dubiraphia	Collector	CG
			Macronychus	Collector	CG
			Microcylloepus	Collector	CG
			Optioservus	Scraper	CG
			Oulimnius	Collector	CG
			Promoresia	Collector	CG
			Stenelmis	Scraper	CG
		Hydrophilidae	Berosus	Predator	CL
			Paracymus	Predator	BU
		Limnichidae	Unidentified	Collector	CG
		Psephenidae	Ectopria	Scraper	CG
			Psephenus	Scraper	CG
		Salpingidae	Unidentified		
		Staphylinidae	Psephidonus	Predator	CL
	Collembola	Isotomidae	Agrenia	Collector	SK
			Isotomurus		
		Poduridae	Podura	Collector	SK
	Diptera	Ceratopogonidae	Unidentified	Predator	SP
			Alluaudomyia	Predator	BU
			Bezzia	Predator	BU
			Ceratopogon	Predator	SP
			Culicoides	Predator	BU
			Dasyhelea	Collector	SP
			Leptoconops	Predator	BU
			Mallochohelea	Predator	BU
			Probezzia	Predator	BU
		Chironomidae	Unidentified	Collector	BU
		Culicidae	Culex	Filterer	SW
		Dolichopodidae	Unidentified	Predator	SP
		Empidae	Unidentified	Predator	SP
		Empididae	Chelifera	Predator	SP
			Clinocera	Predator	CG
			Hemerodromia	Predator	SP
		Psychodidae	Unidentified	Collector	BU
		Simuliidae	Prosimulium	Filterer	CG
			Simulium	Filterer	CG
		Stratiomyiidae	Odontomyia	Collector	SP
			Stratiomys	Collector	SP
		Tabanidae	Unidentified	Predator	SP
			Chrysops	Predator	SP
		Tipulidae	Unidentified	Shredder	BU
			Antocha	Collector	CG

Table B7 (cont.): Functional Feeding Groups (FFG) and Habitat values for Piedmont and Triassic Basin (Merrit and Cummings. 1996). Abbreviations for Habitat are as follows: **BU** - Burrower, **CG** - Clinger, **CL** - Climber, **SK** - Skater, **SP** - Sprawler, and **SW** - Swimmer.

Class	Order	Family	Genus	FFG	Habitat
			Brachypremna	Shredder	BU
			Dicranota	Predator	SP
			Hexatoma	Predator	BU
			Leptotarsus	Shredder	BU
			Limnophila	Predator	BU
			Molophilus	Shredder	BU
			Rhabdomastix	Shredder	BU
			Tipula	Shredder	BU
	Ephemeroptera	Ameletidae	Ameletus	Scraper	SW
		Baetidae	Acentrella	Collector	SW
			Baetis	Collector	SW
			Fallceon	Collector	SW
			Paracloeodes	Scraper	SW
		Caenidae	Caenis	Collector	SP
		Ephemerellidae	Attenella	Collector	CG
			Ephemerella	Collector	CG
			Eurylophella	Collector	CG
			Serratella	Collector	CG
			Timpanoga	Collector	CG
		Heptageniidae	Unidentified	Scraper	CG
			Epeorus	Collector	CG
			Stenacron	Collector	CG
			Stenonema	Scraper	CG
		Isonychiidae	Isonychia	Filterer	SW
		Leptophlebiidae	Habrophlebia	Collector	SW
			Habrophlebiodes	Scraper	SW
			Paraleptophlebia	Collector	SW
	Hemiptera	Velliidae	Unidentified		
	Lepidoptera		Microvelia	Predator	SK
		Noctuidae	Archanara	Shredder	BU
		Pyralidae	Acentria	Shredder	CL
			Crambus	Shredder	CL
			Petrophila	Scraper	CG
		Tortricidae	Archips	Shredder	BU
			Bactra	Shredder	BU
	Megaloptera	Corydalidae	Nigronia	Predator	CG
		Corydalidae	Corydalus	Predator	CG
		Sialidae	Sialis	Predator	BU
	Odonata	Aeshnidae	Unidentified	Predator	CL
			Boyeria	Predator	CL
		Calopterygidae	Calopteryx	Predator	CL
			Hetaerina	Predator	CL
		Coenagrionidae	Argia	Predator	CG

Table B7 (cont.): Functional Feeding Groups (FFG) and Habitat values for Piedmont and Triassic Basin (Merrit and Cummings. 1996). Abbreviations for Habitat are as follows: **BU** - Burrower, **CG** - Clinger, **CL** - Climber, **SK** - Skater, **SP** - Sprawler, and **SW** - Swimmer.

Class	Order	Family	Genus	FFG	Habitat
			Enallagma	Predator	CL
			Ischnura	Predator	CL
		Cordulegastridae	Cordulegaster	Predator	BU
		Corduliidae	Unidentified	Predator	SP
		Gomphidae	Unidentified	Predator	BU
			Dromogomphus	Predator	BU
			Gomphus	Predator	BU
			Lanthus	Predator	BU
			Stylogomphus	Predator	BU
			Stylurus	Predator	BU
		Libellulidae	Unidentified	Predator	SP
	Plecoptera	Chloroperlidae	Unidentified	Predator	CG
			Haploperla	Predator	CG
			Sweltsa	Predator	CG
		Leuctridae	Leuctra	Shredder	SP
			Zealeuctra	Shredder	SP
		Nemouridae	Amphinemura	Shredder	SP
			Nemoura	Shredder	SP
			Podmosta	Shredder	SP
			Prostoia	Shredder	SP
			Shipsa	Shredder	SP
		Perlidae	Acroneuria	Predator	CG
			Perlesta	Predator	CG
			Perlinella	Predator	CG
		Perlodidae	Unidentified	Predator	CG
			Diploperla	Predator	CG
			Diura	Scraper	CG
			Isoperla	Predator	CG
		Taeniopterygidae	Strophopteryx	Shredder	SP
			Taeniopteryx	Shredder	SP
	Trichoptera	Brachycentridae	Micrasema	Shredder	CG
		Calamoceratidae	Ansiocentropus	Shredder	SP
		Glossosomatidae	Agapetus	Scraper	CG
		Hydropsychidae	Unidentified	Filterer	CG
			Ceratopsyche	Filterer	CG
			Cheumatopsyche	Filterer	CG
			Diplectrona	Filterer	CG
			Hydropsyche	Filterer	CG
		Hydroptilidae	Unidentified	Predator	CG
			Agraylea	Predator	CL
			Hydroptila	Predator	CL
			Ochrotrichia	Collector	CG
			Stactobiella	Shredder	CG

<u>Table B7 (cont.):</u> Functional Feeding Groups (FFG) and Habitat values for Piedmont and Triassic Basin (Merrit and Cummings. 1996). Abbreviations for Habitat are as follows: **BU** - Burrower, **CG** - Clinger, **CL** - Climber, **SK** - Skater, **SP** - Sprawler, and **SW** - Swimmer.

Class	Order	Family	Genus	FFG	Habitat
			Stactobiella	Shredder	CG
		Lepidostomatidae	Lepidostoma	Shredder	CL
		Leptoceridae	Ceraclea	Collector	SP
			Oecetis	Predator	CG
		Limnephilidae	Apatania	Scraper	CL
			Chyrandra	Shredder	SP
			Lenarchus	Collector	SP
			Pycnopsyche	Shredder	SP
		Philopotamidae	Chimarra	Filterer	CG
			Dolophilodes	Filterer	CG
			Wormaldia	Filterer	CG
		Polycentropodidae	Cyrnellus	Filterer	CG
			Neureclipsis	Filterer	CG
			Nyctiophylax	Filterer	CG
			Phylocentropus	Filterer	BU
			Polycentropus	Predator	CG
		Psychomyiidae	Lype	Scraper	CG
		Rhyacophilidae	Rhyacophila	Predator	CG
		Uenoidae	Neophylax	Scraper	CG
Oligochaeta			Unidentified		BU
Turbellaria			Unidentified	Predator	
	Macrostomida	Macrostomidae	Macrostomum		
	Tricladida	Planariidae	Unidentified	Omnivore	
			Cura		
			Hymanella		
			Phagocata		

Table B8: Family tolerance values (TV) for Piedmont/Triassic Basin sites (Hilsenhoff, 1987, as revised by Kurtenback, http://www.eclipse.net/~sbwa/ftv.htm).

Phylum	Class	Order	Family	TV
Annelida	Hirudinea	Pharyngobdellida	Erpobdellidae	1
		Rhynchobdellida	Piscicolidae	10
			Glossiphoniidae	10
	Oligochaeta		Unidentified	8
Arthropoda	Arachnida	Acari	Aturidae	4
			Unionicolidae	4
			Torrenticolidae	4
			Sperchonidae	4
			Mideopsidae	4
			Limnesiidae	4
			Lebertiidae	4
			Hydrachnidae	4
			Hygrobatidae	4
	Crustacea	Amphipoda	Crangonyctidae	
			Gammaridae	4
		Decapoda	Cambaridae	6
		Isopoda	Asellidae	8
	Insecta	Coleoptera	Dytiscidae	4
			Psephenidae	4
			Elmidae	4
			Staphylinidae	4
			Dryopidae	5
			Hydrophilidae	5
			Poduridae	
			Isotomidae	10
		Diptera	Stratiomyiidae	
			Culicidae	
			Psychodidae	10
			Tipulidae	3
			Dolichopodidae	4
			Simuliidae	6
			Tabanidae	6
			Empididae	6
			Ceratopogonidae	6
			Chironomidae	6
		Ephemeroptera	Ameletidae	
			Ephemerellidae	1
			Isonychiidae	2
			Leptophlebiidae	2
			Baetidae	4
			Heptageniidae	4
			Caenidae	7

Table B8 (cont.): Family tolerance values (TV) for Piedmont/Triassic Basin sites (Hilsenhoff 1987, as revised by Kurtenback, http://www.eclipse.net/~sbwa/ftv.htm).

Phylum	Class	Order	Family	TV
		Hemiptera	Velliidae	
		Lepidoptera	Noctuidae	
			Pyralidae	5
		Megaloptera	Corydalidae	0
			Sialidae	4
		Odonata	Gomphidae	1
			Aeshnidae	3
			Cordulegastridae	3
			Calopterygidae	5
			Corduliidae	5
			Libellulidae	9
			Coenagrionidae	9
		Plecoptera	Leuctridae	0
			Perlidae	1
			Chloroperlidae	1
			Perlodidae	2
			Taeniopterygidae	2
			Nemouridae	2
		Trichoptera	Uenoidae	
			Glossosomatidae	0
			Calamoceratidae	0
			Rhyacophilidae	0
			Brachycentridae	1
			Lepidostomatidae	1
			Psychomyiidae	2
			Philopotamidae	3
			Limnephilidae	4
			Leptoceridae	4
			Hydroptilidae	4
			Hydropsychidae	4
			Polycentropodidae	6
Coelenterata	Hydrozoa	Hydroida	Hydridae	3
Mollusca	Bivalvia	Pelecypoda	Sphaeriidae	8
			Corbiculidae	8
	Gastropoda	Limnophila	Planorbidae	6
			Ancylidae	7
			Physidae	7
			Lymnaidae	7
		Mesogastropoda	Viviparidae	7
			Valvatidae	7
			Hydrobiidae	7
Platyhelminthes	Turbellaria	Macrostomida	Planariidae	4

B.5 Regression Analysis of IBI vs. % Imperviousness

The inverse relationship between stream biological integrity and watershed imperviousness has been well documented in the past decade (Boward et al. 1999). It has been shown that the threshold for maintaining biological integrity is generally reached between 10 to 20% impervious cover (Booth, 1991, and Booth and Reinelt, 1993). An ordinary least-square simple linear regression analysis of the Benthic IMBI scores versus imperviousness for Fairfax County SPS sites showed a highly significant statistical relationship (for methods used to determine % imperviousness of county sites, see Appendix F). The results of the regression analysis are presented below:

Figure B8: Regression results for IBI vs. % impervious area of all SPS sites.

Ordinary Least Squares Regression

Regression Results

Dependent Variable: IMBI

	Coefficient	Standard Error	t-Statistic	Significance
Constant	78.7071	2.9888	26.3339	0.0000
% Impervious	-1.7319	0.1480	-11.6997	0.0000

Residual Sum of Squares =	38189.13613
Standard Error =	17.62046485
Mean of Y =	48.9955435
Stand Dev of y =	25.50908489
R-squared =	0.526708842
Adjusted R-squared =	0.522860946
F(1,123) =	136.8823112
significance of F =	**1.03E-21**
Durbin-Watson Statistic =	1.450445111
log of likelihood =	-534.9999421
Number of Rows =	125

While the relationship between the IMBI score and % imperviousness at a site was found to statistically significant, a more rigorous regression analysis would be necessary before a strict predictive relationship can be developed from the available data.

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APPENDIX C

FISH PROTOCOLS

C.1 RBP Method for Fish

Fish assemblages represent the apex of most stream communities. They are very sensitive to both natural and anthropogenic changes within a given system and are, therefore, useful indicators of stream health. Fish are also more readily understood and appreciated by the public than are other biological components of streams systems. Therefore, they can be useful tools for developing community interest in environmental and water management issues. The methods employed were based largely upon the EPA's Rapid Bioassessment Protocols V (Barbour et al. 1999). All fish communities surveyed will be sampled from non-tidal freshwater, perennial flowing streams.

C.2 Equipment Requirements

- Smith-Root, Model 12-B, 400 watt, backpack electrofisher (battery powered)
- 12-volt DC batteries (2 to 4) for electrofisher
- rubber gloves (high-voltage rated, insulated)
- chest waders and belts for all participants
- hand dip-nets, both long- and short-handled (1/8 inch mesh)
- block nets (i.e., seines)
- buckets and live car(s) for fish storage and transport
- data sheets (Figure C.2.1)
- data log (waterproof) and pencils
- buffered formalin (17% formaldehyde)
- specimen jars
- waterproof jar labels
- species key and field guide

C.3 Fish Sampling, Identification, and Preservation

Using single or multiple backpack electrofishing units (Smith-Root, model 12), a single sample pass was made through the selected 100-meter reach (number of units will be dependent upon stream width and depth). A block net was deployed at the uppermost reach boundary, and the sample was conducted in the upstream direction. To minimize the risks of mortality or injury to fish, electrofisher unit settings were adjusted to reflect stream water conductivity and corresponding manufacturer recommendations.

Captured specimens were transported in water-filled buckets and maintained in a portable in-stream live car for subsequent examination. Fish were identified to the species level and the representatives in each category were enumerated and recorded.

Special note was made of individuals with eroded fins, parasites, tumors, lesions, hemorrhaging, eye maladies and/or other abnormalities (see bottom of Figure C2). Upon final identification, the fish were then released back into the stream.

Positive field identification is particularly difficult with some specimens, and preservation of representative individuals, in some cases, may be needed for more detailed laboratory examinations. Other specimens were preserved as part of the development a permanent reference collection of fishes found within Fairfax County. Samples were initially preserved in a fixative of 10% formalin solution and later transferred to a 70% ethanol, 5% glycerin solution for long-term storage.

C.4 Development of an Fish Index of Biotic Integrity (IBI)

Efforts were made to develop an IBI for fish communities in County streams. Tolerance values and functional feeding group designations were determined based upon a summation of regional assessments developed by Barbour (1999) (Table C1). Where values differed between geographic areas, the greatest weight was given to studies conducted in the mid-Atlantic and northeast regions of the country.

A variety of individual metrics were evaluated for their responsiveness to a gradient of impairment within streams (Table C2). With the exception of the taxa richness measure, none of the candidate measures showed significant correlation with either surrogates of degradation (i.e., RSAT habitat quality rankings) or actual watershed imperviousness values. As a result, only the total number of distinct taxa at each site was seen as useful in ranking streams countywide.

Many site variables may have had an impact on fish community composition and structure. Such influences may have included proximity to reservoirs and other larger systems (e.g., Potomac River, Occoquan Reservoir), the presence of migration barriers within the drainage and natural seasonal variations in species occurrence/abundance (1999 samples were conducted during the summer only). These potential influences will need to be assessed in future monitoring efforts.

<u>Table C1</u>: Functional Feeding Groups and Tolerance Values for Fish species found within Fairfax County (based on Barbour 1999. Regional studies were given precedence when different (Maryland Coastal Plain and Northeastern US Study)). Abbreviations for tolerance are as follows: T = Tolerant, M = Moderate, I = Intolerant. Abbreviations for Functional Feeding Group are as follows: I = Insectivore, G = Generalist, P = Piscivorous, F = Filter Feeder, H = Herbivorous.

Fish Species	Tolerance	Functional Feeding Group	Fish Species	Tolerance	Functional Feeding Group
Alosa pseudoharengus	*M*	*F*	*Lepomis cyanellus*	*T*	*G*
Ameiurus natalis	*T*	*G*	*Lepomis gibbosus*	*M*	*G*
Ameiurus nebulosus	*T*	*G*	*Lepomis gulosus*	*M*	*P*
Anguilla rostrata	*T*	*P*	*Lepomis macrochirus*	*M*	*I*
Campostoma anomalum	*M*	*H*	*Lepomis megalotis*	*I*	*I*
Carassius auritus	*T*	*G*	*Lepomis microlophus*	*M*	*I*
Catostomus commersoni	*T*	*G*	*Luxilus cornutus*	*M*	*I*
Clinostomus funduloides	*I*	*I*	*Micropterus dolomieu*	*M*	*P*
Cottus girardi	*I*	*I*	*Micropterus salmoides*	*M*	*P*
Cyprinella analostana	*I*	*I*	*Moxostoma erythrurum*	*M*	*I*
Cyprinella spiloptera	*M*	*I*	*Morone americana*	*M*	*P*
Cyprinus carpio	*T*	*G*	*Nocomis micropogon*	*M*	*I*
Dorosoma cepedianum	*M*	*G*	*Notemigonus chrysoleucas*	*T*	*G*
Enneacanthus gloriosus	*M*	*I*	*Notropis amoenus*	*T*	*I*
Erimyzon oblongus	*M*	*G*	*Notropis buccatus*	*M*	*I*
Esox niger	*M*	*P*	*Notropis hudsonius*	*M*	*I*
Etheostoma blennioides	*M*	*I*	*Notropis procne*	*I*	*I*
Etheostoma flabellare	*M*	*I*	*Noturus insignis*	*M*	*I*
Etheostoma olmsteadi	*M*	*I*	*Perca flavescens*	*M*	*G*
Exoglossum maxillingua	*I*	*I*	*Percina peltata*	*I*	*I*
Fundulus diaphanus	*T*	*I*	*Pimephales notatus*	*T*	*G*
Fundulus heteroclitus	*M*	*G*	*Pimephales promelas*	*T*	*G*
Gambusia holbrooki	*M*	*I*	*Pomoxis nigromaculatus*	*M*	*P*
Hybognathus regius	*M*	*H*	*Rhinicthys atratulus*	*T*	*G*
Hypentellium nigricans	*I*	*I*	*Rhinicthys cataractae*	*I*	*I*
Ictalurus punctatus	*M*	*P*	*Semotilus atromaculatus*	*T*	*G*
Lampetra aepyptera	*M*	*F*	*Semotilus corporalis*	*M*	*G*
Lepomis auritus	*M*	*I*	*Umbra pygmaea*	*T*	*G*

<u>Table C2</u>: Metric candidates tested for Fish Index of Biotic Integrity.

Taxa Richness
Number of Native Species
Number of Non-Native Species
Number of Individuals minus Tolerant Species
Number of Sunfish Species
Number of Darter Species
Number of Minnow Species
Number of Minnow Species minus Tolerant Species
Percent Insectivorous Cyprinids
Percent Tolerant (Coastal Plain)
Percent Tolerant (Piedmont and Triassic Basin)
Percent Benthic Invertivore
Percent Benthic Invertivore minus Tolerant Species
Percent Lithophilic Spawners
Percent Lithophilic Spawners minus Tolerant Species
Percent Pioneers
Percent Dominant Individuals
Percent Anomolies
Percent Generalists

C.5 Re-sampling of Fish Populations in 2000

Fairfax County experienced drought conditions throughout much of the summer in 1999, and low stream flow conditions during this period had the potential to influence the local abundance of many species. To assess any possible influences on the samples collected in 1999, approximately 20% of all monitoring locations as well as reference sites within Prince William Forest Park were re-sampled for fish in the summer of 2000. The differences in sample diversity (using a Shannon-Weiner index) between the two sampling periods were considered to be non-significant.

C.6 Fish Sampling Data Sheets

Unlike the benthic macroinvertebrate sampling, the fish sampling protocol did not vary by physiographic province. Therefore, a uniform fish sampling data sheet was used during the Summer 1999 fish sampling session (Figures C1 & C2) for all County streams.

Figure C1: Summer fish sampling field data sheet (front).

Agency: Stormwater Management Branch
Project: Stream Protection Strategy Study

Date:	**Sampling start time:**
Recorder:	**Sampling finish time:**

Stream Name:	**Number of Electorfisher units:**
Stream Order:	**Gear:** block nets (1/4" mesh) size ______, dipnets (1/8" mesh), backpack electrofisher(s), buckets, livewell(s)
Drainage basin:	
Protocol: EPA RBP	

Investigators:	**Electrofisher operator(s):**
	Conductivity (umhos):
	Electrofisher settings:

Weather conditions:

Water conditions:

Approximate habitat composition: % riffle____ % run_____ % pool_____	**Riparian buffer width** (approx.):______m
	Canopy cover: shaded moderate open

Microhabitat abundance:

riffles	abundant	moderate	scarce	absent
undercut bank	abundant	moderate	scarce	absent
aquatic vegetation	abundant	moderate	scarce	absent
snags	abundant	moderate	scarce	absent

General observations:

Figure C2: Summer fish sampling data sheet (back).

Species	**Number of Individuals** (Record with tally marks)*	**Total**	**Comments**
Ameiurus natalis			
Ameiurus nebulosus			
Anguilla rostrata			
Catostomus commersoni			
Clinostomus funduloides			
Cyprinella spilotera			
Cyprinella analostana			
Erimyzon oblongus			
Etheostoma olmstedi			
Exoglossum maxillingua			
Fundulus diaphanus			
Hypentelium nigricans			
Lepomis auritus			
Lepomis cyanellus			
Lepomis gibbosus			
Lepomis macrochirus			
Luxilus cornutus			
Notemigonus chrysoleucas			
Notropis hudsonius			
Notropis procne			
Pimephales notatus			
Rhinicthys atratulus			
Rhinicthys cataractae			
Semotilus atromaculatus			
	Grand Total:		

*Denote individuals w/health problems via superscript:
D=deformity, E=eroded fin, L=lesion, T=tumor, F=fungus, W=wound, I=eye malady, H=hemmorhage, P=parasite

C.7 Taxonomic References for Fish

Barbour, M.T., J. Gerritson, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington D.C.

Jenkins, R. E., and N. M. Burkehead. 1994. Freshwater Fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Rohde, F.C., R.G. Arndt, D.G. Lindquist, and J.F. Parnell. 1994. Freshwater fishes of the Carolinas, Virginia, Maryland, and Delaware. University of North Carolina Press. Chapel Hill, North Carolina.

APPENDIX D

HABITAT ASSESSMENT & STREAM MORPHOLOGY PROTOCOLS

The physical habitat of each SPS site was evaluated using two sets of protocols. During both sampling periods, habitat conditions were examined using a modified version of the US Environmental Protection Agency (US EPA) Rapid Bioassessment Protocol (RBP) (Barbour, *et a*l, 1999), and an assessment that incorporates aspects of the Rapid Stream Assessment Technique (RSAT) (Galli, 1996). Also during the second sample phase, a physical characterization of habitat and channel conditions was conducted using the Incised Channel Evolution Model (ICEM) (Schumm, *et al*, 1984). Both procedures are broad-scale assessments and include examination of extensive sections of stream channel both above and below the sample reach.

D.1 Rapid Stream Assessment Technique (RSAT) Parameters

A modified version of the RSAT approach was used. The RSAT parameters selected for use were mostly qualitative, visual descriptions of stream conditions, which may have an affect the quality or availability of biological habitat. The technique describes certain in-stream features such as fish barriers, logjams and tree falls, characteristics of the substrate (including organic and inorganic composition), aquatic vegetation, and bank substrate description. It also incorporates riparian zone assessment and local watershed descriptions such as surrounding land uses and possible sources of non-point source pollution. Additionally, ambient weather conditions and other visual assessments were recorded. Some of the more qualitative parameters used in the original procedure were omitted due to time constraints or overlap with existing assessments. Please see the habitat data sheets in section D.6 for a complete listing of observed parameters and conditions.

D.2 US EPA Rapid Bioassessment Protocol (RBP) Habitat Assessment Method

The RBP II method for habitat assessment consists of evaluating 10 specific habitat quality parameters, which include riparian, in-stream, and flood plain assessments. Each parameter is scored on a scale of 0 (most impaired condition) to 20 (optimal condition) for a maximum possible score of 200. The scores for each site were summed to obtain an overall rating of habitat quality, which was then used for comparison between sites. The full range of scores from the lowest to the highest was sub-divided into five evenly spaced segments and subsequently assigned an overall habitat verbal description of excellent, good, fair, poor or very poor.

The original EPA version was slightly modified with respect to some of the wording for certain parameters. Changes were made to the text of the Channel Alteration parameter and to the numerical descriptions for Channel Flow Status and Riparian Vegetative Zone Width, based on professional judgement, to better reflect the conditions within Fairfax County. For the specific RBP values please see the numerical (database) appendix.

To account for hydrologic and geologic differences between Piedmont/Triassic streams and those on the Coastal Plain, separate assessment parameters are designated for use within each province (Table D1), as per EPA's protocols. Please see Figures D1 through D4 for specific RBP habitat evaluation parameters and rating categories.

Table D1: Habitat metrics for Piedmont/Triassic and Coastal Plain streams (metrics common to each group may be scored based upon different criteria).

Piedmont/Triassic	Coastal Plain
Epifaunal Substrate/Available Cover	Epifaunal Substrate/Available Cover
Embeddedness	Pool Substrate Characterization
Velocity/Depth Regimes	Pool Variability
Channel Alteration	Channel Alteration
Sediment Deposition	Sediment Deposition
Frequency of Riffles/Bends	Channel Sinuosity
Channel Flow Status	Channel Flow Status
Bank Vegetative Protection	Bank Vegetative Protection
Bank Stability	Bank Stability
Riparian Vegetative Zone Width	Riparian Vegetative Zone Width

D.3 The Incised Channel Evolution Model

The increase in impervious surfaces that accompanies land development and urbanization can have significant impacts on stream stability via altered hydrology. Such activity results in an increased frequency of high discharge storm events, which in turn can have a substantial impact on existing channel and floodplain morphology. In response, stream processes will act to develop a new system equilibrium.

The Incised Channel Evolution Model defines the stages through which stream channel morphology progresses after such a disturbance, and can act as a useful predictor of future conditions (Schumm, *et al*, 1984, Harvey and Watson 1986). A standardized field check sheet (Sewell, 1999) was used to aid staff in identifying the respective stages at each site based upon key physical characteristics such as bank slope, headcutting, sediment deposition and/or erosion, and vegetative colonization (see Table D2 and Figure D10). Visual assessments were conducted both upstream and downstream of study reaches and extended to the nearest major tributary input, road crossing, or other significant feature that may be similarly influencing local hydrology and/or morphology.

At a minimum, assessments were made over two complete bend cycles in stream length in each direction. Most assessments were conducted an average of approximately half a mile upstream and half a mile downstream from the sampling site.

Table D2: Key characteristics of stream stages, as defined by the Incised Channel Evolution Model (ICEM).

STAGE 1	Well developed baseflow and bankfull stages; consistent floodplain features easily identified; one terrace apparent above active floodplain; predictable pattern and steam bed morphology; floodplain covered by diverse vegetation; stream banks ≤ 45°
STAGE 2	Headcuts; exposed cultural features; sediment deposits absent or sparse; exposed bedrock; streambank slopes > 45°
STAGE 3	Stream back sloughing sloughed material eroding; streambank slopes 60° vertical/concave
STAGE 4	Streambank aggrading; sloughed material not eroded; sloughed material colonized by vegetation; baseflow, bankfull and floodplain channel developing; predictable sinuous pattern developing streambank slopes ≤ 45 °
STAGE 5	Well developed baseflow and bankfull channel; consistent floodplain features easily identified.; two terraces apparent above active floodplain; predictable pattern and streambed morphology; streambanks ≤ 45°

Study streams were then prioritized based upon extent of watershed development and the cost and perceived efficacy of potential remediation efforts. Systems in pre-disturbance conditions or those in the later stages of evolution (i.e., those nearest a new equilibrium) were given the highest priority with respect to management recommendations. Special consideration was also given to areas where either immediate or potential risks to cultural features (i.e., property, infrastructure) existed.

D.4 Pebble Count

During the second phase of the sampling, a modified Wolman pebble count (Wolman, 1954) was conducted at each site to assess stream substrate condition (Figure D9). Transects were established at 10-meter intervals starting from the downstream boundary of the reach. At each respective transect, ten “pebbles” or substrate particles were collected from the stream channel. Each of these were measured along the transverse or intermediate axis (i.e., neither the longest nor the shortest dimension). Collections were made at approximately even intervals along each transect, and the sample taken was defined as “the first object encountered by touch and without visual assistance". At least 100 "pebbles" were observed at each site. From this information the mean particle size (D_{50}) was determined to describe the nature and size distribution of the substrate at each site.

To assess the relative quality of macroinvertebrate habitat, with respect to sediment, a minimum of 3 transects were established specifically in riffle environments of the Piedmont/Triassic Basin systems only. If this required number was not provided for in the original sample (i.e., the first 10 transects), then additional sampling of riffle transects was conducted. After regression and correlation analysis of mean particle size (D_{50}) versus the quality of the benthic sample (IMBI), it was found that there was no significant relationship. Thus, no results were presented.

D.5 Riparian Zone Assessment

Riparian buffer zones can greatly influence stream conditions. Vegetative cover along streams limits local erosion, protects stream banks and controls stream productivity and temperature by influencing levels of solar input. During the second sampling period, prior to leaf fall in the autumn, a hand held Forestry Suppliers convex spherical crown densiometer was used to estimate canopy cover. Measurements were taken at a point near the middle of the reach that best reflected local conditions. Four readings were taken: facing upstream, downstream, left bank and right bank. Percent canopy cover estimations were then calculated according to the densiometer manufacturer's specifications.

D.6 Habitat Data Sheets

The data sheets used for the various habitat parameter assessments described in the preceding sub-sections are listed here as a group to promote continuity. These sheets incorporate parameters from RSAT and RBP, and also include fields for water quality data (physio-chemical parameters) which is described in later sections (Appendix E). Also included are the ICEM checklist and the RBP habitat rating reference sheets.

<u>Figure D1</u>: US EPA RBP habitat assessment reference sheet for Coastal Plain province (front).

US EPA RBP Habitat Assessment Reference Sheet for Coastal Plain Areas (front)				
Habitat Paramete	**Category**			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1) Epifaunal Substrate/ Availible Cover	> 50% of substrate favorable for epifaunal colonization & fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (I.e. logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availablity less than desirable; substrate frequently disturbed or removed.	< 10% stable habitat; lack of habitat is obvious; substrate unstable/lacking.
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2) Pool Substrate Character-ization	Mixture of substrate materials, with gravel & firm sand revalent; root mats & submerged vegetation common.	Mixture of soft sand, mud or clay; mud may be dominant; root mats & submerged vegetation may be present; boulder and cobble may provide some habitat.	All mud or clay or sand bottom, very little good habitat.	Hard-pan clay or bedrock, no good habitat present.
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3) Pool Variablity	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present, relative to stream size.	Majority of pools large-deep; very few shallow	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4) Sediment Deposition	<20% of the bottom affected by sediment deposition, little or no enlargement of islands or point bars.	20-50% of the bottom affected; slight deposition in pools; may be some new increase in bar formation, mostly from gravel, sand or fine sediment;	50-80% of the bottom affected; sediment deposits at obstructions, constrictions & bends; moderate deposition of pools prevalent; may be moderate deposition of new gravel, sand or fine sediment on old & new bars.	>80% of the bottom affected; heavy deposits of fine material, increased bar development; score lower if pools are absent due to substantial sediment depostition.
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5) Channel Flow Status	Water reaches base of both lower banks and fills >75% of channel, minimal amount of channel substrate is exposed.	Water fills 75-50% of the available channel; or <50% of channel substrate is exposed	Water fills 50-25% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools, water fills <25% of channel.
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

<u>Figure D2</u>: US EPA RBP habitat assessment reference sheet for Coastal Plain province (back).

US EPA RBP Habitat Assessment Reference Sheet for Coastal Plain Areas (back)				
6) Channel Alteration	Channelization or dredging absent or minimal, <10% of reach disrupted; no obvious shoring structures; may have recovered from past channelization; stream with normal pattern.	Some channelization present, 10-40% of reach channelized or disrupted; may be recovering from past channelization, stream is developing a normal pattern.	Channelization extensive; shoring sturctures present on both banks; 40-80% of stream reach channelized & disrupted; stream does not have a normal pattern.	Banks shored with gabion or cement; >80% of the stream reach channelized & disrupted, stream is a straight channel. Instream habitat greatly altered or removed entirely.
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7) Channel Sinuousity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (note- channel braiding is considered normal in coastal plains & other low-lying areas. This parameter is not easily rated in these areas.	The bends in the stream increase the stream length 2 - 3 times longer than if it was in a straight line	The bends in the stream increase the stream length 1 - 2 times longer than if it was in a straight line	Channel straight; waterway has been channelized for a long distance
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8) Bank Stablity	Banks stable; evidence of erosion or bank failure absent/minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank slouging; 60-100% of bank has erosional scars.
Score (RB)__	Right bank 10 9	8 7 6	5 4 3	2 1 0
Score (LB)__	Left bank 10 9	8 7 6	5 4 3	2 1 0
9) Bank Vegetative Protection	>90% of the streambank surfaces covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	<50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation Is very high; vegetation has been removed to 5 centimeters or less in average stubble height
Score (RB)__	Right bank 10 9	8 7 6	5 4 3	2 1 0
Score (LB)__	Left bank 10 9	8 7 6	5 4 3	2 1 0
10) Riparian Vegetative Zone Width	Width of riparian zone >40 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 40-20 meters; human activities have impacted zone only minimally.	Width of riparian zone 20-10 meters; human activities have impacted zone a great deal.	Width of riparian zone <10 meters; little or no riparian vegetation due to human activities
Score (RB)__	Right bank 10 9	8 7 6	5 4 3	2 1 0
Score (LB)__	Left bank 10 9	8 7 6	5 4 3	2 1 0

Figure D3: US EPA RBP habitat assessment reference sheet for Peidmont/Triassic provinces (front).

US EPA RBP Habitat Assessment Reference Sheet for Peidmont/Triassic Areas (front)				
Habitat Paramet	**Category**			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1) Epifaunal Substrate/ Availible Cover	>70% of substrate favorable for epifaunal colonization & fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (I.e. logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availablity less than desirable; substrate frequently disturbed or removed.	<20% stable habitat; lack of habitat is obvious; substrate unstable/lacking
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2) Embedded-ness	Gravel, cobble & boulder particles in riffles and runs are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble & boulder in riffles and runs particles are 25-50% surrounded by fine sediment.	Gravel, cobble & boulder particles in riffles and runs are 50-75% surrounded by fine sediment.	Gravel, cobble & boulder particles in riffles and runs are >75% surrounded by fine sediment.
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3) Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep & fast-shallow, relative to stream size).	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes.	Only 2 of the 4 regimes present (if fast-shallow or slow-shallow are missing, score lower).	Dominated by 1 velocity/ depth regime (usually slow-deep).
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4) Sediment Deposition	<5% of the bottom affected by sediment deposition, little or no enlargement of islands or point bars.	5-30% of the bottom affected; slight deposition in pools; may be some new increase in bar formation, mostly from gravel, sand or fine sediment;	30-50% of the bottom affected; sediment deposits at obstructions, constrictions & bends; moderate deposition of pools prevalent; may be moderate deposition of new gravel, sand or fine sediment on old & new bars.	>50% of the bottom affected; heavy deposits of fine material, increased bar development; score lower if pools absent due to substantial sedimentation.
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5) Channel Flow Status	Water reaches base of both lower banks and fills >75% of channel, minimal amount of channel substrate is exposed.	Water fills 75-50% of the available channel; or <50% of channel substrate is exposed	Water fills 50-25% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools, water fills <25% of channel.

Figure D4: US EPA RBP habitat assessment reference sheet for Piedmont/Triassic provinces (back).

US EPA RBP Habitat Assessment Reference Sheet for Peidmont/Triassic Areas (back)				
6) Channel Alteration	Channelization or dredging absent or minimal, <10% of reach disrupted; no obvious shoring structures; may have recovered from past channelization; stream with normal pattern.	Some channelization present, 10-40% of reach channelized or disrupted; may be recovering from past channelization, stream is developing a normal pattern.	Channelization extensive; shoring sturctures present on both banks; 40-80% of stream reach channelized & disrupted; stream does not have a normal pattern.	Banks shored with gabion or cement; >80% of the stream reach channelized & disrupted, stream is a straight channel. Instream habitat greatly altered or removed entirely.
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7) Frequency of riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by stream width is <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important	Occurrence of riffles infrequent; distances between riffles divided by stream width is between 7 to 15	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by stream width is between 15 to 25	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided stream width is a ratio of >25
Score_____	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8) Bank Stablity	Banks stable; evidence of erosion or bank failure absent/minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank slouging; 60-100% of bank has erosional scars.
Score (RB)_	Right bank 10 9	8 7 6	5 4 3	2 1 0
Score (LB)_	Left bank 10 9	8 7 6	5 4 3	2 1 0
9) Bank Vegetative Protection	>90% of the streambank surfaces covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	<50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation Is very high; vegetation has been removed to 5 centimeters or less in average stubble height
Score (RB)_	Right bank 10 9	8 7 6	5 4 3	2 1 0
Score (LB)_	Left bank 10 9	8 7 6	5 4 3	2 1 0
10) Riparian Vegetative Zone Width	Width of riparian zone >40 meters; human activities (parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone.	Width of riparian zone 40-20 meters; human activities have impacted zone only minimally.	Width of riparian zone 20-10 meters; human activities have impacted zone a great deal.	Width of riparian zone <10 meters; little or no riparian vegetation due to human activities
Score (RB)_	Right bank 10 9	8 7 6	5 4 3	2 1 0
Score (LB)_	Left bank 10 9	8 7 6	5 4 3	2 1 0

Figure D5: Field data sheet front for Coastal Plain province (Spring 1999).

Coastal Plain
QA/QC: Y N
Reach #: 1 2 NA

Physical Characterization/ Water Quality Field Data Sheet
(front)

Site Code_______
Tree Tag #_______

Stream Name:	Date:	Start Time:
Stream Order:	Recorder	Finish Time:
Investigators:	Roll #:__________	Frame #:__________
Gear:	Comments for Fish Survey:	

RSAT Habitat Assessment Metrics

Category	Value	Parameter	U	M	D
Average canopy cover	________%	Habitat Type	________	________	________
# of tree falls	________	Top Channel Width	________	________	________
# of recent tree falls	________	Bottom Channel Width	________	________	________
# partial fish barriers	________	Wetted Perimeter	________	________	________
# complete fish barriers	________	Average Depth	________	________	________
# of exposed sewer lines	________	L Bank Height	________	________	________
# of large point bars	________	R Bank Height	________	________	________
# of unstable point bars	________	L Bank Substrate	________	________	________
# of log jams	________	R Bank Substrate	________	________	________

Water quality	
Temperature	________
% saturation:	________
Dissolved oxygen	________
Conductivity	________
Specific conductan	________
pH	________
Turbidity	________
Water velocity at run:	
Trial 1	________
Trial 2	________
Trial 3	________
Mean	________

RBP Habitat Assessment Scores

Parameter	Score
1) Epi. Subs./Av. Cov.	________
2) Pool Subs. Char.	________
3) Pool Variability	________
4) Channel Alteration	________
5) Sediment dep.	________
6) Chan. Sinuosity	________
7) Chan. Flow Status	________
8) Bank Veg. Prot.	RB:_______ LB:_______
9) Bank Stability	RB:_______ LB:_______
10) Rip. Veg. Zone W.	RB:_______ LB:_______

Substrate Composition

Inorganic Substrate Components
(Should add up to 100%)

Substrate	% Comp. in Reach
Bedrock	________
Boulder (>256 mm)	________
Cobble (64-256 mm	________
Gravel (2-64 mm)	________
Sand (0.06-2 mm)	________
Silt (0.004 - 0.06 m	________
Clay (<0.004mm)	________

Organic Substrate Components
(May not add up to 100%)

Substrate type	Description	% Composition in Reach
Detritus	Sticks, wood, coarse plant	________
Muck/mud	black, very fine organic matter	________
Marl	grey, shell fragments	________

Figure D6: Field data sheet front for Peidmont/Triassic provinces (Spring 1999).

Peidmont QA/QC: Y N Reach #: 1 2 NA	**Physical Characterization/ Water Quality Field Data Sheet** (front)	Site Code ____ Tree Tag # ____

Stream Name:	Date:	Start Time:
Stream Order:	Recorder	Finish Time:
Investigators:	Roll #:____________	Frame #:______________
Gear:	Comments for Fish Survey:	

RSAT Habitat Assessment Metrics

Category	Value	Parameter	U	M	D
Average canopy cover	________%	Habitat Type	_________	______	_________
# of tree falls	_________	Top Channel Width	_________	______	_________
# of recent tree falls	_________	Bottom Channel Width	_________	______	_________
# partial fish barriers	_________	Wetted Perimeter	_________	______	_________
# complete fish barriers	_________	Average Depth	_________	______	_________
# of exposed sewer lines	_________	L Bank Height	_________	______	_________
# of large point bars	_________	R Bank Height	_________	______	_________
# of unstable point bars	_________	L Bank Substrate	_________	______	_________
# of log jams	_________	R Bank Substrate	_________	______	_________

Water quality	
Temperature	_________
% saturation:	_________
Dissolved oxygen	_________
Conductivity	_________
Specific conductance	_________
pH	_________
Turbidity	_________
Water velocity at run:	
Trial 1	_________
Trial 2	_________
Trial 3	_________
Mean	_________

RBP Habitat Assessment Scores

Parameter	Score
1) Epi. Subs./Av. Cov.	_________
2) Embeddedness	_________
3) Velocity/Depth Regimes	_________
4) Channel Alteration	_________
5) Sediment dep.	_________
6) Frequency of Riffles	_________
7) Channel Flow Status	_________
8) Bank Veg. Prot.	RB:_______
	LB:_______
9) Bank Stability	RB:_______
	LB:_______
10) Rip. Veg. Zone W.	RB:_______
	LB:_______

Substrate Composition

Inorganic Substrate Components (Should add up to 100%)

Substrate	% Comp. in Reach
Bedrock	_________
Boulder (>256 mm)	_________
Cobble (64-256 mm)	_________
Gravel (2-64 mm)	_________
Sand (0.06-2 mm)	_________
Silt (0.004 - 0.06 mm)	_________
Clay (<0.004mm)	_________

Organic Substrate Components (May not add up to 100%)

Substrate type	Description	% Composition in Reach
Detritus	Sticks, wood, coarse plant	_________
Muck/mud	black, very fine organic matter	_________
Marl	grey, shell fragments	_________

Figure D7: Field data sheet back for all provinces (Spring 1999).

Physical Characterization/ Water Quality Field Data Sheet (back)						
Habitat	% of reach represented by:		riffle_____ run_____	pools___________		
	% of each habitat present:		riffle_______	submerged macrophytes________		
			snags________	stream banks___ other________		
	# of Habitats Sampled:		riffle_______	submerged macrophytes________		
			snags________	stream banks___ other________		
Weather Conditions	Today:	storm/heavy rain	showers (intermittent)		partly cloudy	
		rain (steady)	sunny	partly sunny	cloudy (overcast)	
	Past 24 hrs:	storm/heavy rain	showers (intermittent)		partly cloudy	
		rain (steady)	sunny	partly sunny	cloudy (overcast)	
	Has there been a heavy rain in the past 7 days?		Yes	No		
	Estimated Air Temperature_______________					
Riparian zone/ instream features	**Predominant Surrounding Landuse**		**Local water erosion**			
	forest	commercial	none	moderate	heavy	
	field/pasture	industrial				
	agricultural	other_____	**Channelized**	yes	no	
	residential	other_____	**Dam present**	yes	no	
	Canopy cover		**Local watershed NPS pollution**			
	open	moderate	shaded	no evidenc	potential sources	obvious sources
Riparian vegetation	Riparian Zone Width	Right bank:_______	Left bank:____________			
	Dominant vegetation:	trees	shrubs	grasses	herbaceous	
Aquatic Vegetation	Dominant vegetation:	rooted emergent	rooted floating	free floating		
		attached algae	rooted submergent	floating algae		
Sediment/ Substrate	Odors:	normal	chemical	sewage	anaerobic	petroleum
	Oils:	absent	slight	moderate	profuse	other_______
	Deposits:	sludge	sand	sawdust	relict shell	paper fiber other_______
	Are the undersides of deeply embedded stones black? Yes No					
Water	Odors:	normal	sewage	fishy	petroleum	chemical other_______
	Oils:	none	sheen	globs	slick	flecks other_______
	Color:	clear	greenish	brownish	other_______	
Relative amount of trash:		none	slight	moderate	profuse	
Description of trash:						
Comments:						

Figure D8: Field data sheet front for all provinces (Summer 1999).

Protocol:	C.P / Peid.		**Physical Characterization/ Water Quality Field Data Sheet** (front)			Site Code ________	
QA/QC:	Y N						
Reach#:	1 2 N/A						
Habitat	% of reach represented by:		riffle_____	run_____	pools___________		
	% of each habitat present:		riffle_______		submerged macrophytes________		
			snags________		stream banks___	other________	
	# of Habitats Sampled:		riffle_______		submerged macrophytes________		
			snags________		stream banks___	other________	
Weather Conditions	Today:	storm/heavy rain	showers (intermittent)			partly cloudy	
		rain (steady)	sunny		partly sunny	cloudy (overcast)	
	Past 24 hrs:	storm/heavy rain	showers (intermittent)			partly cloudy	
		rain (steady)	sunny		partly sunny	cloudy (overcast)	
	Has there been a heavy rain in the past 7 days?			Yes	No		
	Estimated Air Temperature_______________						
Riparian zone/ instream features	**Predominant Surrounding Landuse**			**Local water erosion**			
	forest	commercial		none	moderate	heavy	
	field/pasture	industrial					
	agricultural	other_____		**Channelized**		yes	no
	residential	other_____		**Dam present**		yes	no
	Canopy cover			**Local watershed NPS pollution**			
	open	moderate	shaded	no evidenc	potential sources	obvious sources	
Riparian vegetation	Riparian Zone Width	Right bank:_______		Left bank:____________			
	Dominant vegetation:	trees	shrubs	grasses	herbaceous		
Aquatic Vegetation	Dominant vegetation:	rooted emergent		rooted floating		free floating	
		attached algae		rooted submergent		floating algae	
Sediment/ Substrate	Odors:	normal	chemical	sewage	anaerobic	petroleum	
	Oils:	absent	slight	moderate	profuse	other_______	
	Deposits:	sludge	sand	sawdust	relict shell	paper fiber	other_______
	Are the undersides of deeply embedded stones black? Yes No						
Water	Odors:	normal	sewage	fishy	petroleum	chemical	other_______
	Oils:	none	sheen	globs	slick	flecks	other_______
	Color:	clear	greenish	brownish	other_______		
Relative amount of trash:			none	slight	moderate	profuse	
Description of trash:							
Comments:							

Figure D9: Field data sheet back for all provinces (Summer 1999).

Pebble Count													
	1	2	3	4	5	6	7	8	9	10	1	2	3
Habitat Type											**Riffle**	**Riffle**	**Riffle**
< 2 mm													
2-4 mm													
4-8 mm													
8-16 mm													
16-32 mm													
32-64 mm													
64-128 mm													
128-256 mm													
256-512 mm													
512-1024 mm													
> 1024 (Bedrock)													

RBP Habitat Assessment	
Parameter	**Score**
1) Substrate	________
2) Pool Sub./ Embeddedness	________
3) Pool Var./ Vel-Depth	________
4) Sed. deposition	________
5) Channel flow status	________
6) Channel alteration	________
7) Chan. Sin./ Freq. riff-bend	________
8) Bank stability	RB:______
	LB:______
9) Bank Vegetation	RB:______
	LB:______
10) Riparian Zone	RB:______
	LB:______

Water Chemistry	
Temperature	_______ C
% saturation	_______%
Dissolved oxygen	_______mg/L
Conductivity:	_______uS
Specific conductance:	_______uS
pH:	_______
Turbidity:	_______nmu
Nitrates (Lot # 1, 2, 3)	_______mg/L
Flouride:	_______mg/L

Canopy Cover- open spaces	
US	________
DS	________
LB	________
RB	________

Trash
none
slight
moderate
profuse

Figure D10: Incised Channel Evolution Model data sheet and check list (Summer 1999).

Channel Evolution Model Data Sheet	
Site Code:________________	Pictures: roll# ____________ frames ______________
Channel Stability Indicator	Comments
STAGE 1 ☐ well developed baseflow and bankfull change ☐ consistent floodplain features easily identified ☐ one terrace apparent above active floodplain ☐ predictable pattern and stream bed morphology ☐ floodplain covered by diverse vegetation ☐ streambanks ≤ 45°	**General** Comments:
STAGE 2 ☐ headcuts ☐ exposed cultural features ☐ sediment deposits absent or sparse ☐ exposed bedrock ☐ streambank slopes > 45°	
STAGE 3 ☐ streambank sloughing ☐ sloughed material eroding ☐ streambank slopes 60° vertical/concave ☐ erosion on inside of bends ☐ accelerated bend migration	
STAGE 4 ☐ streambank aggrading ☐ sloughed material not eroded ☐ sloughed material colonized by vegetation ☐ baseflow, bankfull and floodplain channel developing ☐ predictable sinuous pattern developing ☐ streambank slopes ≤ 45°	
STAGE 5 ☐ well developed baseflow and bankfull channel ☐ consistent floodplain features easily identified ☐ two terraces apparent above active floodplain ☐ predictable pattern and streambed morphology ☐ streambanks ≤ 45°	

D.7 References

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APPENDIX E

PHYSIO-CHEMICAL STREAM WATER SAMPLING PROTOCOLS

The chemical constituents of water can have a direct influence on stream biota. The impact of various chemical inputs on living organisms can be acute (immediate) or chronic (occurring over a long period), and may limit stream communities even when quality habitat is available. A variety of basic chemical parameters are useful for assessing immediate concerns in a given system as well for highlighting situations where more detailed chemical analysis may be required.

Water samples were tested twice at each site, once when sampling macroinvertebrates and once when sampling fish. Results were recorded on the habitat data sheets. Dissolved oxygen (mg/L), pH, temperature (°C), conductivity (μS), %O_2 saturation and turbidity were recorded during both sampling periods, while nitrate and fluoride measurements were recorded only once, during the summer sampling round. The meters and the corresponding parameters being examined are listed in Table E1.

Table E1: List of meters used for water quality parameters.

METER	**PARAMETER**
Hach Pocket Colorimeter for Nitrates	[NO_3^-] Nitrate (mg/L)
Hach Pocket Colorimeter for Fluoride	[F^-] Fluoride (mg/L)
YSI, Model 85	Dissolved oxygen (mg/L), % O_2 saturation, temperature (^oC), conductivity and specific conductance (μS)
LaMotte 2020 Turbidimeter	Turbidity (NMU)
Fisher Scientific Acumet portable pH meter	pH

Additional QA/QC procedures for water chemistry sampling performed:

- Equipment was calibrated with known standards on a weekly basis. Each instrument was checked each day before going out into the field.

- At the cessation of each sampling period (spring vs. summer), meters were inspected, maintenance performed, and sent back to the manufacturer for factory re-calibration when necessary.

- At 10% of sites, measurements were made in an adjacent upstream reach with conditions similar to those of the original sites (same as randomly selected fish, benthic, and habitat QA/QC sites). All chemical samples were taken at a riffle or a shallow section of the stream with the highest velocity.

APPENDIX F

SPATIAL ANALYSIS USING GLOBAL POSITIONING SYSTEM (GPS) AND GEOGRAPHIC INFORMATION SYSTEMS (GIS)

F.1 Global Positioning System

Spatial information (latitude/longitude) on all SPS sites was collected using a Trimble ProXR GPS unit. This is a portable, differential GPS system. Locations were marked at the both ends of each sampling reach. Differential correction of rover unit data was performed as postprocessing. Base station data necessary for differential correction were downloaded from the following website: www.ngs.noaa.gov/cors/data.html, which is maintained by the National Oceanographic and Atmospheric Administration.

After differential correction had been completed for all study sites, the files were combined into a single corrected file and exported to an ArcView format for use in a GIS environment.

F.2 Geographic Information Systems

Drainage area delineation

Procedures were developed for automated delineation of watersheds using information on spot elevations, and the stream network coverage for the area of interest. The procedures use the spot elevations and stream network coverage to create Digital Elevation Models (DEMs) with streams “burned in” i.e. cells representing the stream network in the DEM explicitly identified, employing routines available in the ArcView Spatial Analyst extension for raster-based analysis. The DEMs were used in conjunction with public domain Avenue scripts (Olivera and Maidment, 1998) to generate input grids required for raster-based identification of surface drainage areas, including a drainage network extracted directly from the DEM (sometimes referred to as “gridded” streams). The procedures developed were used for automated delineation of watershed boundaries for over 125 sampling points employed in the SPS study, ranging in area from 250 acres to over 8 mi^2.

Current imperviousness estimation

GIS-based procedures were developed for direct estimation of current imperviousness levels utilizing available information on building footprints, major and minor roads, and sidewalks. The procedures essentially entail clipping polygon or line data layers containing features that make up impervious cover using the boundary of the area of interest. The area contained within impervious features in the resulting theme is summed, and the ratio of this area to the total area is the fraction of impervious area. For the sidewalk data layer, which was only available as a line theme, area was estimated by assuming an appropriate constant width (4 feet). In addition, the building footprint data layer did not contain driveway areas. To estimate the total driveway area, the number of buildings designated as single family residential in the attribute table was first determined. The number obtained was then multiplied by an assumed average driveway area (450 ft^2) to obtain the total driveway area.

Future imperviousness estimation

Future imperviousness levels were estimated using the current County zoning map. Zoning districts specified in the County Zoning Ordinance were assigned imperviousness values based upon values reported in the Fairfax County Zoning Ordinances for open space requirements, the County's Public Facilities Manual and the CBLAD Local Assistance Manual. The current zoning data layer was first unioned with the subwatershed layer obtained through the drainage area delineations performed previously. The predicted future imperviousness value for each subwatershed was then obtained by area-weighting each zoning district contained within each subwatershed.

F.3 References

Olivera, F. and D. R. Maidment (1998), HEC-PrePro v. 2.0: An ArcView Pre-Processor for HEC's Hydrologic Modeling System. Proceedings of the 18th ESRI Users Conference, San Diego, CA

APPENDIX G

COUNTYWIDE STREAM RANKING SYSTEM

In order to assess and rank the county's streams, a procedure that allows the incorporation of multi-dimensional data was needed. A useful technique for displaying multi-dimensional data was suggested by Andrews (1972). Plotting data using this technique greatly facilitates visual assessment of similar or dissimilar data sets (i.e.: sampling sites). Additionally, a "reference curve" derived from reference site data can be used as a basis for comparing all other stream curves. Hence, the greater the numerical (Euclidean distance) departure from the reference curve, the more disturbed or degraded the compared site is. This hierarchy of numerical departures from a reference condition curve is the basis for the relative ranking of all County SPS stream-monitoring sites.

G.1 Andrews Curves Procedure

The curves are calculated by inputting well-correlated sampling data into a generic formula and plotting the resulting values on a continuous line from $-\pi$ to π on the x-axis. There is no limit to the number of environmental variables that can be used in the formula, however, the variables that are used must be run through a stepwise-multiple regression to determine acceptable levels of correlation. Therefore, a list of candidate variables such as width/depth ratios, fish metrics, habitat scores, pebble counts, etc. was compiled and then tested to determine the level of correlation to the dependant variable (IMBI score). The values of the individual variables must be standardized to account for differences in the scale and units of the data before running the correlation. After the stepwise-multiple regression has been run and the poorly correlated candidate variables omitted, the remaining variables are then ranked in order of greatest to least correlation. This is then the order that they are input into the following formula:

$$f(t) = \frac{X_1}{\sqrt{2}} + X_2 \sin(t) + X_3 \cos(t) + X_4 \sin(2t) + X_5 \cos(2t) + ...$$

where:

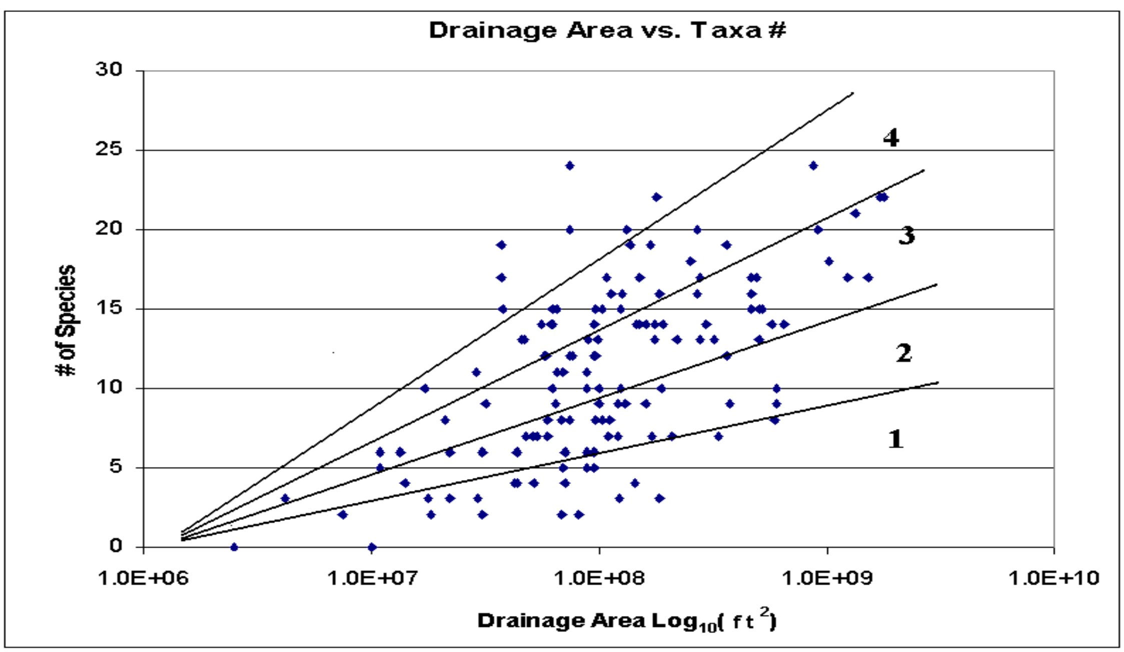
X_1 = dependant variable
X_2 = most highly correlated variable
X_3 = second most highly correlated variable
X_4 = third most highly correlated variable

The UNISTAT statistical software package (UNISTAT Limited, ver. 4.51) was used to perform the stepwise multiple regression on the 12 potential environmental site variables. The candidate variables chosen for use in the formula were (in decreasing correlation): Benthic IBI, %Imperviousness, # of Fish Taxa and Total RBP Habitat Score. Differences between the Coastal Plain and Piedmont data sets were accounted for in the data prior to Andrews Curves calculation. For example, the IBI has two components, a CMBI which measures Coastal Plain benthic faunal integrity on a scale of 0 to 100, as does its Piedmont Province counterpart, the IMBI. This is also the case with the RBP habitat assessment: two separate RBP habitat ranking systems (scoring from 0 to 200) which account for morphological and geological differences in the two physiographic provinces. Essentially, an RBP score of 120 in either province denotes the same degree of disturbance regardless. The same is true for the two IBIs. The % Imperviousness variable is not influenced by province.

G.2 Calibrating the Fish Component

It has been shown that the expected number of fish species present increases linearly with increasing stream order due to ecological factors (Schlosser 1982). Also, fish populations may vary between provinces due primarily to geomorphology and certain zoogeographic features (Bailey and Smith 1981). Therefore, before sites of different steam order or from different provinces can be compared, these differences must be accounted for. To address the species vs. order issue, the tri-sectioning method was employed (Fausch et al.1983). This technique involves plotting the number of fish species versus stream order or drainage area. A 95th percentile line, called a "maximum species richness line" is then drawn along the gradient. The remaining area under the line is then evenly divided into two or more wedge-shaped areas. The sites falling in each section will receive a corresponding score of 1 to 4 depending on the proximity to the 95th percentile line (see Figure G1).

Figure G1: Graph of sectioned fish taxa number for all sites.



Fish populations from each physiographic province (plus the Quantico Creek Reference watershed) were visually compared using the total fish taxa values for each site. The three populations were very closely distributed when plotted against their drainage areas. Therefore it could be concluded that the maximum expected number of species at a site (with respect to drainage areas) is relatively constant across all three provinces.

G.3 Stream Rankings

To determine the degree of numerical departure of a given curve from the "reference curve" a simple Euclidean distance is used at each point along the line. Since a line is an infinite series of continuous points, the determination that the series from $-\pi$ to π should be divided into 200 points ($2\pi/200$) was considered a sufficient increment for plotting the curves and for testing the departures between a given curve and the reference curve. The Euclidean departure is computed as follows:

$$\sum_{i=1}^{200} (X_{ref,i} - X_{obj,i})^2$$

where:

X_{ref} = Andrews value of reference curve

X_{obj} = Andrews value of objective curve

After calculating the Euclidean departures for all curves (including the 11 reference sites) the resulting values were evenly sub-divided into 5 ranking categories: Excellent, Good, Fair, Poor, and Very Poor. The Quantico Creek Watershed reference sites were removed from the final ranking procedure, leaving only the County sites. See Table G1 for County site rankings and values of the Euclidean departures from the reference condition curve.

Table G1: Ranking categories and Andrews Curves Euclidean departures from reference condition curves.

Fairfax SPS Sites Euclidian Departures from Reference Conditions (without Quantico Sites)									
Excellent		*Good*		*Fair*		*Poor*		*Very Poor*	
KCKC01	114.8	PNCL01	758.2	DFDF04	1146.8	DFSF01	1699.0	CAIR01	2490.5
JMJM01	313.2	NIJB01	840.7	HCHC03	1176.8	CUFB02	1727.6	ACAC02	2664.5
SASA03	322.5	DFDF03	858.3	LRLR03	1205.8	CUCU04	1794.0	PMLP01	2685.7
DFCH01	344.0	NINI01	864.4	CUCB01	1212.3	ACAC06	1799.4	CAHR03	2706.5
WRWR02	367.1	LRLR02	864.8	LRLR01	1254.8	ACAC05	1834.6	DFPB01	2714.4
SASA01	405.1	PCPC04	944.3	DFLD01	1257.8	PCPC03	1847.0	DFWC02	2716.3
OCEH01	415.2	CUCU05	953.5	DFSB02	1274.1	DFDF02	1890.0	ACAC03	2794.9
PCSR01	448.3	CUCU03	957.4	WRWR01	1370.9	DFWC01	1922.9	LHLH01	2890.5
PHCC01	473.3	DCDC01	1027.5	PHPH02	1375.9	CUFB01	1924.8	PCSI01	2915.0
TUTU01	486.1	PCMI01	1039.8	PCPC01	1377.7	DFCR02	1970.6	CABA01	2987.6
BLBT01	519.8	NINI02	1041.2	SASA02	1417.1	SUSU01	1981.8	HCHC02	3005.9
RDRT01	551.1	DFDF05	1041.5	PHPI01	1464.5	ACLA01	1999.1	CAHR02	3064.1
BNBN01	611.7	MBGR01	1050.2	SUSU02	1503.2	PMPM02	2041.2	DEDE01	3067.1
JMJM02	658.0	DCDC04	1053.4	MBMB01	1507.4	DFCR01	2077.2	ACBB01	3086.1
PNMR01	689.2	PCSR03	1067.1	DFRB01	1509.1	ACLB01	2086.9	DFSB01	3293.2
OMOM01	713.9	PHPH03	1079.1	SUFL01	1545.3	PMPM03	2199.2	LHPS01	3308.0
MBGR02	744.9	DFRR01	1092.8	CUBR02	1551.3	HCHC01	2236.6	CAPK01	3333.7
		PNPN01	1094.5	CUER02	1558.5	ACAC07	2307.1	PMPM01	3385.8
		PHPH01	1102.1	DFPR01	1574.0	SUSU03	2307.6	ACDR01	3419.3
		CUBR01	1128.3	PCSR02	1583.3	SCSC02	2321.7	LHNB01	3728.1
		DFRB02	1131.3	PHPI02	1621.9	PCPC02	2338.7	SCSC01	3858.2
		CUCU02	1143.2	PCRA01	1626.0	CATK01	2353.0	ACAC01	3870.6
				PCRA02	1681.6	CAHR01	2393.5	ACLC01	3875.7
				DFDF01	1684.3	DCNF01	2418.6	CATR01	4108.5
						ACAC04	2442.4	BEBE01	4132.9
								FMLO01	4820.8

G.4 References

Andrews, D.F. 1972. Plots of High Dimensional Data, Biometrics: 28: 125-36.

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APPENDIX H

VOLUNTEER STREAM MONITORING

H.1 Stream Monitoring Programs and Protocols

There are two established programs for concerned citizens interested in volunteer stream monitoring in Fairfax County. The Audubon Naturalist Society (ANS), which coordinates a local program through the Webb Sanctuary in Clifton, Virginia, and the Northern Virginia Soil and Water Conservation District (NVSWCD). The following pages consist of general and detailed volunteer monitoring instructions and the official data forms for the two organizations. The NVSWCD material is presented first, followed by the ANS forms. For even more detailed protocols or other general information call (703) 324-1425 to reach the NVSWCD or (301) 652-9188 to reach the ANS. For the location of a coordinator or ongoing program near you, call the Webb Sanctuary at (703) 803-8400 or the NVSWCD office at (703) 324-1425.

The Northern Virginia Soil and Water Conservation District's volunteer stream-monitoring program used the Save Our Streams (SOS) protocol developed by the Izaak Walton League (Firehock 1994). This protocol combines visual habitat assessment and limited water chemistry measurements with macroinvertebrate sampling. The benthic macroinvertebrate survey is based on species richness (i.e. the number of species present) and general tolerance of those species to anthropogenic stressors. It does not take into to account the relative abundance of those species (i.e. how many individuals of each type are present). Modifications to the protocol have occurred as a result of research conducted at Virginia Tech with statewide volunteer data. As of spring 2001, the NVSWCD program will be using the Virginia Save Our Streams protocol. This protocol consists of fine-tuning of the taxa tolerance ratings, such as the separation of net-spinning caddisflies from other less tolerant forms. The new protocol uses actual counts of insects, allowing a better definition of the community structure. Lastly, a quantitative multi-metric-index has been developed similar to the IMBI to give an overall quantitative ranking of stream health.

The Audubon Naturalist Society uses a modified version of the U.S. EPA Rapid Bioassessment Protocol for benthic macroinvertebrates. They also combine visual habitat assessment with the benthic sampling. Invertebrates are identified to family, where possible, or to the highest taxonomic resolution practicable. Currently, the protocol does not include a biological rating system. Plans are underway to incorporate an IBI-type rating system into the protocol. This would allow much more direct comparison with professional data.

H.2 References

Firehock, Karen. 1994. Save our Streams Volunteer Trainer's Handbook. The Izaak Walton League of America. Arlington, Virginia.

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