

8.0 Permit

D. Discharge Characterization

Baltimore County and 10 other municipalities in Maryland have been conducting discharge characterization monitoring since the early 1990's. From this expansive monitoring, a statewide database has been developed that includes hundreds of storms across numerous land uses. Summaries of this dataset and other research performed nationally effectively characterize stormwater runoff in Maryland for NPDES municipal stormwater purposes. These data shall be used by Baltimore County for guidance to improve stormwater management programs and develop watershed restoration projects. Monitoring required under this permit is now designed to assess the effectiveness of stormwater management programs and watershed restoration projects developed by the County. Details about this monitoring can be found in PART III. H.

H. Assessment of Controls

Assessment of controls is critical for determining the effectiveness of the NPDES stormwater management program and progress toward improving water quality. Therefore, Baltimore County shall use chemical, biological, and physical monitoring to document work toward meeting the watershed restoration goals identified above. Additionally, the County shall continue physical stream monitoring in the Windlass Run to assess the implementation of the *2000 Maryland Stormwater Design Manual* or other innovative stormwater management technologies approved by MDE. Specific monitoring requirements are described below.

1. Watershed Restoration Assessment

The County shall monitor the Scotts Level Branch, or, select and submit for MDE's approval a new watershed restoration project for monitoring. Ample time shall be provided so that pre-restoration monitoring, or characterization monitoring can take place. Priority will be given to new practices where little monitoring data exist or where the cumulative effects of watershed restoration activities can be assessed. An outfall and associated in-stream station, or other locations based on an approved study design shall be monitored. The minimum criteria for chemical, biological, physical monitoring are as follows:

a. Chemical Monitoring

- i. Twelve (12) storm events shall be monitored per year at each monitoring location with at least three occurring per quarter. Quarters shall be based on the calendar year. If extended dry weather periods occur, baseflow samples shall be taken at least once per month at the monitoring stations if flow is observed;
- ii. Discrete samples of stormwater flow shall be collected at the monitoring stations using automated or manual sampling methods. Measurements of pH and water temperature shall be taken;

iii. At least three (3) samples determined to be representative of each storm event shall be submitted to a laboratory for analysis according to methods listed under 40 CFR Part 136 and event mean concentrations (EMC) shall be calculated for:

Biochemical Oxygen demand (BOD ₅)	Total Lead
Total Kjeldahl Nitrogen (TKN)	Total Copper
Nitrate plus Nitrite	Total Zinc
Total Suspended Solids	Total Phosphorus
Total Petroleum Hydrocarbons (TPH)	Oil and Grease*
Fecal Coliform or E. coli	(*Optional).

iv. Continuous flow measurements shall be recorded at the in-stream monitoring station or other practical locations based on an approved study design. Data collected shall be used to estimate annual and seasonal pollutant loads and for the calibration of the watershed assessment models.

b. Biological Monitoring

- i. Benthic macroinvertebrate samples shall be gathered each Spring between the outfall and in-stream stations or other practical locations based on an approved study design; and
- ii. The County shall use the U.S. Environmental Protection Agency's (EPA) Rapid Bioassessment Protocols (RBP), Maryland Biological Stream Survey (MBSS), or other similar method approved by MDE.

c. Physical Monitoring

- i. A geomorphologic stream assessment shall be conducted between the outfall and in-stream monitoring locations or in a reasonable area based on an approved study design. This assessment shall include an annual comparison of permanently monumented stream channel cross-sections and the stream profile;
- ii. A stream habitat assessment shall be conducted using techniques defined by the EPA's RBP, MBSS, or other similar method approved by MDE; and
- iii. A hydrologic and/or hydraulic model shall be used (e.g., TR-20, HEC-2, HSPF, SWMM, etc.) to analyze the effects of rainfall discharge rates; stage; and if necessary, continuous flow on channel geometry.

d. Annual Data Submittal: The County shall describe in detail its monitoring activities for the previous year and include the following:

- i. EMCs submitted on MDE's long-term monitoring database as specified in PART IV below;

Chemical, biological, and physical monitoring results and a combined analysis for the Scotts Level Branch or other approved monitoring

- ii. locations; and

- iii. Any requests and accompanying justifications for proposed modification to the monitoring program.

2. Stormwater Management Assessment

The County shall continue monitoring the Windlass Run for determining the effectiveness of the *2000 Maryland Stormwater Design Manual* for stream channel protection. Physical stream monitoring protocols shall include:

- a. An annual stream profile and survey of permanently monumented cross-sections in the Windlass Run to evaluate channel stability in conjunction with the implementation of the *2000 Maryland Stormwater Design Manual*.
- b. A comparison of the annual stream profile and survey of the permanently monumented cross-sections with baseline conditions for assessing areas of aggradation and degradation; and
- c. A hydrologic and/or hydraulic model shall be used (e.g., TR-20, HEC-2, HEC-RAS, HSPF, SWMM, etc.) to analyze the effects of rainfall discharge rates; stage; and, if necessary, continuous flow on channel geometry.

8.1 Introduction

The third term of the Baltimore County – NPDES MS4 Permit that became effective June 15, 2005 resulted in a change in the long-term monitoring location. The long-term monitoring site was moved from Spring Branch in the Loch Raven watershed to Scotts Level Branch in Gwynns Falls watershed. This report will present the research design and initial monitoring data for Scotts Level Branch (8.2), and the data for Windlass Run (8.3).

8.2 Scotts Level Branch Long-Term Monitoring

The Baltimore County NPDES Municipal Stormwater Discharge Permit requires monitoring of restoration effectiveness. For the first two rounds of the 5-year permit, the Spring Branch subwatershed had been monitored to determine the effectiveness of the stream restoration in promoting stream stability, reduction in pollutant loads, and improvement in the benthic macroinvertebrate community. Using the experience gained in monitoring Spring Branch, a more effective monitoring program has been designed for the Scotts Level Branch subwatershed, as detailed below.

Scotts Level Branch is located in the Gwynns Falls watershed in the Patapsco/Back River Basin. The 303(d) lists these waters as being impaired by nutrients, suspended sediments, and fecal coliform bacteria. In addition, Scotts Level Branch is listed as impaired for biology. The TMDLs for nutrients and bacteria are in the process of completion. The TMDL for nutrients has identified a reduction of 15% nitrogen and phosphorus loads from urban non-point sources as needed to meet water quality standards. The TMDL for bacteria has identified a ~98% reduction for human and domestic pet sources.

While the Spring Branch study monitored the effectiveness of one large restoration project, the Scotts Level Branch monitoring is designed on the basis that a number of restoration projects will be implemented within the subwatershed over a period of time. The ability to detect effects

of individual restoration projects will be dependent on the size of the restoration project in relation to the total subwatershed size. Therefore each restoration project will be monitored for project effectiveness, dependent on staff availability. The cumulative effects of restoration will be measured at the long-term in-stream monitoring site.

In order to assess restoration progress in the Scotts Level Branch subwatershed, a paired watershed, before-after design concept will be used. Two additional subwatersheds within Gwynns Falls, Powdermill Run and Upper Gwynns Falls (above Gwynnbrook Road) have been selected as the “paired” subwatersheds (Figure 8-1).

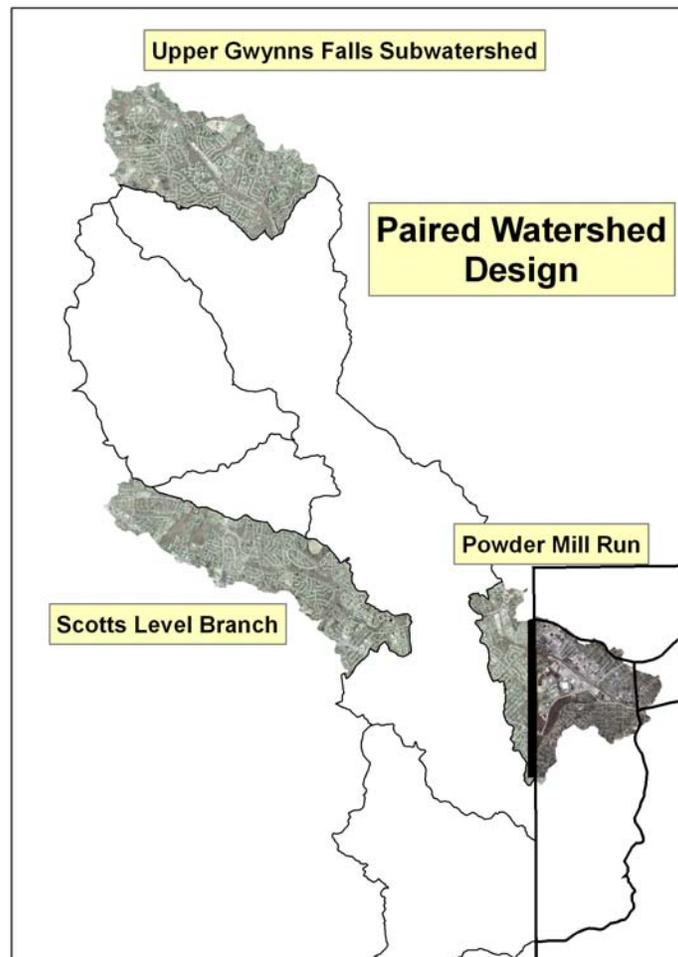


Figure 8-1: Subwatersheds to be Used in the Paired Watershed Monitoring Design.

Table 8-1 presents a comparison between the three subwatersheds in relation to overall size, land use composition, percent impervious cover, and stream length. The third subwatershed (Upper Gwynns Falls) was added due to the fact that Baltimore City will be doing stream restoration work in the Powder Mill Run subwatershed. Restoration work will also be conducted in the

Upper Gwynns Falls subwatershed in the future, with restoration work in Scotts Level Branch delayed for several years.

Table 8-1: Scotts Level Branch, Powder Mill Run, and Upper Gwynns Falls Information

Parameter	Scotts Level Branch	Powder Mill Run	Upper Gwynns Falls
Area (acres)	2,186	2,436	2,637
Land Use			
% Residential	91.1	63.4	74.9
% Commercial/Ind	6.0	32.5	6.3
% Forest	2.9	4.1	11.6
Impervious Cover (%)	23.7	33.8	21.4
Stream Miles	8.0	5.9	11.1

The monitoring will consist of flow monitoring, chemical monitoring, geomorphological monitoring, and biological monitoring as described below.

8.2.1 Monitoring Design

8.2.1.1 Flow Monitoring

Each of the three subwatersheds has had a gage installed and operated by the US Geological Survey (Table 8-2) with funding provided in total for the Powder Mill Run and Scotts Level Branch gages and in part for the Upper Gwynns Falls gage (Delight). USGS will provide the rating curves for the gages and annual data. A 36" outfall near the headwater of Scotts Level Branch will be monitored for discharge and chemistry. A weir will be installed to permit continuous flow monitoring with a water level sensor installed and operated by Baltimore County. This outfall has a drainage area of 15.9 acres with ~35% impervious cover. The land use is ~88% medium residential and therefore representative of the major land use in each of the subwatersheds.

Table 8-2: USGS Gage Information

Gage Number	Location	Measurements			Real Time	Period of Record
		Stage	Discharge	Precipitation		
01589197	Upper Gwynns Falls	X	X	X	Yes	October, 1998 - Current
01589305	Powder Mill Run	X	X		Yes	November, 2005 – Current
01589290	Scotts Level Branch	X	X		Yes	November, 2005 – Current

The flow monitoring will be used in conjunction with the chemical monitoring (described below) to determine pollutant loads and in relation to the geomorphological monitoring. Over time the flow data will be assessed for any changes in relation to restoration work that is conducted in the subwatersheds.

8.2.1.2 Chemical Monitoring

The chemical monitoring will include both storm event and baseflow monitoring components. The standard list of chemicals detailed in the permit requirements will be analyzed. Figure 8-2 displays the location of the chemical monitoring sites in Scotts Level Branch by type.

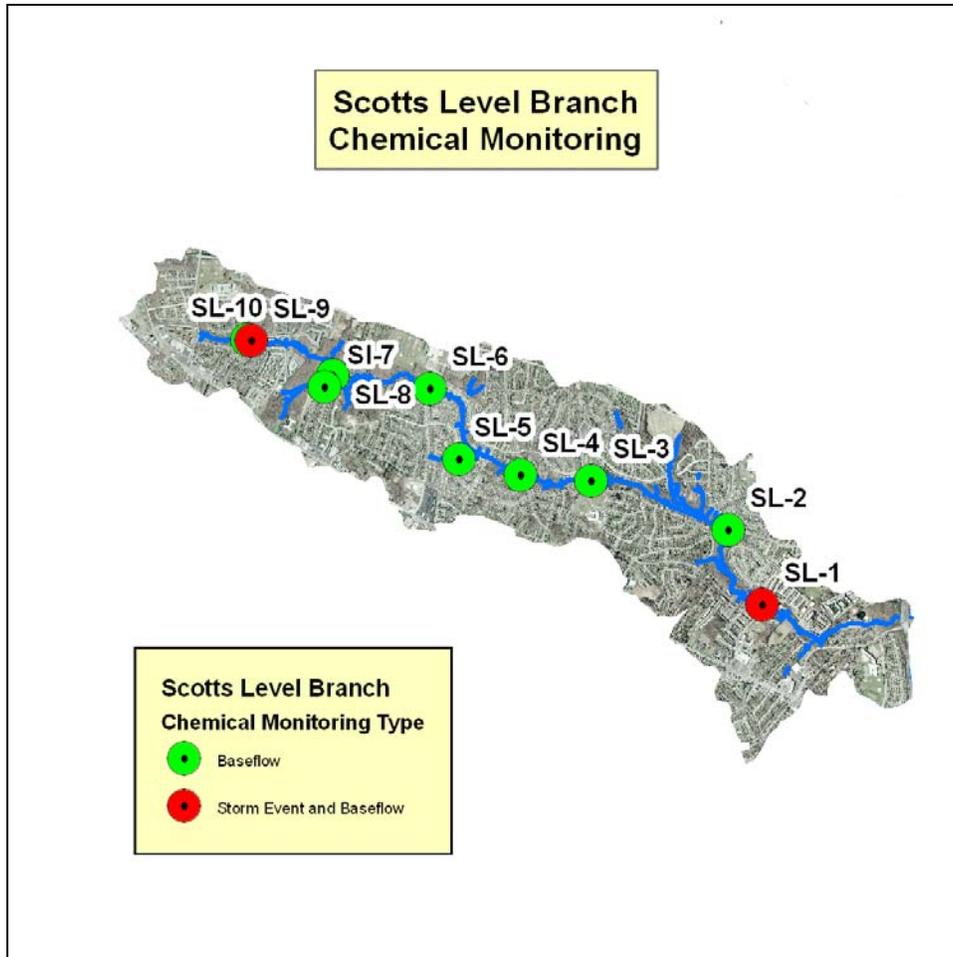


Figure 8-2: Scotts Level Branch Chemical Monitoring Locations

Storm Event Monitoring

Storm event monitoring will occur at each of the three USGS gages and at the outfall. The two Scotts Level Branch storm event monitoring sites (SL-1 in-stream, and SL-9 outfall) will be monitored for 12 storms each calendar year seeking to acquire samples for the entire hydrograph. At the other two USGS gages (Powder Mill Run and Upper Gwynns Falls) storm event grab samples will be collected to represent a range of stage discharges. The data from all four sites will be analyzed using regression analysis to determine the relationship between discharge and pollutant concentration. These relationships will then be used in conjunction with the flow data collected from the USGS operated gages and the water level sensor operated by DEPRM. The results and subsequent analysis following restoration will be used to determine annual loads and any load reductions due to restoration activities.

The pollutant load data collected from the Scotts Level Branch outfall will be used to estimate the wash load (the load derived from the land surface). While the pollutant load estimate derived from the Scotts Level Branch in-stream site will estimate the watershed load, which includes both the wash load and the load derived from stream bank erosion. The geomorphological analysis (see below) will attempt to determine the stream channel erosion component via changes in the channel cross-section and analysis of the pollutant concentration of the stream

bank and bed. Thus the wash load (derived from the outfall data) plus the stream erosion load (derived from the geomorphological data) should equal the watershed load (derived from the in-stream monitoring data). These data should provide an estimate of the relative proportions of pollutants derived from the land surface and the stream corridor. This will have important implications for restoration efforts in urban settings. If, as the literature suggests, a large component of the sediment and total phosphorus load is derived from the stream channel, then in order to meet sediment and phosphorus load reduction requirements for TMDLs and the Chesapeake Bay Program additional effort will need to be focused on stream restoration.

Baseflow Monitoring

Scotts Level Branch baseflow monitoring will occur at the outfall (SL-9), two tributary locations, and six mainstem locations for a total of 10 baseflow monitoring sites (Figure 8-7). Within Powder Mill Run baseflow monitoring will take place at the USGS gage and two upstream sites that are representative of each major branch (one in the County and one in the City). Baseflow monitoring in Upper Gwynns Falls will occur only at the USGS gage site. The baseflow sites in Scotts Level Branch, Powder Mill Run, and Upper Gwynns Falls will be monitored quarterly during baseflow conditions (preceded by a minimum of 72 hours dry weather).

Analysis of baseflow pollutants is especially important in relation to nitrogen. Research work conducted by the County, indicates that ~50% of the nitrogen load occurs during dry weather conditions. The baseflow sampling will be used in conjunction with the storm event sampling to partition the annual discharge and pollutant load between baseflow (dry weather) conditions and storm event conditions.

8.2.1.3 Geomorphological Monitoring

The geomorphological monitoring is intended to provide an estimate of stream erosion and deposition rates, and an estimate of the pollutant load derived from stream channel erosion. In addition, it is intended over time to provide an estimate of the effects of restoration on stream stability on both a project basis and over the entire subwatershed.

In order to assure unbiased selection of cross-section locations, Scotts Level Branch and Powder Mill Run were divided into 30 equal length stream segments, 20 in Scotts Level Branch (Figure 8-3) and 10 in Powder Mill Run (Figures 8-4). Within each segment a point was randomly selected, using a GIS subroutine, for location of permanent cross sections. These cross sections will be monitored annually with the results overlaid to provide an assessment of the amount of channel change. Three longitudinal profile reaches will be selected in Scotts Level Branch for annual assessment.

Stream bank and bed core samples will be collected in the vicinity of the permanent cross sections for laboratory analysis of bulk density, particle size distribution, total nitrogen, and total phosphorus. These will be one-time sample collections, with 10% of the sites, randomly selected, for a second round of sample collection to provide an analysis of annual variability. Based on the annual and long term change, and the results of the core samples, the estimated annual sediment, total nitrogen, and total phosphorus loads will be calculated for comparison with the chemical monitoring results derived from the in-stream monitoring site.

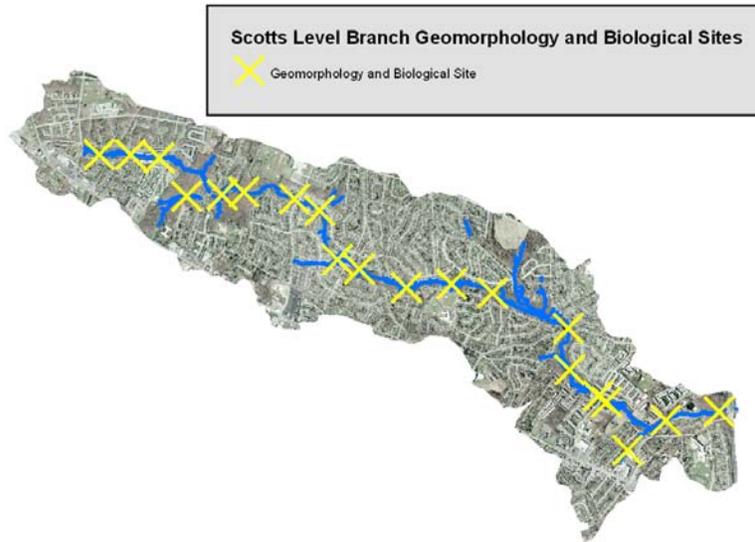


Figure 8-3: Scotts Level Branch Geomorphological and Biological Monitoring Site Locations

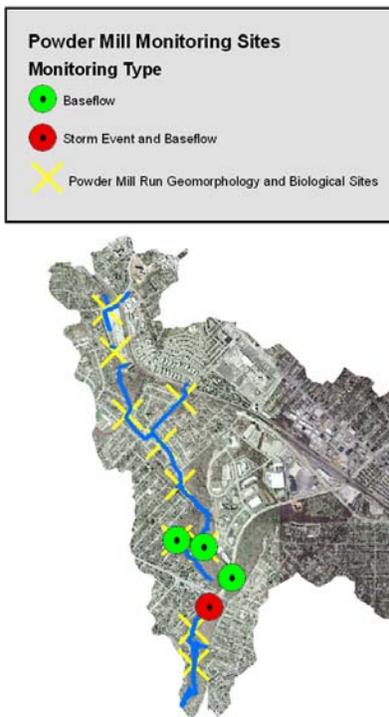


Figure 8-4: Powder Mill Run Geomorphological and Biological Monitoring Sites

8.2.1.4 Biological Monitoring

Benthic macroinvertebrate samples will be collected annually at every other randomly selected cross section monitoring site in the spring index period (March-April) (10 samples from Scotts Level Branch and 5 samples from Powder Mill Run) using Maryland Biological Stream Survey (MBSS) collection methods. Sample identification will be to the Genus taxonomic level or the lowest practical identification level. At the time of sample collection, a MBSS stream habitat assessment will be conducted. Fish assemblage monitoring will be conducted during the summer index period (June-September) at 3 sites in Scotts Level Branch and 3 Sites in Powder Mill Run on stream reaches associated with the randomly selected cross sections using MBSS methodologies.

The results of the biological monitoring will be compared with results from the cross sectional monitoring and the habitat analysis. In addition, the results will be compared between the two subwatersheds and to reference sites within Baltimore County. Inter-annual comparisons and changes in the biological community will be related to restoration progress within Scotts Level Branch.

8.3 Scotts Level Branch Long-Term Site Monitoring Results

8.3.1 Flow Monitoring

The U.S. Geological Survey under an agreement with Baltimore County installed a continuous gage on Scotts Level Branch where it crosses Rolling Road on September 29, 2005. This site is designated as SL-1. They also installed a continuous gage on Powder Mill Run below Liberty Road. In the fall of 2007, a weir with a continuous gage will be installed at the outfall in Scotts Level Branch to provide a continuous discharge record. The data for Scotts Level Branch are analyzed in this report. Next years report will include the Powder Mill Run, Upper Gwynns Falls, and the preliminary data from the Scotts Level Branch outfall gage site (SL-9).

Precipitation Data: Hourly and daily precipitation data were acquired from the Baltimore Washington International Airport (BWI). These data were recorded conjunction with the Scotts Level Branch discharge data discussed below. For calendar year 2006 one hundred days recorded measurable precipitation. The daily data were analyzed for precipitation amount (Table 8-3). As can be seen from Table 8-3, over a third of the days recorded less than a 0.1 inch of precipitation. Precipitation over one inch occurred on only 13% of the days, but accounted for 47.4% of the total amount of the precipitation in 2006. The maximum daily rainfall was 2.75 inches recorded on June 25, 2006. A total of 42.78 inches of precipitation, slightly over the long-term average, was recorded at BWI for 2006.

Table 8- 3: Precipitation Data Analysis for Calendar 2006

Precipitation Category	# of Days	% Days	Total Amount	% of accumulation
<.1	35	35 %	1.33	3.1 %
.1-.5	34	34 %	8.36	19.5 %
.5-1.0	18	18 %	13.11	30.6 %
1.0-1.5	9	9 %	11.06	26.9 %
1.5-2.0	1	1 %	1.78	4.1 %
2.0-2.5	2	2 %	4.29	10.0 %
2.5-3.0	1	1 %	2.75	6.4 %
Total	100		42.78	

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Often storms span more than one day. The hourly precipitation data were used to delimit individual storms, by identifying the initiation of rain events greater than .05 inches, and the end of the storm event defined as greater than six hours with no rainfall recorded. A total of 58 distinct storms were identified. These storms were analyzed for amount of precipitation, intensity (inches/hour), and duration. The results of this analysis are presented in Table 8-4.

Table 8-4: 2006 Precipitation Amount, Intensity, and Duration by Category

Precipitation Category (Inches)	Precipitation Amount				Intensity		Duration		
	# Storms	% Storms	Total Precip.	% Precip.	# Storm	% storms	Duration Category (Hours)	# storms	% torms
≤ .1	11	19.0	.89	2.1	22	37.9	1 – 3	21	36.2
.1 - .25	10	17.2	1.88	4.4	20	34.5	3 – 6	12	20.7
.26 - .50	9	15.5	3.01	7.1	7	12.1	6 – 9	7	12.1
.51 - .75	6	10.3	3.33	7.8	7	12.1	9 – 12	5	8.6
.76 – 1.00	6	10.3	5.34	12.5	1	1.7	12 – 15	3	5.2
1.01 – 1.50	10	17.2	11.95	28.0	1	1.7	15 – 18	3	5.2
1.51 – 2.00	2	3.4	3.4	8.0	0		18 – 21	3	5.2
2.01 – 3.00	2	3.4	4.61	10.8	0		21 – 24	1	1.7
3.01 – 4.00	1	1.7	3.63	8.5	0		>24	3	5.2
> 4.00	1	1.7	4.11	9.6	0				
Total	58	100	42.15	98.8	58			58	

Over one third (36.2%) of the storms were less than .25 inches in total amount of precipitation, but these storms accounted for only 6.5% of the total amount of rainfall. Conversely, slightly over one quarter of the storms (27.4%) were over one inch in total amount of rainfall and these storms accounted for almost two thirds (64.9%) of the total amount of precipitation in 2006. The largest storm for 2006 recorded 4.11 inches of precipitation over a 27-hour period. The highest intensity recorded at BWI in 2006 was 1.16 inches per hour. The majority of storms (72.4%) highest recorded hourly intensity was less than a quarter inch per hour. Likewise most storms (56.9%) were less than 6 hours in duration.

Flow Data: The Scotts Level Branch gage data includes 15-minute discharge readings from the period of September 29, 2005 to June 19, 2007. The entire record was analyzed for storm events. The data were visually scanned to determine the inception of each storm event. The termination of the event was based on three hours of discharge at the same rate. A total of 117 storm events for the period were identified, of which, 69 occurred in the calendar year 2006. Figure 8-5 displays the daily discharge and precipitation for calendar year 2006. The correlation coefficient was determined to be $r = .71$. While a relatively high correlation exists between daily precipitation and discharge, it is not perfect. This is due to the distance between the recording rain gage (BWI) and the Scotts Level Branch gage and timing of the storms between the two sites. The database was further coded to reflect the concurrence of storms as indicated by the increase in discharge and the precipitation from recorded at BWI. This resulted in 67 storms that had an overlap of both precipitation and storm discharge, and an increase in the correlation coefficient to $r = .92$.

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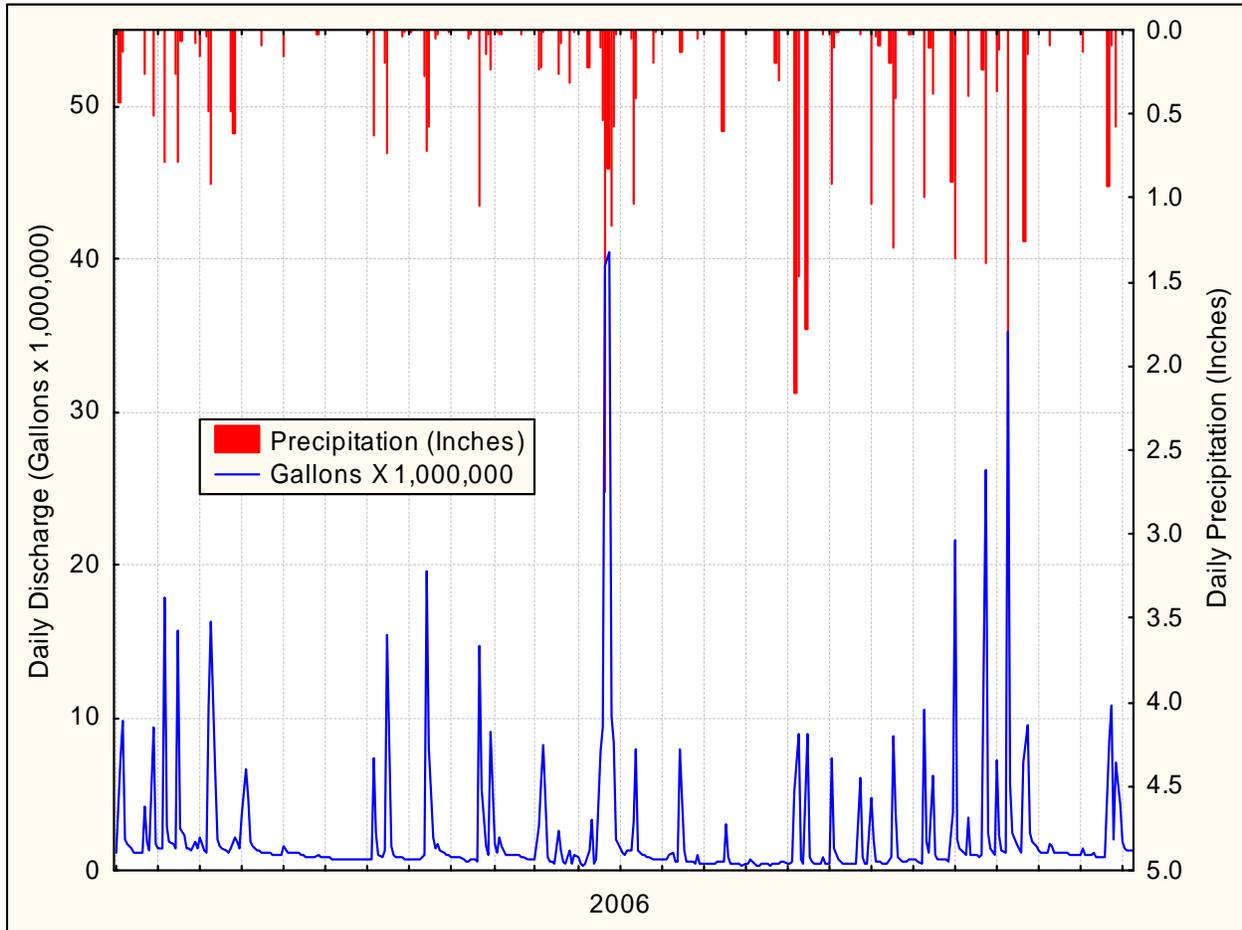


Figure 8-5: Calendar Year 2006 Daily Precipitation and Discharge

Using the data this set of data for the 67 storms, the runoff coefficient was calculated for each storm. The average runoff coefficient was .247, with a maximum of .941 and a minimum of .032.

The data were further analyzed to determine the proportion of runoff to total precipitation, and the relative proportions of baseflow and storm event runoff. These data were analyzed by season for calendar year 2006. The results are presented in Table 8-5.

Table 8-5: Seasonal Precipitation and Runoff Characteristics

Parameter	Winter	Spring	Summer	Fall	Total
Precipitation Amount	6.18	12.2	10.52	13.80	42.78
Precipitation %	14.4 %	28.5 %	24.6 %	32.3 %	---
Runoff %	57.8 %	40.0 %	18.6 %	32.3 %	34.8 %
Evapotranspiration %	42.2 %	60.0 %	81.4 %	67.5 %	65.2 %
Storm flow %	48.3 %	73.0 %	55.5 %	60.8 %	61.0 %
Baseflow %	51.7 %	27.0 %	44.5 %	39.2 %	39.0 %

For calendar year 2006 the precipitation was not evenly distributed. Approximately one-third fell in the fall of the year, while the winter exhibited a relatively dry period. A third of the precipitation was accounted for by stream flow while the balance was assumed to be evapotranspiration. The evapotranspiration is the result of the evaporation of water, which is

temperature dependant and the transpiration of water due to plants. Thus the expectation is that winter should exhibit the lowest evapotranspiration rates and summer the highest rate. The results for Scotts Level Branch bear this out with 42.2% and 81.4% evapotranspiration rates for winter and summer, respectively. As is characteristic of urban watersheds, Scotts Level Branch exhibits a shift in runoff from baseflow dominated to storm flow dominated. For the year, 61% of the flow was determined to be storm flow using the criteria described above, while only 39% was characterized as baseflow.

8.3.2 Chemical Monitoring

The data analysis for chemical monitoring includes three components, storm event monitoring (8.3.2.1), baseflow monitoring (8.3.2.2), and the calculation of pollutant loads (8.3.2.3)

8.3.2.1 Storm Event Monitoring Results

The chemical results from the storm event monitoring at the Scotts Level Branch in-stream monitoring site was analyzed in conjunction with the discharge data recorded by the USGS gage. Both the chemical and the discharge data were \log_{10} transformed prior to regression analysis. The data for the regression equations was censored by removing any chemical data that was below the detection limit for any constituent. Regression equations were determined for Total Suspended Solids, TKN, Nitrate/Nitrite, Total Nitrogen, and Total Phosphorus. The results are displayed in Table 8-6 and graphically in Figures 8-6 through 8-10.

Table 8-6: Regression Equations Relationship Between Discharge (CFS) and Pollutant Concentrations

Parameter	Regression Equation
Total Suspended Solids	$0.7706 + 0.5443 * (\log \text{ cfs})$
Total Kjeldahl Nitrogen	$-0.3056 + 0.1209 * (\log \text{ cfs})$
Nitrate/Nitrite	$-0.0302 - 0.2106 * (\log \text{ cfs})$
Total Nitrogen	$0.1565 - 0.0338 * (\log \text{ cfs})$
Total Phosphorus	$-1.5063 + 0.3614 * (\log \text{ cfs})$

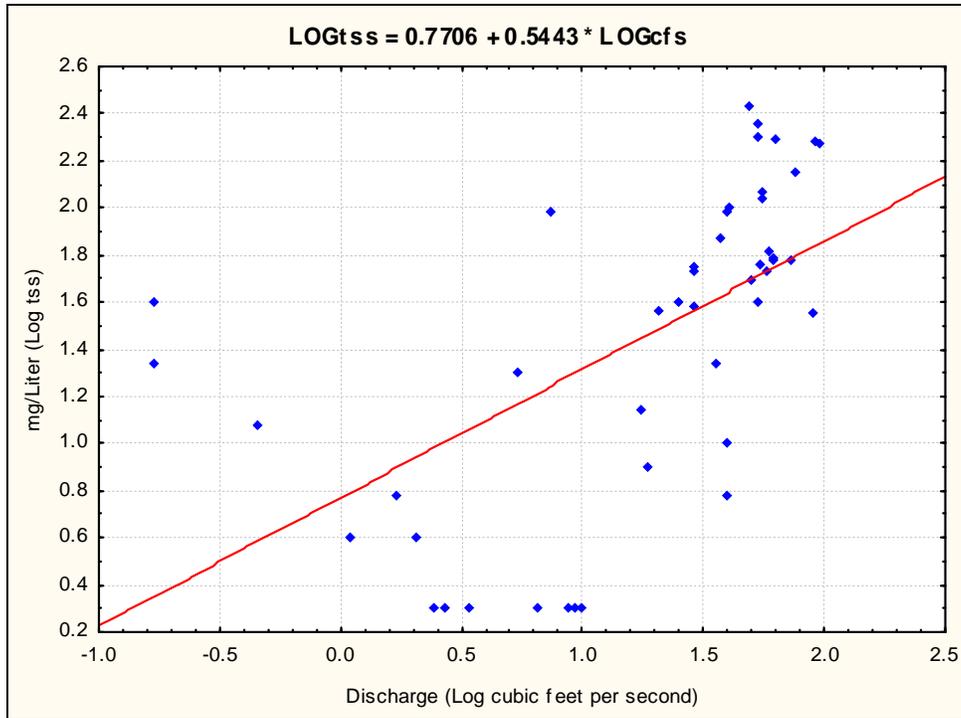


Figure 8-6: Total Suspended Solids (TSS) Data and Regressions for 2005-2007.

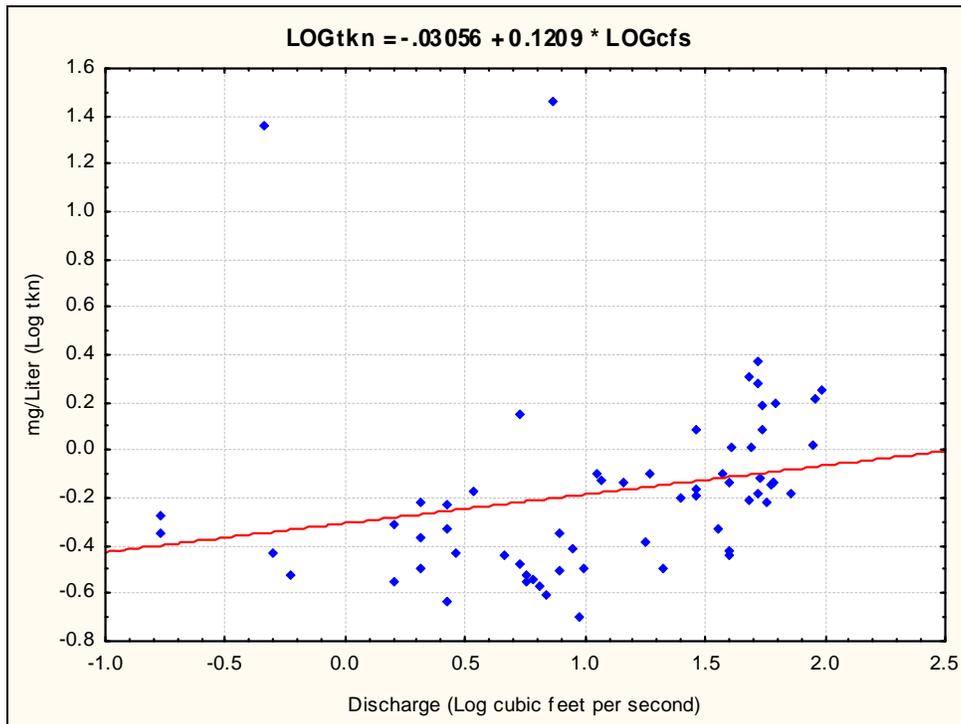


Figure 8-7: Total Kjeldahl Nitrogen (TKN) Data and Regressions for 2005-2007.

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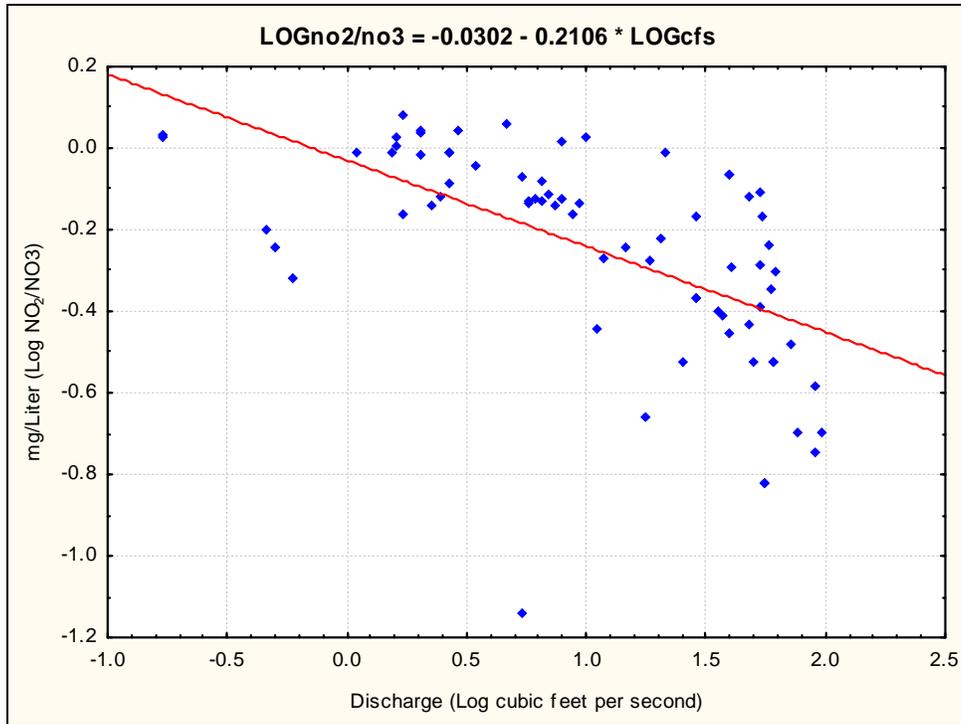


Figure 8-8: Nitrate/Nitrite (NO₂/NO₃) Data and Regressions for 2005-2007.

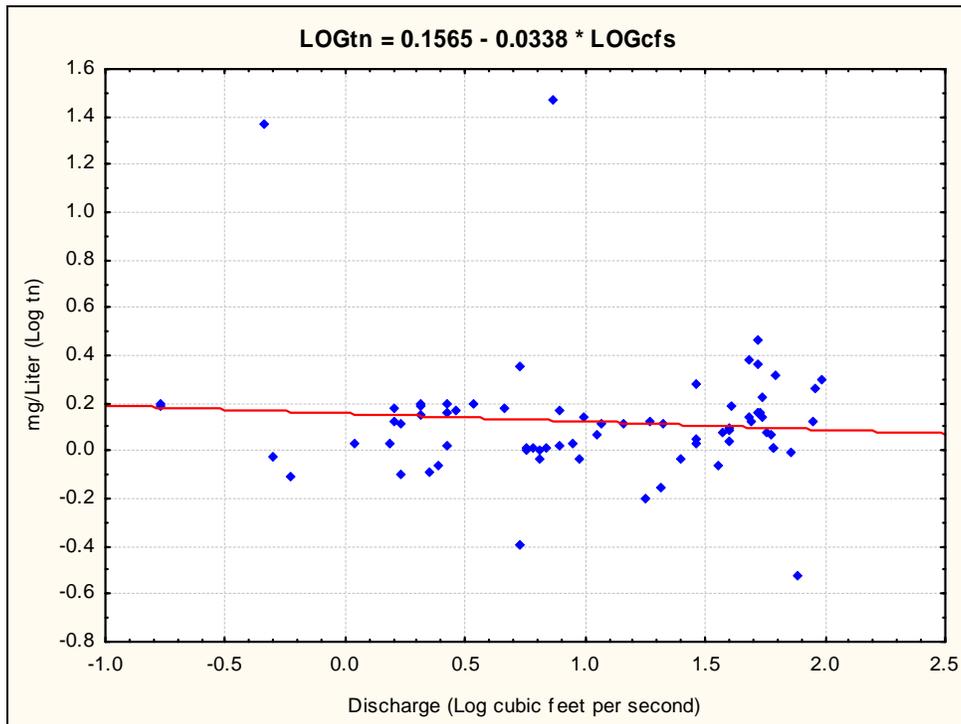


Figure 8-9: Total Nitrogen (TN) Data and Regressions for 2005-2007.

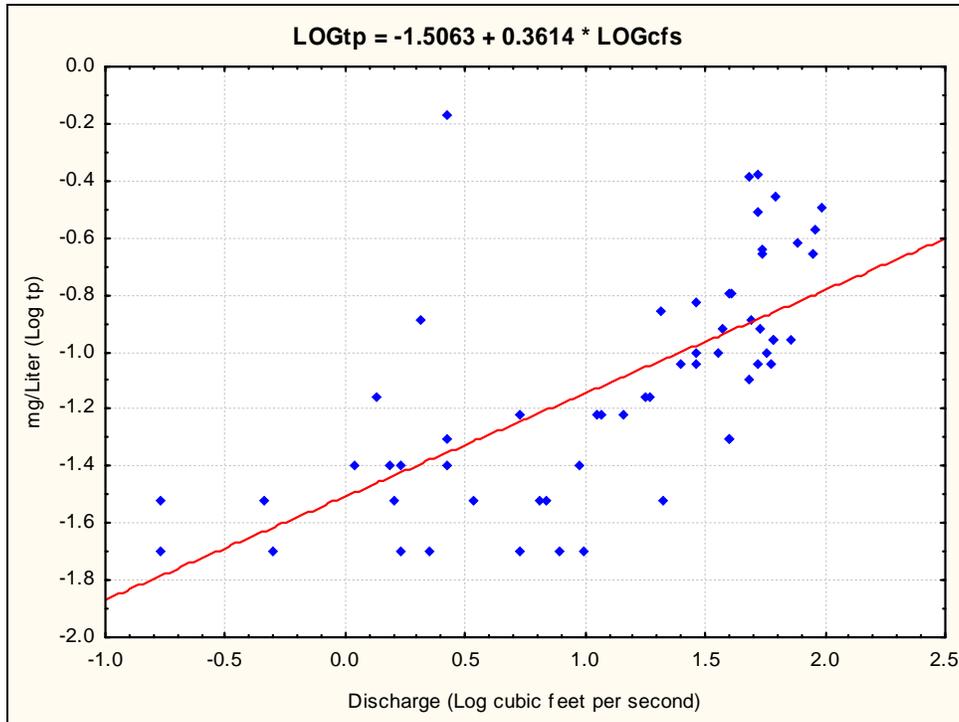


Figure 8-10: Total Phosphorus (TP) Data and Regressions for 2005-2007.

Total Suspended Solids and Total Phosphorus exhibited strong positive relationships with discharge, while Nitrate/Nitrite Nitrogen displayed a strong negative relationship with discharge. The TKN relationship with discharge was relatively weak and positive, and the Total Nitrogen (TKN+Nitrate/Nitrite Nitrogen) was relatively weak and negative.

The regression equations were used to calculate the chemical concentrations for each 15 minute interval for recorded discharge. The log chemical concentrations were then back transformed. This permitted the calculation of the flow weighted Event Mean Concentrations for each of the 117 storms identified in the USGS gage data record. Figures 8-11 through 8-15 show the Event Mean Concentrations for Total Suspended Solids (TSS), Total Kjeldahl Nitrogen (TKN), Nitrate/Nitrite, Total Nitrogen (TN), and Total Phosphorus (TP).

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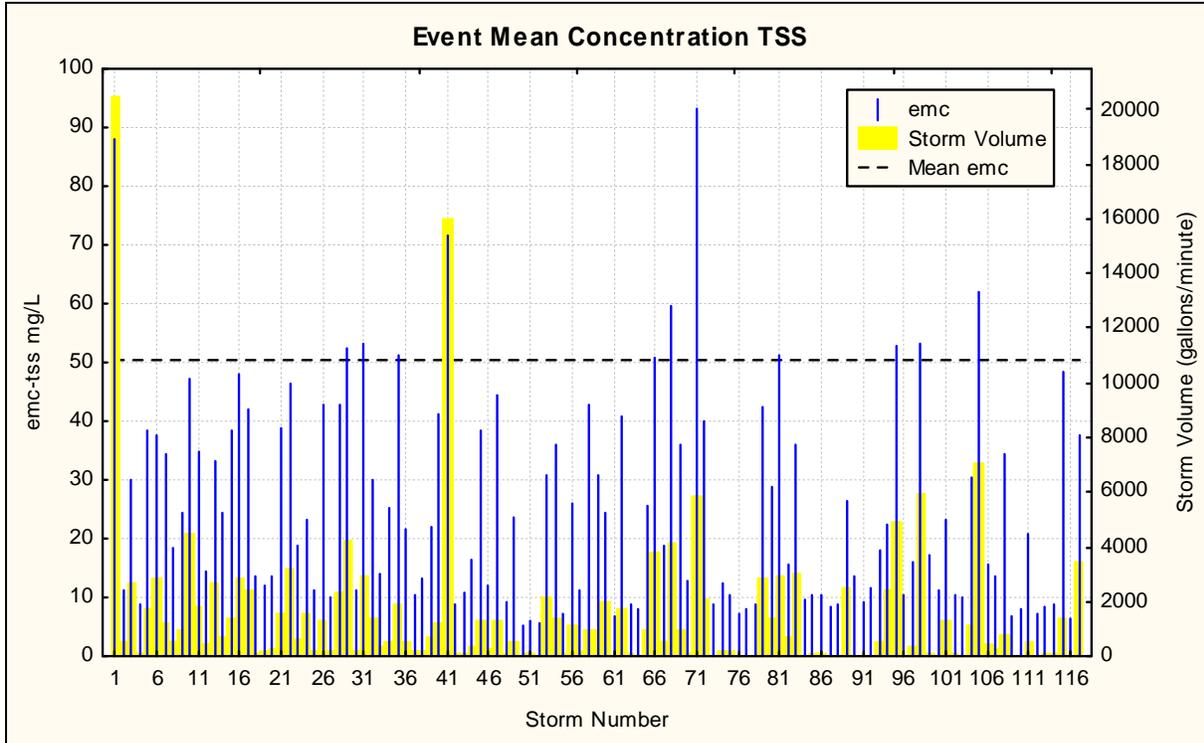


Figure 8-11: Event Mean Concentration for Total Suspended Solids (TSS)

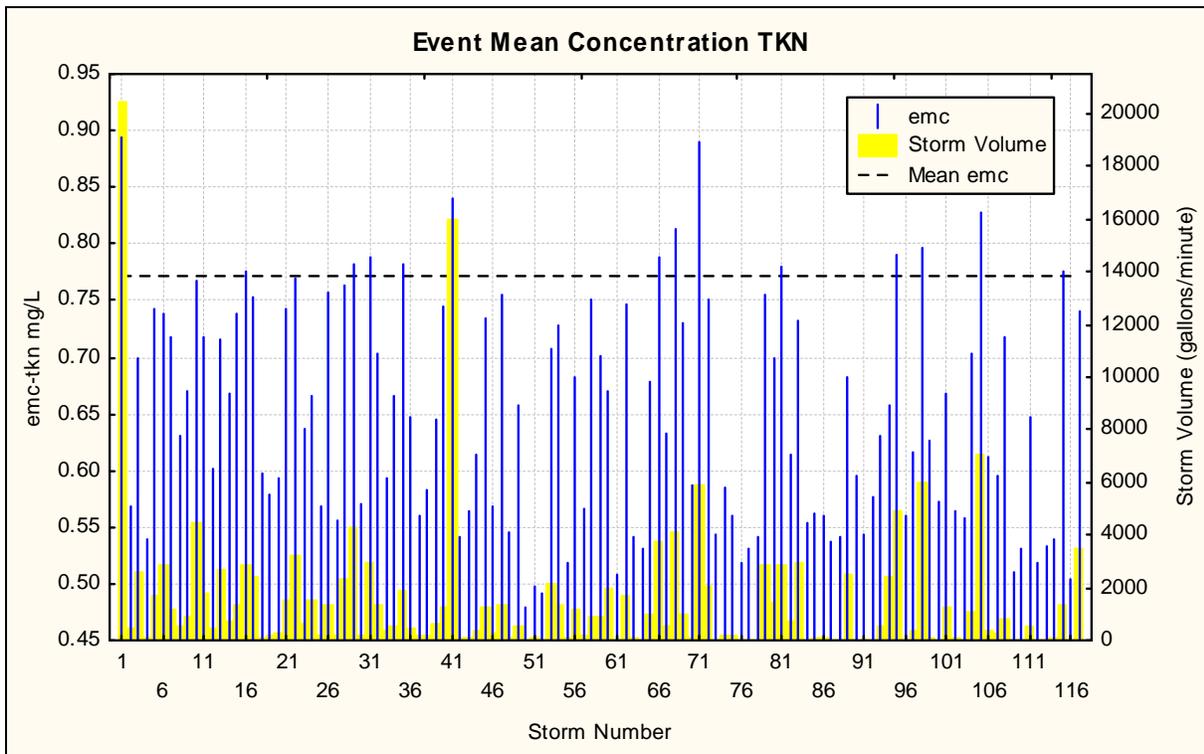


Figure 8-12: Event Mean Concentration for Total Kjeldahl Nitrogen (TKN)

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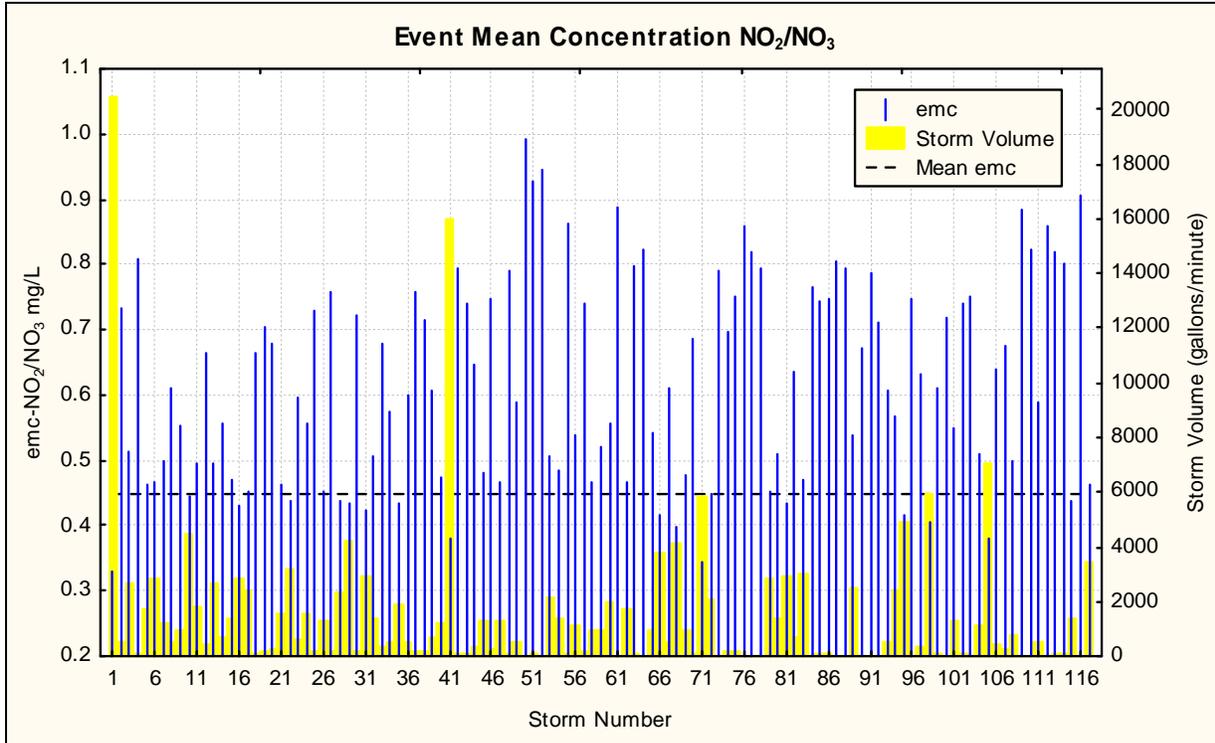


Figure 8-13: Event Mean Concentration for Nitrate/Nitrite (NO₂/NO₃)

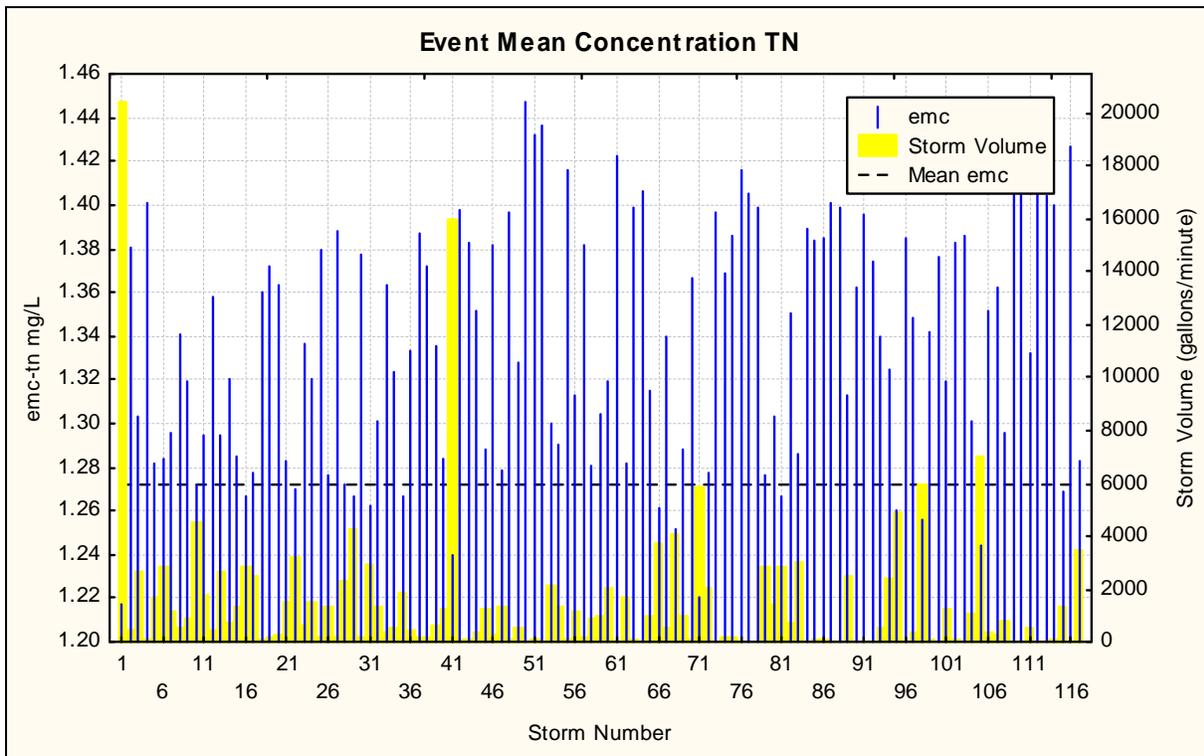


Figure 8-14: Event Mean Concentration for Total Nitrogen (TN)

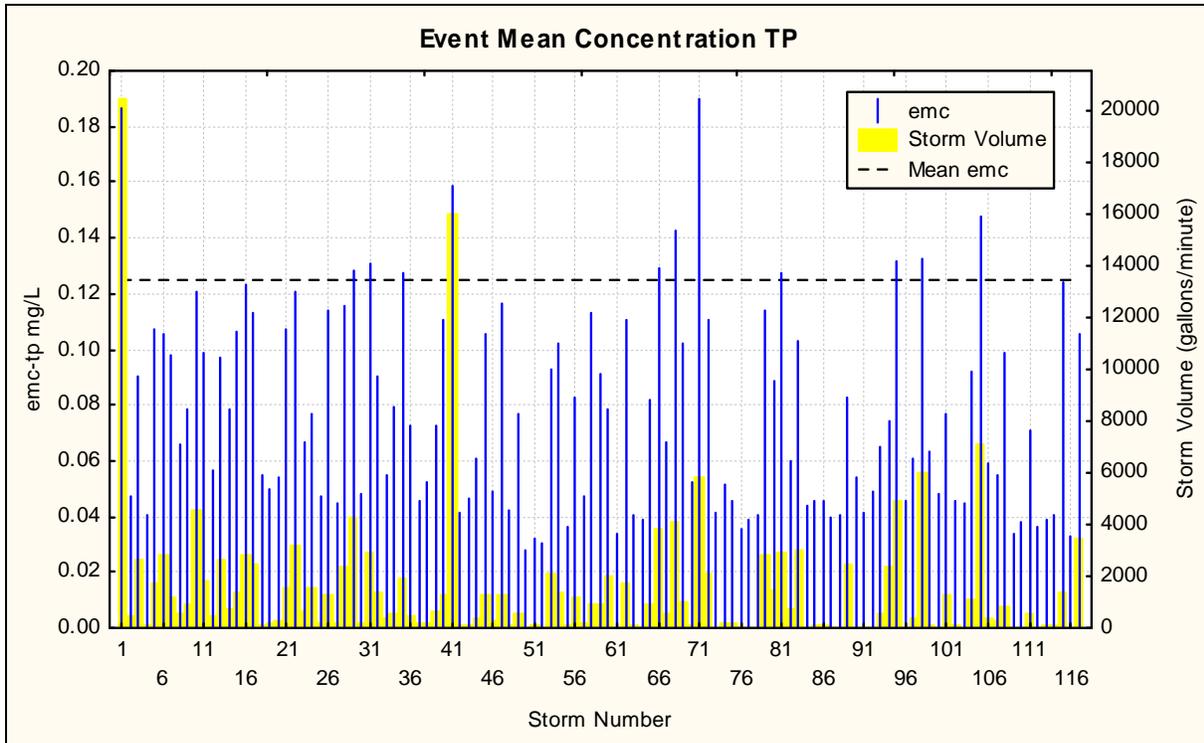


Figure 8-15: Event Mean Concentration for Total Phosphorus (TP)

8.3.2.2 Baseflow Monitoring Results

Scotts Level Branch baseflow monitoring occurred at the outfall (SL-9), two tributary locations, and six mainstem locations for a total of 10 baseflow monitoring sites (Figure 8-2). Within Powder Mill Run baseflow monitoring will take place at the USGS gage and two up-stream sites that are representative of each major branch (one in the County and one in the City). To date, one set of baseflow measurements for Powder Mill have been completed. Baseflow monitoring in Upper Gwynns Falls will occur only at the USGS gage site. The baseflow sites in Scotts Level Branch, Powder Mill Run, and Upper Gwynns Falls will be monitored quarterly during baseflow conditions (preceded by a minimum of 72 hours dry weather).

Analysis of baseflow pollutants is especially important in relation to nitrogen. Research work conducted by the County, indicates that ~50% of the nitrogen load occurs during dry weather conditions. The baseflow sampling will be used in conjunction with the storm event sampling to partition the annual discharge and pollutant load between baseflow (dry weather) conditions and storm event conditions.

Pollutant loads were examined for each of the baseflow sites. SL-09 was excluded because flow data was missing for most of the samples. Total Suspended solids were excluded from the baseflow analyses because limited conclusions can be drawn from this parameter during a baseflow sample. Many factors can affect the total suspended solids including small construction projects and car washing. These factors may only affect the stream for the limited time the sample is taken and can be misleading if extrapolated for a longer period of time. The results obtained were standardized to both daily pollutant load for drainage area and a daily load per acre and are shown in table 8-7.

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Table 8-7: Daily Baseflow Pollutant Loads for Scotts Level Branch Sites

Site	Acres	TKN (mg/L)	TKN Daily Load (#s)	TKN Daily Load (#s per acre)	NO ₂ /NO ₃ (mg/L)	NO ₂ /NO ₃ Daily Load (#s)	NO ₂ /NO ₃ Daily load (#s per acre)
SL-01	2,186	0.34	1.62	0.0007	0.90	6.56	0.0030
SL-02	1,908	0.33	2.06	0.0011	0.99	6.26	0.0033
SL-03	1,434	0.28	0.94	0.0007	1.05	3.15	0.0022
SL-04	1,167	0.29	0.97	0.0008	1.07	4.12	0.0035
SL-05 - Trib	202	1.53	1.13	0.0056	2.65	1.13	0.0056
SL-06	742	0.52	0.97	0.0013	1.08	1.98	0.0027
SL-07 - Trib	62	0.22	0.02	0.0004	0.95	0.18	0.0029
SL-08	451	0.26	0.39	0.0009	1.07	1.73	0.0038
SL-10	265	0.20	0.21	0.0008	1.27	1.18	0.0045
Site	Acres	TN (mg/L)	TN Daily Load (#s)	TN Daily Load (#s per acre)	TP (mg/L)	TP Daily Load (#s)	TP Daily Load (#s per acre)
SL-01	2,186	1.22	8.29	0.0038	0.031	1.17	0.00053
SL-02	1,908	1.29	8.15	0.0043	0.023	1.83	0.00096
SL-03	1,434	1.36	4.11	0.0029	0.020	1.21	0.00084
SL-04	1,167	1.41	5.27	0.0045	0.015	0.86	0.00073
SL-05 Trib.	202	4.44	2.26	0.0112	0.192	0.14	0.00068
SL-06	742	1.60	2.95	0.0040	0.022	0.75	0.00101
SL-07 Trib.	62	1.17	0.20	0.0032	0.016	0.09	0.00139
SL-08	451	1.34	2.12	0.0047	0.014	0.64	0.00142
SL-10	265	1.46	1.40	0.0053	0.010	0.01	0.00004

A number of observations are possible based on the information in Table 8-7. First Site SL-05, a tributary with a drainage area of 202 acres has disproportionately high concentrations of all nutrient parameters. These high concentrations will be investigated to determine the source. Second, there is in general a decrease in nitrate/nitrite concentrations in a downstream direction (SL-10 → SL-1), along with a decrease in per acre load, exclusive of the tributaries. The same pattern of decrease in a downstream direction is exhibited by total phosphorus per acre loads but not as strongly. This could be the result of nutrient uptake by biota in the stream as the water passes downstream.

8.3.2.3 Pollutant Load Calculations

Data from the USGS gage was recorded at 15-minute intervals from September 9, 2005 through June 19, 2007 resulting in >60,300 individual discharge readings. The regression equations determined above from the Storm event samples, relating pollutant concentration to discharge, were used to determine the pollutant concentration for each 15-minute interval. From this data the load was calculated for each 15-minute interval using the following formula:

$$P_L = (P_C * .000008345) * (CFS * 448.8 * 15), \text{ where}$$

P_L = Pollutant Load,

P_C = Pollutant Concentration,

.000008345 = Conversion factor to convert mg/L to pounds per gallon,

CFS = Cubic feet per second,

448.8 = Conversion factor to convert cubic feet per second to gallons per minute

15 = number of minutes in the interval.

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The results obtained by the above formula were standardized to both an annual pollutant load for the drainage area and an annual pollutant load per acre. In addition, the data were analyzed for seasonal loads, storm event pollutant loads, and the percent of the load delivered during baseflow conditions (Table 8-8).

Table 8-8: Pollutant Load Characteristics for Calendar Year 2006

Parameter	Pounds/ Year	Pound/Acre	% by Season	Storm Event #s	% Load as Baseflow
TSS					
Winter	43,920	20.1	16.7%	37,135	15.4%
Spring	111,407	51.0	42.4%	107,701	3.3%
Summer	21,550	9.9	8.2%	19,513	9.5%
Fall	86,011	39.3	32.7%	79,768	7.3%
Total	262,888	120.3		244,116	7.1%
TKN					
Winter	1,142	0.52	22.5%	722	36.7%
Spring	1,772	0.81	34.9%	1,511	14.7%
Summer	603	0.28	11.9%	428	28.9%
Fall	1,554	0.71	30.6%	1,171	24.7%
Total	5,071	2.32		3,832	24.4%
NO₂/NO₃					
Winter	1,105	0.51	25.9%	477	56.9%
Spring	1,258	0.58	29.5%	821	34.7%
Summer	664	0.30	15.5%	325	51.1%
Fall	1,243	0.57	29.1%	663	46.7%
Total	4,271	1.95		2,285	46.5%
TN					
Winter	2,367	1.08	24.3%	1,274	46.2%
Spring	3,130	1.43	32.2%	2,416	22.8%
Summer	1,312	0.60	13.5%	800	39.0%
Fall	2,911	1.33	30.0%	1,909	34.4%
Total	9,920	4.45		6,399	34.2%
TP					
Winter	134.2	0.061	19.2	102.9	23.4%
Spring	275.1	0.126	39.4	257.0	6.6%
Summer	67.5	0.031	9.7	56.7	16.0%
Fall	222.1	0.102	31.8	193.4	12.9%
Total	698.9	0.320		609.9	12.7%

There are distinct seasonal differences in the delivery of nutrient and total suspended solids pollutant loads, with summer being the season of reduced load delivery for all pollutants analyzed. Approximately one-quarter of the precipitation fell during the summer season, but only 18.6% of this precipitation was reflected in the stream flow (Table 8-5). This summer decrease in stream flow results in a decrease in the delivery of pollutants.

Baseflow accounts for a negligible amount of the pollutant load delivery for Total Suspended Solids (7.1%) and Total Phosphorus (12.7%). Conversely, baseflow accounts for 46.5% of the nitrate/nitrite nitrogen load and 34.2% of the total nitrogen load. The TKN (ammonia and organic nitrogen) load has about one-quarter of the load delivered during baseflow conditions. Organic nitrogen will be mobilized within the stream channel and washed into the stream during storm events.

8.3.3 Geomorphological Monitoring

The geomorphological monitoring is intended to provide an estimate of stream erosion and deposition rates, and an estimate of the pollutant load derived from stream channel erosion. In addition, it is intended over time to provide an estimate of the effects of restoration on stream stability on both a project basis and over the entire subwatershed. In order to assure unbiased selection of cross-section locations, Scotts Level Branch and Powder Mill Run were divided into 30 equal length stream segments, 20 in Scotts Level Branch (Figure 8-3) and 10 in Powder Mill Run (Figures 8-4). Within each segment a point was randomly selected, using a GIS subroutine, for location of permanent cross sections. These cross sections will be monitored annually with the results overlaid to provide an assessment of the amount of channel change. Note that we were not able to obtain permission from the landowner for 2 of the 20 cross sections, therefore only 18 of the randomly selected cross sections were done in 2006 and 2007. Two longitudinal profile reaches were selected in Scotts Level Branch for annual assessment. In addition to the above sections, 4 legacy cross sections dating from 2000 and 2004 along with 2 associated longitudinal profiles were done in 2006 and 2007 and overlaid. These sections were part of a separate (WERF) study. Although not randomly selected, they can provide useful longer term information on changes that have occurred in the stream channels of Scotts Level.

Streambank Soil Sampling: Two sets of Stream bank and bed core samples were collected in the vicinity of the permanent cross sections for laboratory analysis of bulk density, particle size distribution, total nitrogen, and total phosphorus and other constituents. One of the two sets was taken in the vicinity of Scotts Level Cross Section # 13, and the other set was taken from Powder Mill Cross Section # 2. Eventually, it is planned to sample each of the 30 cross sections of both streams. The samples will be one-time sample collections, with 10% of the sites, randomly selected, for a second round of sample collection to provide an analysis of annual variability. The data from each cross section will allow either positive or negative loading estimates to be made for the cross sections. These estimates, if extended to represent their respective stream segments may provide information helpful in understanding the sediment and chemical flux of the stream system. Based on the annual and long term change, and the results of the core samples, the estimated annual sediment, total nitrogen, and total phosphorus loads will be calculated for comparison with the chemical monitoring results derived from the in-stream monitoring site. Chemical analysis results are not yet available.

Scotts Level Branch Geomorphological Monitoring Results: Overlays of the 18 randomly selected cross sections show the changes that occurred between the 2006 and 2007 measurement dates. In addition to the 18 random sites, 4 legacy cross sections were re-measured in 2006 and 2007 that had been part of a separate earlier project in 2000 and 2001. Overlays of these cross sections between time periods were also done. Tables 8-9 and 8-10 present a quantification of the changes in terms of aggradation (filling) or degradation (cutting) within the active channel, and Table 8-11 below (listed from upstream to downstream) summarizes Tables 8-9 and 8-10. To supplement the cross sections, 2 longitudinal thalweg profiles (ranging from 200' – 400' in length) were measured in the vicinity of CX# 20 and CX# 8, and 2 were measured in the vicinity of the 4 legacy cross sections. The data files and plots can be viewed on the separate data CD accompanying this report.

As can be seen from the Table 8-11, all of the random cross sections remained relatively unchanged during 2006-2007 in terms of net change (cut or fill) except Cross Section # 1 that

experienced large net deposition particularly along the channel sides (Fig. 8.16). This location is characterized by a steep gradient leading into it. The cross sectional area acts as a flatter depositional zone.

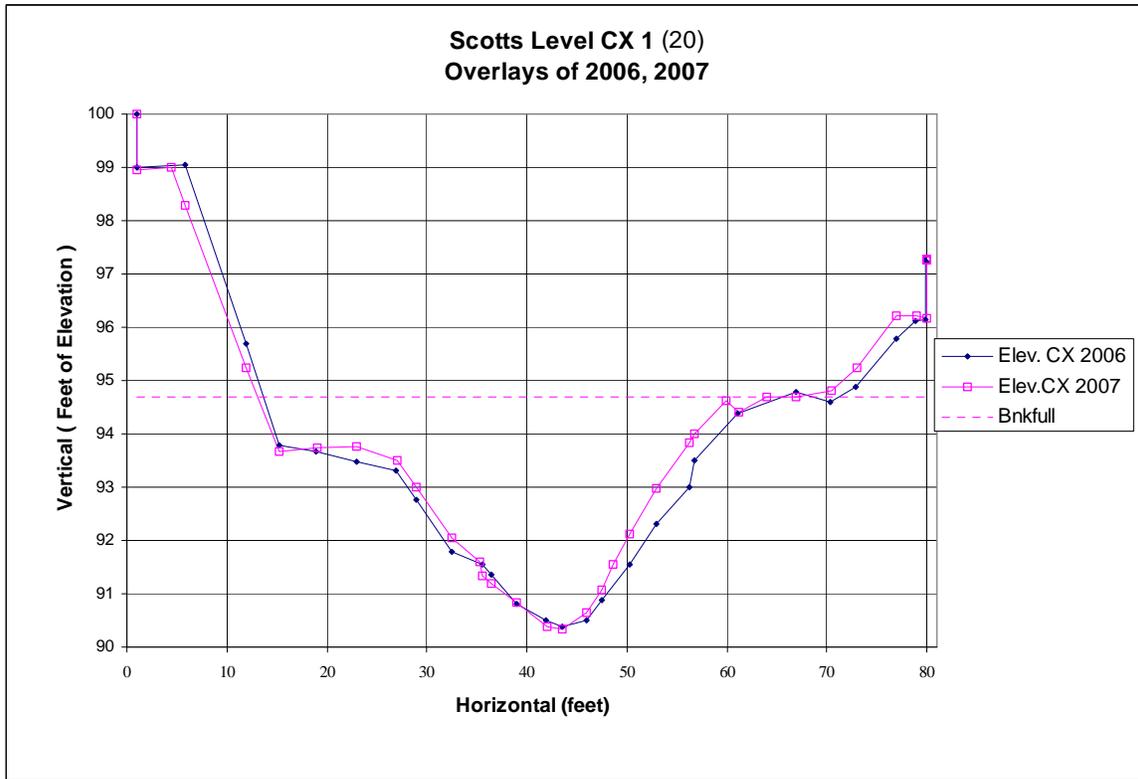


Figure 8-16: Scotts Level Branch Geomorphological Cross Section 1 Overlay showing net deposition especially on the channel sides between the 2006 and 2007 surveys.

The two upstream legacy cross sections (WERF) within a highly maintained area experienced relatively large deposition between 2001 and 2007 time periods, and moderate aggradation between 2006 and 2007. Their associated longitudinal profile showed moderate aggradation and degradation between 2000 and 2007, but moderate aggradation between 2006 & 2007. The overall gradient, riffle-pool frequency and depths remained relatively unchanged except for substantial filling in the downstream pool area along the upstream legacy profile between 2001 & 2007.

The two downstream legacy cross sections in the forested area showed slight to moderate degradation between 2001 and 2007, and both slight aggradation and degradation during 2006 & 2007. Their associated profiles showed slight degradation between 2001 and 2007, but slight aggradation in 2006 & 2007 and their overall gradient, riffle-pool frequency and depths remained relatively unchanged. Since most of the input hydrology to the Scotts Level is off impervious area, the sediment fluxes within the stream channel are most likely part of the process of the stream reworking its surrounding legacy flood plain sediments ultimately transporting them into the Gwynns Falls mainstem and beyond. The data now being collected should serve as an important baseline prior to monitoring the effects of future stream channel and stormwater management improvements in the watershed.

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Table 8-9: Scotts Level Branch Cross Sections - Cut and Fill Amounts

SL 20: Change (cu ft)	Period: 2006 – 2007	SL 10: Change (cu ft)	Period: 2006 – 2007
Total Cut	-1.6	Total Cut	-1.4
Total Fill	0.4	Total Fill	2.8
Total Change	2.0	Total Change	4.2
Net Change	-1.2	Net Change	1.4
SL19: Change (cu ft)	Period: 2006 – 2007	SL 9: Change (cu ft)	Period: 2006 – 2007
Total Cut	-1.3	Total Cut	-1.2
Total Fill	4.2	Total Fill	0.9
Total Change	5.5	Total Change	2.1
Net Change	2.9	Net Change	-0.3
SL 18: Change (cu ft)	Period: 2006 – 2007	SL 8: Change (cu ft)	Period: 2006 – 2007
Total Cut	-1.7	Total Cut	-1.1
Total Fill	3.1	Total Fill	2.7
Total Change	4.8	Total Change	3.8
Net Change	1.4	Net Change	1.6
SL 17: Change (cu ft)	Period: 2006 – 2007	SL 7: Change (cu ft)	Period: 2006 – 2007
Total Cut	-2.3	Total Cut	-4.4
Total Fill	0.4	Total Fill	0.4
Total Change	2.7	Total Change	4.8
Net Change	-1.9	Net Change	-4.0
SL 16: Change (cu ft)	Period: 2006 – 2007	SL 6: Change (cu ft)	Period: 2006 – 2007
Total Cut	-1.8	Total Cut	-2.5
Total Fill	0.8	Total Fill	0.2
Total Change	2.6	Total Change	2.7
Net Change	1.0	Net Change	-2.3
SL 15: Change (cu ft)	Period: 2006 – 2007	SL 5*: Change (cu ft)	Period: 2006 – 2007
Total Cut	-0.2	Total Cut	NA
Total Fill	1.4	Total Fill	NA
Total Change	1.6	Total Change	NA
Net Change	1.2	Net Change	NA
SL 14: Change (cu ft)	Period: 2006 – 2007	SL 4*: Change (cu ft)	Period: 2006 – 2007
Total Cut	-5.8	Total Cut	NA
Total Fill	3.9	Total Fill	NA
Total Change	9.7	Total Change	NA
Net Change	-1.9	Net Change	NA
SL 13: Change (cu ft)	Period: 2006 – 2007	SL 3: Change (cu ft)	Period: 2006 – 2007
Total Cut	-3.0	Total Cut	0.0
Total Fill	-1.8	Total Fill	1.5
Total Change	4.8	Total Change	1.5
Net Change	-1.2	Net Change	1.5
SL 12: Change (cu ft)	Period: 2006 – 2007	SL 2: Change (cu ft)	Period: 2006 – 2007
Total Cut	-5.4	Total Cut	-3.9
Total Fill	2.1	Total Fill	0.9
Total Change	7.5	Total Change	4.8
Net Change	-3.3	Net Change	-3.0
SL 11: Change (cu ft)	Period: 2006 – 2007	SL 1: Change (cu ft)	Period: 2006 – 2007
Total Cut	-0.6	Total Cut	-0.8
Total Fill	1.8	Total Fill	14.2
Total Change	2.4	Total Change	15.0
Net Change	1.2	Net Change	13.4

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* Permission from private property owners for sampling SL 5 and SL 4 has not yet been obtained, therefore there are no results.

Table 8-10: Scotts Level Branch Cross Sections (WERF Cross Sections) - Cut and Fill Amounts

FHM-2-SL 2 (Straight) : Change (cu ft)	Period: 2006 – 2007	Period 2000 – 2007
Total Cut (negative value)	-3.4	-3.5
Total Fill	2.5	2
Total Change	5.9	5.5
Net Change	-0.9	-1.5
FHM2-SL 1 (Bend): Change (cu ft)	Period: 2006 – 2007	Period 2000 – 2007
Total Cut (negative value)	-0.4	-3.6
Total Fill	2.5	.8
Total Change	2.9	4.4
Net Change	2.1	-2.8
SL 2-2HM (Straight): Change (cu ft)	Period: 2006 – 2007	Period 2000 – 2007
Total Cut (negative value)	-.02	-0.7
Total Fill	8.4	10.8
Total Change	8.2	11.4
Net Change	8.5	10.1
SL 1-2HM (Bend): Change (cu ft)	Period: 2006 – 2007	Period 2000 – 2007
Total Cut (negative value)	-1.7	-5.9
Total Fill	7.0	11.9
Total Change	8.7	17.9
Net Change	5.3	6

Table 8-11: Scotts Level Branch Stream Channel Changes Over Time

SL #	CX 01-07	CX 06-07	TW 00-07	TW 06-07
20		SD		A
19		A		
18		SA		
2HM –CX1 (bend)	A (large)	A	D	A
2HM –CX2 (straight)	A (large)	A	D	A
FHM2-CX1 (bend)	D	A	(01-07) SD	SA
FHM2-CX2 (straight)	SD	SD	(01-07) SD	SA
17 (Trib.)		D		
16		SA		
15		SA		
14		D		
13		SD		
12		D		
11		SA		
10		SA		
9		SD		
8		SA		D
7		A		
6		D		
5		NA		

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4		NA		
3		SA		
2		D		
1		A (large)		

Symbols: a: aggradation, d: degradation, s:slight, m:moderate

The results of the initial cross-section measurements are found on the separate data CD accompanying this report.

Powder Mill Run Monitoring Results: Overlays of the 10 randomly selected cross sections show the changes that occurred during the year between 2006 and 2007 measurement dates. Table 8-12 presents a quantification of these changes in terms of aggradation (filling) or degradation (cutting) within the active channel, and Table 8-13 below summarizes Table 8-12. As can be seen, all of the cross sections remained relatively stable in terms of net change during the study year except Cross Section # 1 that experienced large net downcutting within the channel. This exceptional case is likely due to the cross section being located across a short steep fall line where hydraulic forces are high. That along with the high and erodable stream banks that confine the flows creates a dynamic setting. The data files and plots can be viewed on the separate data CD accompanying this report.

Table 8-12: Powder Mill Run Cross Sections - Cut and Fill Amounts

PM 10: Change (cu ft)	Period: 2006 – 2007	PM 5: Change (cu ft)	Period: 2006 – 2007
Total Cut	-0.6	Total Cut	-4.1
Total Fill	3.8	Total Fill	3.6
Total Change	4.4	Total Change	7.7
Net Change	3.2	Net Change	-0.5
PM 9: Change (cu ft)	Period: 2006 – 2007	PM 4: Change (cu ft)	Period: 2006 – 2007
Total Cut	-0.4	Total Cut	-1.2
Total Fill	1.9	Total Fill	1.4
Total Change	2.3	Total Change	2.6
Net Change	1.5	Net Change	0.2
PM 8: Change (cu ft)	Period: 2006 – 2007	PM 3: Change (cu ft)	Period: 2006 – 2007
Total Cut	-0.5	Total Cut	-0.7
Total Fill	1.8	Total Fill	3.8
Total Change	2.3	Total Change	4.5
Net Change	1.3	Net Change	3.2
PM 7: Change (cu ft)	Period: 2006 – 2007	PM 2: Change (cu ft)	Period: 2006 – 2007
Total Cut	-0.6	Total Cut	-2.2
Total Fill	3.1	Total Fill	2.3
Total Change	3.7	Total Change	4.5
Net Change	2.5	Net Change	.1
PM 6: Change (cu ft)	Period: 2006 – 2007	PM 1: Change (cu ft)	Period: 2006 – 2007
Total Cut	-2.2	Total Cut	-28.6
Total Fill	0.8	Total Fill	2.2
Total Change	3.0	Total Change	30.8
Net Change	1.4	Net Change	-26.4

Table 8-13: Powdermill Run Stream Channel Changes Over Time

PM #	CX 06-07
10	a

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9	sa
8	sa
7	a
6	sd
5	sd
4	sa
3	sa
2	sa
1	d

Symbols: a: aggradation, d: degradation, c: coarsening, fining, p: planiform change, s:slight, m:moderate

8.3.4 Biological Monitoring Results

The biological monitoring will be used to measure the response of the benthic macroinvertebrate and fish communities to restoration of Scotts Level Branch and Powder Mill Run.

Benthic macroinvertebrate and fish sampling were conducted as per MBSS protocols. Benthic macroinvertebrates were sampled annually during the spring index period (March 1st - April 30th). Macroinvertebrates were sampled at randomly selected stations in 2005 and 2006. Fish were sampled at two stations in 2005, and seven stations in 2006. The Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) were calculated using metrics developed by MBSS for Piedmont streams. The BIBI and FIBI scoring criteria are: 1.00-1.99 (Very Poor), 2.00-2.99 (Poor), 3.00-3.99 (Fair), and 4.00-5.00 (Good). Stream physical habitat was assessed when macroinvertebrates were collected. The protocol measured components of stream physical habitat, including fish habitat quality, macroinvertebrate habitat quality, stream depth and velocity diversity, riffle quality, pool quality, the percentage of sediment surrounding stream bottom substrates, and the percentage of shading in the stream reach. Each parameter was estimated on a scale of 0-20, except for sediment and shading, which were percentage estimates.

The IBI scores are shown in Table 8-14. Only two stations had better than Very Poor biological condition. Stations SL-6 and SL-17, in 2006, were rated Poor. The FIBI scores were Poor in 2005, and Poor or Very Poor in 2006. The average BIBIs for Scotts Level Branch and Powder Mill Run were Very Poor in 2005 and 2006, while the FIBIs were Poor (Table 8-14). Physical habitat condition tended to be degraded (Appendix 8-1). In Scotts Level Branch, only 48% of the stations rated 50% or more of the total possible score for physical habitat quality. Similarly, 50% of the Powder Mill Run stations achieved 50% or better of the total possible physical habitat score.

Table 8-14: Scotts Level Branch and Powder Mill Run IBI Scores

Year	Station	BIBI Score	Condition	FIBI Score	Condition
2005	SL-2	1.67	Very Poor	N/A	N/A
2005	SL-4	1.67	Very Poor	N/A	N/A
2005	SL-6	2.00	Poor	N/A	N/A
2005	SL-7	1.67	Very Poor	2.00	Poor
2005	SL-12	1.33	Very Poor	N/A	N/A
2005	SL-16	1.67	Very Poor	N/A	N/A
2005	SL-17	2.67	Poor	N/A	N/A
2005	SL-18	1.33	Very Poor	NA/	N/A
2005	SL-19	1.33	Very Poor	2.33	Poor

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2005	SL-20	1.33	Very Poor	N/A	N/A
	Mean	1.70	Very Poor	2.17	Poor
2005	PM-1	1.33	Very Poor	NA	N/A
2005	PM-4	1.67	Very Poor	N/A	N/A
2005	PM-6	1.67	Very Poor	N/A	N/A
	Mean	1.56	Very Poor	N/A	N/A
2006	SL-2	1.00	Very Poor	N/A	N/A
2006	SL-3	1.33	Very Poor	2.33	Poor
2006	SL-4	1.00	Very Poor	N/A	N/A
2006	SL-8	1.00	Very Poor	2.33	Poor
2006	SL-11	1.00	Very Poor	N/A	N/A
2006	SL-13	1.00	Very Poor	1.33	Very Poor
2006	SL-14	1.33	Very Poor	N/A	N/A
2006	SL-16	1.00	Very Poor	2.33	Poor
2006	SL-18	1.33	Very Poor	N/A	N/A
2006	SL-19	1.00	Very Poor	2.00	Poor
	Mean	1.1	Very Poor	2.07	Poor
2006	PM-1	1.33	Very Poor	N/A	N/A
2006	PM-2	N/A	N/A	2.00	Poor
2006	PM-3	1.33	Very Poor	N/A	N/A
2006	PM-5	1.67	Very Poor	2.33	Poor
	Mean	1.44	Very Poor	2.17	Poor

8.4 Windlass Run Monitoring – Stormwater Management Assessment

Baltimore County's National Pollutant Discharge Elimination System (NPDES) permit requires the monitoring of a subwatershed for geomorphological impacts resulting from development under the revised Stormwater Management Design Manual. In order to comply with this component of the permit, Baltimore County conducted a comprehensive review of the available land for development. An analysis using geographic information systems (GIS) was used for selection of the monitoring subwatershed. The characteristics for determination of the selected subwatershed were:

- 1) an area of open undeveloped land, and
- 2) an area with a zoning category that would lead to development.

Nearly all new development and redevelopment will be effected by the guidelines in the new stormwater design manual, but the denser developments are expected to show a more dramatic change to the stream system. Therefore the study area must have a zoning category of sufficient density to affect the stability of the stream system. The results of a countywide screening, followed by field verification led to the selection of Windlass Run as the monitoring subwatershed.

The Windlass Run subwatershed is 1,926 acres, and has the potential for a large amount of future development. The level of imperviousness in the subwatershed is currently about 3 % and is expected to increase to well over 20%. Much of the undeveloped land is zoned for manufacturing. The development in this subwatershed has not already occurred because the extension of MD route 43 has not yet been completed. This roadway will be the primary access to these properties and is needed for the intense level of development expected in this subwatershed. This level of high-density development would be expected to have a severe impact on the water quality and stability of Windlass Run. The protection provided by the new

stormwater management regulations should be easily visible through monitoring of the stream conditions.

Windlass Run is a Coastal Plain stream system typified by a stable, low gradient, sinuous, unconfined, silt and sand channel within well-developed floodplains. Average Rosgen bankfull width and corresponding bankfull depths are 10 and 2 feet, respectively. The Windlass Run system is very stable, and there are no areas of moderate or severe streambank erosion. One year of stream gage data was recorded by U.S.G.S. in 1992 – 1993. Well-vegetated stream buffers surround the stream. The upper portion exhibits multiple channels, which are stable and meander through non-tidal wetlands. These conditions are reflective of those described in the Bird River watershed plan that was completed in 1995.

Monitoring in the Windlass Run watershed includes stream geomorphological monitoring, and biological monitoring. The Baltimore County NPDES Municipal Stormwater Discharge Permit only requires the stream stability geomorphological monitoring. In 2002, a water level sensor was installed on the mainstem at Bird River Road and downstream of the Route 43 road construction and the area of future major development. Baseflow and storm event, water chemistry data was collected at this site. Due to high flood levels and unstable channel conditions the sensor was moved to within 100' above the "new" Route 43 crossing on Windlass Run in 2004 where stream conditions are more stable. A rating curve is still in development for the water level sensor

8.4.1 Stream Geomorphologic Monitoring

Six (6) sites throughout the Windlass Run subwatershed have been selected for monitoring and are shown in Figure 8-17 below. The site selection process took into consideration the location of future development and the extension of MD Route 43. Three sites are located along the mainstem; two above (WR3, WR5) and one below (WR2) the crossing of the proposed MD Route 43 highway extension. One, on a tributary (WR4) is upstream within the area of proposed industrial and high-density development, and down stream of Route 43. One other cross section (WR6) is located on a tributary within the area of proposed development. The last cross section (WR1) is a reference site located on a tributary near the bottom of the subwatershed. This tributary is within an area zoned for agricultural uses and should not be affected by the other development activities in the watershed. Sites WR1 and WR6 are not down slope or downstream of any of the Route 43 construction.

The geomorphic monitoring consists of a channel cross-section measurement, a channel slope/profile measurement and a Wolman pebble count. Cross sections were selected on the reach between meander bends and where the conditions best represented confined flow. Rebar was placed above the banks of the stream for permanently marking the end points of the six selected cross sections. Profiles were also surveyed at all of the cross section reaches and include the cross sections. The procedures outlined by D. Rosgen (1996) were generally used for channel classification and stability assessment at each of the six permanent site locations. In the spring of 2002, 2003, 2004, 2005, 2006, and again in the spring of 2007, the six cross sections and profiles were surveyed. Note, however, that no profile was done at Cross Section #6 in 2002 and 2003 due to heavy vegetation. Pebble counts, sinuosity, and a Rosgen Level 3 assessment were also completed at each site. The monitoring will continue yearly.

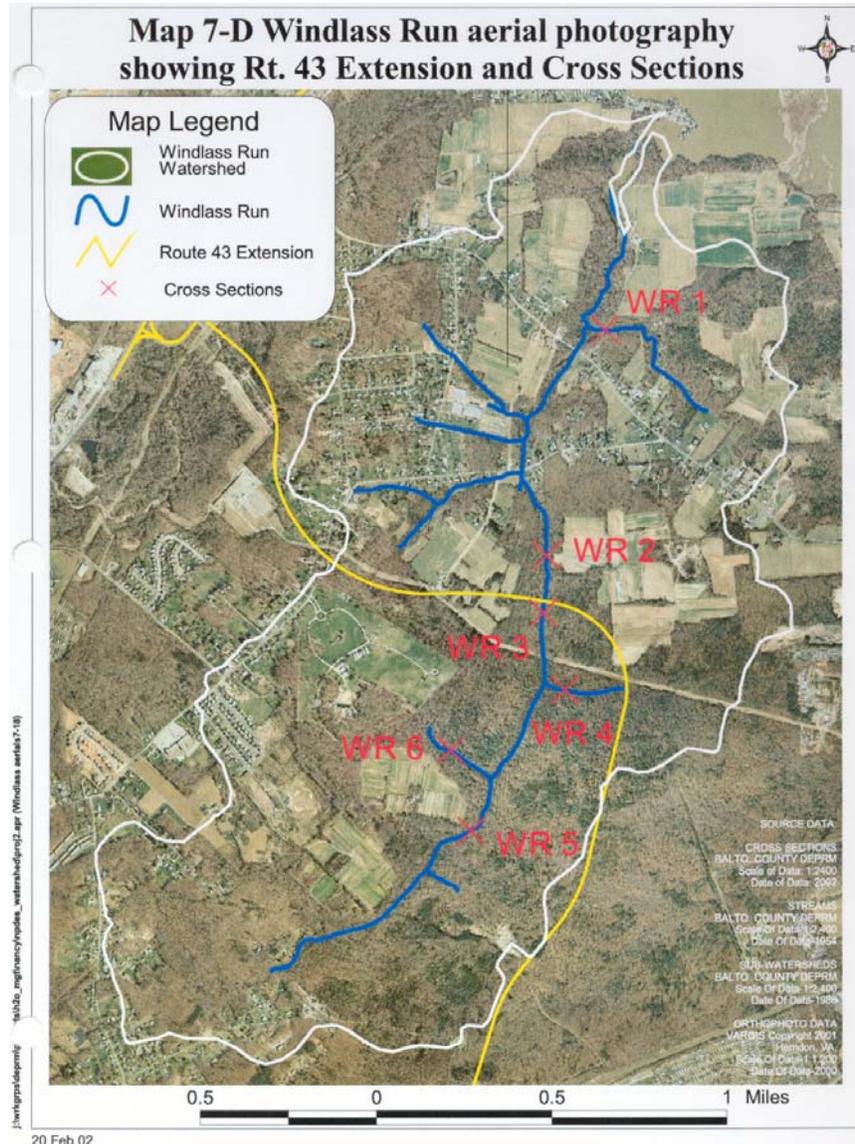


Figure 8-17: Windlass Run Aerial Photograph Showing Monitoring Station Locations.

Windlass Run Monitoring Results:

The cross sections between 2002 and 2007 were overlaid to reveal any morphological changes. The change in the reaches over the two study intervals can be summarized as follows:

Reach 1 (Reference reach on a tributary)

- A scour hole appeared at the cross section in 2003. No further change was observed during that time period.
- The profile deepened at the upper end and remained unchanged at the lower end during 2002 – 2007 including deepening somewhat overall during 2006 – 2007.
- The substrate coarsened slightly during both time periods
- Discussion: This section shows that approximately 1.5 feet of localized incision (scour hole) occurred in 2003 in the channel bed, however no changes occurred in the banks, the

overbank area or the rest of the thalweg profile. There was no apparent causal factor for the scour hole right at the cross section, however tropical storm Isabele (Fall, 2003) is believed to be the precipitating event. Since 2002 the overall gradient over the longitudinal profile has flattened due to a 0.2 – 0.3 foot decrease in the upstream elevation of both the thalweg profile. There only change in 2006 - 2007 was a slight deepening in the overall profile.

Reach 2 (On the mainstem below the Route 43 crossing)

- Only a slight cutting was observed in the cross section over both time periods.
- The thalweg has been active in the profile since 2002 with both aggradation and degradation over time and the thalweg length. It incised overall in 2006 -2007, and aggraded (0.6 ft) in 2005- 2006.
- The substrate shows some coarsening over both time intervals.
- Note: 2004 was the last year that agricultural operations were underway in the vicinity of Reach 2. During the last 2 years, mass grading has supplanted the agricultural activity.

Reach 3 (Just above Route 43 crossing)

- A slight channel enlargement occurred between 2002 – 2007, however little change except slight overbank deposition was observed in the cross section during 2006 – 2007. The thalweg degraded overall prior to 2004, and held steady in 2005 – 2006 and 2006 - 2007, although wavelike cut and fill oscillations of about 0.6 ft amplitude occurred within the profile between the last two years.
- The pebble count indicated a slight coarsening over both time periods.

Reach 4 (On a tributary below Route 43)

- Very slight aggradation in 2006-2007 following slight downcutting in the CX over 2005-2006 and through 2002-2007.
- Moderate incision (0.4 ft) overall in the thalweg over 2002-2007 including slight incision during 2006-2007.
- Moderate coarsening of the substrate during 2002-2007, except slight re-finishing over the past year (2006-2007).

Reach 5 (On mainstem above Route 43)

- The cross section had a 1½ foot planiform shift to the left and a slight deepening (0.3 ft) between 2002 – 2007, with some of this occurring during 2004. It was stable by 2005-2007.
- The profile experienced some degradation in the upper and lower ends with aggradation in the middle portion during 2002-2007. Slight overall degradation occurred during 2005 - 2007.
- A slight coarsening occurred over Reach 5 over both time periods.

Reach 6 (On a tributary unaffected by Route 43)

- The cross section re-deepened by 1/3 of its capacity (0.6 ft) during 2006-2007 from aggradation the prior year. There was little overall change from 2002 - 2007.

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- The thalweg incised overall from 2004 – 2007, including some additional degradation during 2005 –2007, however the lower portion of the channel diverted to the left due to sediment accumulations impinging at the diversion point during 2006-2007. No data prior to 2004 was collected.
- A marked coarsening of channel material, with the occurrence of many particles in the 0.1 – 0.5 mm grain size, occurred by the Spring of 2005, but by Spring 2006 the substrate had returned back to its finer original state. A re-coarsening occurred by 2007.

The results discussed above are displayed in Tables 8-15 and 8-16.

Table 8-15: Windlass Run Cross Sections - Cut and Fill Amounts

WR 1: Change (cu ft)	Period: 2006 – 2007	Period 2002 – 2007
Total Cut (negative value)	-1.2	-7.2
Total Fill	2.2	4.5
Total Change	3.4	11.7
Net Change	1.0	-2.7
WR 2: Change (cu ft)	Period: 2006 – 2007	Period 2002 – 2007
Total Cut (negative value)	-5.7	-2.8
Total Fill	0.3	1.4
Total Change	6.0	4.2
Net Change	-5.4	1.4
WR 3: Change (cu ft)	Period: 2006 – 2007	Period 2002 – 2007
Total Cut (negative value)	-0.9	-5.6
Total Fill	2.3	0.6
Total Change	3.2	6.2
Net Change	1.4	-5.0
WR 4: Change (cu ft)	Period: 2006 – 2007	Period 2002 – 2007
Total Cut (negative value)	0.0	-2.9
Total Fill	1.4	0.1
Total Change	1.4	3.0
Net Change	1.4	-2.8
WR 5: Change (cu ft)	Period: 2006 – 2007	Period 2002 – 2007
Total Cut (negative value)	-1.4	-3.1
Total Fill	0.8	2.1
Total Change	2.2	5.2
Net Change	-0.6	-1.0
WR 6: Change (cu ft)	Period: 2006 – 2007	Period 2002 – 2007
Total Cut (negative value)	-2.3	-1.1
Total Fill	0.1	0.2
Total Change	2.4	1.3
Net Change	-2.2	-0.9

Table 8-16: Windlass Run Stream Channel Changes Over Time

WR #	Down slope Of Rt. 43	CX 02-07	CX 06-07	TW 02-07	TW 06-07	Pebble 02-07	Pebble 06-07
2	yes	<i>sd (p)</i>	<i>d</i>	<i>a & d</i>	<i>d</i>	<i>mc</i>	<i>sc</i>
3	yes	<i>D</i>	<i>a</i>	<i>d</i>	<i>a & d</i>	<i>sc</i>	<i>sc</i>
4	yes	<i>D</i>	<i>a</i>	<i>md</i>	<i>sd</i>	<i>mc</i>	<i>sf</i>

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5	no	<i>sd(p)</i>	<i>sd</i>	<i>a & d</i>	<i>d</i>	<i>sc</i>	<i>sc</i>
1	no	<i>D</i>	<i>sa</i>	<i>d</i>	<i>sa & sd</i>	<i>sc</i>	<i>sc</i>
6	no	<i>Sd</i>	<i>d(p)</i>	<i>d</i>	<i>d</i>	<i>0</i>	<i>c</i>

Symbols: a: aggradation, d: degradation, c: coarsening, fining, p: planiform change, s:slight, m:moderate

The Windlass Run stream channels are generally low gradient and well connected with their flood plains at bankfull flows. They also have good riparian vegetational coverage along their banks. The stream system is almost entirely within a well-forested setting providing good habitat, erosional resistance, and canopy coverage. Windlass Run presently appears to be in a near pristine condition except the tributary at CX 6 that is being impacted by sediment due to off road RV useage that churns up a large amount of mud just upstream. Some visual evidence of increased hydrology was observed at CX4, however it could be due to rainfall patterns during the past year. Windlass Run emerged from a record rainfall year including tropical storm “Isabele” in 2003 with apparently little change in morphology or habitat quality. The major part of construction of the Highway 43 extension occurred in the watershed during 2004, however no significant change that could be attributed to this impact was noted. Cross sections #2, #3, and #4 are the locations that are downstream or down slope of this construction. The several years of completed pre-development monitoring, except the construction work on Highway 43, has determined the pre-conditions, and provide a solid, quantifiable basis for detecting any important future changes due to development in the subwatershed that is now underway.

8.4.2 Biological Monitoring

Benthic macroinvertebrate data is being used to approximate the degree of disturbance in the Windlass Run watershed. The changes in the benthic macroinvertebrate community between pre- and post-construction will help assess the effectiveness of the new stormwater regulations and document the impact of the extension of Route 43 and the subsequent development of the Windlass Run watershed.

Benthic macroinvertebrate sampling was conducted as per MBSS protocols. Benthic macroinvertebrates were sampled annually, during the spring index period (March 1st - April 30th), at WR-1, WR-2, WR-3, WR-4, and WR-5, as shown in Figure 8-16. WR-1 was not sampled in 2004 and 2006 because a beaver dam downstream of the station, on the Windlass Run mainstem, was causing backwater effects within the station reach. Data for WR-1 from 2005 are missing because the sorted sample had dried before it could be identified. A Benthic Index of Biotic Integrity (BIBI) was calculated using metrics developed by MBSS for Coastal Plain streams. The BIBI scoring criteria are: 1.00-1.99 (Very Poor), 2.00-2.99 (Poor), 3.00-3.99 (Fair), and 4.00-5.00 (Good). Stream physical habitat was assessed when macroinvertebrates were collected. Three different protocols were used for the habitat assessments. In 2002, the Save Our Streams protocol was followed. In 2003, a modified Environmental Protection Agency Rapid Bioassessment protocol was used. Since 2004, MBSS protocols have been followed. The protocols changed as DEPRM’s biological assessment program developed and expanded. All protocols measured similar components of stream physical habitat, including fish habitat quality, macroinvertebrate habitat quality, stream depth and velocity diversity, riffle quality, pool quality, the percentage of sediment surrounding stream bottom substrates, and the percentage of shading in the stream reach. Each parameter is estimated on a scale of 0-20.

The BIBI scores are shown in Table 8-17.

Table 8-17: Windlass Run BIBI Scores

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Year	WR-1	WR-2	WR-3	WR-4	WR-5	Mean	Std Dev
2002	2.43	1.57	2.43	3.00	1.86	2.25	0.55
2003	2.14	1.57	1.29	1.00	1.86	1.57	0.45
2004	NA	1.29	1.86	NA	1.57	1.57	0.28
2005	2.71	2.43	1.57	NA	1.00	1.92	0.78
2006	NA	3.29	4.43	2.14	2.43	3.07	1.02

Only three stations had better than Poor biological condition. WR-4 in 2002, and WR-2 in 2006, were rated Fair. WR-3 in 2006 was rated Good. All other station-year combinations were rated Very Poor or Poor. The mean BIBI increased between 2005 and 2006. The generally poor biological condition, followed by improvement in 2006, suggests that the macroinvertebrate community was limited by physical and chemical disturbance associated with vegetable farming (disruption of the soil, pesticide application, runoff). Physical habitat condition tended to decrease over time (Figure 8-18). Habitat scores were standardized by dividing the sum of the individual parameter scores by the total possible score, to account for the changes in protocols used over the study period and allow comparison among years. The relatively low physical habitat condition may reflect the farming land use, or it may be an artifact of the changes in assessment protocols.

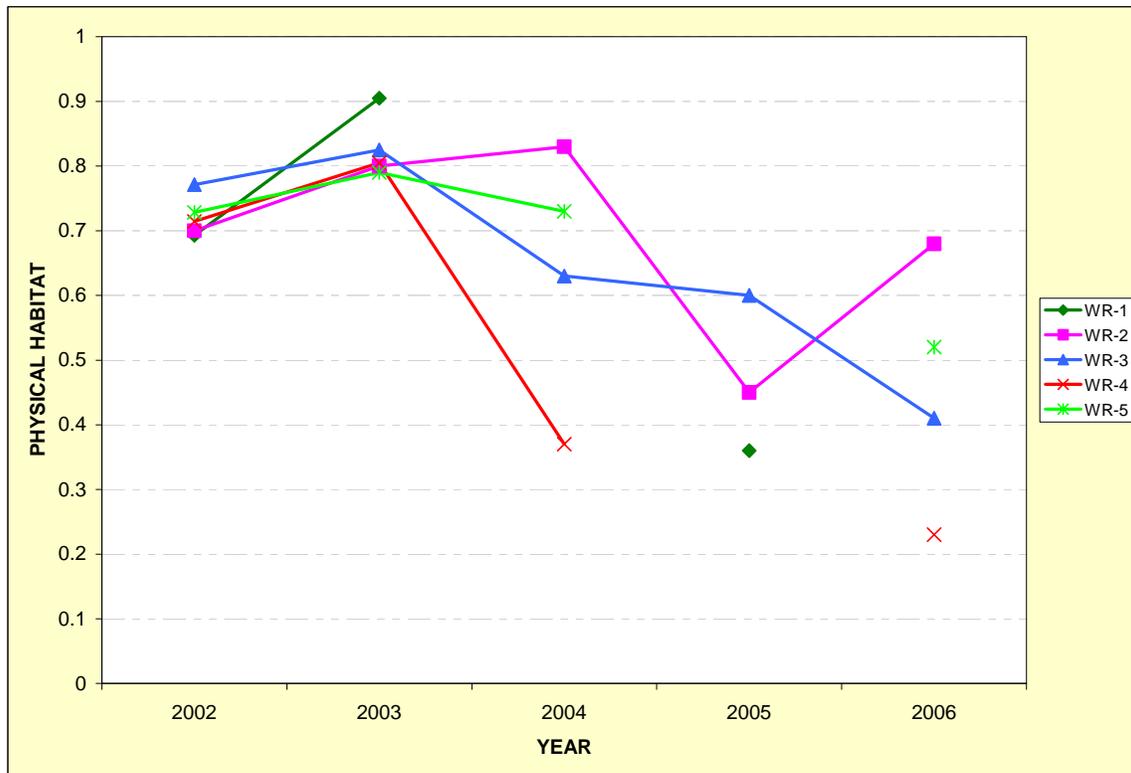


Figure 8-18: Windlass Run Physical Habitat Scores
Appendix 8-1: Scotts Level Branch and Powder Mill Run Physical Habitat

Station	Year	Survey	IH	ES	VDD	PGEQ	RRQ	E	S
SL-2	2005	Benthos	12	14	10	11	14	27	95
SL-4	2005	Benthos	7	10	11	10	9	80	85
SL-6	2005	Benthos	15	14	13	12	10	60	97
SL-7	2005	Benthos	11	9	12	12	10	75	60
SL-12	2005	Benthos	9	10	10	10	10	65	35

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SL-16	2005	Benthos	13	12	13	13	12	65	95
SL-17	2005	Benthos	9	10	8	10	8	75	99
SL-18	2005	Benthos	10	8	9	11	2	95	50
SL-19	2005	Benthos	9	10	8	8	6	75	60
SL-20	2005	Benthos	12	13	11	10	12	70	75
PM-1	2005	Benthos	8	9	12	11	13	25	80
PM-4	2005	Benthos	7	3	12	8	7	45	90
PM-6	2005	Benthos	4	4	8	6	7	55	50
SL-2	2006	Benthos	9	11	10	10	8	60	70
SL-3	2006	Benthos	1	5	3	2	0	0	50
SL-4	2006	Benthos	15	15	14	16	13	70	75
SL-8	2006	Benthos	11	15	12	11	10	90	70
SL-11	2006	Benthos	10	13	11	10	9	50	45
SL-13	2006	Benthos	12	11	12	11	11	85	70
SL-14	2006	Benthos	5	8	5	7	7	50	30
SL-16	2006	Benthos	13	11	13	13	11	25	75
SL-18	2006	Benthos	6	5	8	11	0	100	50
SL-19	2006	Benthos	6	6	8	8	6	50	10
PM-1	2006	Benthos	16	15	19	15	17	20	75
PM-3	2006	Benthos	3	4	3	6	6	75	75
PM-5	2006	Benthos	11	14	11	10	10	20	70
SL-3	2006	Fish	0	2	3	0	2	0	60
SL-8	2006	Fish	6	9	11	9	7	20	85
SL-13	2006	Fish	15	6	12	15	8	10	90
SL-16	2006	Fish	14	11	11	16	6	15	85
SL-19	2006	Fish	8	7	10	10	9	60	45
PM-2	2006	Fish	6	9	8	6	10	25	65
PM-5	2006	Fish	13	10	11	13	6	60	70

Definitions: Instream habitat (IH) and epifaunal substrate (ES) describe the extent of stable habitat for fish and macroinvertebrates, respectively. Velocity/depth diversity (VDD) documents the presence of slow, fast, shallow, and deep water. Pool/glide/eddy quality (PGEQ) and riffle/run quality (RRQ) describe the extent of slow and fast water, respectively. Each parameter is rated on a scale from 0-20, with condition categories of Optimal (16-20), Sub-Optimal (11-15), Marginal (6-10), and Poor (0-5). Embeddedness (E) is a percentage estimate of the amount of fine particles covering coarse stream bottom substrates. Shading is a percentage estimate of the amount of wetted stream channel shaded by vegetation or other structure.