8.0 Permit Requirements

D. <u>Discharge Characterization</u>

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. <u>Assessment of Controls</u>

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 requirement are described below.

1. <u>Watershed Restoration Assessment</u>

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. <u>Chemical Monitoring</u>

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:

Biochemcial 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 Agenciy'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 be 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 monitoring data for Scotts Level Branch (8.2, 8.3), and the data for Windlass Run (8.4).

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 have been completed. 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 in Baltimore Harbor. 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, Powder Mill Run and Upper Gwynns Falls (above Gwynnbrook Road) have been selected as the "paired" subwatersheds (Figure 8-1).

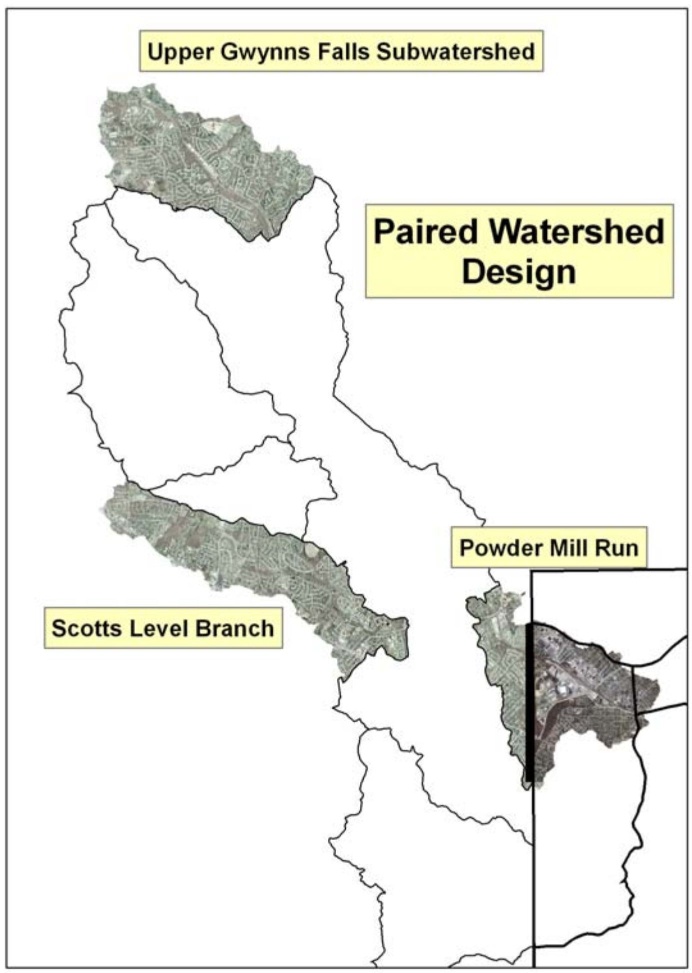


Figure 8-1: Subwatersheds to be used in the Paired Watershed Monitoring Design.

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 beginning in a few 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 by Baltimore County 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 was installed to permit continuous flow monitoring with a water level sensor installed and operated by Baltimore County. USGS has a preliminary rating curve, but technical issues need to be worked out before it will be finalized. 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.

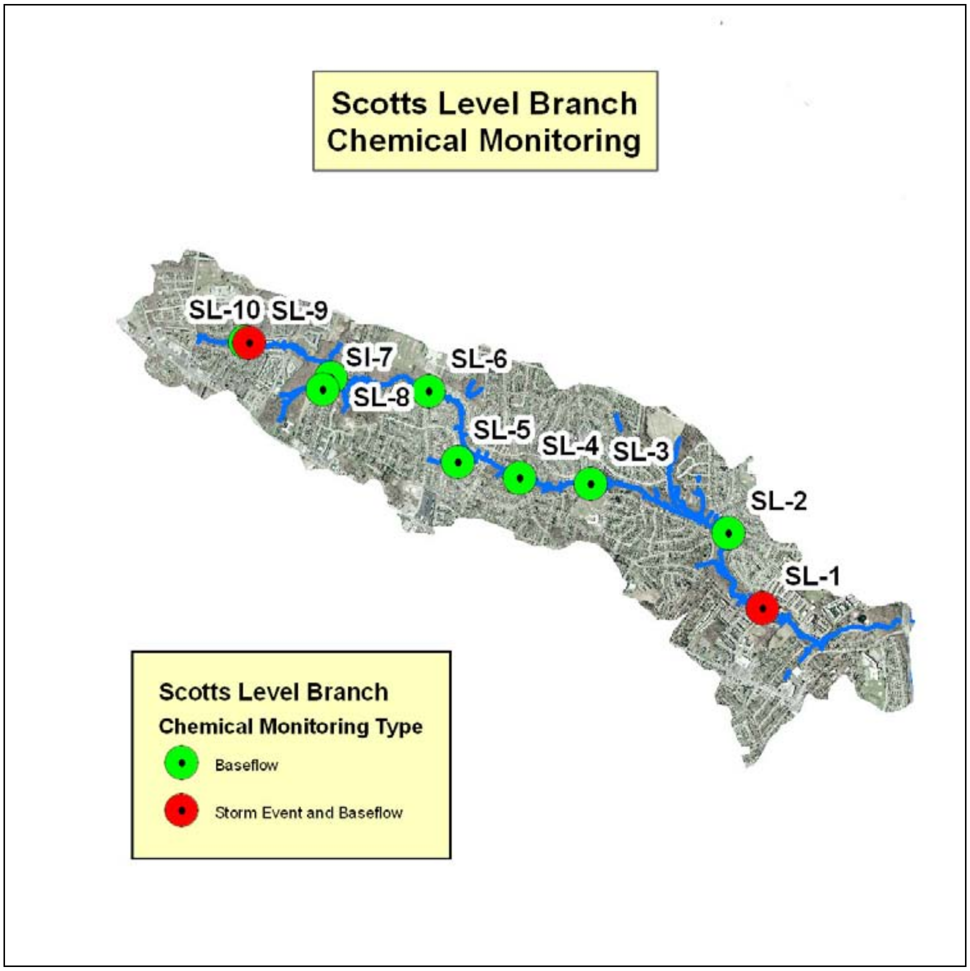


Figure 8-2: Scotts Level Branch Chemical Monitoring Locations

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 USGS gage at the Upper Gwynns Falls storm event grab samples will be collected to represent a range of stage discharges. The data for the Powder Mill site will come from Baltimore City. 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 8-2). 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). 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 annul 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.

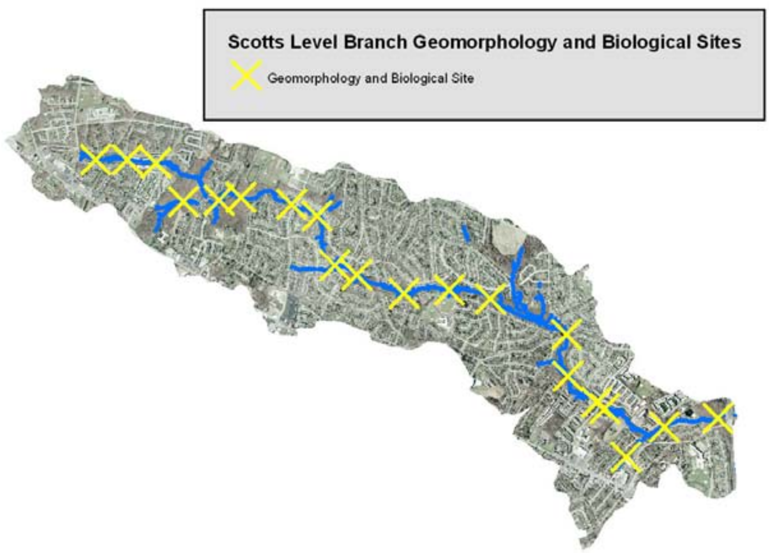


Figure 8-3: Scotts Level Branch Geomorphological and Biological Monitoring Site Locations

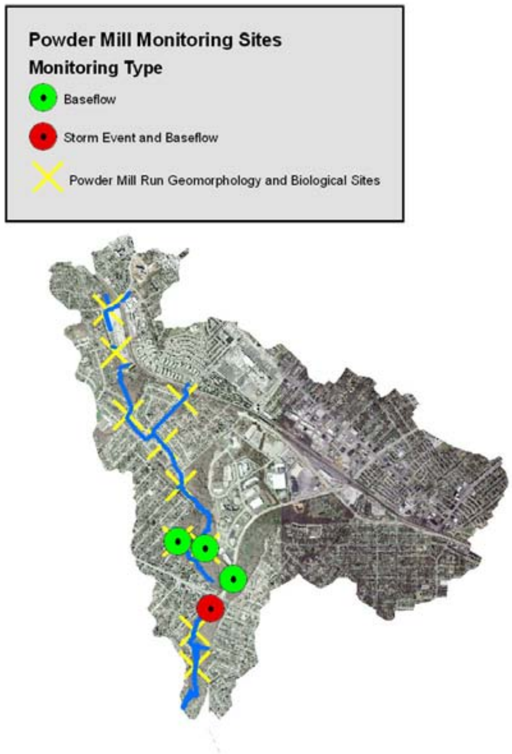


Figure 8-4: Powder Mill Run Geomorphological and Biological Monitoring Sites

<u>*8.2.1.4 Biological Monitoring*</u>

Benthic macroinvertebrate and fish sampling will be conducted annually at five fixed stations on Scotts Level Branch and three fixed stations on Powder Mill Run, during the appropriate index periods (March-April for macroinvertebrates, June-September for fish). Maryland Biological Stream Survey (MBSS) methods will be followed. Macroinvertebrate identification will be to the Genus taxonomic level or the lowest practical identification level. At the time of sample collection, the appropriate MBSS stream habitat assessment will be conducted.

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 was 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.

Precipitation Data: Hourly and daily precipitation data were acquired from the Department of Public Works stream gage located on Saint Luke's Lane. These data were recorded in conjunction with the Scotts Level Branch discharge data discussed below. Calendar year 2008 had one hundred twenty-nine days of recorded measurable precipitation. The daily data were analyzed for precipitation amount (Table 8-3). As can be seen from Table 8-3, a little less than 40% of the days recorded less than a 0.1 inch of precipitation. Precipitation over one inch occurred on only 9% of the days, but accounted for 40.0% of the total amount of the precipitation in 2007. The maximum daily rainfall was 3.44 inches recorded on September 27, 2008. A total of 43.68 inches of precipitation, more than the long-term average (~42 inches), was recorded at the Department of Public Works rain gauge for 2008.

Table 8- 3: Precipitation Data Analysis for Calendar 2008

Precipitation Category	# of Days	% Days	Total Amount	% of accumulation
<.1	50	39%	1.61	3.7%
.1-<.5	51	40%	11.51	26.4%
.5-<1.0	18	14%	13.13	30.1%
1.0-<1.5	5	4%	6.75	15.5%
1.5-<2.0	2	2%	3.09	7.1%
2.0-<2.5	2	2%	4.15	9.5%
2.5-<3.0	0	0%	0.00	0.0%
3.0-3.5	1	1%	3.44	7.9%
Total	**129**		**43.68**	

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 51 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: 2008 Precipitation Amount, Intensity, and Duration by Category

Precipitation Category (Inches)	Accumulation Amount				Intensity (inches/hour)			Duration (hours)		
	# Storms	% Storms	Total Acc.	% Acc.	Intensity Category	# Storm	% storms	Duration Category	# storms	% storms
< .1	2	3.9	0.17	0.5	< .1	21	41.2	<1	10	19.6
.1 - <.25	15	29.4	2.36	7.2	.1 - <.25	20	39.2	1 – <3	9	17.6
.25 - <.50	11	21.6	4.02	12.3	.25 - <.50	8	15.7	3 – <6	12	23.5
.50 - <.75	9	17.6	5.47	16.7	.50 - <.75	1	2.0	6 – <9	9	17.6
.75 – <1.00	5	9.8	4.52	13.8	.75 – <1.00	0	0.0	9 – <12	6	11.8
1.00 – <1.50	6	11.8	7.73	23.6	1.00 – <1.50	0	0.0	12 – <15	2	3.9
1.50 – <2.00	0	0.0	0.00	0.0	1.50 – <2.00	1	2.0	15 – <18	0	0.0
2.00 – <3.00	2	3.9	4.80	14.7	2.00 – <3.00	0	0.0	18 – <21	1	2.0
3.00 – <4.00	1	2.0	3.67	11.2	3.00 – <4.00	0	0.0	21 – <24	0	0.0
>4.00	0	0.0	0.00	0.0	>4.00	0	0.0	>24	2	3.9
Total	**51**	**100**	**32.74**	**100**		**51**	**100**		**51**	**100**

About 33% of the storms were less than 0.25 inches in total amount of precipitation, but these storms accounted for only 7.9% of the total amount of rainfall. Only 17.7% of the storms were over one inch in total amount of rainfall and these storms accounted for almost half (49.5%) of the total amount of precipitation in 2008. The largest storm for 2008 recorded 3.67 inches of precipitation over approximately a 25-hour period. The highest intensity recorded at the DPW gauge in 2008 was 1.96 inches per hour. The majority of storms (80.4%) highest recorded hourly intensity was less than or equal to a quarter inch per hour. Likewise slightly more than half of the storms (60.7%) were less than 6 hours in duration.

Flow Data: The Scotts Level Branch gage data includes 15-minute discharge readings from the period of October 1, 2005 to March 9, 2009. 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 371 storm events for the period were identified, of which, 125 occurred in the calendar year 2008. Figure 8-5 displays the daily discharge and precipitation for calendar year 2008. The correlation coefficient was determined to be r = .84. The database was further coded to reflect the concurrence of storms as indicated by the increase in discharge and the precipitation from recorded at the DPW Rolling Road gauge. This resulted in 46 storms that had an overlap of both precipitation and storm discharge, and an increase in the correlation coefficient to r = .98, during 2008.

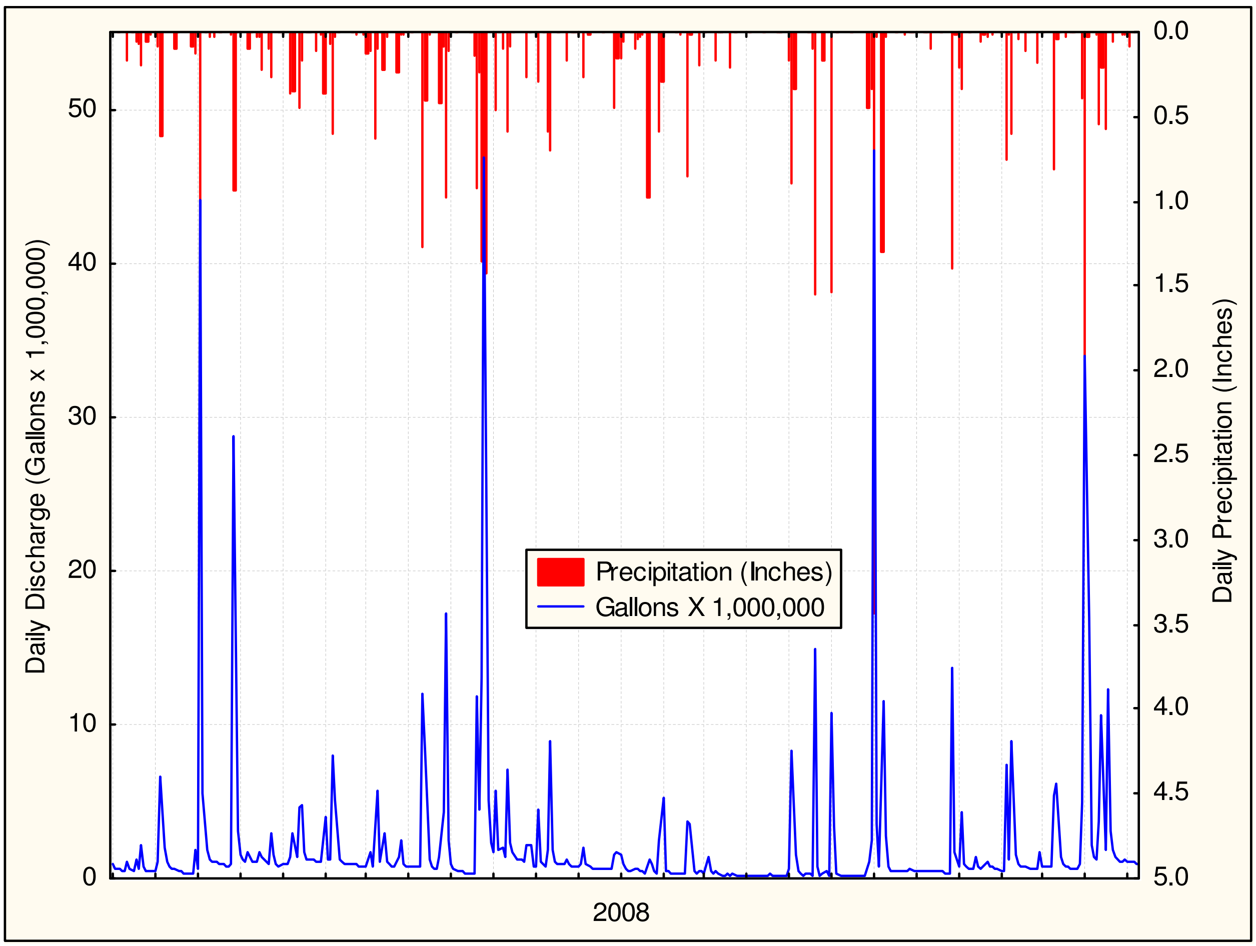


Figure 8-5: Calendar year 2008 Daily Precipitation and Discharge

Using this set of data for the 46 storms, the runoff coefficient was calculated for each storm. The average runoff coefficient was .214, with a maximum of .605 and a minimum of .031.

The 125 storm data set was 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 2008. The results are presented in Table 8-5.

Table 8-5: Seasonal Precipitation and Runoff Characteristics

Parameter	Fall	Winter	Spring	Summer	Total
Precipitation Amount	14.08	8.13	12.43	9.04	43.68
Precipitation %	32.2 %	18.6 %	28.5 %	20.7 %	---
% of precipitation volume accounted for by Runoff	30.1%	41.5%	32.8%	16.8%	31.2%
% of precipitation volume accounted for by Evapotranspiration	69.9 %	58.5%	67.2%	83.2%	68.8 %
% of stream flow accounted for by Storm flow	82.0%	65.6%	74.5%	75.7%	74.8%
% of stream flow accounted for by Baseflow %	18.0%	34.4%	25.5%	24.3%	25.2 %

For calendar year 2008 the precipitation was about evenly distributed. The fall and spring exhibited higher precipitation than the spring and summer. About thirty-one percent 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 58.5% and 83.2% 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, 74.8% of the flow was determined to be storm flow using the criteria described above, while only 25.2% 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 DPW 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, Total Copper, Total Lead, Total Zinc, Chloride and Sodium. The results are displayed in Table 8-6 and graphically in Figures 8-6 through 8-15.

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

Parameter	Regression Equation
Total Suspended Solids	0.8469+0.5636*(log cfs)
Total Kjeldahl Nitrogen	-0.2288+0.12*(log cfs)
Nitrate/Nitrite	-0.2595-0.1348*(log cfs)

Total Nitrogen	0.0973+0.0177*(log cfs)
Total Phosphorus	-1.2931+0.2991*(log cfs)
Total Copper	-2.3728+0.3096*(log cfs)
Total Lead	-3.2392+0.4466*(log cfs)
Total Zinc	-2.3304+0.5702*(log cfs)
Chloride	1.5722+0.0066*(log cfs)
Sodium	1.475+0.1008*(log cfs)

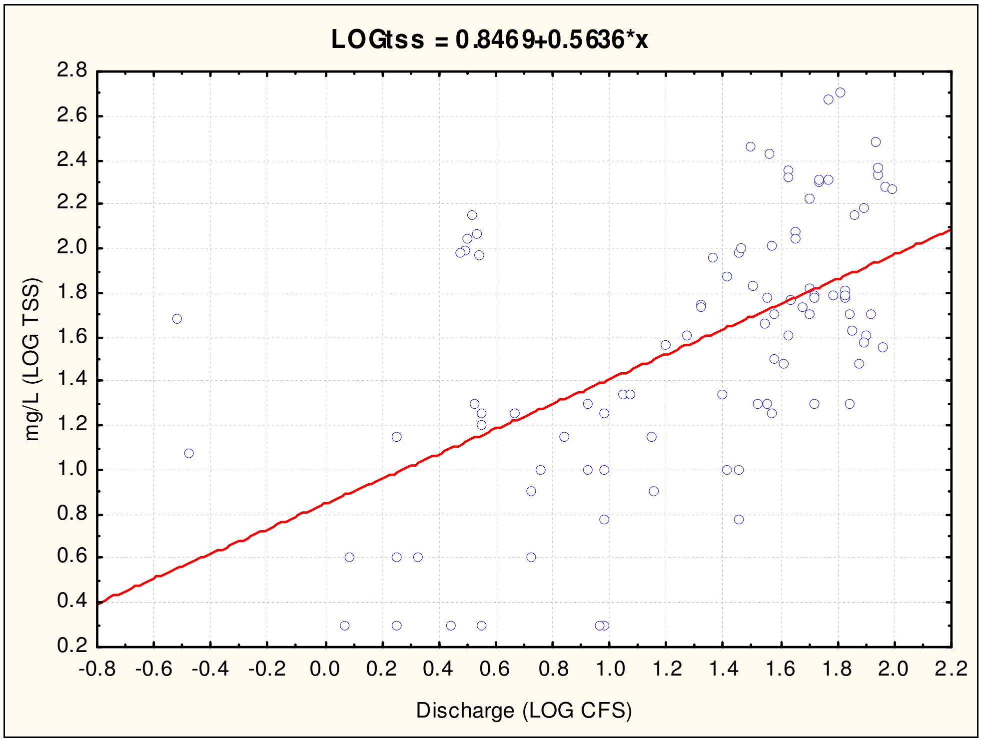


Figure 8-6: Total Suspended Solids (TSS) Data and Regressions for 2005-2009.

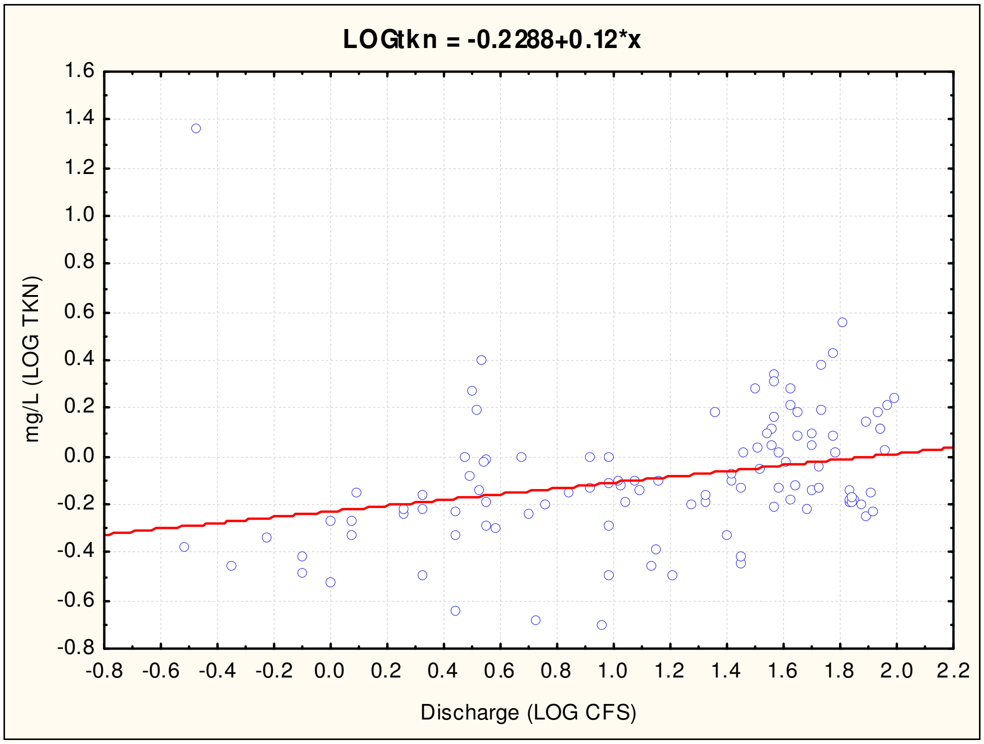


Figure 8-7: Total Kjeldahl Nitrogen (TKN) Data and Regressions for 2005-2009.

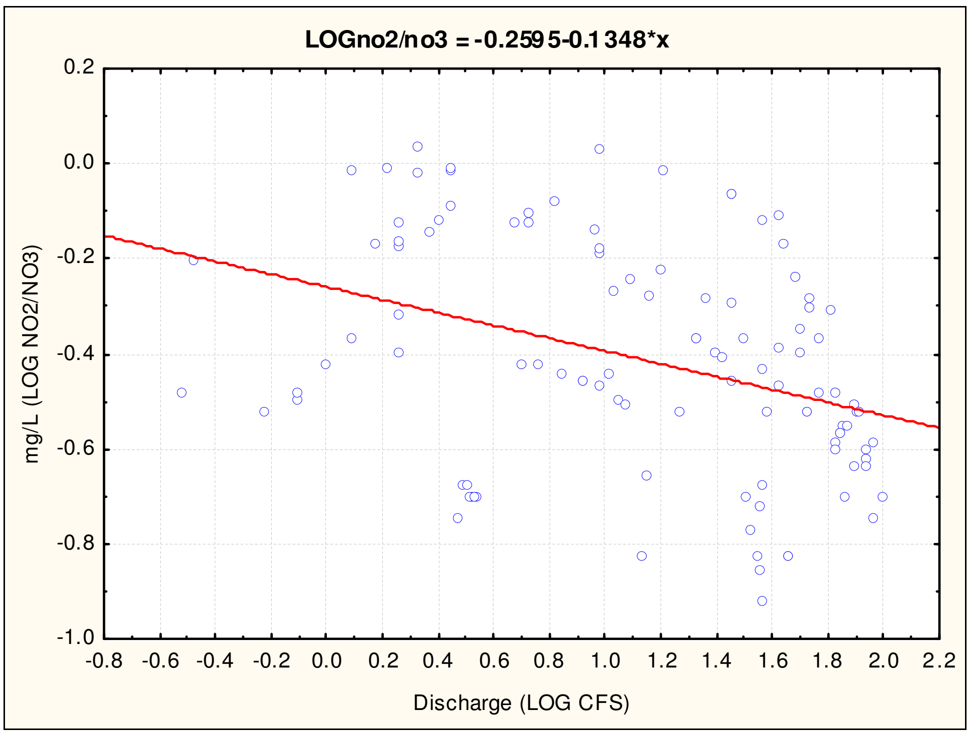


Figure 8-8: Nitrate/Nitrite (NO_2/NO_3) Data and Regressions for 2005-2009.

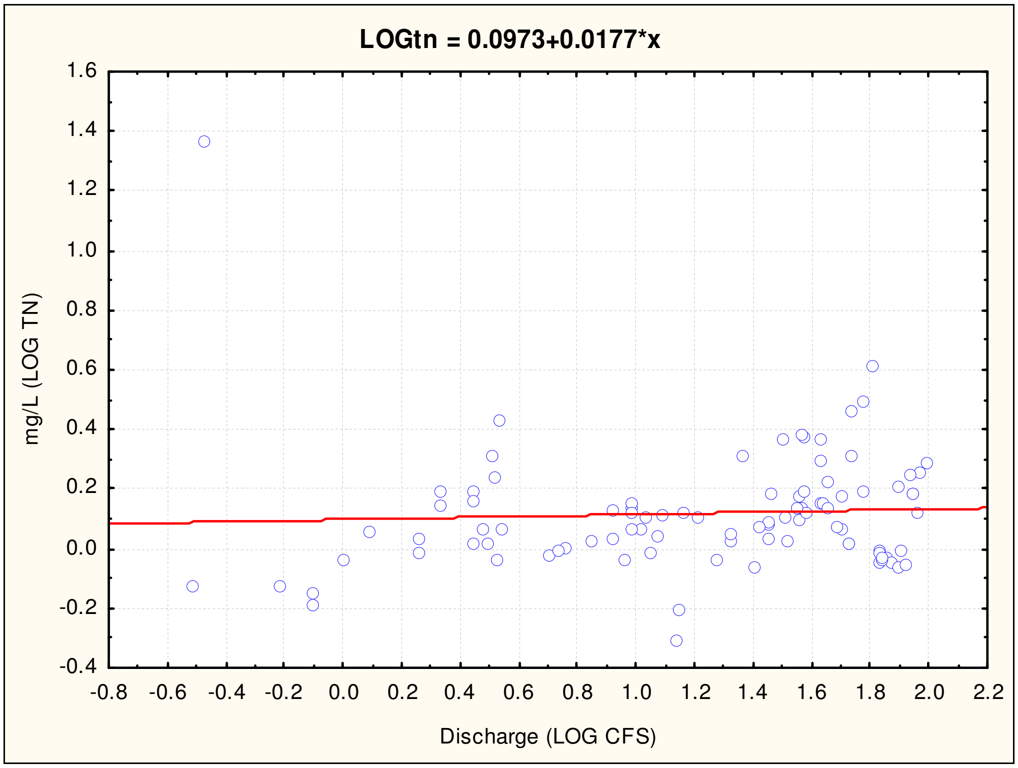


Figure 8-9: Total Nitrogen (TN) Data and Regressions for 2005-2009.

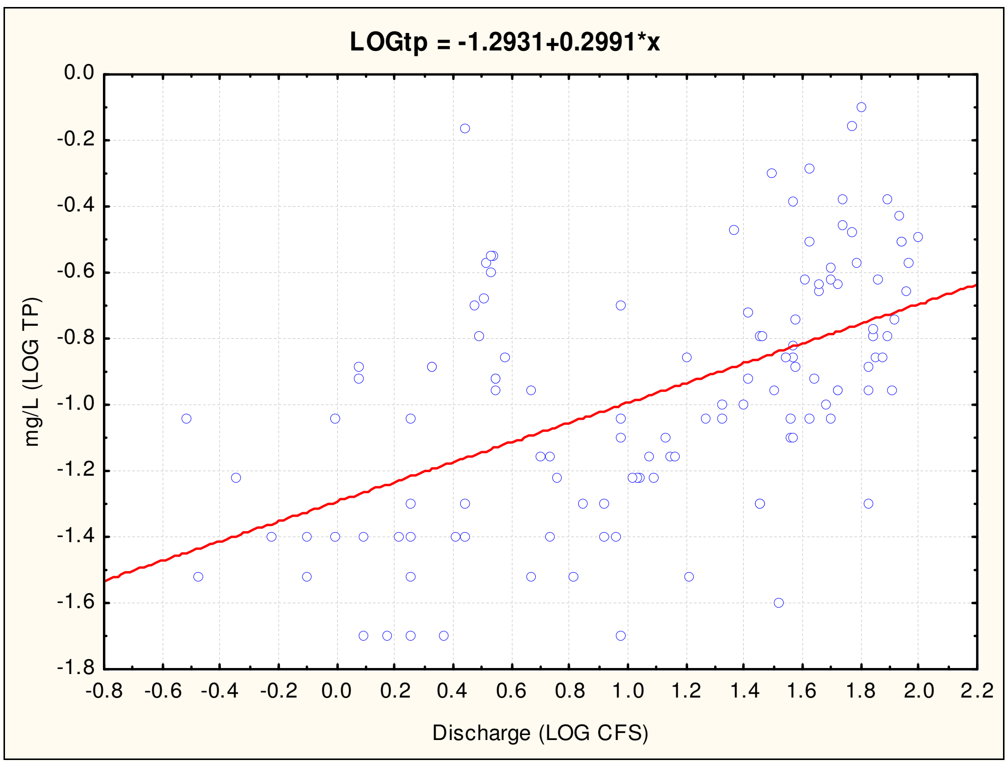


Figure 8-10: Total Phosphorus (TP) Data and Regressions for 2005-2009.

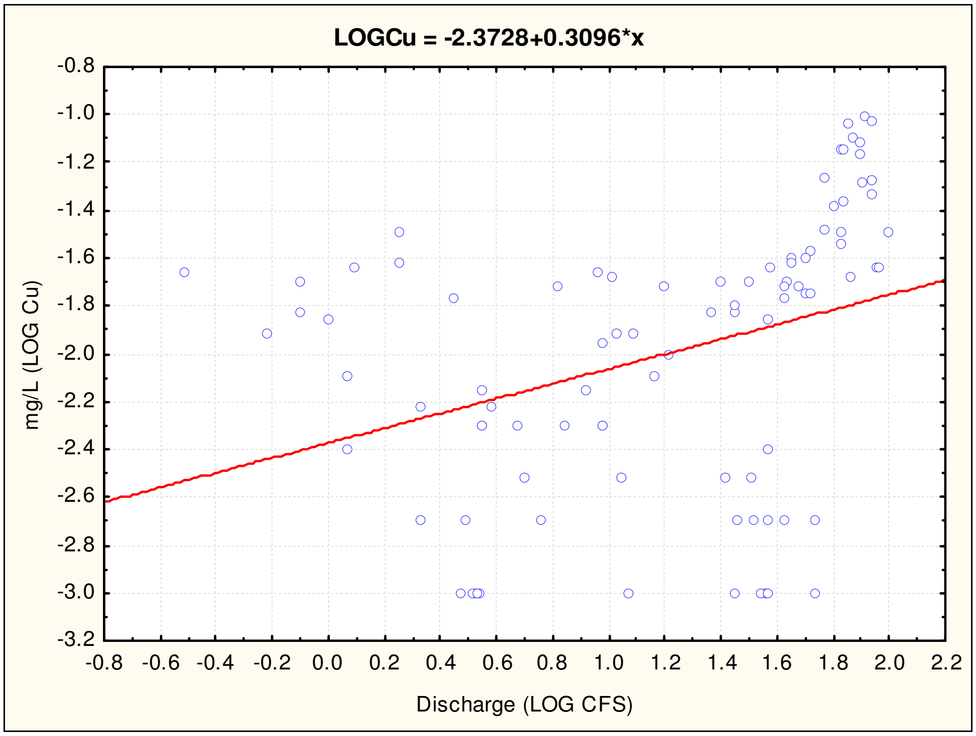


Figure 8-11: Total Copper (Cu) Data and Regressions for 2005-2009.

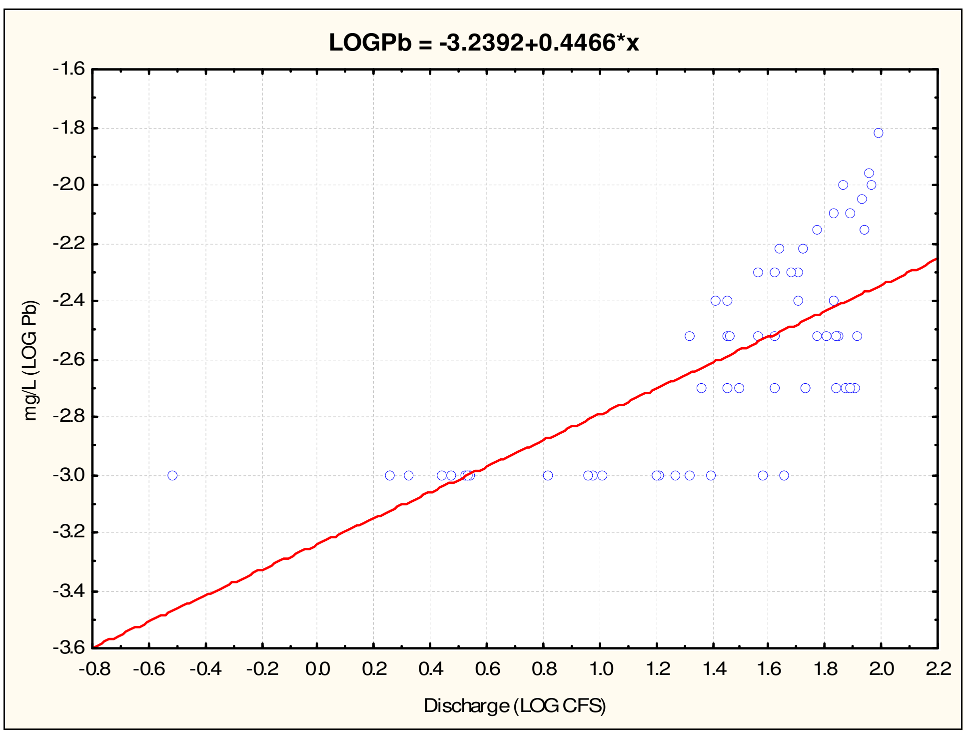


Figure 8-12: Total Lead (Pb) Data and Regressions for 2005-2009.

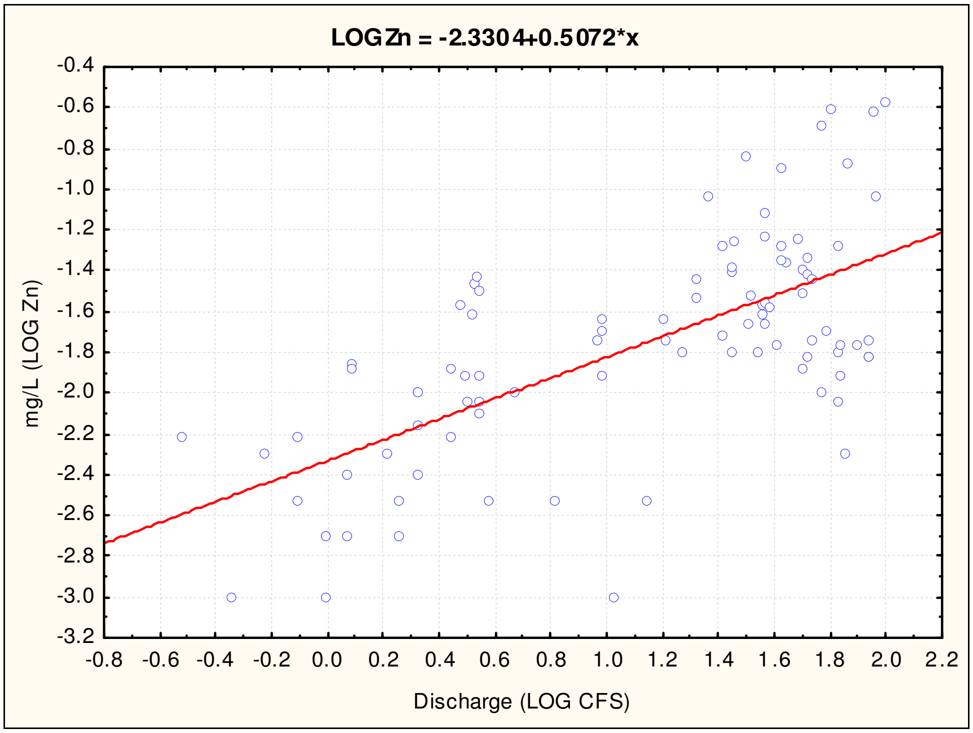


Figure 8-13: Total Zinc (Zn) Data and Regressions for 2005-2009.

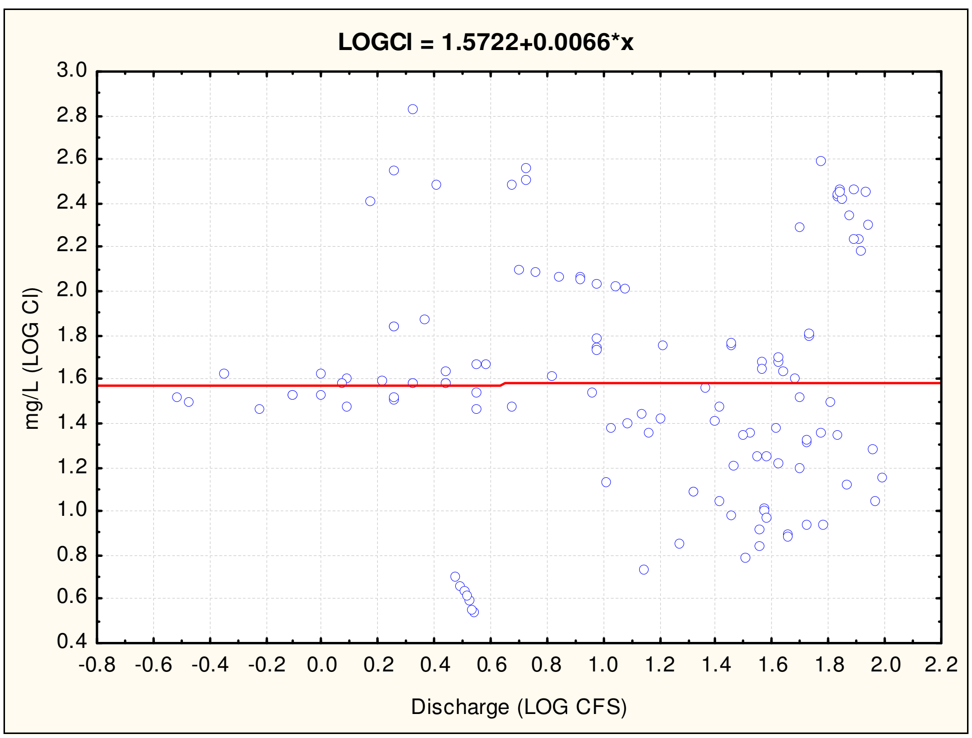


Figure 8-14: Chloride (Cl) Data and Regressions for 2005-2009.

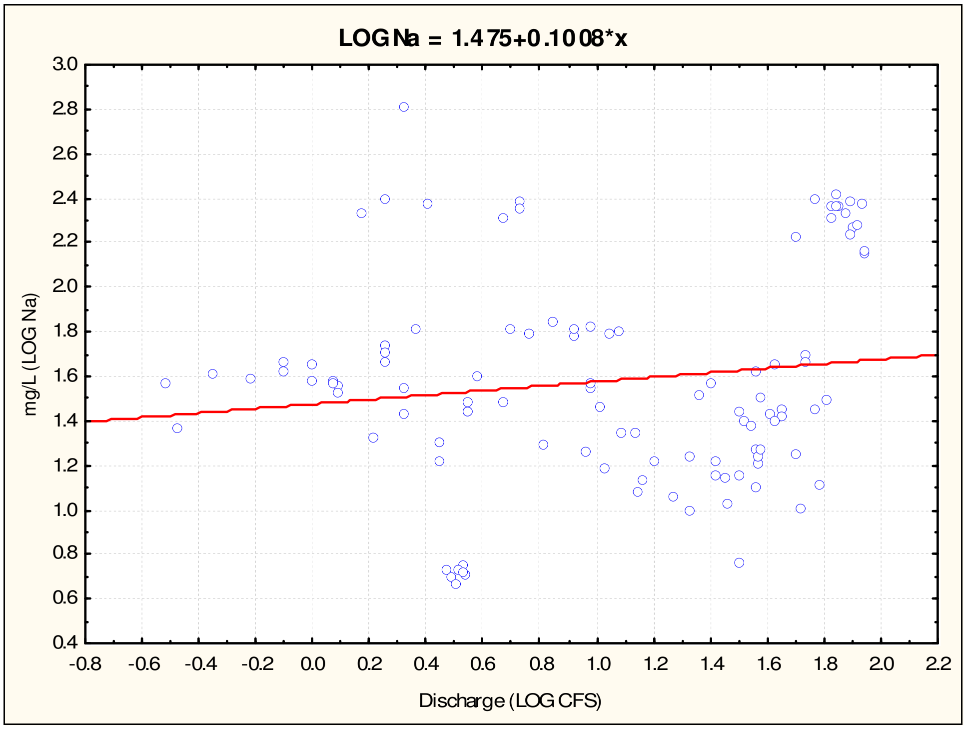


Figure 8-15: Sodium (Na) Data and Regressions for 2005-2009.

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

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 371 storms identified in the USGS gage data record. Figures 8-16a through 8-25b show the Event Mean Concentrations for Total Suspended Solids (TSS), Total Kjeldahl Nitrogen (TKN), Nitrate/Nitrite, Total Nitrogen (TN), and Total Phosphorus (TP), Total Copper, Total Lead, Total Zinc, Chloride, and Sodium.

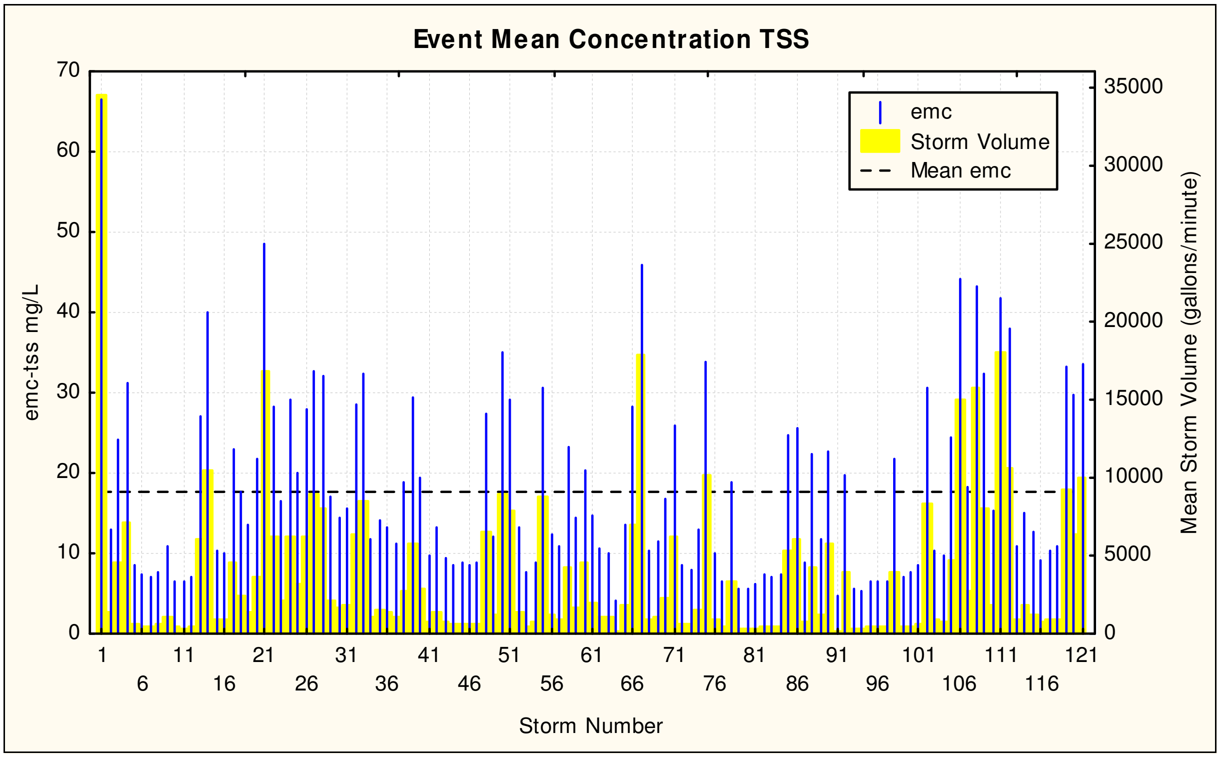


Figure 8-16a: Event Mean Concentration for Total Suspended Solids (TSS) 2005-2006

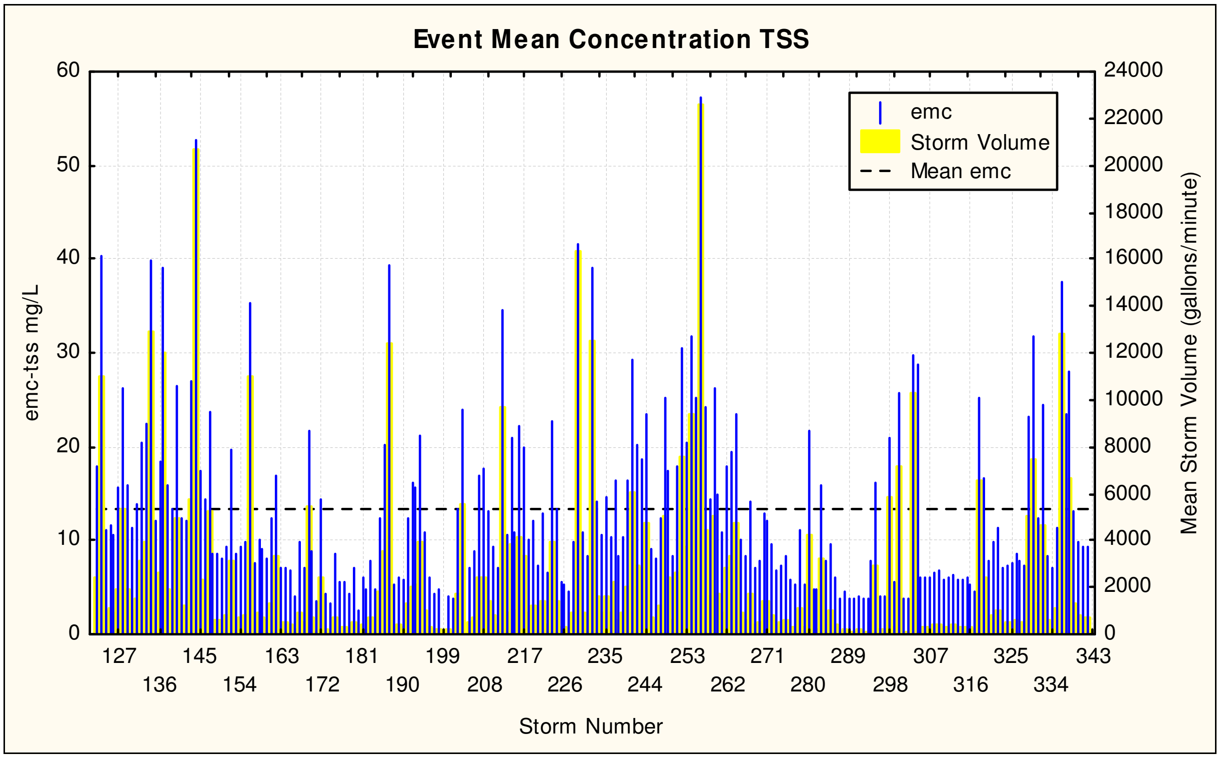


Figure 8-16b: Event Mean Concentration for Total Suspended Solids (TSS) 2007-2008

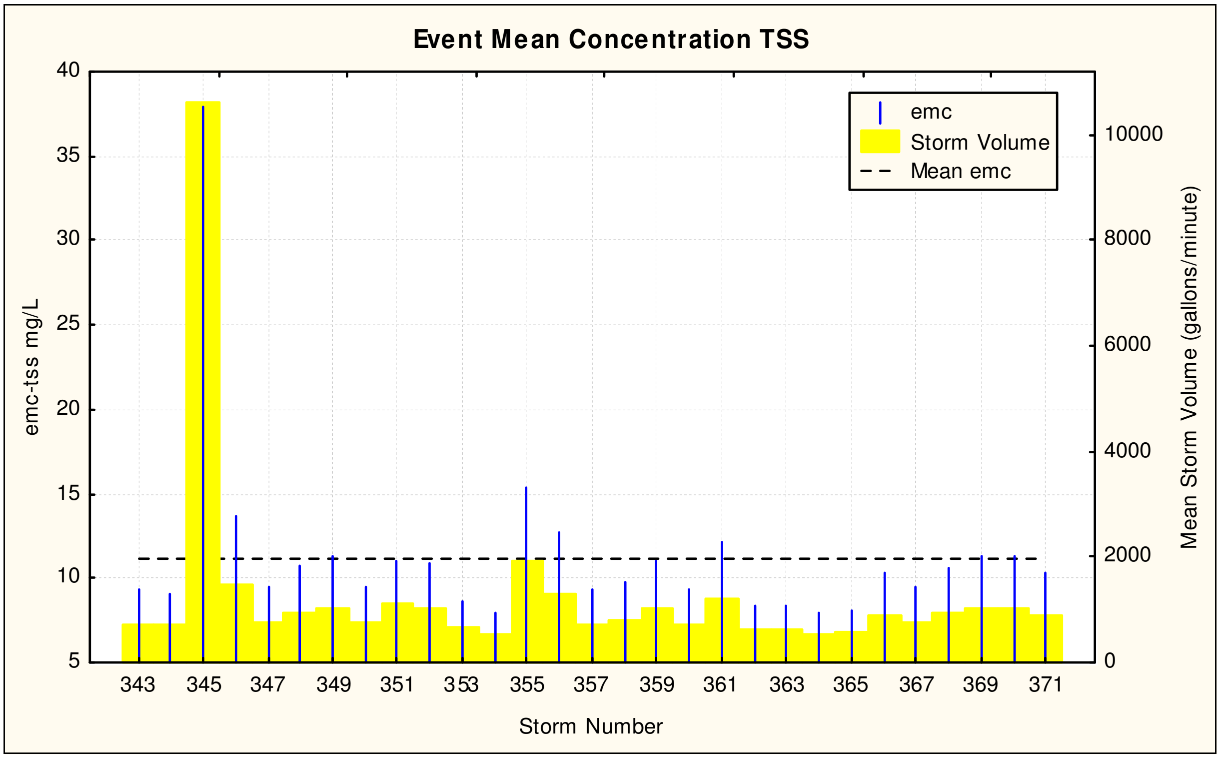


Figure 8-16c: Event Mean Concentration for Total Suspended Solids (TSS) 2009

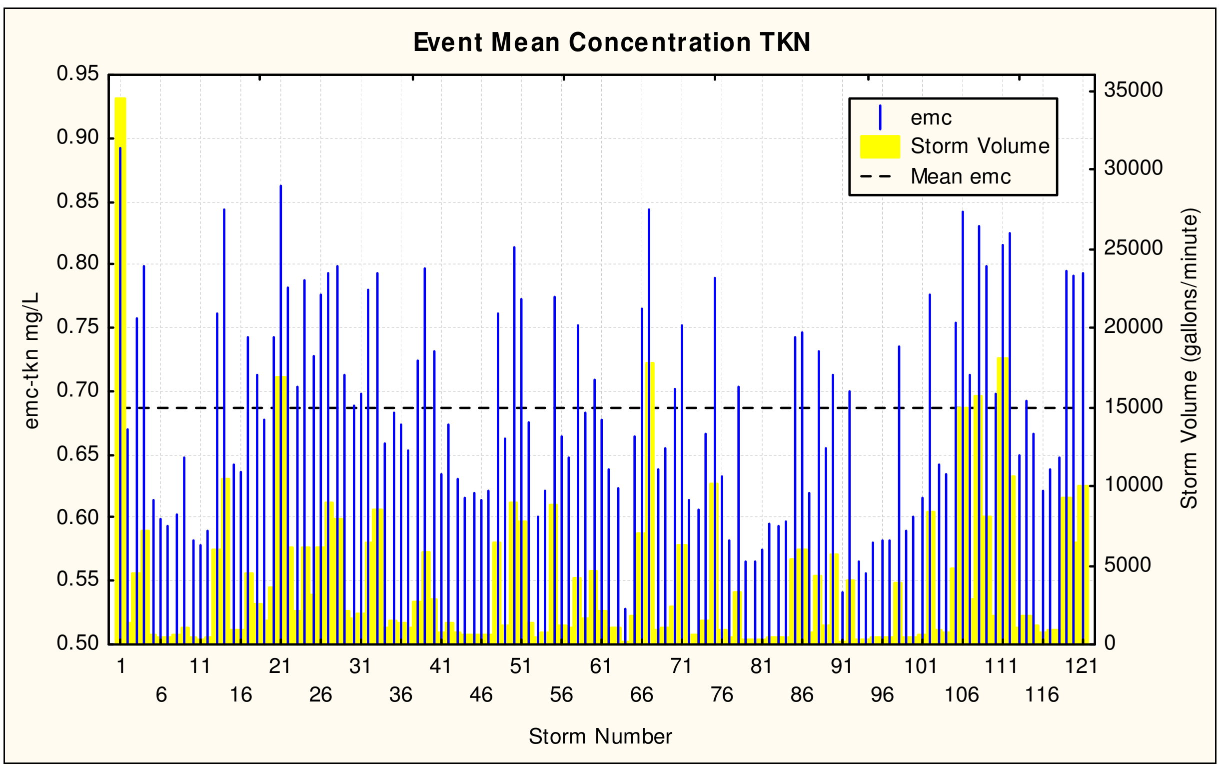


Figure 8-17a: Event Mean Concentration for Total Kjeldahl Nitrogen (TKN) 2005-2006

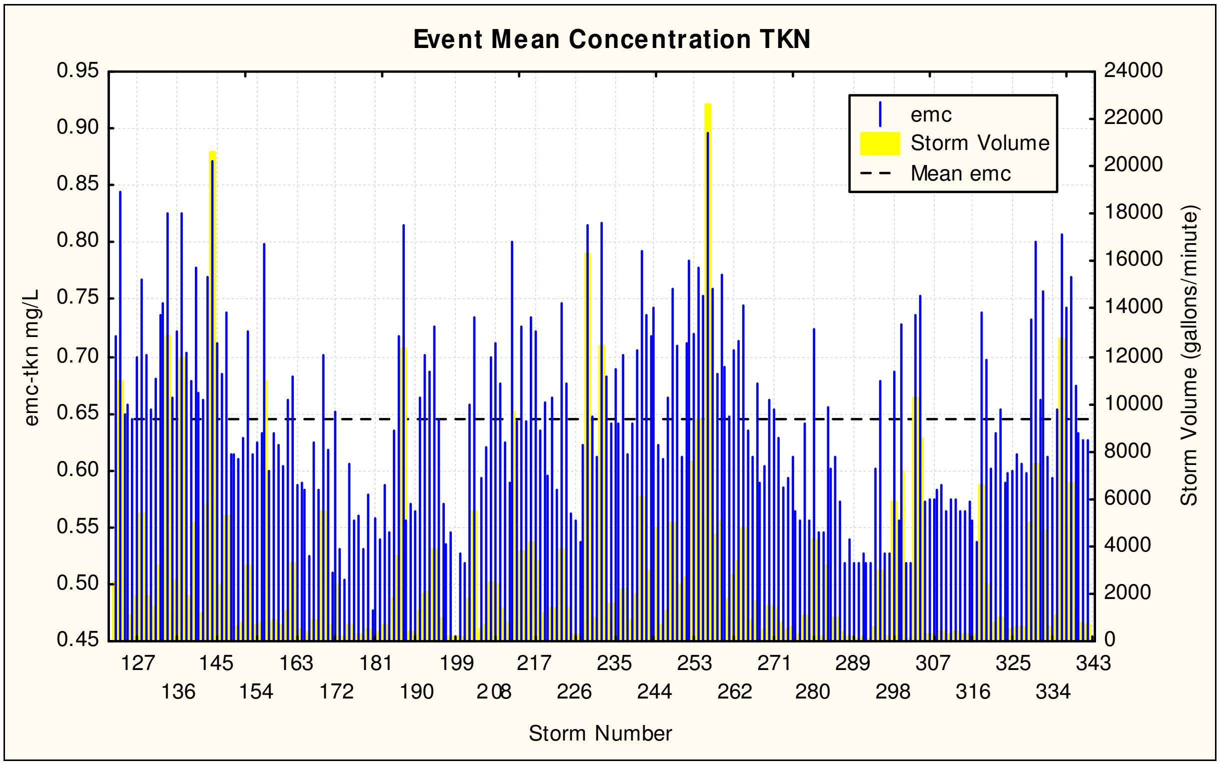


Figure 8-17b: Event Mean Concentration for Total Kjeldahl Nitrogen (TKN) 2007-2008

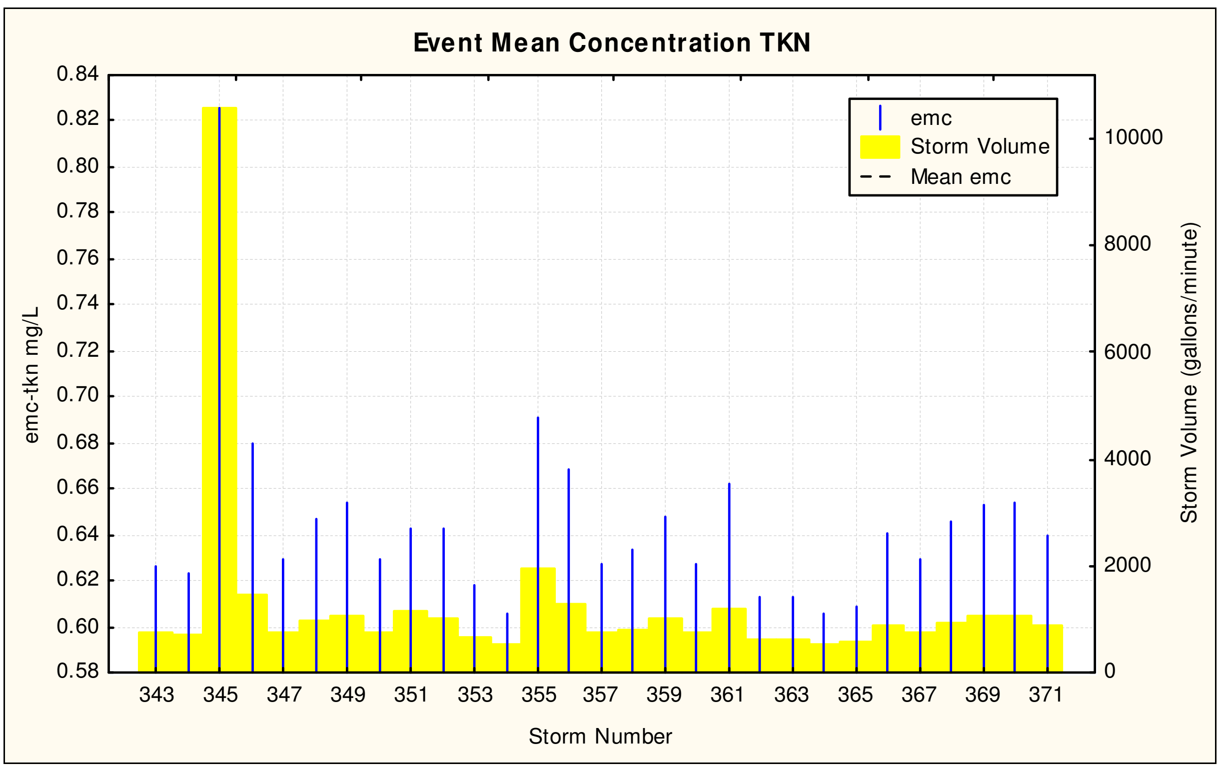


Figure 8-17c: Event Mean Concentration for Total Kjeldahl Nitrogen (TKN) 2009

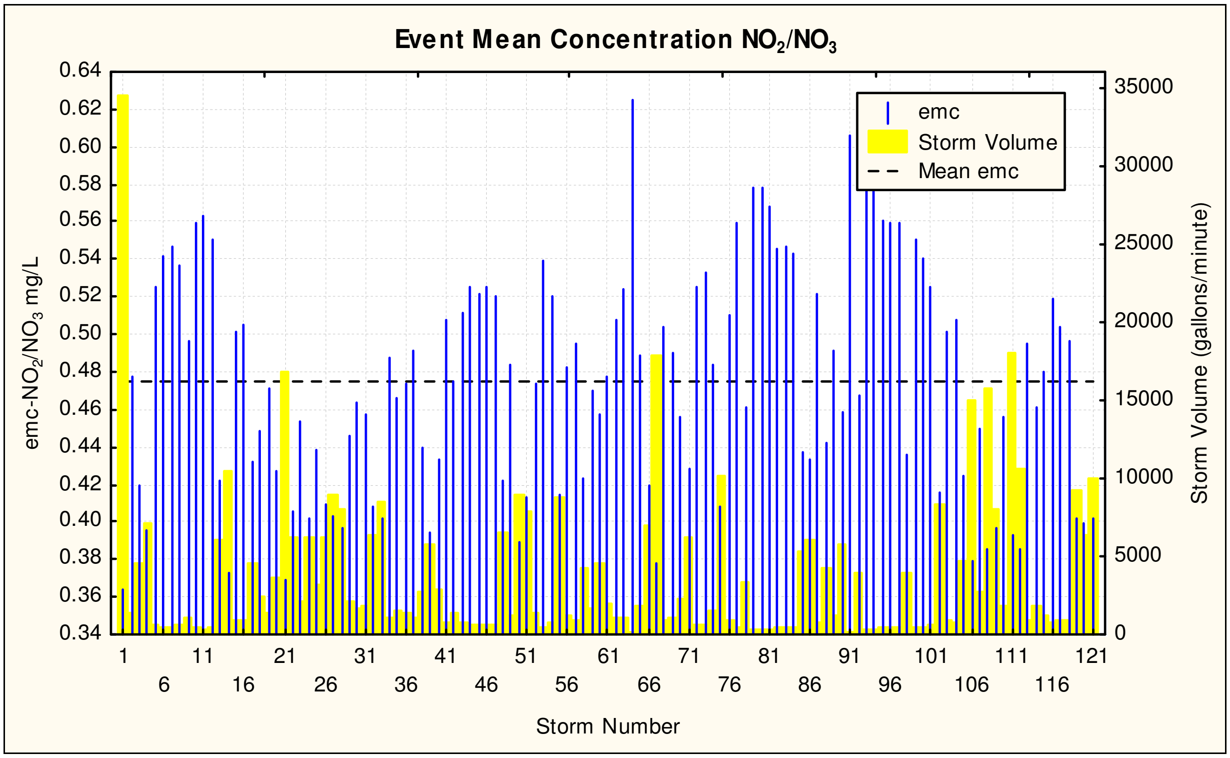


Figure 8-18a: Event Mean Concentration for Nitrate/Nitrite (NO_2/NO_3) 2005-2006

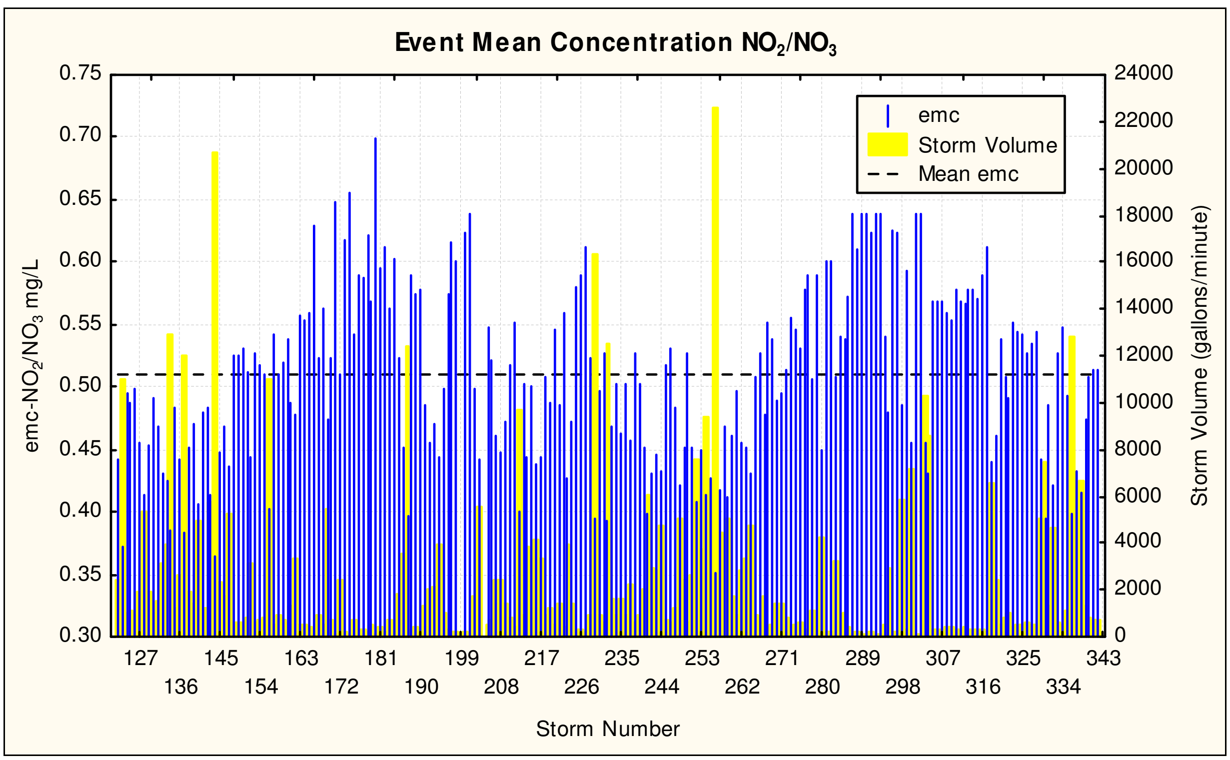


Figure 8-18b: Event Mean Concentration for Nitrate/Nitrite (NO_2/NO_3) 2007-2008

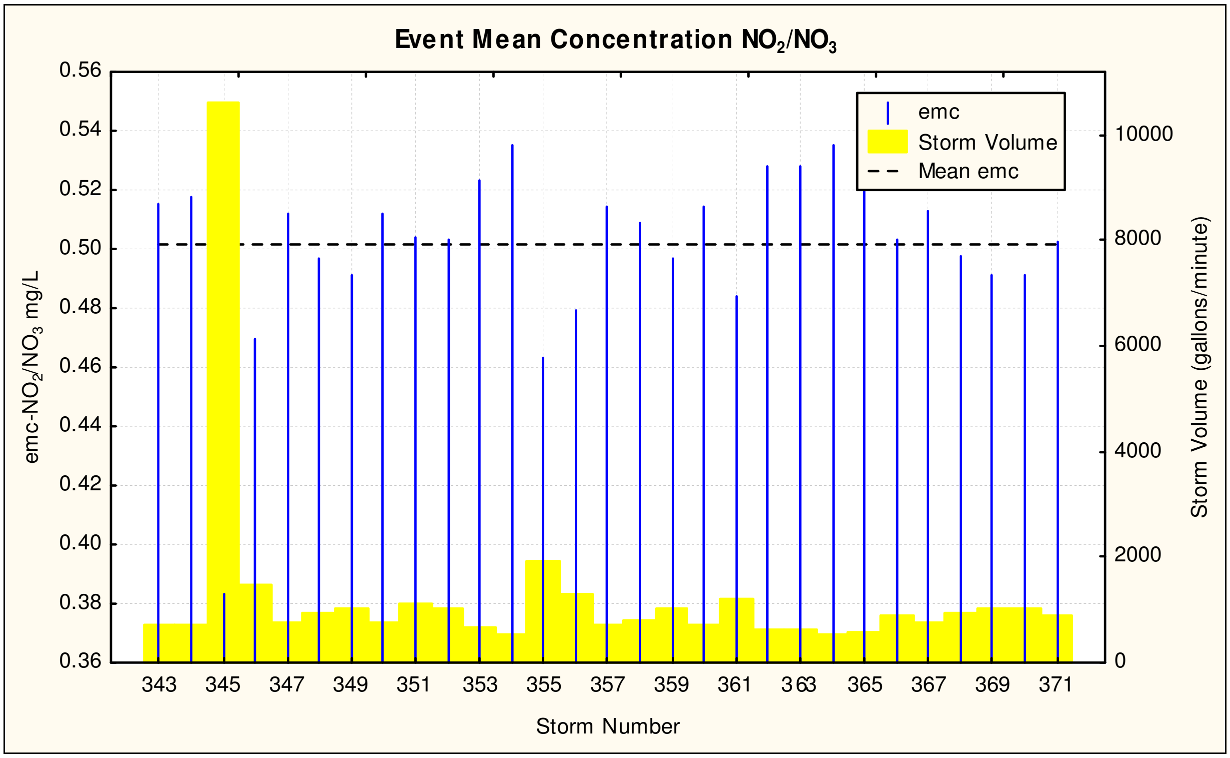


Figure 8-18c: Event Mean Concentration for Nitrate/Nitrite (NO_2/NO_3) 2009

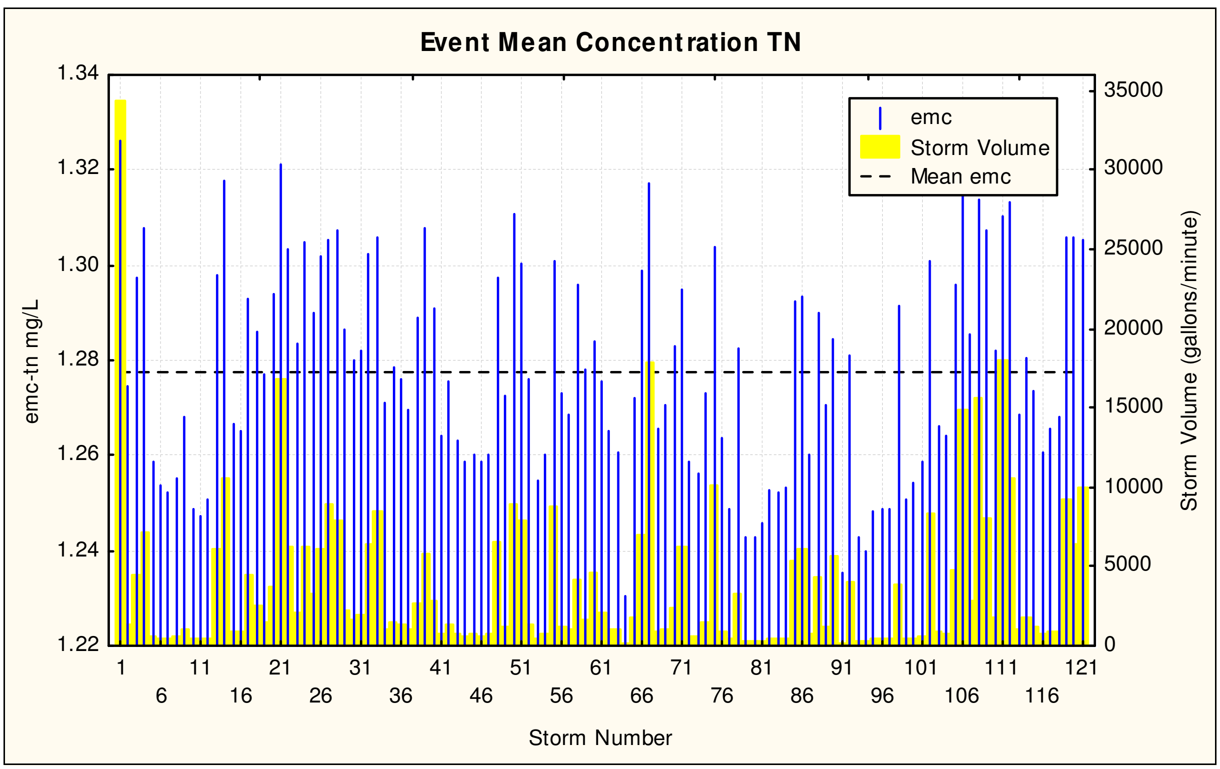


Figure 8-19a: Event Mean Concentration for Total Nitrogen (TN) 2005-2006

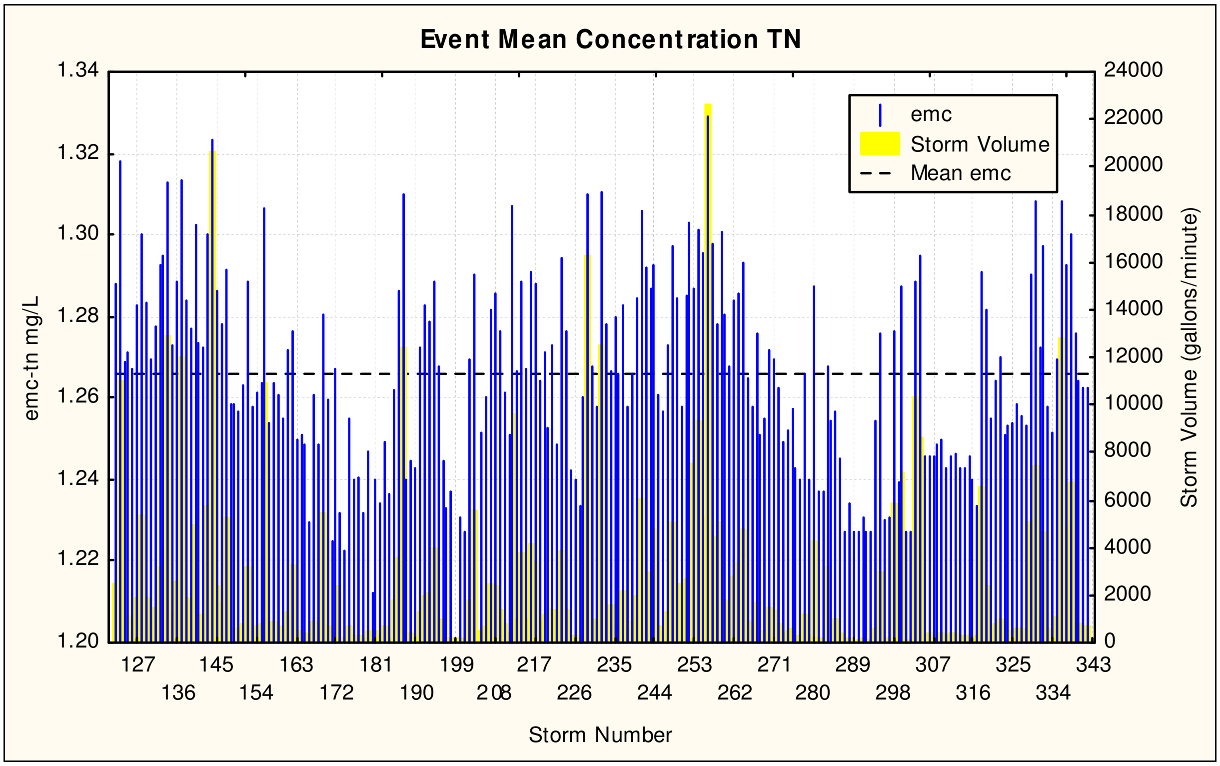


Figure 8-19b: Event Mean Concentration for Total Nitrogen (TN) 2007-2008

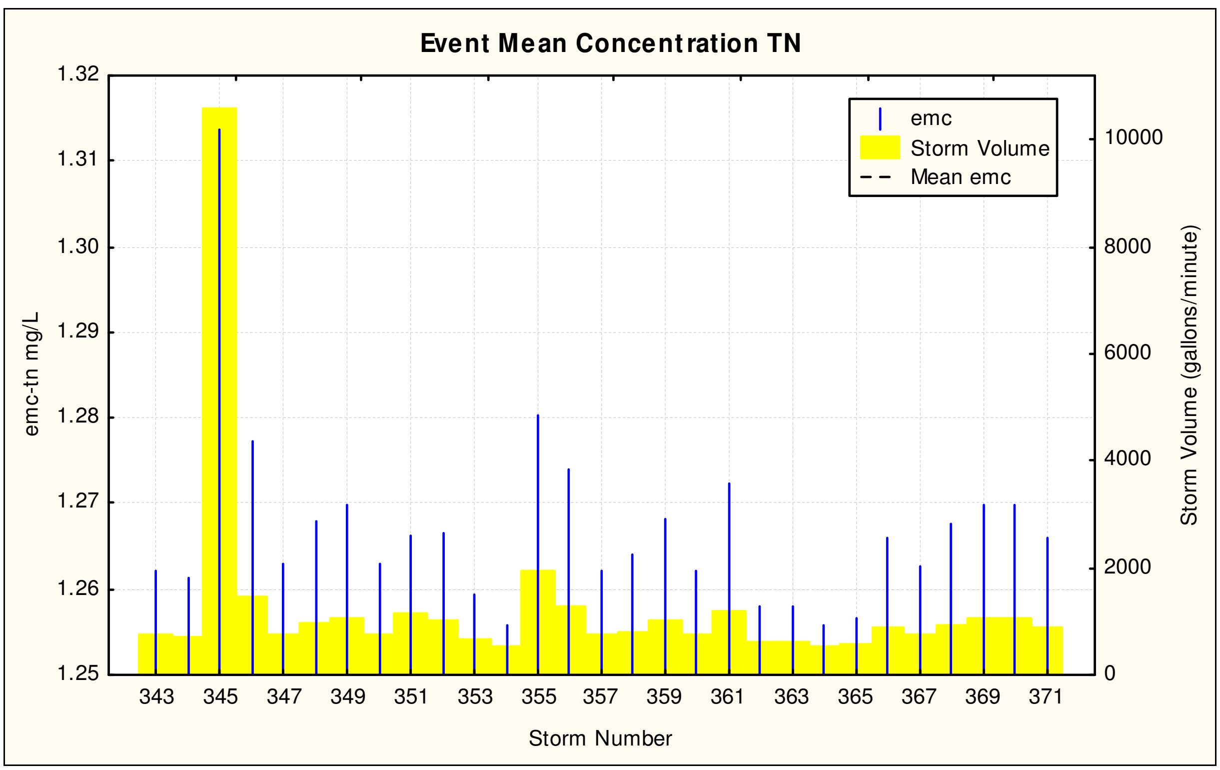


Figure 8-19c: Event Mean Concentration for Total Nitrogen (TN) 2009

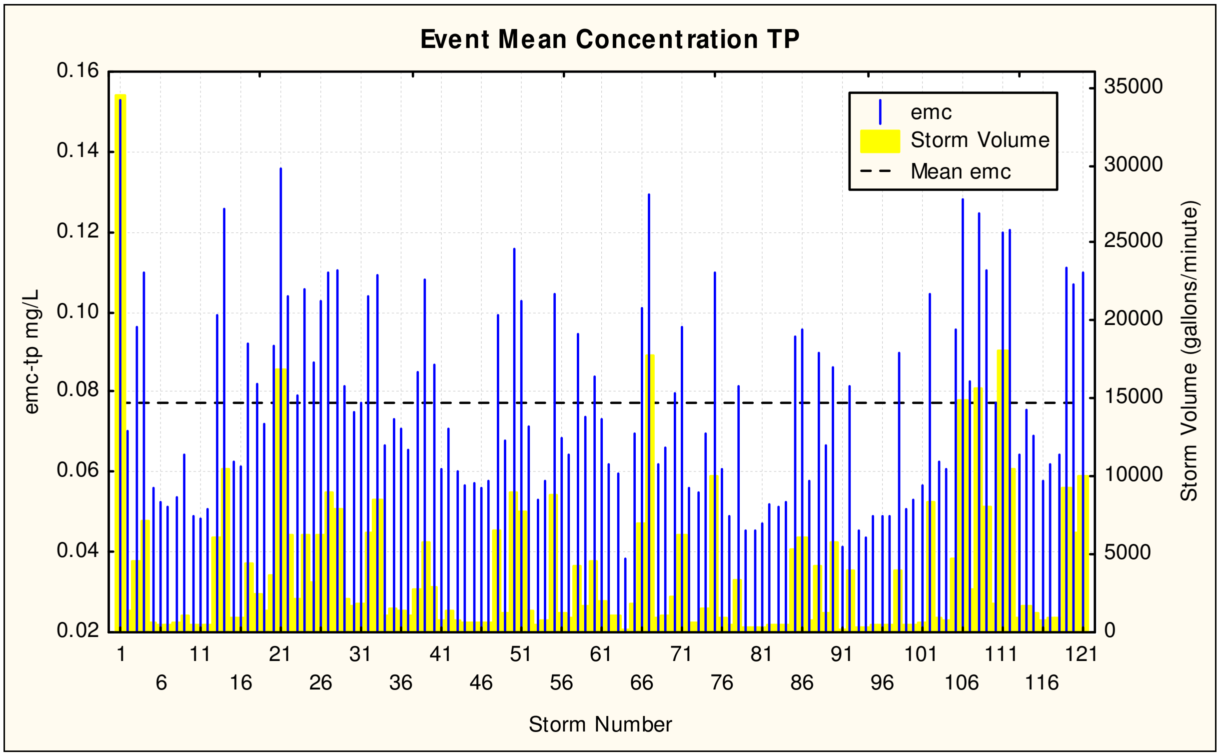


Figure 8-20a: Event Mean Concentration for Total Phosphorus (TP) 2005-2006

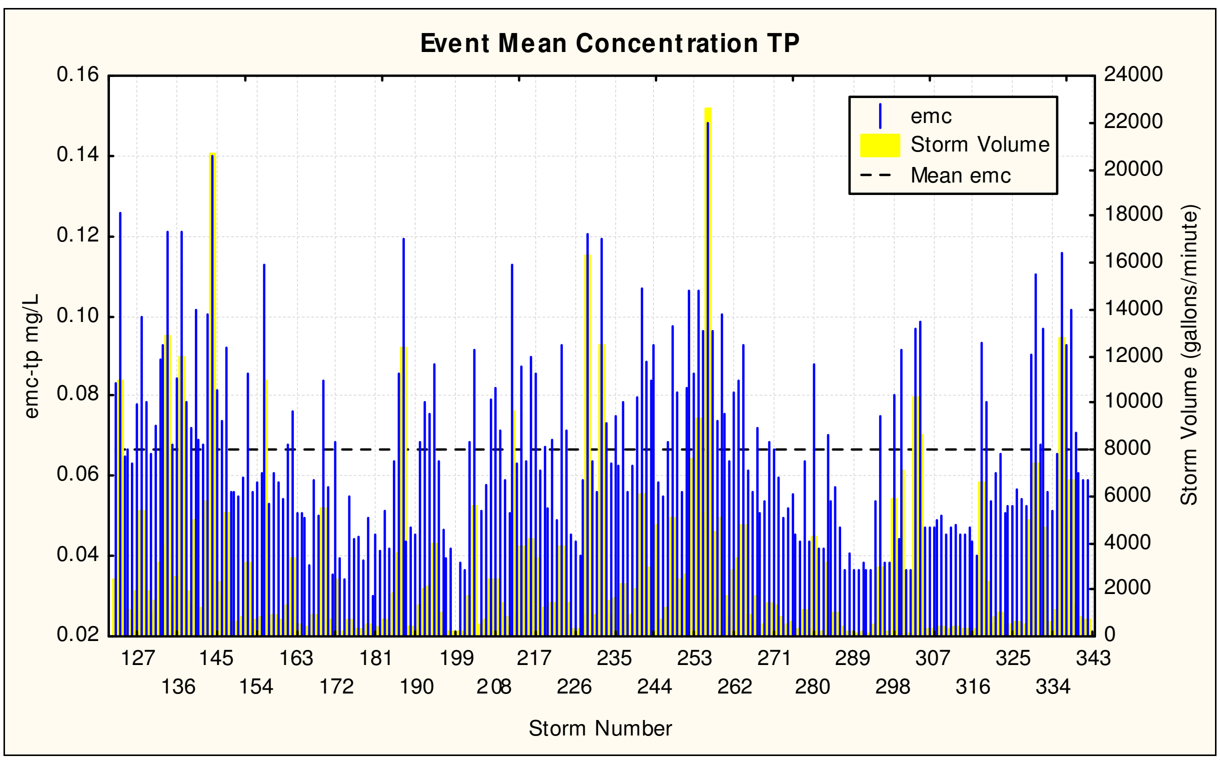


Figure 8-20b: Event Mean Concentration for Total Phosphorus (TP) 2007-2008

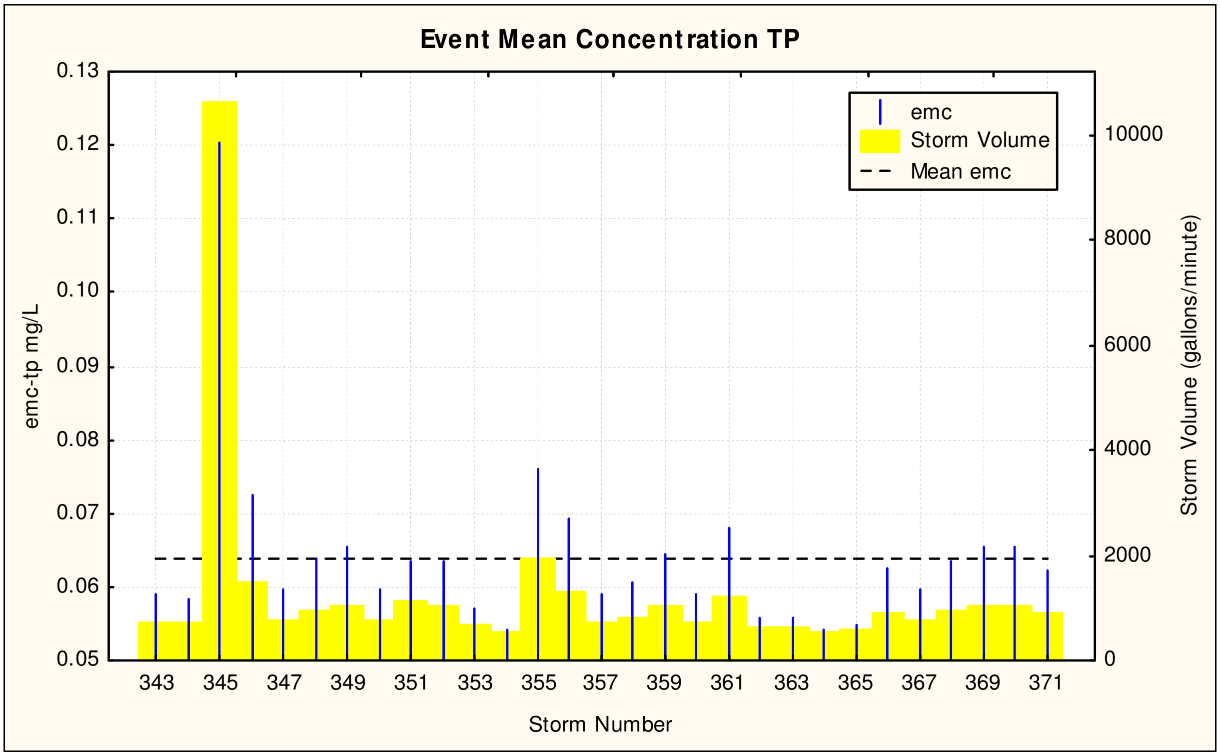


Figure 8-20c: Event Mean Concentration for Total Phosphorus (TP) 2009

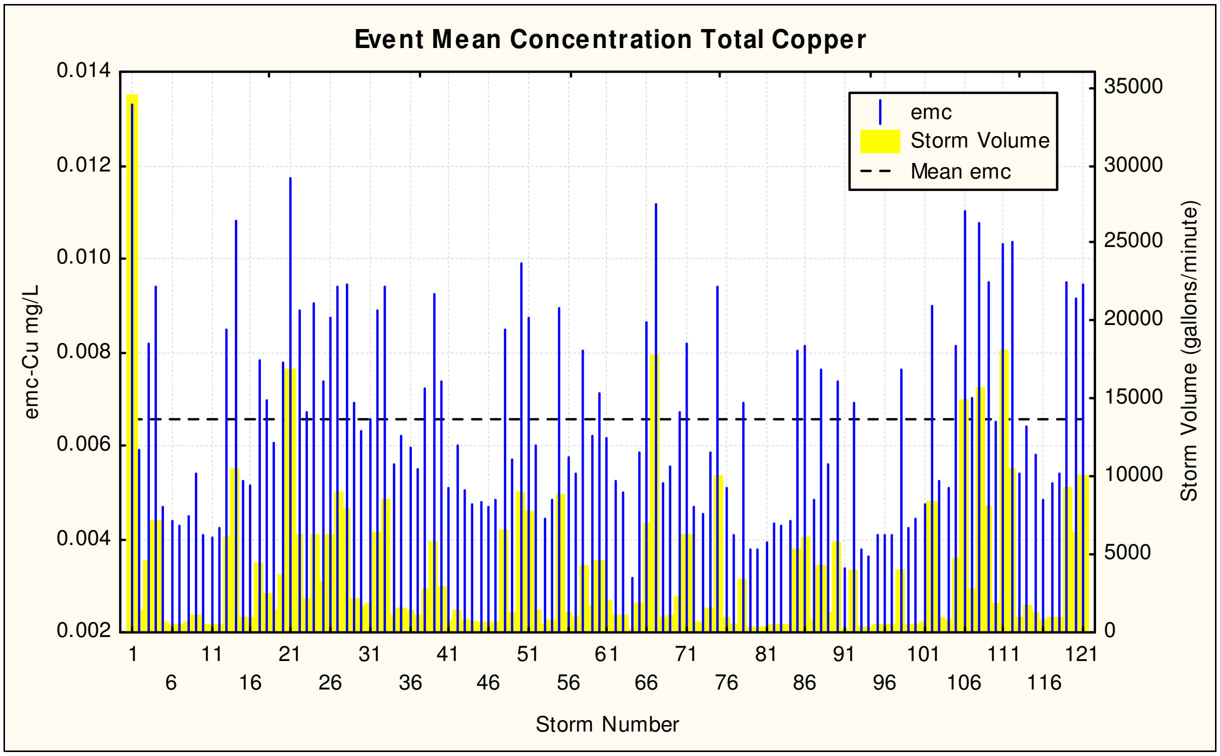


Figure 8-21a: Event Mean Concentration for Total Copper 2005-2006

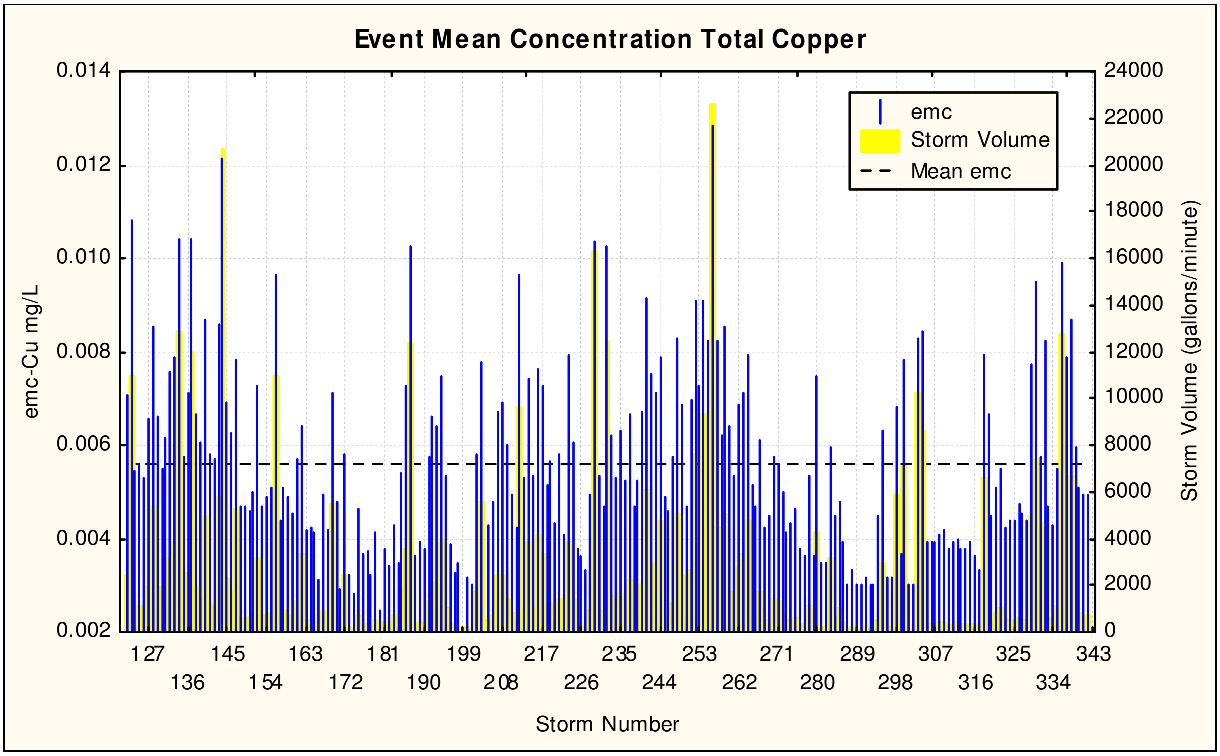


Figure 8-21b: Event Mean Concentration for Total Copper 2007-2008

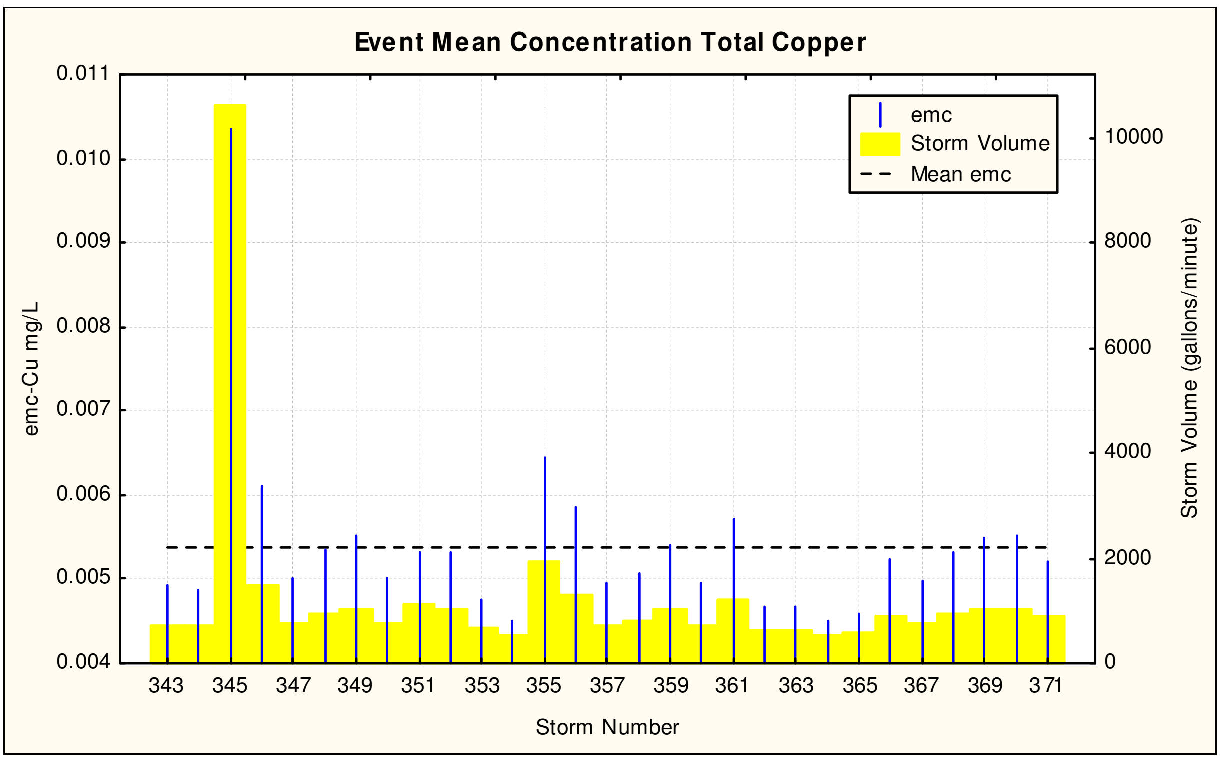


Figure 8-21c: Event Mean Concentration for Total Copper 2009

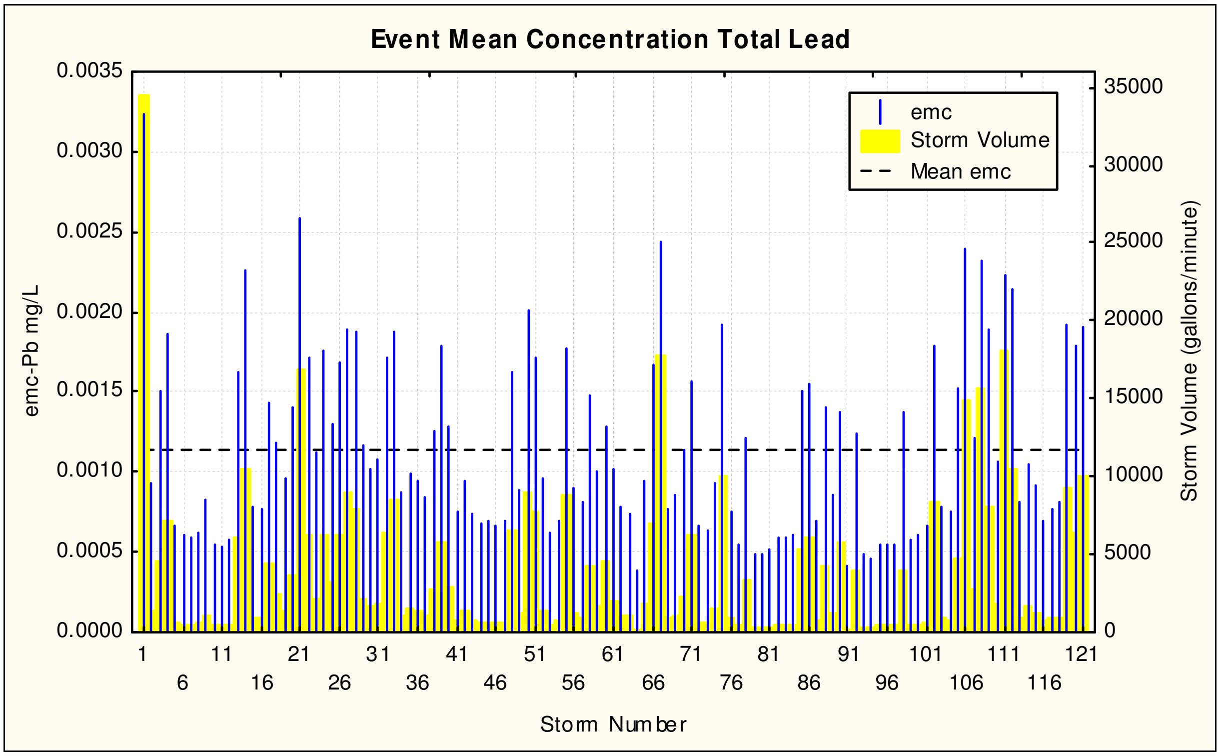


Figure 8-22a: Event Mean Concentration for Total Lead 2005-2006

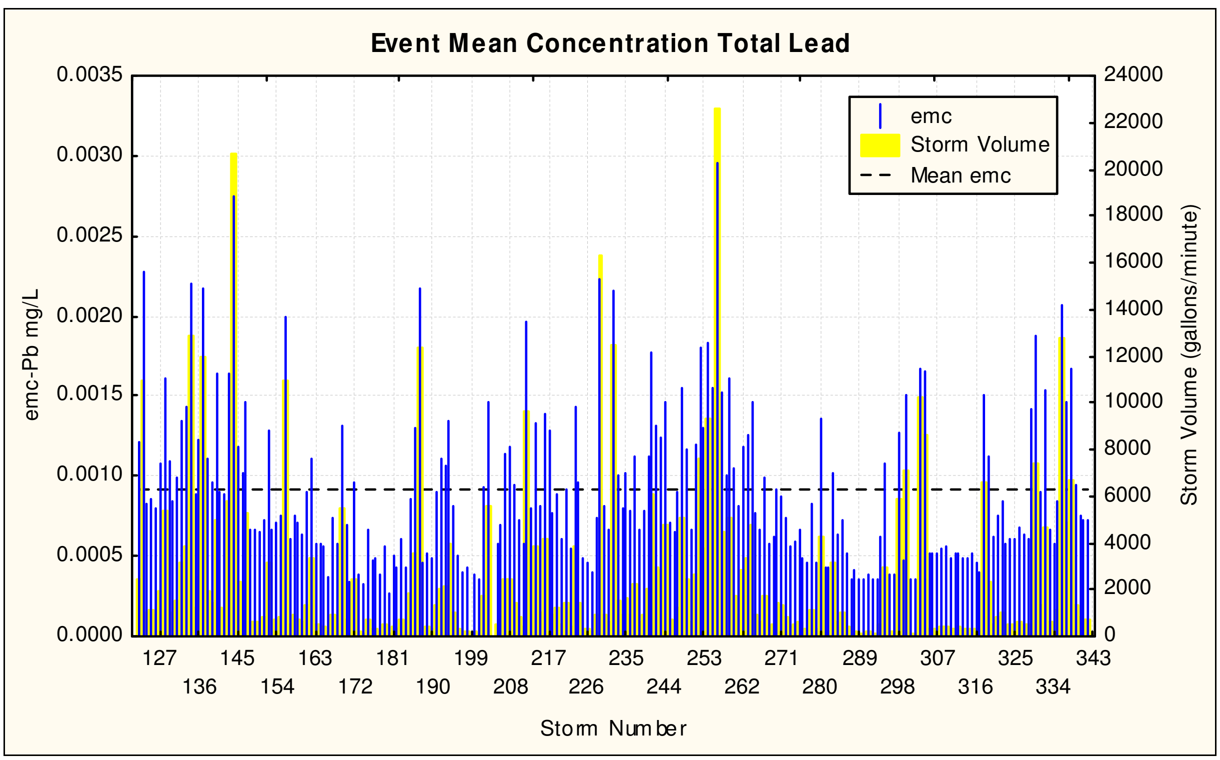


Figure 8-22b: Event Mean Concentration for Total Lead 2007-2008

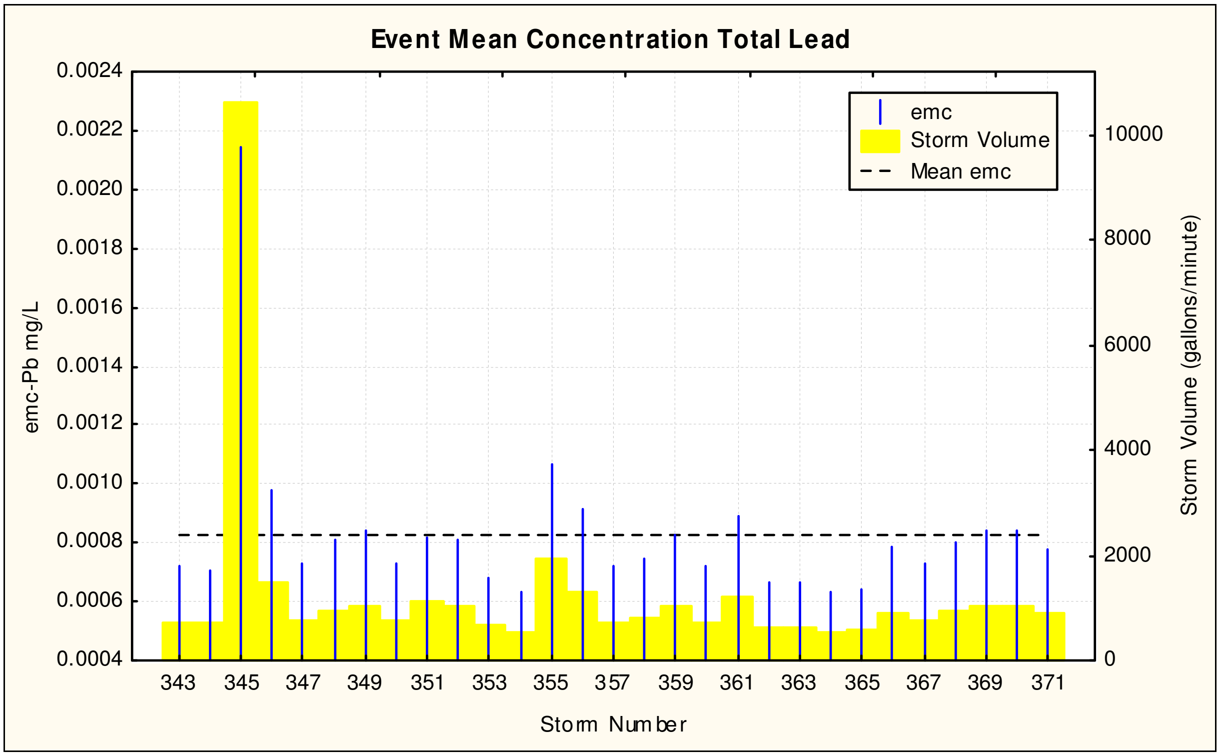


Figure 8-22c: Event Mean Concentration for Total Lead 2009

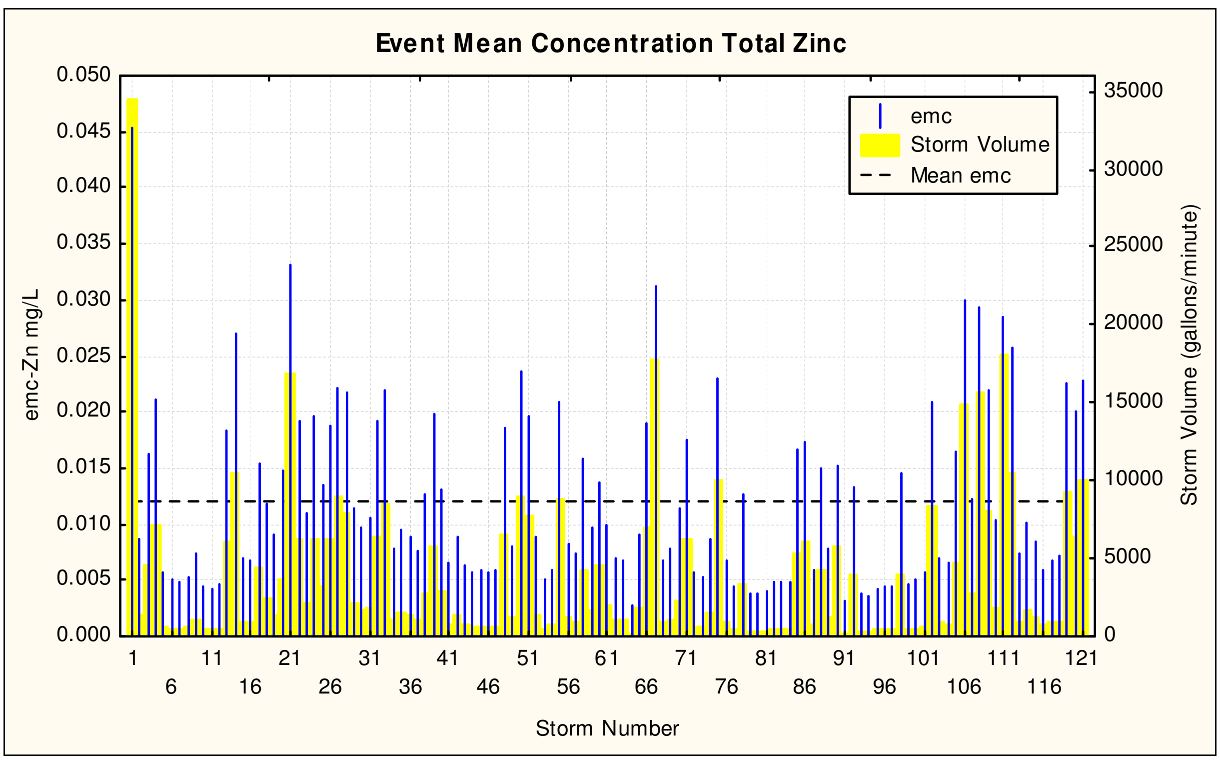


Figure 8-23a: Event Mean Concentration for Total Zinc 2005-2006

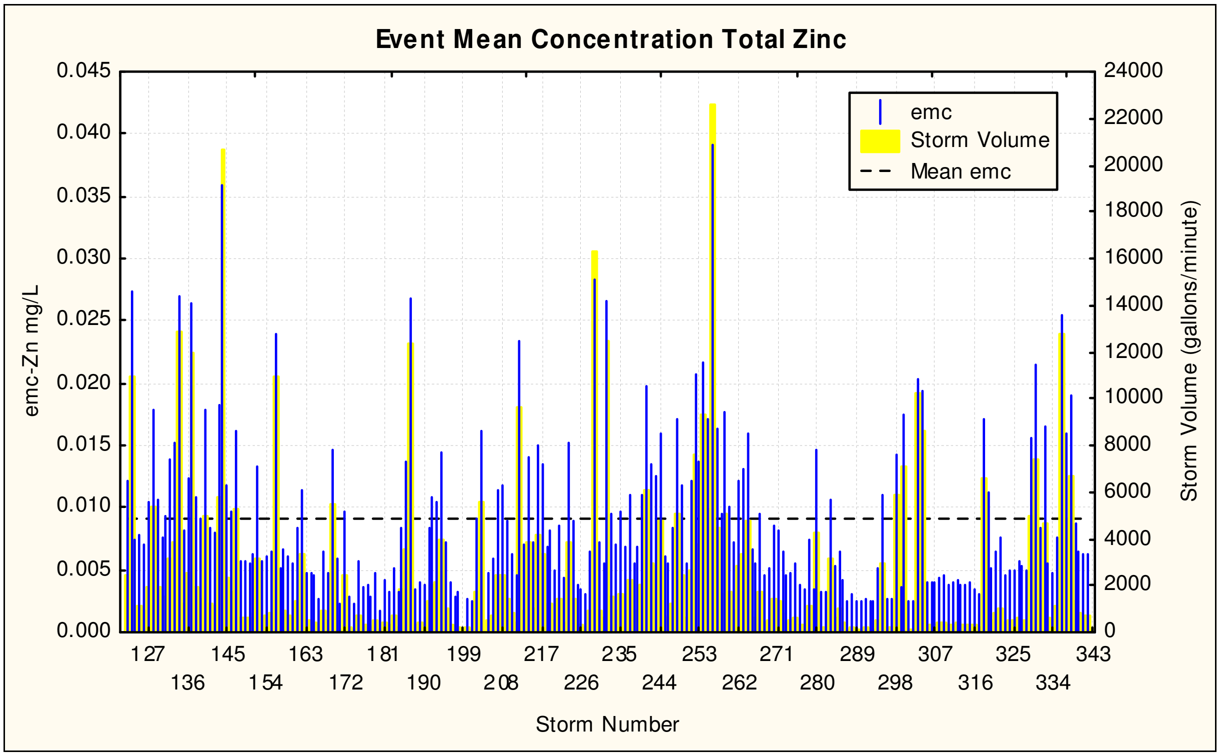


Figure 8-23b: Event Mean Concentration for Total Zinc 2007-2008

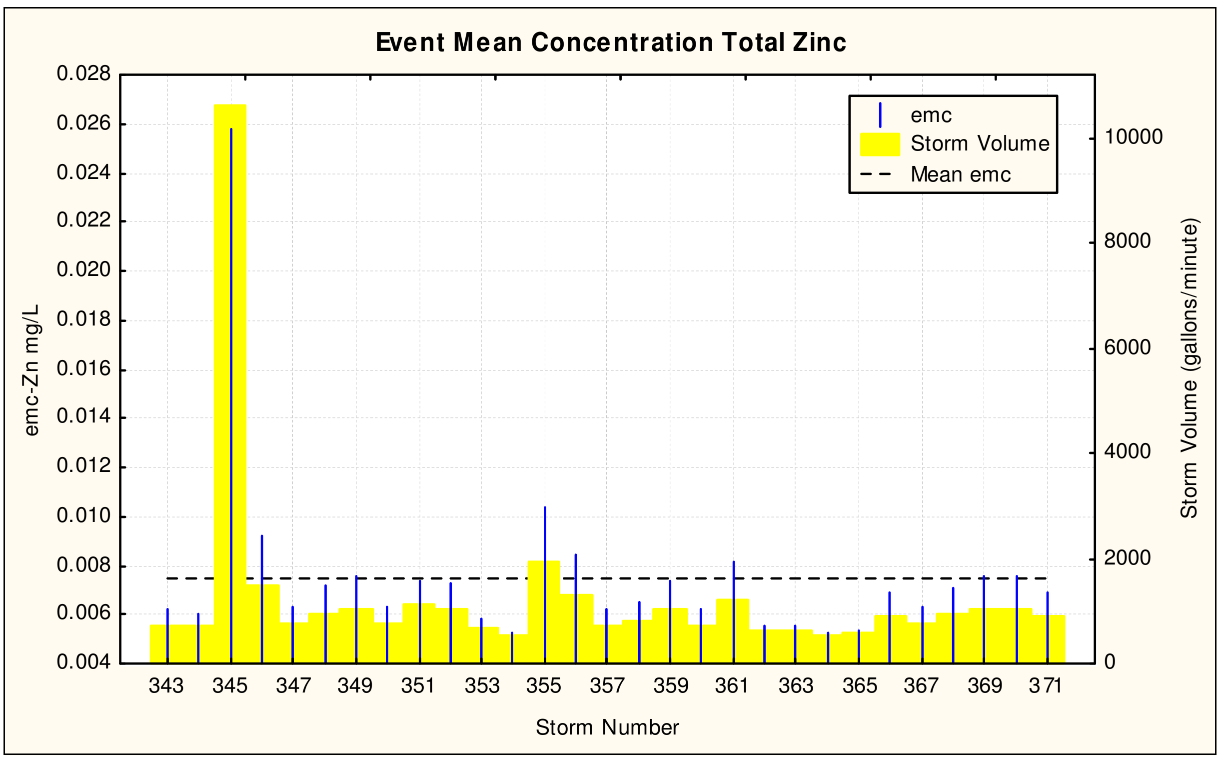


Figure 8-23c: Event Mean Concentration for Total Zinc 2009

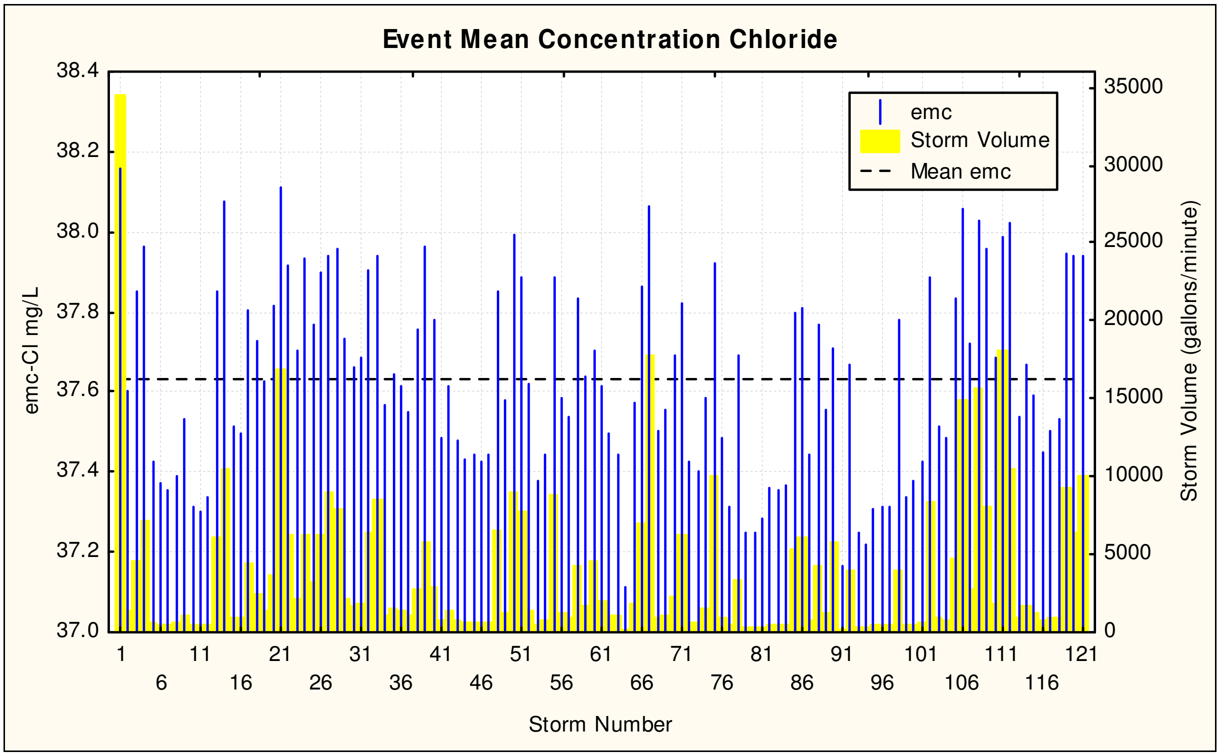


Figure 8-24a: Event Mean Concentration for Chloride 2005-2006

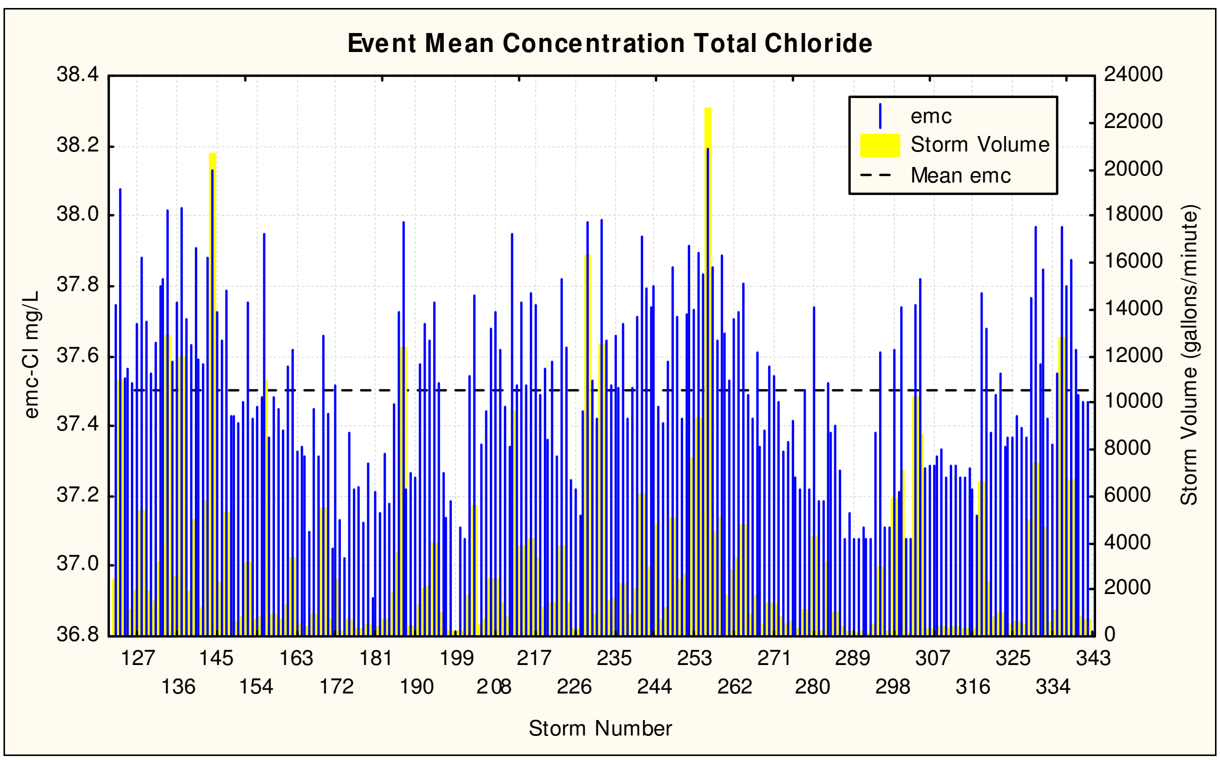


Figure 8-24b: Event Mean Concentration for Chloride 2007-2008

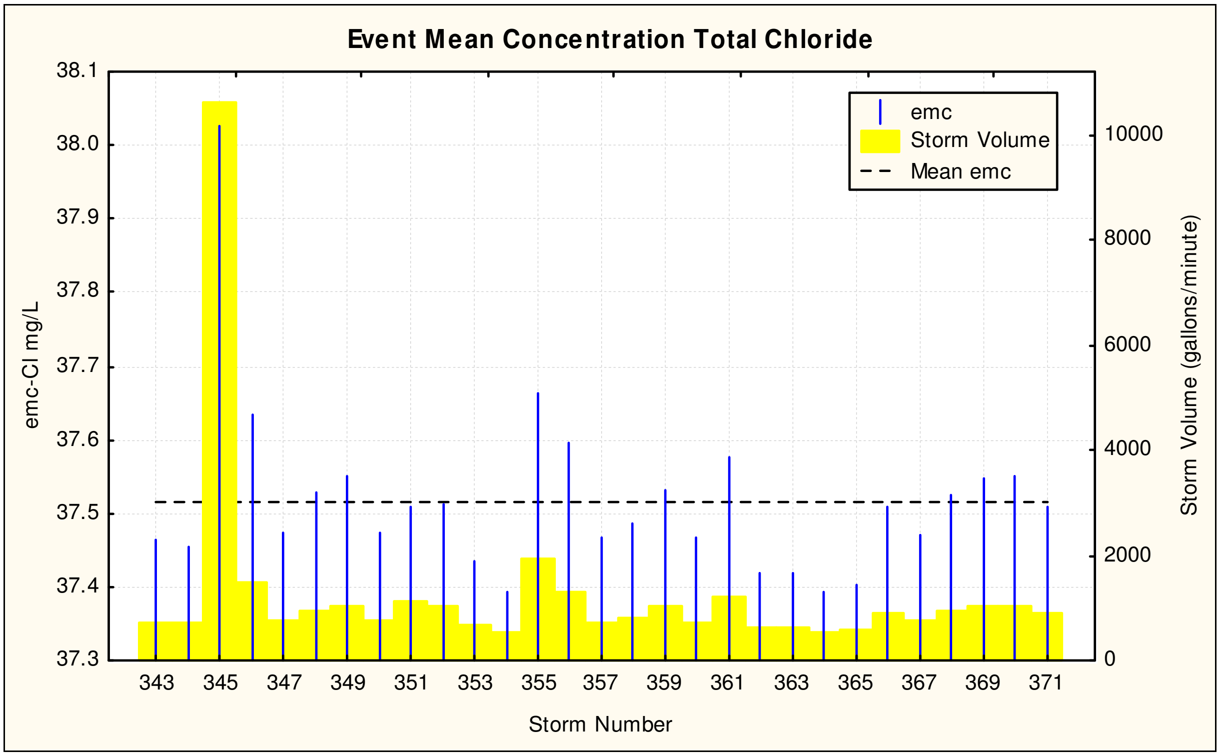


Figure 8-24c: Event Mean Concentration for Chloride 2009

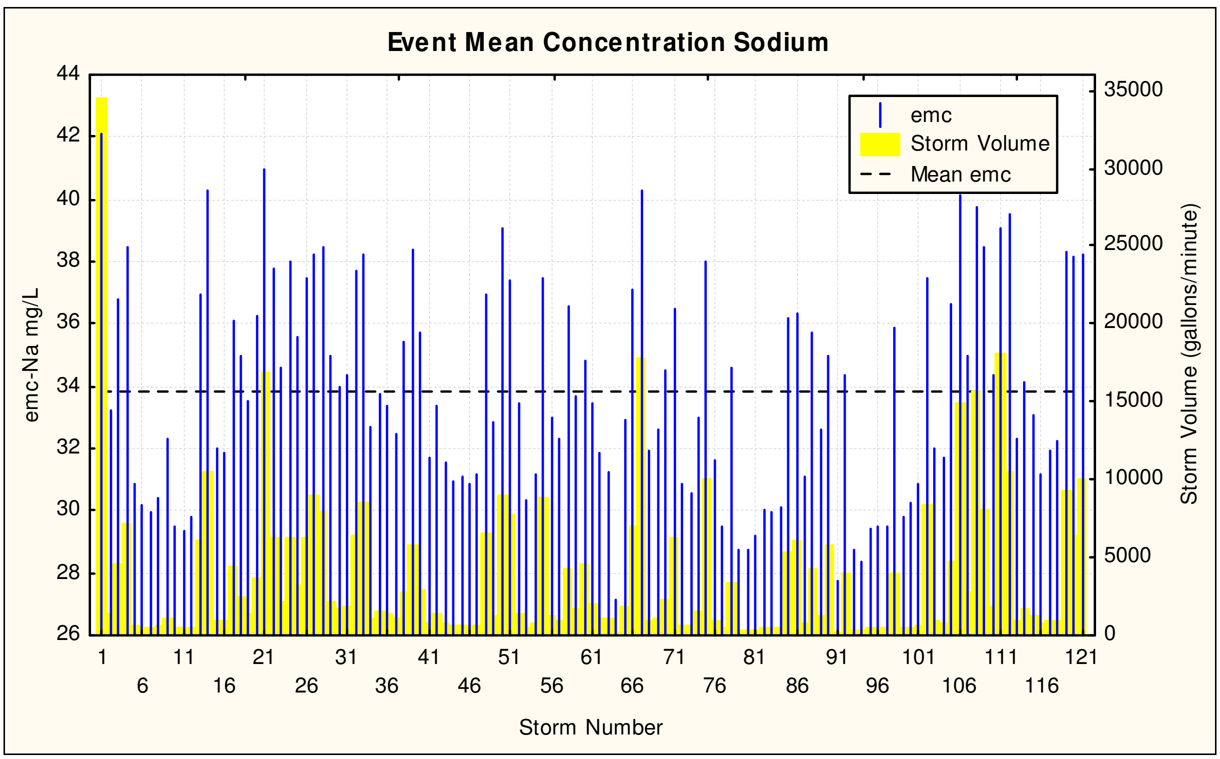


Figure 8-25a: Event Mean Concentration for Sodium 2005-2006

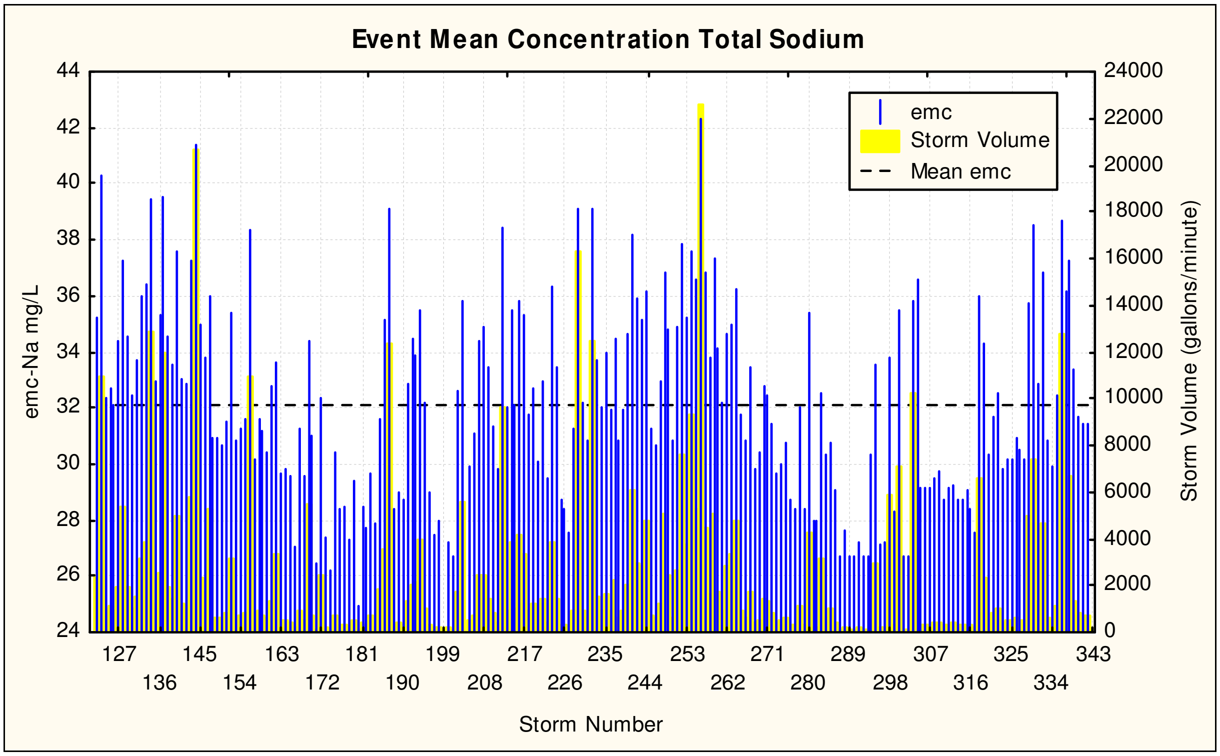


Figure 8-25b: Event Mean Concentration for Sodium 2007-2008

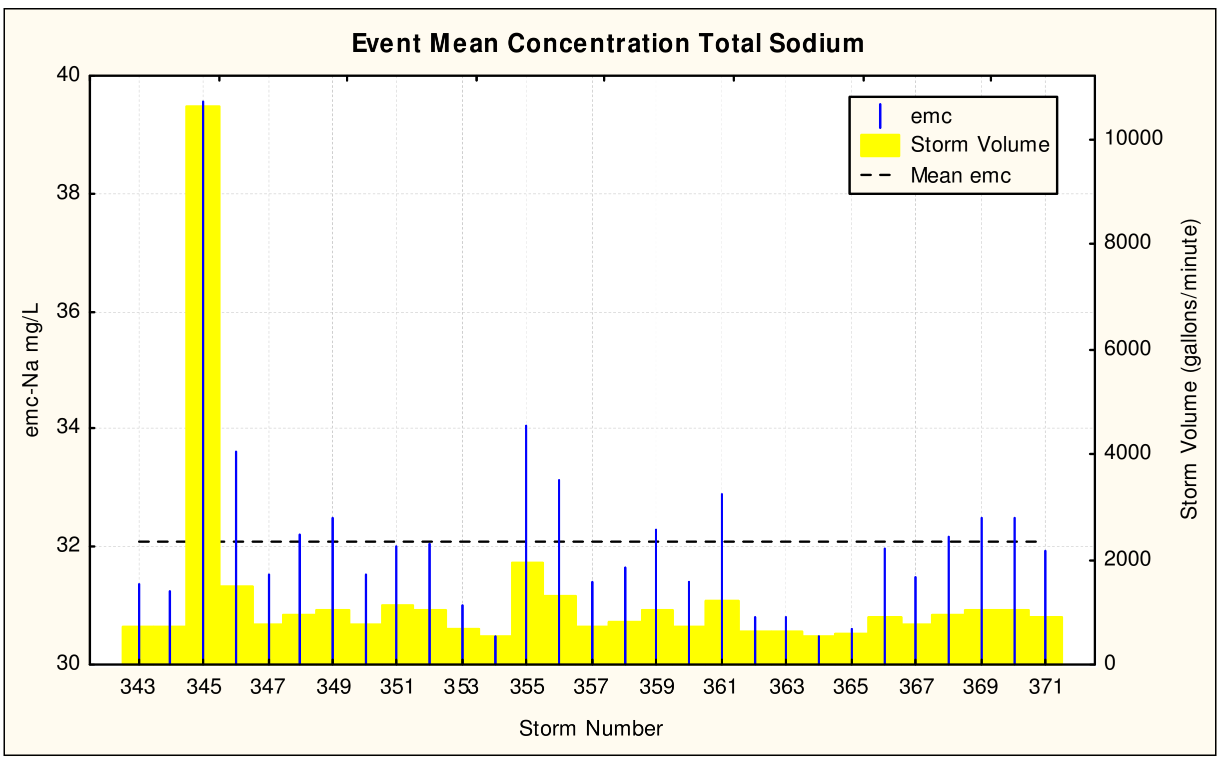
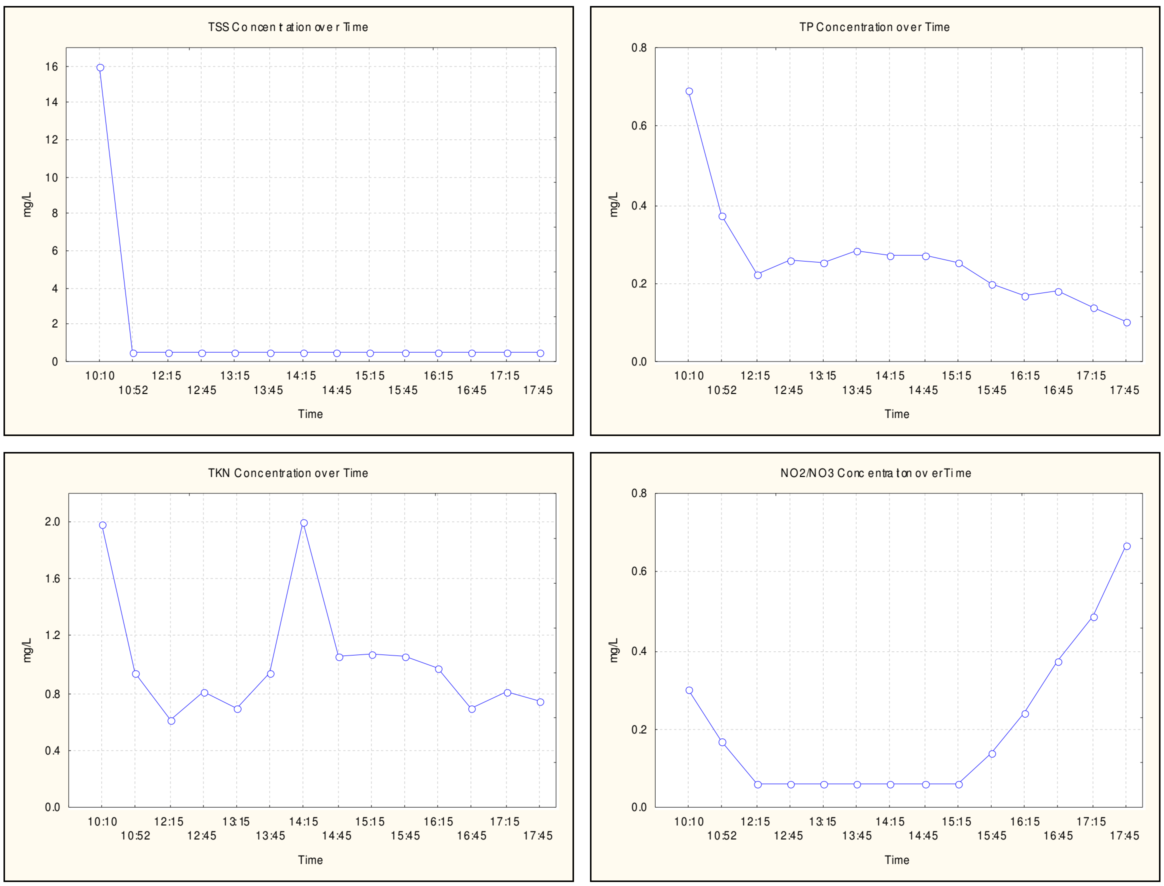


Figure 8-25c: Event Mean Concentration for Sodium 2009

Although we do not yet have a relationship between concentration and discharge at the outfall site, we have been collecting storm event samples at the outfall. Figure 8-26 shows one storm as an example of how the concentration for TSS, TP, TKN, Nitrate/Nitrite, and Total Copper changes over time during the storm. The precipitation started at 9:15 and ended at 13:15. The 10:10 and 12:15 samples are rising stages and the rest are falling stages. The total rainfall for the storm was 0.72 inches. Levels for all five parameters are high at the beginning of the storm. TSS showed the biggest drop, with all but the first sample being below the detection limit. Total Copper was also below detection limit for all but the first and last sample. When the problems with the discharge rating curve at the outfall are resolved, EMCs and pollutant loads will be reported.



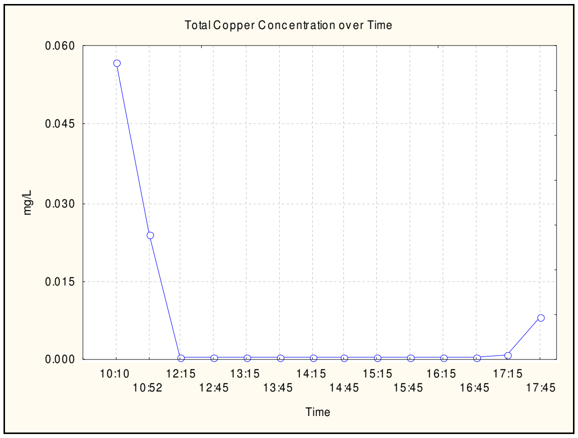


Figure 8-26: Concentration over Time for TSS, TP, TKN, NO2/NO3, Total Copper during storm event on 11/13/08

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 took 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). Baseflow monitoring in Upper Gwynns Falls occurred only at the USGS gage site. The baseflow sites in Scotts Level Branch, Powder Mill Run, and Upper Gwynns Falls should be monitored quarterly during baseflow conditions (preceded by a minimum of 72 hours dry weather). Baseflow sampling occurred three times for Scott's Level and once for Powder Mill Run.

Analysis of baseflow pollutants is especially important in relation to nitrogen. Research conducted by the County indicates that ~50% of the nitrogen load occurs during dry weather conditions. The baseflow sampling was 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.

Table 8-7: 2008 Daily Baseflow Pollutant Loads for Scott's 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	0.32	1.2254	0.0006	0.70	3.59	0.0016
SL-02	1,908	0.29	1.0941	0.0006	0.75	3.38	0.0018
SL-03	1,434	0.22	0.1921	0.0001	0.85	2.04	0.0014
SL-04	1,167	0.25	0.4019	0.0003	0.83	1.92	0.0016
SL-05 - Trib	202	0.94	0.0476	0.0002	2.42	0.85	0.0042

SL-06	742	0.40	0.2963	0.0004	0.92	1.03	0.0014
SL-07 - Trib	62	0.22	0.0340	0.0005	0.95	0.33	0.0053
SL-08	451	0.19	0.2863	0.0006	0.98	1.59	0.0035
SL-10	265	0.21	0.2869	0.0011	1.13	1.07	0.0040
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	1.09	4.81	0.0022	0.056	0.20	0.00009
SL-02	1,908	1.12	4.47	0.0023	0.042	0.08	0.00004
SL-03	1,434	1.19	2.23	0.0016	0.040	0.04	0.00003
SL-04	1,167	1.23	2.33	0.0020	0.044	0.07	0.00006
SL-05 Trib.	202	3.70	0.90	0.0045	0.147	0.02	0.00010
SL-06	742	1.46	1.33	0.0018	0.042	0.03	0.00004
SL-07 Trib.	62	1.18	0.36	0.0058	0.016	0.00	0.00000
SL-08	451	1.26	1.87	0.0041	0.029	0.04	0.00009
SL-09 - Outfall							
SL-10	265	1.38	1.36	0.0051	0.048	0.06	0.00023

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 are suspected to be from the stormwater management pond in which this tributary originates or from small sewage leakages. The investigation into this is still ongoing. Second, there is in general a decrease in nitrate/nitrite concentrations in a downstream direction (SL-10 → SL-1). The same pattern of decrease in a downstream direction is exhibited by total phosphorus and total nitrogen. 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 October 1, 2005 through March 3, 2009 resulting in 120,575 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:

$P_L = (P_C * .000008345) * (CFS * 448.8 * 15)$, 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.

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 USGS gaged site (SL-01) Calendar Year 2008

Parameter	Pounds/ Year	Pound/Acre	% by Season	Storm Event lbs.	% Load as Storm Flow	Baseflow lbs.	% Load as Baseflow
TSS							
Fall	122,441	56.01	24.0%	119,340	97.5%	3,101	2.5%
Winter	77,775	35.58	15.2%	71,933	92.5%	5,842	7.5%
Spring	90,279	41.30	17.7%	85,586	94.8%	4,693	5.2%
Summer	27,781	12.71	5.4%	26,812	96.5%	969	3.5%
Total	**510,481**	**233.52**		**472,382**	**92.5%**	**38,099**	**7.5%**
TKN							
Fall	1,825	0.83	33.7%	1,596	87.5%	229	12.5%
Winter	1,354	0.62	25.0%	990	73.1%	364	26.9%
Spring	1,660	0.76	30.6%	1,340	80.7%	320	19.3%
Summer	581	0.27	10.7%	480	82.6%	101	17.4%
Total	**5,420**	**2.48**		**4,406**	**81.3%**	**1,014**	**18.7%**
NO_2/NO_3							
Fall	790	0.36	30.3%	588	74.4%	202	25.6%
Winter	684	0.31	26.2%	390	57.0%	294	43.0%
Spring	802	0.37	30.8%	534	66.6%	268	33.4%
Summer	330	0.15	12.7%	221	67.0%	109	33.0%
Total	**2,606**	**1.19**		**1,733**	**66.5%**	**873**	**33.5%**
TN							
Fall	2,772	1.27	32.3%	2,298	82.9%	474	17.1%
Winter	2,185	1.00	25.5%	1,458	66.7%	727	33.3%
Spring	2,645	1.21	30.8%	1,996	75.5%	649	24.5%
Summer	978	0.45	11.4%	751	76.8%	227	23.2%
Total	**8,580**	**3.92**		**6,503**	**75.8%**	**2,077**	**24.2%**
TP							
Fall	302	0.14	35.9%	281	93.0%	21	7.0%
Winter	205	0.09	24.4%	170	82.9%	35	17.1%
Spring	252	0.12	30.0%	222	88.1%	30	11.9%
Summer	82	0.04	9.8%	74	90.2%	8	9.8%
Total	**841**	**0.38**		**747**	**88.8%**	**94**	**11.2%**
Total Copper							
Fall	26.1	0.0119	36.0%	24.4	93.5%	1.7	6.5%
Winter	17.7	0.0081	24.4%	14.8	83.6%	2.9	16.4%
Spring	21.7	0.0099	29.9%	19.2	88.5%	2.5	11.5%
Summer	7.1	0.0032	9.8%	6.4	90.1%	0.7	9.9%
Total	**72.6**	**0.0332**		**64.8**	**89.3%**	**7.8**	**10.7%**
Total Lead							
Fall	6.1	0.0028	37.2%	5.9	96.7%	0.2	3.3%
Winter	4.0	0.0018	24.4%	3.6	90.0%	0.4	10.0%
Spring	4.8	0.0022	29.3%	4.4	91.7%	0.4	8.3%
Summer	1.5	0.0007	9.1%	1.4	93.3%	0.1	6.7%
Total	**16.4**	**0.0075**		**15.3**	**93.3%**	**1.1**	**6.7%**
Total Zinc							
Fall	83.8	0.0383	38.6%	81.7	97.5%	2.1	2.5%
Winter	53.1	0.0243	24.4%	49.2	92.7%	3.9	7.3%
Spring	61.5	0.0281	28.3%	58.4	95.0%	3.1	5.0%
Summer	18.9	0.0086	8.7%	18.3	96.8%	0.6	3.2%
Total	**217.3**	**0.0994**		**207.6**	**95.5%**	**9.7**	**4.5%**

Sodium							
Fall	79,939	36.57	32.2%	65,835	82.4%	14,104	17.6%
Winter	63,456	29.03	25.5%	41,897	66.0%	21,559	34.0%
Spring	76,672	35.07	30.8%	57,401	74.9%	19,271	25.1%
Summer	28,536	13.05	11.5%	21,718	76.1%	6,818	23.9%
Total	**248,603**	**113.73**		**186,851**	**75.2%**	**61,752**	**24.8%**
Chloride							
Fall	86,442	39.54	33.4%	74,935	86.7%	11,507	13.3%
Winter	64,887	29.68	25.1%	46,687	72.0%	18,200	28.0%
Spring	79,387	36.32	30.7%	63,358	79.8%	16,029	20.2%
Summer	28,050	12.83	10.8%	22,877	81.6%	5,173	18.4%
Total	**258,766**	**118.37**		**207,857**	**80.3%**	**50,90**	**19.7%**

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 20.7% of the precipitation fell during the fall season, 24.3% 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 (7.5%), Total Phosphorus (11.2%), Total Zinc (4.5%) and Total Lead (6.7%), and Total Copper (10.7%). The Nitrite/Nitrate load has about one-third of its load delivered during baseflow conditions. TKN (ammonia and organic nitrogen) has 18.7% of its load delivered during baseflow conditions. Organic nitrogen will be mobilized both within the stream channel and washed into the stream during storm events.

8.3.3 Geomorphological Monitoring Results

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.

Scotts Level Branch Geomorphological Monitoring Results: Overlays of the 18 randomly selected cross sections show the changes that occurred in 2007-2008 and 2005-2008. Figure 8-27 shows an overlay of CX #1. Table 8-9 presents the amount of aggradation (filling) or degradation (cutting) within the active channel, and Table 8-10 (listed from upstream to downstream) summarizes Table 8-9. Data in Table 8-9 were annualized to standardize aggradation and degradation estimates. The data files and plots can be viewed on the separate data CD accompanying this report. All of the random cross sections remained relatively unchanged during 2007-2008 in terms of net change (Table 8-10). Cross Section #1 showed a larger net change (fill) during 2005-2008. This reach is characterized by a steep gradient leading into a flatter depositional zone at the cross section. The reach also integrates the sediment fluxes from the entire upstream study area, which may explain the more pronounced fill as compared to the other cross sections.

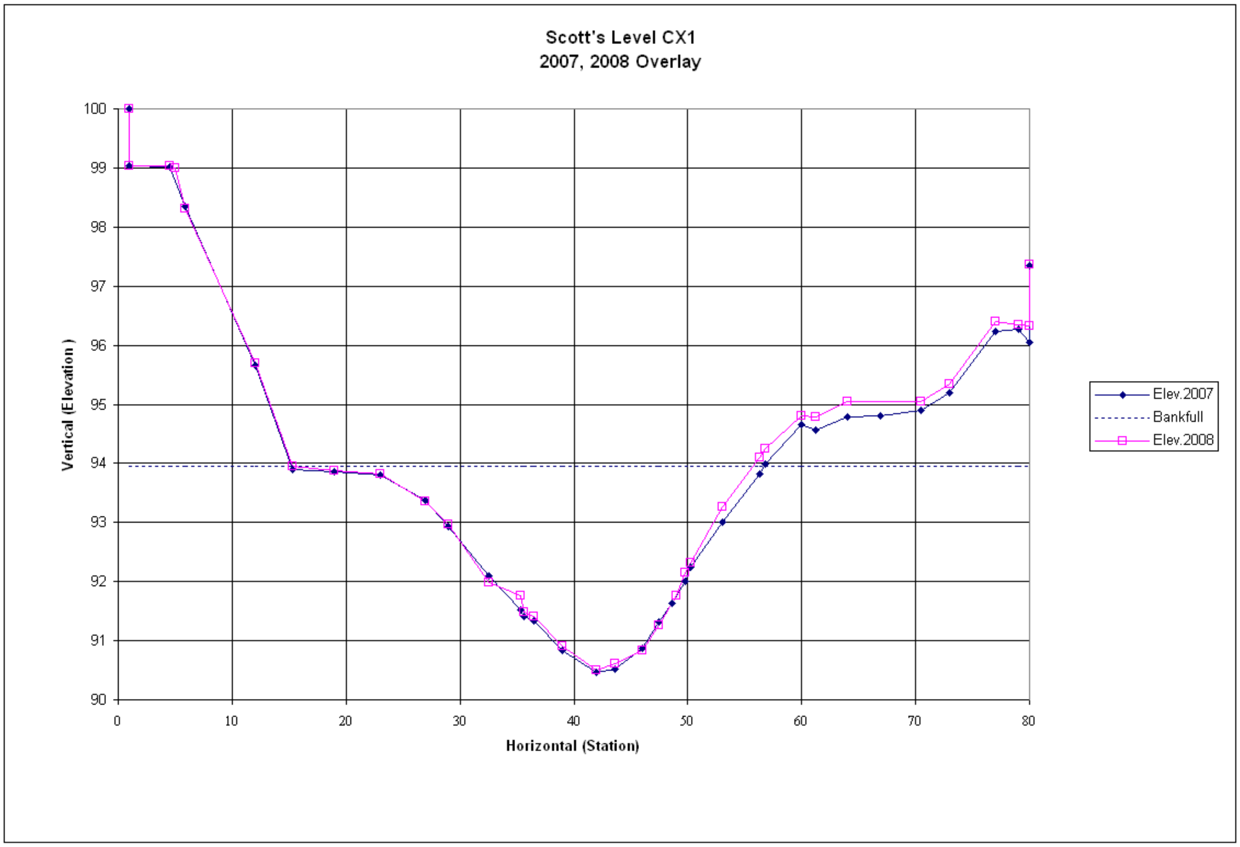


Figure 8-27: Scotts Level Branch Geomorphological Cross Section 1 Overlay showing net deposition especially on the right channel side between the 2007 and 2008 surveys.

Since most of the input hydrology to Scotts Level is from 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 and 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. The results of the initial cross-section measurements are found on the separate data CD accompanying this report.

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

SL 20: Change (cu ft)	Period: 2007 – 2008	Period: 2005 – 2008	SL 10: Change (cu ft)	Period: 2007 – 2008	Period: 2005 – 2008
Total Cut	-0.4	-0.2	Total Cut	-1.9	-0.5

Total Fill	2.9	1.1	Total Fill	0.7	0.6
Total Change	3.3	1.3	Total Change	2.6	1.1
Net Change	2.5	0.9	Net Change	-1.2	0.1
SL19: Change (cu ft)	**Period: 2007 – 2008**	**Period: 2005 – 2008**	**SL 9: Change (cu ft)**	**Period: 2007 – 2008**	**Period: 2005 – 2008**
Total Cut	-0.4	0.0	Total Cut	-4.3	-0.8
Total Fill	3.3	1.8	Total Fill	0.7	0.7
Total Change	3.7	1.8	Total Change	5.0	1.5
Net Change	2.9	1.8	Net Change	-3.6	-0.1
SL 18: Change (cu ft)	**Period: 2007 – 2008**	**Period: 2005 – 2008**	**SL 8: Change (cu ft)**	**Period: 2007 – 2008**	**Period: 2005 – 2008**
Total Cut	-6.9	-2.2	Total Cut	-5.1	-2.0
Total Fill	3.0	0.2	Total Fill	0.2	0.2
Total Change	9.9	2.4	Total Change	5.3	2.2
Net Change	-3.9	-2.0	Net Change	-4.9	-1.8
SL 17: Change (cu ft)	**Period: 2007 – 2008**	**Period: 2005 – 2008**	**SL 7: Change (cu ft)**	**Period: 2007 – 2008**	**Period: 2005 – 2008**
Total Cut	-1.6	-0.7	Total Cut	-1.0	-1.8
Total Fill	0.6	0.2	Total Fill	6.5	0.2
Total Change	2.2	0.9	Total Change	7.5	2.0
Net Change	-1.0	-0.5	Net Change	5.5	-1.6
SL 16: Change (cu ft)	**Period: 2007 – 2008**	**Period: 2005 – 2008**	**SL 6: Change (cu ft)**	**Period: 2007 – 2008**	**Period: 2005 – 2008**
Total Cut	-2.7	-0.5	Total Cut	-0.3	-0.7
Total Fill	0.1	0.6	Total Fill	2.3	0.1
Total Change	2.8	1.1	Total Change	2.6	0.8
Net Change	-2.6	0.1	Net Change	2.0	-0.6
SL 15: Change (cu ft)	**Period: 2007 – 2008**	**Period: 2005 – 2008**	**SL 5*: Change (cu ft)**	**Period: 2007 – 2008**	**Period: 2005 – 2008**
Total Cut	-2.4	-0.3	Total Cut	NA	NA
Total Fill	0.8	0.9	Total Fill	NA	NA
Total Change	3.2	1.2	Total Change	NA	NA
Net Change	-1.6	0.6	Net Change	NA	NA
SL 14: Change (cu ft)	**Period: 2007 – 2008**	**Period: 2005 – 2008**	**SL 4*: Change (cu ft)**	**Period: 2007 – 2008**	**Period: 2005 – 2008**
Total Cut	-3.5	-1.1	Total Cut	NA	NA
Total Fill	0.6	0.6	Total Fill	NA	NA
Total Change	4.1	1.7	Total Change	NA	NA
Net Change	-2.9	-0.5	Net Change	NA	NA
SL 13: Change (cu ft)	**Period: 2007 – 2008**	**Period: 2005 – 2008**	**SL 3: Change (cu ft)**	**Period: 2007 – 2008**	**Period: 2005 – 2008**
Total Cut	-0.6	-0.7	Total Cut	0.0	0.0
Total Fill	2.2	0.8	Total Fill	2.2	0.9
Total Change	2.8	1.5	Total Change	2.2	0.9
Net Change	1.6	0.1	Net Change	2.2	0.9
SL 12: Change (cu ft)	**Period: 2007 – 2008**	**Period: 2005 – 2008**	**SL 2: Change (cu ft)**	**Period: 2007 – 2008**	**Period: 2005 – 2008**
Total Cut	-0.2	-2.9	Total Cut	-1.0	-0.7
Total Fill	2.5	1.9	Total Fill	1.6	0.5
Total Change	2.7	4.8	Total Change	2.6	-1.2
Net Change	2.3	-1.0	Net Change	0.6	-0.2

SL 11: Change (cu ft)	Period: 2007 – 2008	Period: 2005 – 2008	SL 1: Change (cu ft)	Period: 2007 – 2008	Period: 2005 – 2008
Total Cut	-0.5	-0.5	Total Cut	-0.2	-1.2
Total Fill	2.6	1.4	Total Fill	6.1	7.6
Total Change	3.1	1.9	Total Change	6.3	8.8
Net Change	2.1	0.9	Net Change	5.9	6.4

* 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 Stream Channel Changes Over Time.

SL #	CX 2007-2008	CX 2005-2008
20	a	a
19	a	a
18	d	d
17 (Trib.)	d	d
16	d	a
15	d	a
14	d	d
13	a	a
12	a	d
11	a	a
10	d	a
9	d	d
8	d	d
7	a	d
6	a	d
5	NA	NA
4	NA	NA
3	a	a
2	a	d
1	a	a

Symbols: a: aggradation, d: degradation

The aggradation/degradation and stream bank soil chemistry data, when combined with water chemistry data, allows examination of pollutant loads for various components of the Scotts Level Branch watershed. The expectation is that instream water quality estimates are equal to the sum of stream bank and watershed wash-off estimates. Table 8-11 shows loads for Total Nitrogen, Total Phosphorus, and Sediment from the instream and stream bank components of the Scotts Level Branch watershed for 2006 and 2007. Estimates of sediment loads were based on Total Suspended Solids for instream water quality and stream bank soil weights for geomorphology. Instream water quality data were taken from the 2007 NPDES Report. The pollutant load for Total Phosphorus was highest in stream bank soils, because soil particles bind phosphorus. Therefore streams typically have elevated phosphorus concentrations during stormflow. The load for Total Nitrogen was highest for instream water quality. Groundwater contributes most of the nitrogen (as baseflow) in a watershed. Sediment loads were greatest in stream bank soils in both years. Missing from this discussion is the watershed wash-off estimate, which will be made using the Scotts Level Branch outfall. The United States Geological Survey is developing a flow-rating curve for the outfall. Pollutant loads for the outfall will be included in the 2010 NPDES report, after the rating curve is complete.

Table 8-11: Pollutant Load Estimates- Comparison between Water Quality Monitoring and Geomorphology for Scotts Level Branch, 2006 - 2008

	2006		2007		2008	
Parameter	Instream Water Quality Pollutant Load (lbs/yr)	Geomorphology Pollutant Load (lbs/yr)	Instream Water Quality Pollutant Load (lbs/yr)	Geomorphology Pollutant Load (lbs/yr)	Instream Water Quality Pollutant Load (lbs/yr)	Geomorphology Pollutant Load (lbs/yr)
TN	9,747	3,634	6,804	3,201	8,580	2,282
TP	944	1,134	582	999	841	712
Sediment	362,882	1,608,633	192,205	1,416,805	510,481	1,010,274

Extending this analysis to the entire watershed (geomorphology station SL-1), which includes the portion below the gage, for stream bank soils shows loads of 1,943 lbs/yr and 772 lbs/yr for Total Nitrogen in 2007 and 2008, respectively. Total Phosphorus loads are 606 and 241 lbs/yr for 2007 and 2008, respectively. Sediment loads are 859,906 lbs/yr and 341,818 lbs/yr in 2007 and 2008, respectively. In 2007 and 2008, both nitrogen and phosphorus were processed in the stream reach upstream of Rolling Road. The sediment load was lower for the entire subwatershed than it was for the Rolling Road reach, suggesting deposition in the Rolling Road reach, which is the furthest downstream site. This analysis has begun to show patterns of nutrient and sediment loading to Scotts Level Branch. Continued water quality and stream bank soil sampling, along with estimates of loads from the outfall, should provide more refined estimates of the relative contribution of each of these components to the pollutant loads within the watershed, as well as estimates of export from the watershed. These data will allow DEPRM to more accurately determine the contribution of the various flow components to overall pollutant load estimates, and will form the basis for more accurate determination of benefits from future stream restoration.

Powder Mill Run Geomorphological Monitoring Results: Overlays of the 10 randomly selected cross sections show the changes that occurred during 2007 and 2008. 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 summarizes Table 8-12. The data suggest that Powder Mill is more actively aggrading and degrading than Scott's Level Branch. Four of the ten cross sections showed net change greater than 5 cubic feet per year. The largest change (aggradation) occurred at Cross Section #6. The stream channel at this location is flat and would be expected to act as a depositional area. It is likely that one of the larger storms during the measurement interval removed a large amount of sediment from upstream and deposited it here. Cross Sections #1, #2, and #5 experienced relatively large amounts of degradation in 2007-2008. These cross sections are located just downstream of high gradient stream reaches. Cross Section #5 is downstream of a paved road and bridge abutment, and illustrates localized stream response to upstream impervious cover. In contract, Cross Sections #9 and #10 are measured within a gabion-lined channel, which buffers the specific locations from large changes in cut and fill. However, the next downstream cross section (#8), which experienced degradation, may illustrate the effects of this stream bank and bed armoring. The imperviousness of the upstream channel likely concentrates high flows and causes downstream channel instability. All 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: 2007 – 2008	Period: 2005 – 2008	PM 5: Change (cu ft)	Period: 2007 – 2008	Period: 2005 – 2008
Total Cut	-2.1	-3.3	Total Cut	-6.8	-3.2
Total Fill	1.0	0.2	Total Fill	0.7	0.9
Total Change	3.1	3.5	Total Change	7.5	4.1
Net Change	-1.1	-3.1	Net Change	-6.1	-2.3
PM 9: Change (cu ft)	**Period: 2007 – 2008**	**Period: 2005 – 2008**	**PM 4: Change (cu ft)**	**Period: 2007 – 2008**	**Period: 2005 – 2008**
Total Cut	-1.3	-3.4	Total Cut	-2.3	-0.9
Total Fill	1.2	1.9	Total Fill	1.8	0.6
Total Change	2.4	5.3	Total Change	4.1	1.5
Net Change	-0.1	-1.5	Net Change	-1.5	-0.3
PM 8: Change (cu ft)	**Period: 2007 – 2008**	**Period: 2005 – 2008**	**PM 3: Change (cu ft)**	**Period: 2007 – 2008**	**Period: 2005 – 2008**
Total Cut	-4.7	-0.4	Total Cut	-1.6	-1.4
Total Fill	0.5	1.1	Total Fill	1.9	0.0
Total Change	5.2	1.5	Total Change	3.5	1.4
Net Change	-4.1	0.7	Net Change	0.3	-1.4
PM 7: Change (cu ft)	**Period: 2007 – 2008**	**Period: 2005 – 2008**	**PM 2: Change (cu ft)**	**Period: 2007 – 2008**	**Period: 2005 – 2008**
Total Cut	-3.0	-8.3	Total Cut	-6.0	-3.3
Total Fill	0.7	0.0	Total Fill	0.2	0.0
Total Change	3.7	8.3	Total Change	6.2	3.3
Net Change	-2.3	-8.3	Net Change	-5.8	-3.3
PM 6: Change (cu ft)	**Period: 2007 – 2008**	**Period: 2005 – 2008**	**PM 1: Change (cu ft)**	**Period: 2007 – 2008**	**Period: 2005 – 2008**
Total Cut	-0.1	-0.8	Total Cut	-4.5	-7.3
Total Fill	8.3	0.6	Total Fill	11.8	1.2
Total Change	8.4	1.4	Total Change	16.3	8.5
Net Change	8.2	-0.2	Net Change	-7.3	-6.1

Table 8-13: Powder Mill Run, 2007-2008 and 2005-2008 Stream Channel Changes

PM #	CX 2007-2008	CX 2005-2008
10	d	d
9	d	d
8	d	a
7	d	d
6	a	d
5	d	d
4	d	d

3	a	d
2	d	d
1	d	d

Symbols: a: aggradation, d: degradation

8.3.4 Biological Monitoring Results

Benthic macroinvertebrate and fish sampling were conducted as per MBSS protocols. Benthic macroinvertebrates were sampled between March 18th and March 25th, and fish were sampled between July 18th and September 11th. Scotts Level Branch was sampled at SL-1, SL-6, SL-9, SL-14, and SL-18. Powder Mill Run was sampled at PM-1, PM-4, and PM-10. 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 and fish were collected using the MBSS Physical Habitat Index. 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. Physical habitat data were converted to physical habitat index (PHI) scores and rated using criteria from Southerland et al (2005). Minimally degraded stations had PHI scores of 81-100, partially degraded stations had PHI scores of 66-80, degraded stations had PHI scores of 51-65, and severely degraded stations had PHI scores of 0-50.

The IBI scores are shown in Figure 8-28. All BIBIs were in the Very Poor condition category, except for SL-9, which was rated Poor. The FIBI scores for all sites in Scotts Level were Poor. The FIBI scores in Powder Mill were Poor at PM-1 and PM-4 and Very Poor at PM-10. FIBI scores were always higher than BIBI scores. Fish in both Scotts Level Branch and Powder Mill Run are better able than benthic macroinvertebrates to survive the acute and chronic water quality problems within both streams. The mobility of fish likely allows them to better exploit good habitat and avoid such episodic events as high storm flows. The PHI scores are shown in Figure 8-29. Scotts Level Branch physical habitat condition was degraded at SL-1 and SL-6, and severely degraded at SL-9, SL-14, and SL-18. Powder Mill Run physical habitat was degraded at PM-1, partially degraded at PM-4, and severely degraded at PM-10. Physical habitat was scored lowest at the upstream sites in both streams.

The benthic and fish communities of Scotts Level Branch and Powder Mill Run show the effects of environmental stress. Both are low in diversity and are primarily composed of pollution tolerant organisms. Stream habitat is degraded and provides poor living space for both benthos and fish. Results of biological monitoring have been consistent since monitoring began in 2005, which suggests that the baseline biological condition has been identified. These baseline data will be useful in monitoring and identifying the effects of stream restoration.

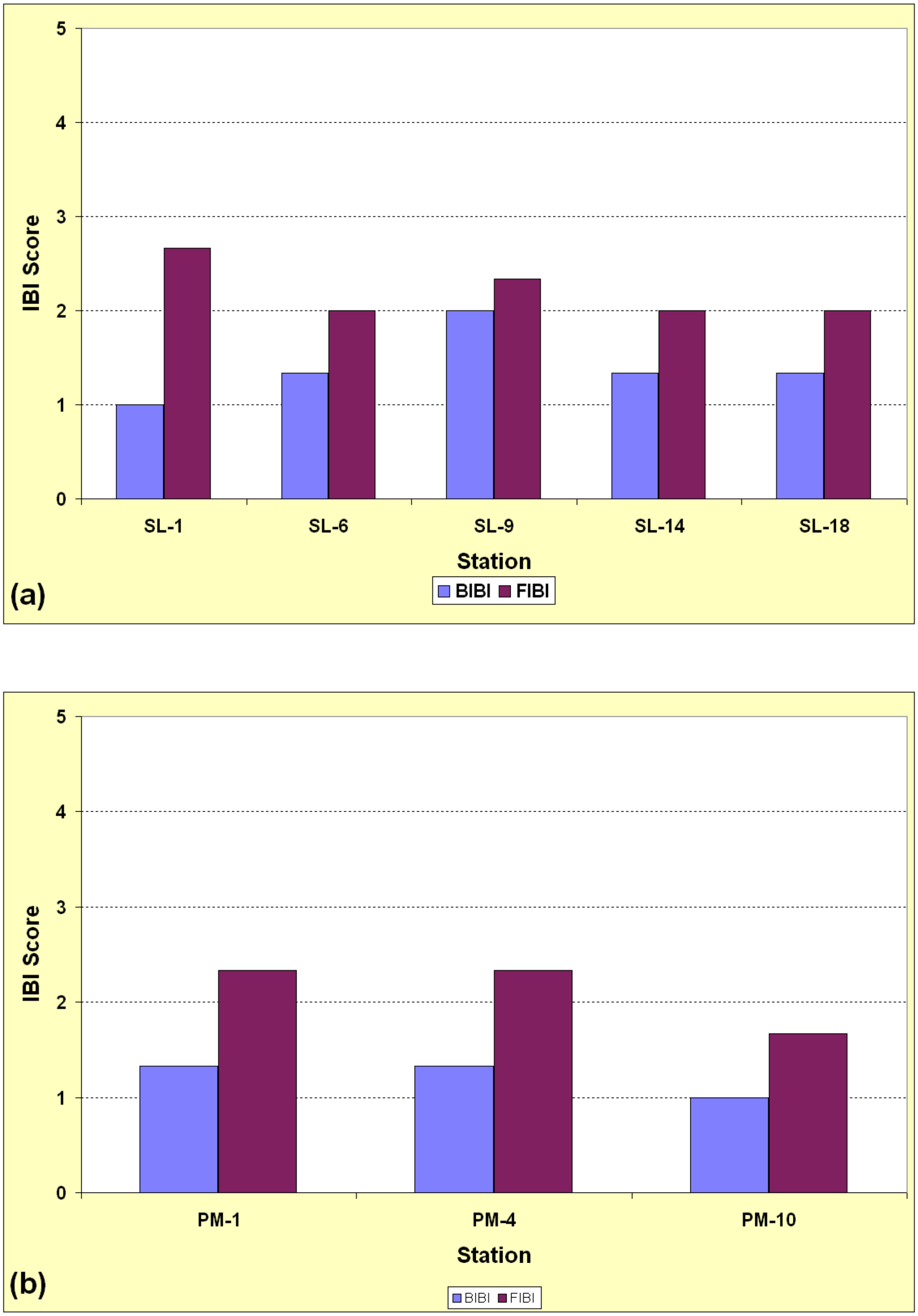


Figure 8-28: (a) Scotts Level Branch and (b) Powder Mill Run IBI Scores

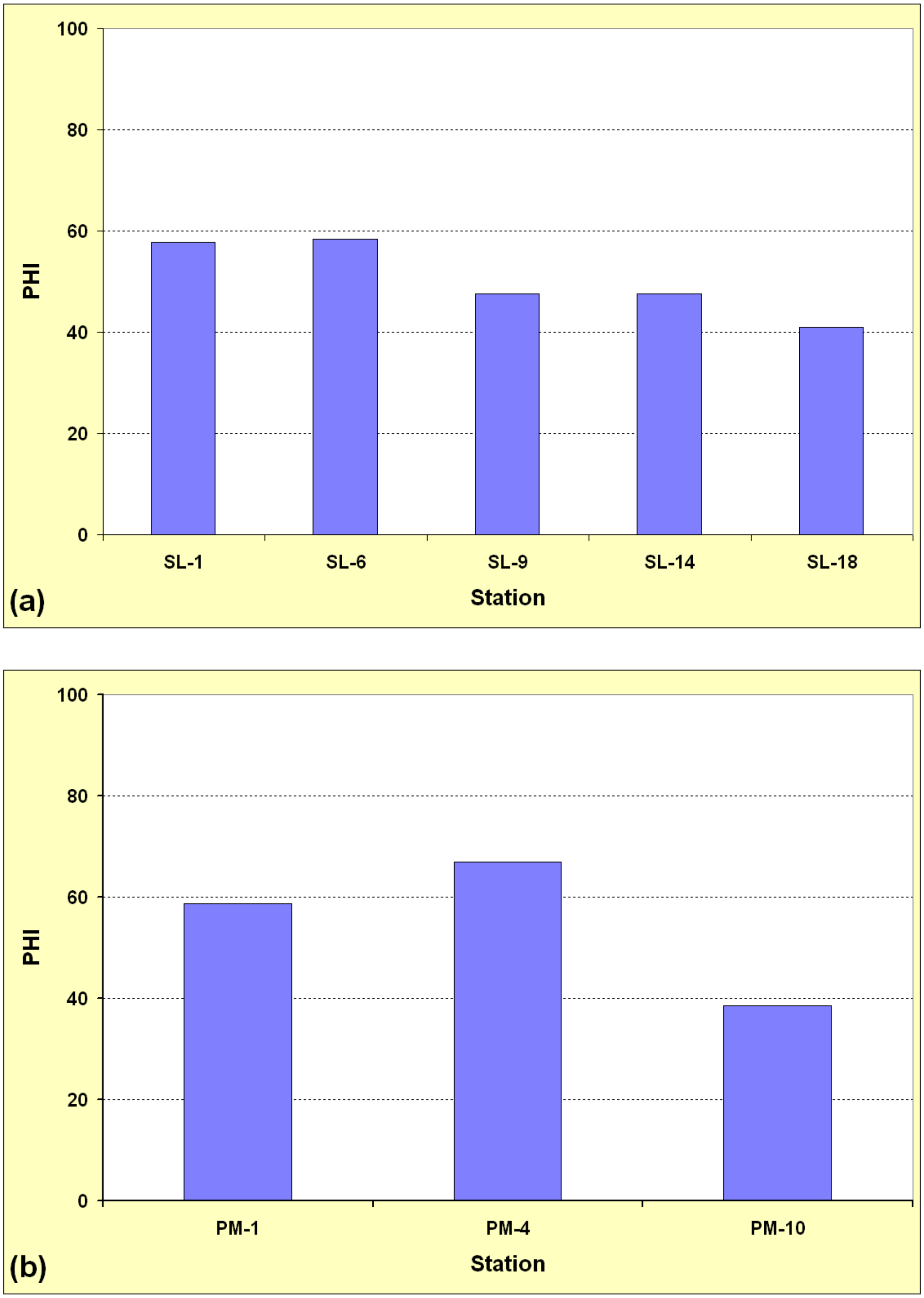


Figure 8-29: (a) Scotts Level Branch and (b) Powder Mill Run PHI Scores

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 is beginning to occur now that the extension of MD route 43 has been completed. This roadway is the primary access to these new properties and is needed for the intense level of development expected in this subwatershed. If this high-density development is not controlled, it is 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.

8.4.1 Stream Geomorphologic Monitoring

Six (6) sites in the Windlass Run subwatershed have been selected for monitoring and are shown in Figure 8-30 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 extension. One site (WR4) is on a tributary (WR4) within the area of proposed industrial and high-density development, and down stream of Route 43. Another cross section (WR6) is located on a tributary within the area of proposed development. The last cross section (WR1) is a reference site 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 spring 2002-2008, 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.

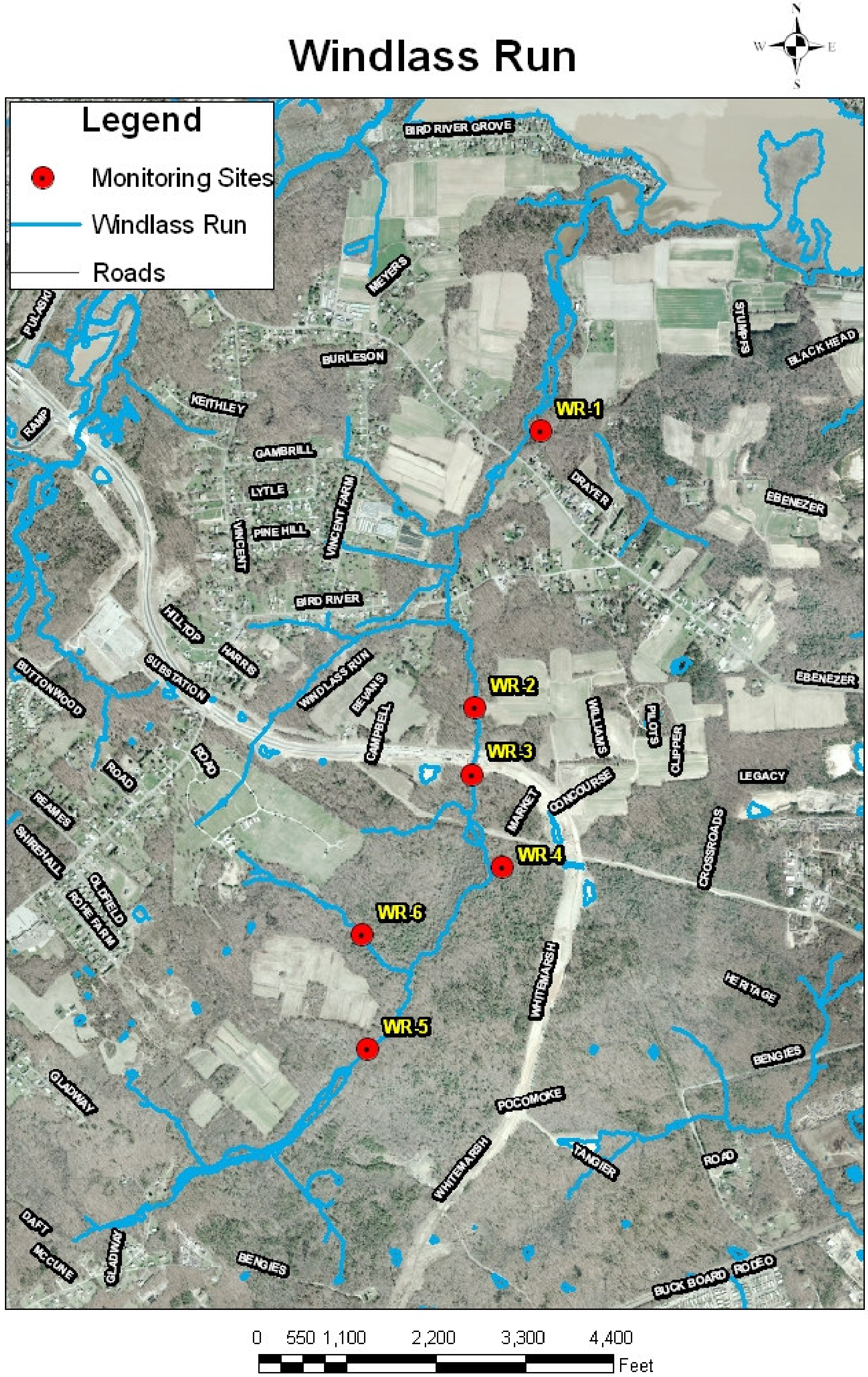


Figure 8-30: Windlass Run Aerial Photograph Showing Monitoring Station Locations.

Figures 8-31 through 8-34 show the progression of development in Windlass Run, from 1995-2007, in years for which orthophotographs were available. Development occurring in the interval between years is summarized below. Changes in geomorphology and biology related to the land disturbance caused by development are discussed in the results for each monitoring component.

1995 – 2002:

- A small housing development was built 2,850 feet northwest of WR-5.
- Two driveways were cleared 1,520 feet west of WR-2.

2002 – 2005:

- The roadbed for the Route 43 extension was cleared.

2005 – 2007:

- The Route 43 extension was paved.
- A roadway was cleared 2,470 feet southwest of WR-5.
- Land clearing and grading for commercial/industrial complexes occurred 1,330 feet east of WR-6, 95 feet east of WR-2, WR-3, and WR-4, and 380 feet west of WR-1.

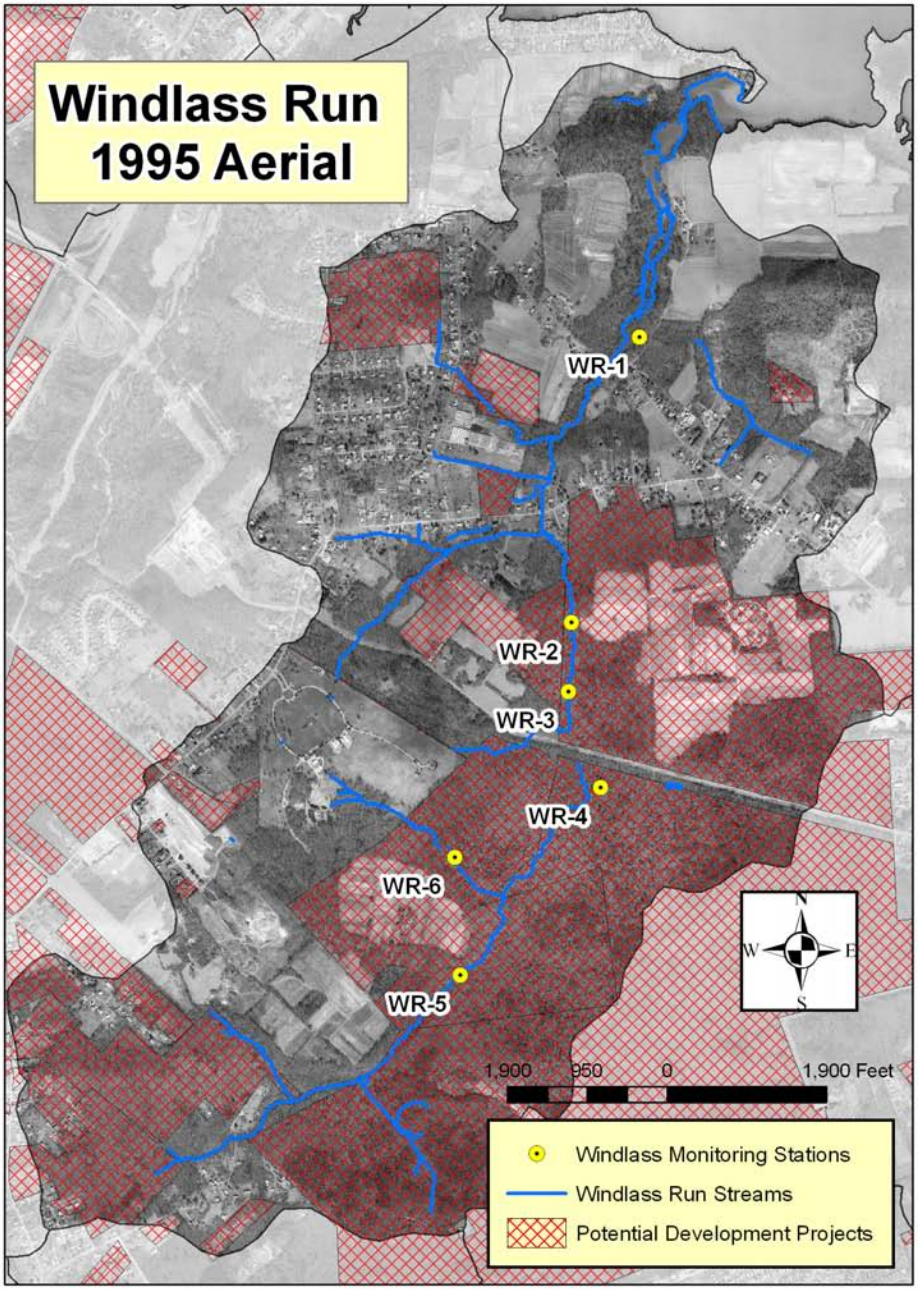


Figure 8-31: Orthophotograph of Windlass Run watershed, 1995.

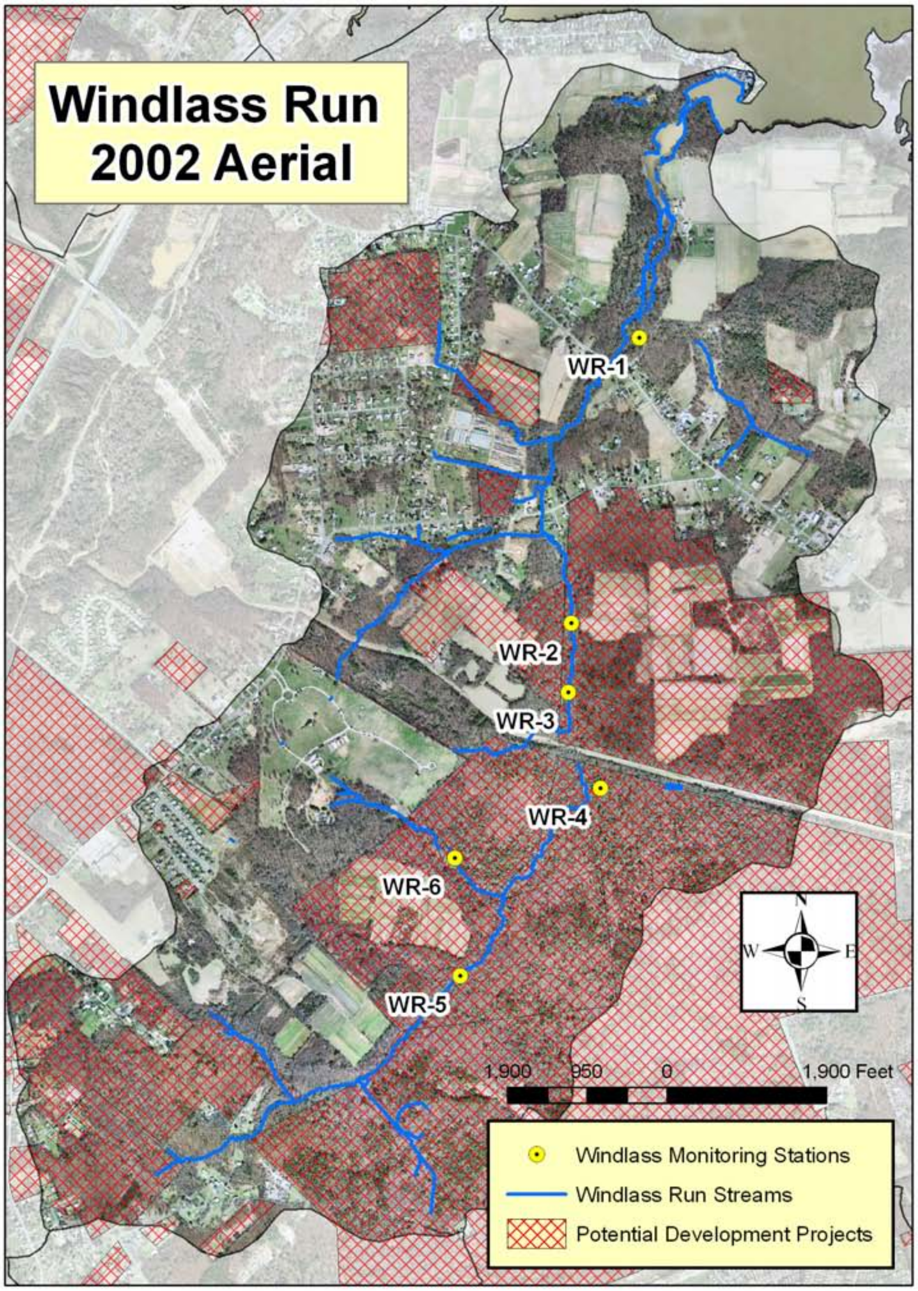


Figure 8-32: Windlass Run watershed orthophotograph, 2002.

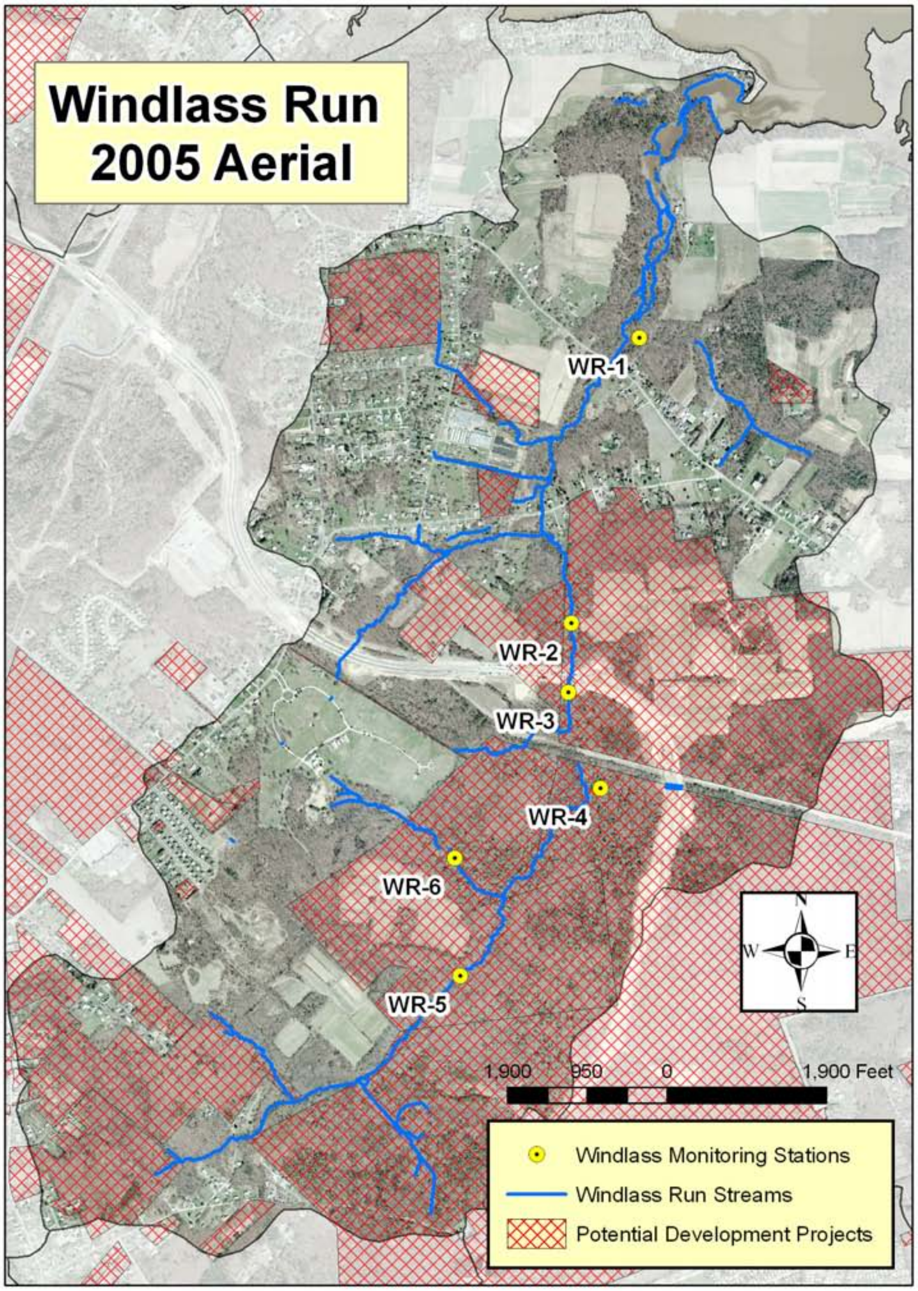


Figure 8-33: Windlass Run orthophotograph, 2005.

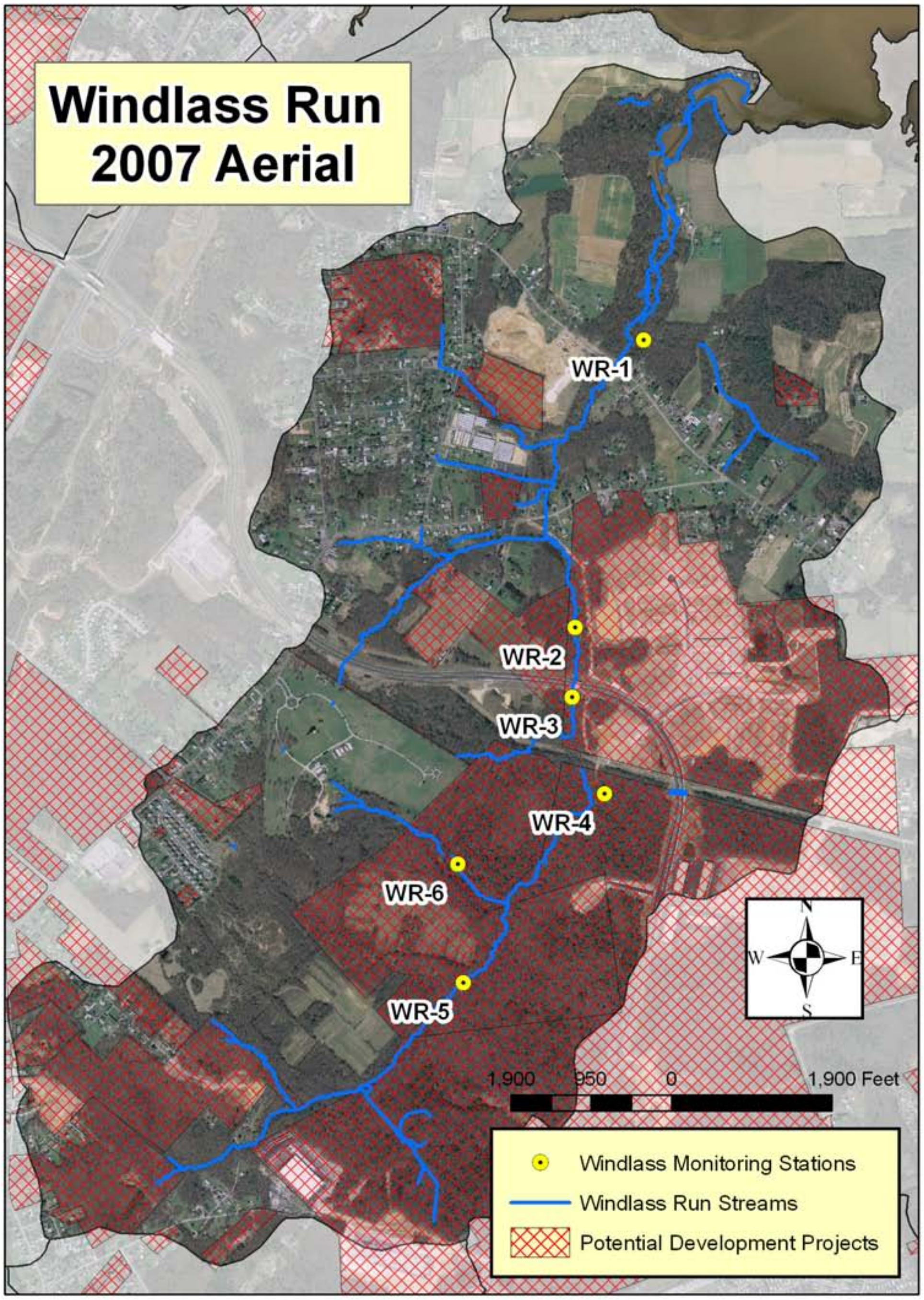


Figure 8-34: Windlass Run orthophotograph, 2007.

Windlass Run Monitoring Results:

The cross sections were overlaid to reveal any morphological changes between 2008-2009 and 2002-2009. The change in the reaches over the two study intervals are discussed below and summarized in Figure 8-35 and Tables 8-14 and 8-15.

Reach 1 (Reference reach on a tributary)

- There was no change in the profile during 2008-2009, but it aggraded between 2002-2009.
- The substrate fined during 2008-2009, but coarsened overall between 2002-2009.
- 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 Isabel (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 the thalweg profile.

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

- Note: 2004 was the last year of active agriculture in the fields east of Reach 2. During 2005-2007, mass grading supplanted the agricultural activity. In late 2007, development began in the reach and has continued to the present.
- A slight fill was observed in the cross section's left bank during 2007-2008.
- The thalweg has been active in the profile since 2002 with both aggradation and degradation over time and over the thalweg length. It incised overall in 2008-2009, but aggraded between 2002-2009. The active nature of this reach over the study period makes it unlikely that recent changes in the profile are due to development.
- The substrate coarsened during both 2008-2009 and 2002-2009. The stream channel's native sediment is fine clay and sand; therefore it is probable that the coarsening has been caused by the soil movement and grading.

Reach 3 (Just above Route 43 crossing)

- A slight channel enlargement occurred during 2002 – 2008, however little change except slight cutting was observed in the cross section during 2007 – 2008. The thalweg degraded overall prior to 2004, and held steady in 2005 – 2006 and 2006 – 2007, but deepened again in 2008-2009. The wavelike cut and fill oscillations of about 0.6 ft amplitude within the profile continued in 2008.
- The pebble count indicated a slight coarsening overall and between 2008-2009. As with WR-2, the change in substrate composition is probably related to development.

Reach 4 (On a tributary below Route 43)

- Very slight aggradation in 2007-2008 and 2002-2008.
- Aggradation in the thalweg over 2002-2009 and during 2008-2009.
- Coarsening of the substrate during 2002-2009, including coarsening over the past year (2008-2009).
- These slight changes are likely related to the completion of a commercial park directly upstream of this reach.

Reach 5 (On mainstem above Route 43)

- The stream channel shifted 1-foot to the left and deepened slightly (0.3 ft) from 2002 – 2008, with some of this occurring during 2004. It continued to be stable in 2007-2008.
- The profile degraded slightly over its entirety during 2008-2009. Overall, degradation occurred during 2002 - 2009.
- Coarsening occurred in Reach 5 over 2002-2009, with slight fining in 2008-2009.

Reach 6 (On a tributary unaffected by Route 43)

- The cross section filled in by 0.7 ft during 2007-2008. This was responsible for overall aggradation during 2002 - 2008.
- The thalweg incised overall from 2004 – 2009, including some additional degradation during 2005 –2007. The lower portion of the channel diverted to the left due to sediment accumulations impinging at the diversion point during 2006-2007. The thalweg experienced some filling between 2008-2009. 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 2005, but by 2006 the substrate had returned back to its finer original state. A re-coarsening occurred by 2007, followed by fining in 2008 and coarsening in 2009. Overall, substrates have coarsened between 2002-2009.
- It is likely that an active ATV trail, which crosses upstream of the profile, is responsible for the changes in sediment deposition. There has been no appreciable upstream change in land use over the study period.

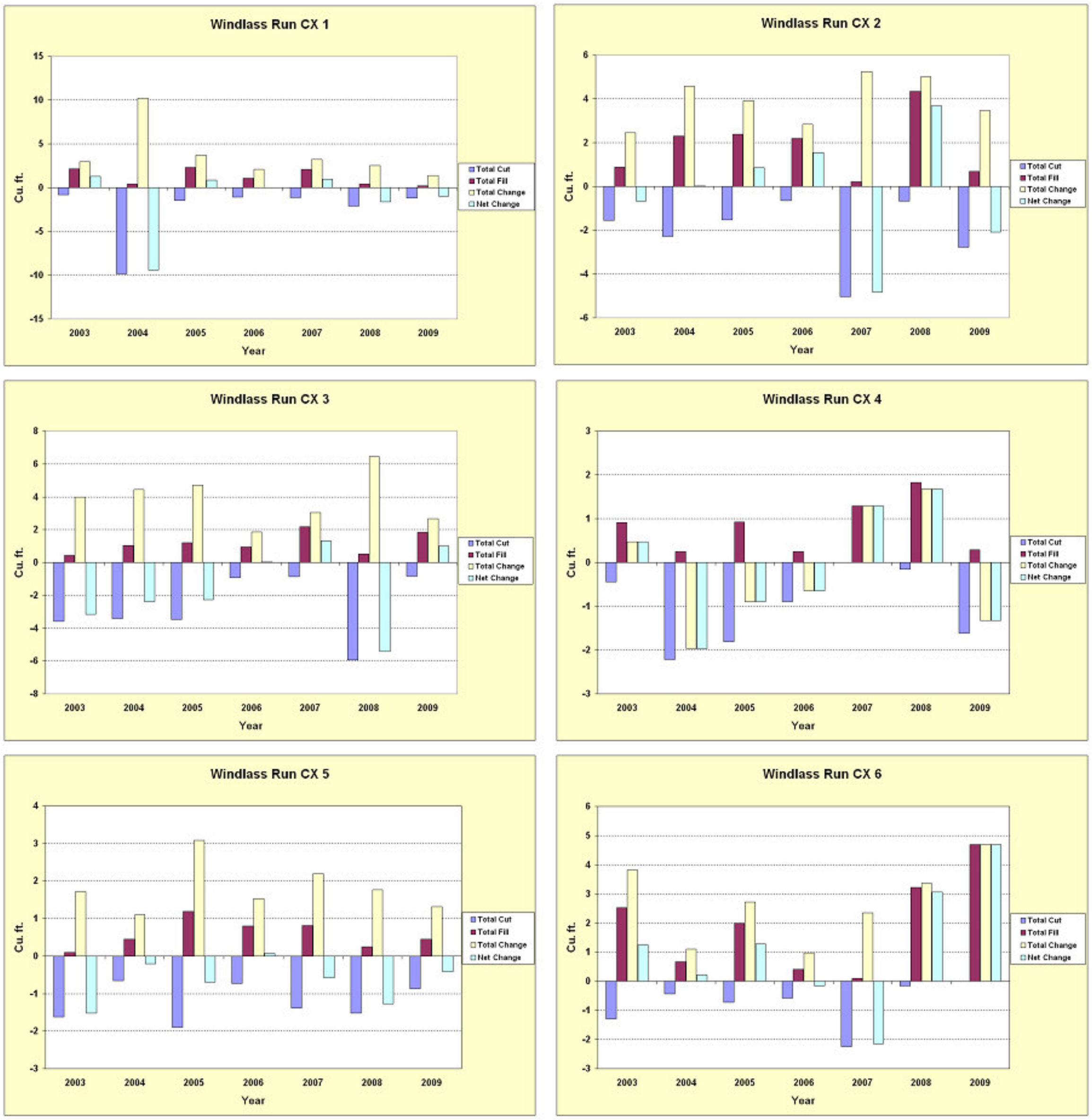


Figure 8-35: Summary of cross-sectional changes in Windlass Run during entire study period.

Table 8-14: Windlass Run Cross Sections - Cut and Fill Amounts

WR 1: Change (cu ft)	Period: 2008 – 2009	Period 2002 – 2009
Total Cut (negative value)	-1.2	-1.3
Total Fill	0.2	0.4
Total Change	1.4	1.7
Net Change	-1.0	-0.9
WR 2: Change (cu ft)	**Period: 2008 – 2009**	**Period 2002 – 2009**
Total Cut (negative value)	-2.8	-0.3
Total Fill	0.7	0.9
Total Change	3.5	1.2
Net Change	-2.1	0.6
WR 3: Change (cu ft)	**Period: 2008 – 2009**	**Period 2002 – 2009**
Total Cut (negative value)	-0.8	-0.9
Total Fill	1.8	0.2
Total Change	2.6	1.1
Net Change	1.0	-0.7
WR 4: Change (cu ft)	**Period: 2008 – 2009**	**Period 2002 – 2009**
Total Cut (negative value)	-1.6	-0.2
Total Fill	0.3	0
Total Change	1.9	0.2
Net Change	-1.3	-0.2
WR 5: Change (cu ft)	**Period: 2008 – 2009**	**Period 2002 – 2009**
Total Cut (negative value)	-0.9	-0.4
Total Fill	0.4	0.4
Total Change	1.3	0.8
Net Change	-0.5	0
WR 6: Change (cu ft)	**Period: 2008 – 2009**	**Period 2002 – 2009**
Total Cut (negative value)	0	-0.2
Total Fill	4.7	0.3
Total Change	4.7	0.5
Net Change	4.7	0.1

Table 8-15: Windlass Run Stream Channel Changes Over Time

WR #	Down slope Of Rt. 43	*CX 02-09*	*CX 08-09*	*TW 02-09*	*TW 08-09*	*Pebble 02-09*	*Pebble 08-09*
2	yes	*sa*	*sd*	*a*	*a*	*c*	*c*
3	yes	*sd*	*sa*	*d*	*d*	*c*	*c*
4	yes	*sd*	*sd*	*a*	*a*	*c*	*c*
5	no	*0*	*sd*	*d*	*d*	*c*	*f*
1	no	*sd*	*sd*	*a*	*d*	*c*	*f*
6	no	*sa*	*a*	*d*	*a*	*c*	*c*

Symbols: a: aggradation, d: degradation, c: coarsening, f: 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 usage 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 Isabel 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. Construction of several business parks and other industries began in 2007. The several years of completed pre-development monitoring may now be used as the baseline condition to detect any important changes due to development in the subwatershed.

8.4.2 Biological Monitoring

Benthic macroinvertebrates are being used as indicator organisms to monitor the effects of disturbance in the Windlass Run watershed. The condition of the benthic macroinvertebrate community before and after development will help determine the effectiveness of the new stormwater regulations at maintaining the suitability of Windlass Run for aquatic life.

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 8-10. 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). The BIBI scores are shown in Figure 8-36 and discussed in relation to the development timeline presented above. 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 visually estimated. Only physical habitat data collected since 2004 are reported here using the MBSS Physical Habitat Index, which converts field measurements to a score from 0-100. Habitat is rated as Minimally Degraded (81-100), Partially Degraded (66-80), Degraded (51-65), or Severely Degraded (0-50). PHI scores are shown in Figure 8-37.

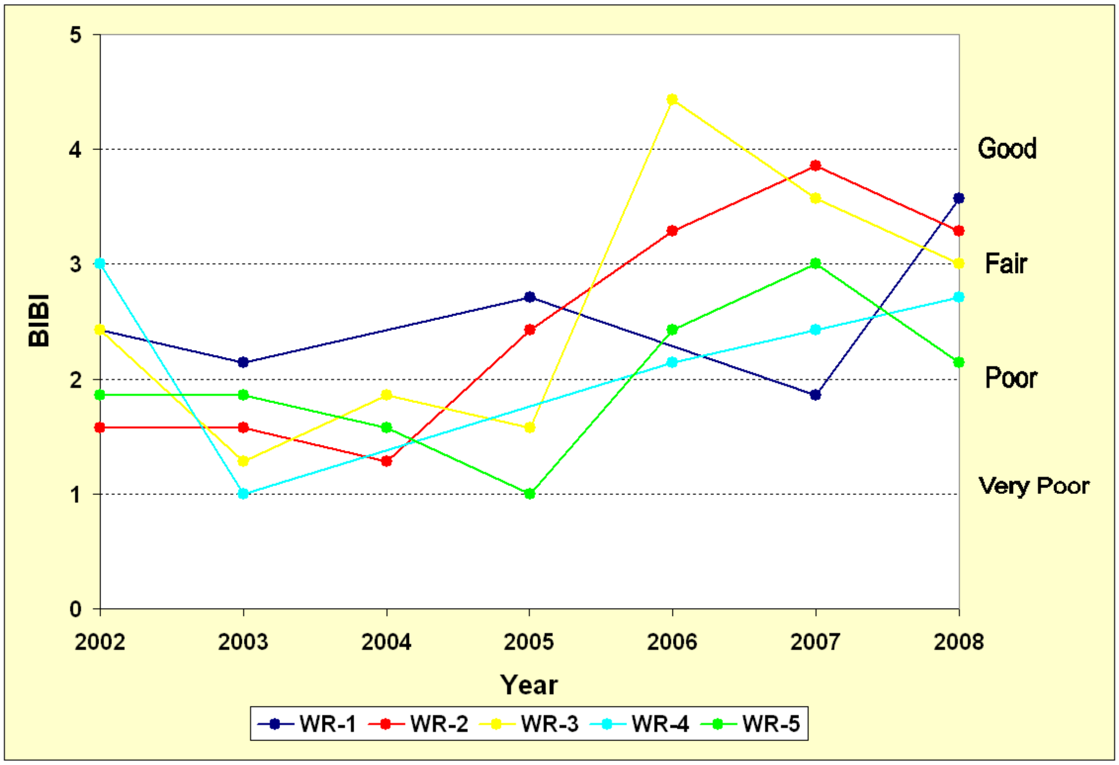


Figure 8-36: Windlass Run BIBI Scores

1995 – 2002:

- Biological condition in 2002 was typical of streams experiencing long periods of agriculture land use.

2002 – 2005:

- Biological condition remained consistent at all stations. Although there were some year-to-year changes in biological condition category, stations were rated Very Poor or Poor. Habitat condition was minimally degraded at all stations, except for WR-4 in 2004 and WR-5 in 2005 (Partially Degraded).

2005 – 2007:

- Biological condition generally improved during this interval, which was the period of greatest construction activity to date. Habitat condition slowly declined from Minimally Degraded to Partially Degraded.

To examine these trends further, functional feeding group composition was calculated. Functional feeding groups are useful because they classify benthic macroinvertebrates according to their feeding mode. Land disturbance may influence functional feeding group composition by changing autochthonous and allochthonous food resources available for benthic macroinvertebrates. Data are presented in Table 8-16. There was a shift in functional group composition from generalist feeders to specialist feeders. The percentage of collectors (which encompasses a variety of generalist feeding modes) decreased from 2002-2005 to 2005-2007. During the same intervals, the percentage of filterers and predators consistently increased. The small increases in sediment resulting from development were probably responsible for the increase in filterers. The predators responded to the shift in the macroinvertebrate assemblage. The presence of macroinvertebrates with specialized feeding strategies indicates good water quality and diverse habitat conditions.

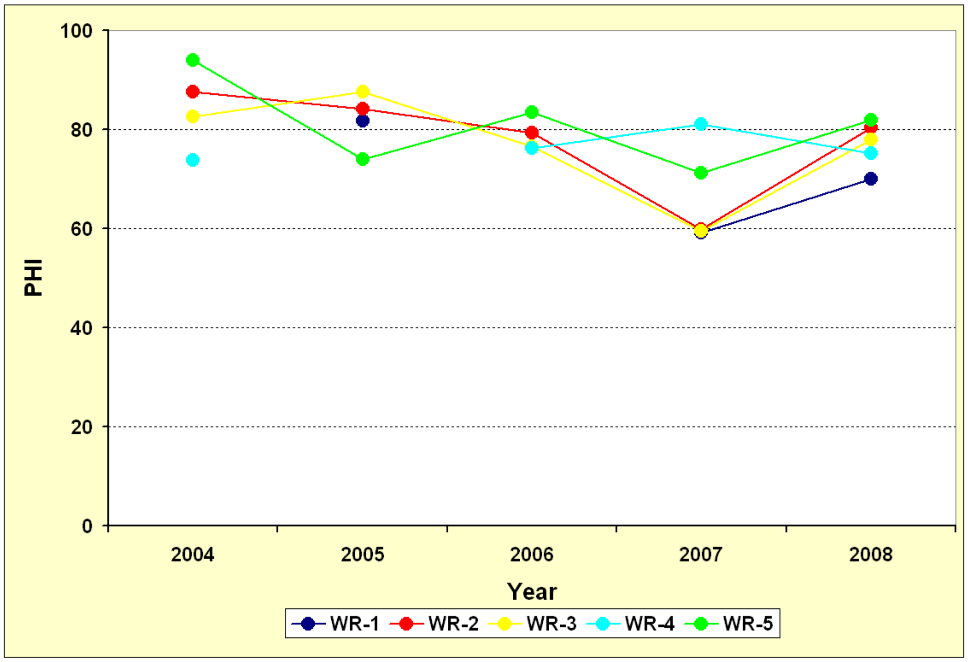


Figure 8-37: Windlass Run Physical Habitat Scores

Table 8-16: Windlass Run Functional Feeding Group Means

Interval	FFG	WR-1	WR-2	WR-3	WR-4	WR-5
2002 to 2005	%collectors	53.8	55.9	45.8	81.2	47.0
	%filterers	6.3	25.2	43.2	12.9	36.8
	%predators	2.1	3.2	2.2	1.2	1.3
	%scrapers	30.0	2.9	0.9	1.8	0.0
	%shredders	1.2	1.4	2.0	0.0	9.1
2005 to 2008	%collectors	37.1	42.6	36.5	32.7	30.5
	%filterers	47.3	33.5	22.6	30.6	53.2
	%predators	3.4	14.9	19.4	5.0	9.2
	%scrapers	4.4	3.6	5.9	17.3	2.1
	%shredders	3.9	4.1	12.5	12.6	4.4

The recent subtle changes in geomorphology suggest that development is influencing Windlass Run, especially in Reaches 2, 3, and 4. The most notable difference is in substrate composition, which has coarsened in the affected reaches. The biological data are less clear, as biological condition has improved since the beginning of development. The effects of a long history of agricultural land use will need to be identified before the effects of recent development are fully understood. The relative stability of the stream channels facilitated identification of the beginning of development-related change in Reaches 2, 3, and 4. Further monitoring will help determine the effectiveness of storm-water management techniques applied in Windlass Run.