FINAL REPORT

CALIFORNIA DEPARTMENT OF TRANSPORTATION DISTRICT 7 LITTER MANAGEMENT PILOT STUDY

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State of California - Business, Transportation and Housing Agency
Department of Transportation
Environmental Program (MS-27)
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URSGWC Project No. 58-977001NJ.01-FR400

June 26, 2000

June 26, 2000

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Subject: Final Report - Litter Management Pilot Study
Contract No. 43A0004C
URSGWC Project No. 58-977001NJ.01-FR400

Dear Roger and Gary:

In accordance with Contract 43A0004C, Task Order No. 18, enclosed please find the Final Report for the Litter Management Pilot Study (LMPS). Distribution of this report represents completion of the LMPS and fulfills URS's responsibilities related to Task Order 18. Please note that additional copies have been provided to Mr. Bill Evans for distribution to the plaintiffs.

Please call us at (619) 294-9400 if you have any questions.

Very truly yours,

URS GREINER WOODWARD CLYDE

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TABLE OF CONTENTS

Section 1 Introduction and Study Design 1-1

1.1 Background 1-1
1.2 Objectives 1-1
1.3 Study Design 1-2
1.3.1 Study Plan Section 2 – Identification and Monitoring of Litter 1-2
1.3.2 Study Plan Section 3 – Selection of Test and Control Areas 1-4
1.3.3 Study Plan Section 4 – BMPs to be Tested 1-4
1.3.4 Study Design Modifications 1-7
1.4 Comments 1-8

Section 2 Site and Equipment Descriptions 2-1

2.1 Site Locations and Outfall Descriptions 2-1
2.2 Monitoring Equipment 2-9
2.2.1 Litter Monitoring Equipment 2-9
2.2.2 Chemical Water Quality Monitoring Equipment 2-12
2.3 Equipment Installation 2-12

Section 3 BMP Implementation 3-1

3.1 Inlet Cleaning 3-1
3.2 Street Sweeping – Site 1W 3-2
3.2.1 BMP Implementation Strategy 3-2
3.3 Manual Litter Pick-Up – Site 1E 3-3
3.3.1 Manual Litter Pick-Up BMP Implementation Strategy 3-3
3.4 Structural Controls 3-6
3.4.1 Modified Inlet Grate 3-6
3.4.2 Bicycle Grate 3-7
3.4.3 Litter Inlet Deflector 3-7
3.5 Caltrans Maintenance Activities 3-10

Section 4 Monitoring 4-1

4.1 Monitoring Procedures for Chemical Water Quality and Litter Sampling 4-1
4.1.1 Pre-Event SOPs 4-1
4.1.2 Grab Sampling SOPs 4-3
4.1.3 Post-Event SOPs 4-3
4.2 Storm Event Hydrographs 4-4
4.2.1 QA/QC of the Raw Data 4-5
4.2.2 Field Investigation and Reevaluation of Watershed Areas and Freeway Surface Conditions 4-7
4.2.3 Catchment Hydrology Observations and Estimated Final Catchment Areas 4-7
4.2.4 Event Overview 4-8

4.2.5 Total Seasonal Rainfall and Flow Data 4-23
4.3 Other Monitoring Activities..... 4-23
4.3.1 Inlet Deposition Monitoring 4-23
4.3.2 Street Sweeper Debris Characterization 4-29
4.3.3 Litter Pick-Up Debris Characterization 4-32
4.3.4 LID Observations..... 4-34

Section 5 Chemical Water Quality Data..... 5-1

5.1 Sample Analysis..... 5-1
5.1.1 Chemical Water Quality Parameters and Analytical Methods 5-1
5.1.2 Sample Compositing..... 5-1
5.1.3 Prioritization of Analytical Parameters..... 5-2
5.1.4 QA/QC 5-3
5.2 Data Management 5-9
5.3 Data Analysis 5-9
5.3.1 Event Mean Concentrations..... 5-9
5.3.2 Seasonal Mass Quantities 5-15
5.3.3 Data Observations..... 5-15

Section 6 Litter Characterization Data..... 6-1

6.1 Characterization Protocols 6-1
6.2 Data Management 6-2
6.2.1 Database Setup..... 6-3
6.2.2 Data Entry 6-3
6.2.3 Data Quality Assurance/Quality Control (QA/QC)..... 6-3
6.3 Litter and Vegetative Material Characteristics 6-4
6.3.1 Wet Weight of Material 6-4
6.3.2 Air-Dried Weight of Litter..... 6-5
6.3.3 Volumes of Litter..... 6-6
6.3.4 Numbers of Items..... 6-6
6.3.5 Categories by Sources..... 6-6
6.3.6 Oven-Dried Weights 6-8
6.3.7 Floatable Portion of Litter..... 6-12
6.3.8 Litter Spike Recovery 6-12
6.4 Event Litter Data..... 6-20

Section 7 Data Analysis..... 7-1

7.1 BMP Effectiveness..... 7-1
7.1.1 Collected Field Data Summary..... 7-1
7.1.2 Cumulative Monitoring Results..... 7-1
7.1.3 Methods of Data Analysis..... 7-4
7.1.4 Statistical Results – Normalized by Area 7-7
7.1.5 Statistical Results – Normalized by Flow..... 7-9

7.1.6 Results of Total System Litter Analysis 7-10
7.1.7 Statistical Analysis of Water Quality Data 7-11
7.2 Other Analyses 7-16
7.2.1 Evaluation of Relationships between Litter and Site Hydrology 7-16
7.2.2 Evaluation of Relationship between Litter and Chemical Constituent Quantities 7-17
7.2.3 Assessment of Wet vs. Dry Inlet Deposition for the LID BMP 7-23

Section 8 Conclusions and Recommendations 8-1

8.1 Conclusions 8-1
8.1.1 BMP Effectiveness 8-1
8.1.2 Conclusions Related to Other Observations 8-4
8.2 Recommendations 8-7
8.2.1 Recommendations for Further Study 8-7

Section 9 References 9-1

Appendices

Appendix A LMPS Dry and Wet Weather Field Investigation Findings
Appendix B Field and Contact Forms
Appendix C Description of False Start Events
Appendix D QA/QC Analysis of Hydrologic Data
Appendix E Event Hydrographs and Hyetographs
Appendix F SOP for Inlet Deposition Monitoring
Appendix G Chemical Water Quality Data Tables and Charts
Appendix H Litter Characterization Protocol and Lab Data Sheets
Appendix I Litter Data Pie Charts
Appendix J Outfall Litter Data Plots
Appendix K Statistical Analysis of Litter BMP Effectiveness
Appendix L Comparison of Litter and Chemical Constituents
Appendix M LID Laboratory Testing
End Pocket Electronic Database Files

Tables

Table 2–1 Field Study Site Information
Table 2–2 Estimated Watershed Areas and Pair Designations for LMPS Outfalls
Table 2–3 Chemical Water Quality Equipment Components
Table 3–1 Sites 1W and 1E Non–Structural BMP Implementation
Table 4–1 Results of Final Regression Analysis of Rainfall/Runoff Curves After QA/QC of Data Based on Revised Watershed Areas
Table 4–2 Summary of Hydrologic Data for Monitored Storm Events
Table 4–3 Description of Hydrologic Data Abnormalities and Adjustments
Table 4–4 Seasonal Rainfall and Total Flow
Table 5–1 Chemical Water Quality Parameters and Analytical Methods
Table 5–2 Prioritization of Chemical Water Quality Parameters
Table 5–3 Nitrate Holding Times in Excess of 48 Hours
Table 5–4 Automated Sampler Tubing Equipment Blank Results Compared to Year 1 EMCs
Table 5–5 MS/MSD Recoveries Outside Control Limits
Table 5–6 Expected MS/MSD Recoveries Based on MS/MSD Concentrations
Table 5–7 Summary of Field Duplicate Results for Grab Samples
Table 5–8 Results of QA/QC Analysis for Year 1
Table 5–9 Results of QA/QC Analysis for Year 2
Table 5–10 Event Mean Concentrations and Station Means for Total Nickel
Table 5–11 Seasonal Mass Quantities for Caltrans LMPS Control Outfalls
Table 5–12 Caltrans LMPS Station Means from Combined Years of Monitoring
Table 6–1 Moisture Contents of Litter and Vegetative Material
Table 6–2 Percent Floatable Litter by Volume
Table 6–3 Spike Colors by Event
Table 6–4 Number of Spike Items Recovered by Date Recovered and Associated Event
Table 6–5 Percent of Total Spike Material Recovered at Each Outfall by Color
Table 6–6 Recovery of Spike Items by Type
Table 6–7 Event Litter Data
Table 6-8 Comparison of Site AADT to Control Outfall Litter Loads
Table 7–1 1998/1999 Storm Season Year 1 Litter Monitoring Results
Table 7–2 1999/2000 Storm Season Year 2 Litter Monitoring Results
Table 7–3 Results of Evaluation of BMP Effectiveness (Data Normalized by Catchment Area)
Table 7–4 Results of Evaluation of BMP Effectiveness (Data Normalized by Flow Volume)
Table 7–5 Significant Results on Mean or Median Difference between Treatment and Control Outfalls

Figures

Figure 1–1 Site Area Locations - Caltrans LMPS
Figure 2–1 Site 1 Caltrans LMPS (Western portion)
Figure 2–2 Site 1 Caltrans LMPS (Eastern portion)
Figure 2–3 Site 6 Caltrans LMPS
Figure 2–4 Site 8 Caltrans LMPS
Figure 3–1 LID Schematic – Site 8

Figure 4–1 Site 1 E (Litter Pick-Up) Outfalls 42 and 46 – Event No. 1998-01 11/08/98
Figure 4–2 Inlet Material Volumes Based on Inlet Deposition Monitoring at Site 1E – Litter Pick-Up
Figure 4–3 Inlet Material Volumes Based on Inlet Deposition Measurements at Site 1W – Street Sweeping
Figure 4–4 Inlet Material Volumes Based on Inlet Deposition Measurements at Site 6 – Modified Inlet
Figure 4–5 Inlet Material Volumes Based on Inlet Deposition Measurements at Site 8 – Bicycle Grate (Year 1) and LID (Year 2)
Figure 4–6 Drainage System, Street Sweeper, and ROW Litter Composition by Air-Dried Weight
Figure 4–7 Drainage System, Street Sweeper, and ROW Litter Composition by Volume
Figure 4-8 Drainage System, Street Sweeper, and ROW Litter Composition by Count
Figure 5–1 Box and Whisker Plot – Total Nickel (µg/l)
Figure 6–1 Percent Vegetative Material by Wet Weight
Figure 6–2 Litter Category Distribution by Air-Dried Weight for All Events Combined
Figure 6–3 Litter Category Distribution by Volume for All Events Combined
Figure 6–4 Litter Category Distribution by Count for All Events Combined
Figure 6–5 Litter Usage Distribution by Air-Dried Weight for All Events
Figure 6–6 Litter Usage Distribution by Volume for All Events
Figure 6–7 Litter Usage Distribution by Count for All Events
Figure 6-8 Usage Distribution by Air-Dried Weight by Year
Figure 7–1 Example Plot of Cumulative Air-Dried Weight of Litter Per Acre – Site 1E Litter Pick-Up
Figure 7–2 Flowchart of Selecting the Preferred Statistical Method
Figure 7–3 Distribution of Event Percentage Difference by BMPs for Count (Data Normalized by Catchment Area)
Figure 7–4 Box Plots of Constituents that Showed a Statistical Difference between Treatment and Control Outfalls
Figure 7–5 Correlation between Event Peak Flow and Litter Load
Figure 7–6 Correlation between Event Total Flow and Litter Load
Figure 7–7 Correlation between Antecedent Days and Litter Load
Figure 7–8 Correlation between Event Maximum Rainfall Intensity and Litter Load
Figure 7–9 Correlation between Event Peak Flow, Antecedent Days, and Litter Load
figure 7–10 Seasonal Rainfall (In) vs. Total Air-Dried Weight Combined Site Outfalls - Trigger and Non-Trigger Events
Figure 7–11 Outfall Wet Weather Material Volumes (not Normalized) and Dry Weather Inlet Material Volumes – Site 8 (LID)

Photos

2–1 Typical Freeway and Shoulder Conditions – Site 1E (Litter Pick-Up)
2–2 Typical Freeway and Shoulder Conditions – Site 1W (Street Sweeping)
2–3 Typical Freeway and Shoulder Conditions – Site 6 (Modified Inlet Grate)
2–4 Typical Freeway and Shoulder Conditions – Site 8 (LID-1999/2000; Bicycle Grate-1998/2000)
2–5 Typical Litter Monitoring Bag at Outfall

2–6 Litter Monitoring Station with Fence Enclosure
2–7 Chemical Water Quality Monitoring Station
2–8 Enclosure with Automatic Sampler, Battery, Cell Phone, and Data Logger for Chemical Water Quality Monitoring
3–1 Pipeline Cleaning Using Wet Jetting Method and Vactor Hose
3–2 Mechanical Broom Sweeper
3–3 Modified Inlet Grate – Site 6
3–4 Bicycle Grate – Site 8
3–5 LID – Site 8
3–6 Fire Damage at Top of Slope Near Outfall 1-52 – Solar Panel Pole is Shown
4–1 Calibration Frame Used to Measure Volume of Sweeper Debris
4–2 Typical Litter in Sweeper Debris Collected from Site 1W, Harris to Gertrude, on 4/1/99
4–3 Typical Litter in Outfall Debris from Outfall 1-58, Event 1998-11, 3/25/99
6–1 Typical Litter on a Drying Screen

AAH	Adopt-A-Highway
AAHMC	Adopt-a-Highway Maintenance Corporation
ac	Acres
ANOVA	Analysis of Variance
BMP	Best Management Practice
CEL	Calscience
cf	cubic feet
CMP	corrugated metal pipe
COV	Coefficient of Variation
CSUS	California State University Sacramento
DI	Deionized
EMC	Event Mean Concentrations
EPA	Environmental Protection Agency
g	grams
Ha	Hectare
HOV	high occupancy vehicle lane
kg	kilogram
l	liter
LCS	Laboratory Control Samples
LID	Litter Inlet Deflector
LMPS	Litter Management Pilot Study
LWA	Larry Walker & Associates
mg	milligram
ml	milliliter
MS/MSD	Matrix Spike/Matrix Spike Duplicates
ND	Non Detect
NRDC	Natural Resources Defense Council
PM	Post Mile
QA/QC	quality assurance and quality control
QPFs	Quantitative Precipitation Forecasts
RPD	relative percent difference
ROW	Right of Way
SEC	Storm Event Coordinator
SMBRP	Santa Monica Bay Restoration Project
SOPs	Standard Operating Procedures
Study Plan	Final Detailed Study Design and Plan
TAG	Technical Advisory Group
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TPH	Total Petroleum-Hydrocarbon
TSS	total suspended solids
UCLA	University of California Los Angeles
µg	microgram
URSGWC	URS Greiner Woodward Clyde

The Litter Management Pilot Study (LMPS) is one of many ongoing programs undertaken by Caltrans to improve the quality of runoff from Caltrans highway drainage facilities. The focus of the LMPS is field testing and evaluation of litter management practices to assess their effectiveness in reducing litter that is discharged from Caltrans storm water conveyance systems. The LMPS is a Caltrans study in response to the Stipulation and Order RE 1997-1998 Drain Inlet Cleaning Program, Attachment 1. The LMPS is a two-year field study that was conducted during the 1998/1999 and 1999/2000 rain seasons, following the methodology presented in the May 18, 1998 Final Detailed Study Design and Plan, Caltrans Document No. CTSW-RT-98-057 (Study Plan). This Final Report fulfills the requirements of the Stipulation in accordance with the Study Plan, and describes study implementation, data, and results that were obtained during the two year study.

Caltrans has brought together a team to design and implement this study consisting of the following parties:

- Caltrans Environmental Program
- California State University Sacramento (CSUS), Office of Water Programs
- URS Greiner Woodward Clyde (URSGWC)
- University of California Los Angeles (UCLA), Civil and Environmental Engineering Department

URSGWC has provided consulting services related to majority of LMPS activities related to project scoping, design, technical implementation, field monitoring, data review and analysis. UCLA has provided laboratory testing and prototype development of the Litter Inlet Deflector (LID) Best Management Practice (BMP) that was evaluated during year 2 of the LMPS. This team effort, in addition to review and input received from the project Technical Advisory Group (TAG), has shaped the overall direction of the LMPS and monitored compliance with study objectives.

The objective of the LMPS is to evaluate the effectiveness of structural and non-structural BMPs that could result in a reduction of litter in the Caltrans freeway storm drain system. The structural BMPs focus on freeway drain inlet modifications. The non-structural BMPs that were evaluated include increasing the frequency of mechanical broom street sweeping from monthly to weekly and increasing the frequency of manual litter pick-up programs from monthly to weekly.

Four sites (see Figure 1-1) were identified and matched with BMPs as follows:

- Site 1E – Litter Pick-Up: Eastbound Interstate 105, Post Mile (PM) 12.30 to PM 12.87
- Site 1W – Street Sweeping: Westbound Interstate 105, PM 12.87 to 12.30
- Site 6 – Structural BMP, Modified Inlet Grate: Eastbound Freeway 60, PM 15.12 to 15.58
- Site 8 – Structural BMP, LID (1999/2000), Bicycle Grate (1998/1999): Eastbound and Westbound Freeway 60, PM 5.60 to PM 5.95

Site locations are identified in Figure 1-1. Six outfalls are monitored at each site. Three outfalls at each site convey surface water from the BMP treatment area, and the other three convey

surface water from control areas. Each treatment outfall is paired with a control outfall and site details are summarized in Table ES-1.

This study has defined litter in storm water as:

- Manufactured items that can be retained by ¼-inch mesh made from paper, plastic, cardboard, etc.
- Materials that are not of natural origin (i.e., does not include sand, soil, gravel, vegetation, etc.)

Litter was quantified by weight (24-hour air-dried), volume, and count. Litter monitoring was conducted by attaching ¼-inch mesh collection bags to the 24 study outfalls. Eight of the 24 outfalls were also monitored for flow, rainfall, and chemical water quality parameters (see Table 5-1). When a litter collection bag was removed from an outfall for analysis, it was immediately replaced. All litter that came through the outfall during the study period was collected, characterized, and quantified. A litter lab was setup and protocols were developed to quantitatively measure and characterize the litter collected during the LMPS.

Litter samples were also collected and characterized for each trigger storm. Litter was collected from each of the 24 outfalls during 10 storms during the first year of the study, between November 1, 1998 and April 30, 1999, and for 13 storms during the second year of the study between October 1, 1999 and April 1, 2000. Chemical water quality samples were collected for 20 trigger storms monitored during the study. The litter from the first storm was used to fine-tune the litter measuring characterization protocols in the litter lab.

Table ES-1
FIELD STUDY SITE INFORMATION

Study Site Number	Study Site Location	Subject BMP	Monitored "Treatment" Outfalls	Monitored "Control" Outfalls	Study Pair Designation
1E	I-105 Eastbound (Lynwood) between Gertrude Ave. and Atlantic Blvd. overpass (PM12.30 to PM12.87)	Manual litter pick-up	1-47 1-46 1-44 *treatment frequency pick-up once per week	1-B110 1-42 1-B111 **control frequency pick-up once per four weeks	LP1 LP2 LP3
1W	I-105 Westbound (Lynwood) between Atlantic Blvd. and Gertrude Ave. overpass (PM12.87 to PM12.30)	Street sweepers (mechanical brooms)	1-58 1-59 1-60 *treatment frequency sweep once per week	1-52 1-50 1-51 **control frequency sweep once per four weeks	P1 P2 P3
6	Freeway 60, Pomona freeway (Hacienda Heights) between Turnbull Canyon undercrossing and Kwis St. overcrossing (PM 16.12 to PM 15.58)	Modified inlet grate (option A – perforated steel plate)	6-20H 6-20F 6-20B *treatment employs perforated plate on inlet	6-20G 6-20E 6-20C **control employs conventional grate inlet	P1 P2 P3
8	Freeway 60, Pomona freeway (Montebello and Monterey Park) between Garfield Ave.	LID (1999/2000)	8-B001 8-24B 8-24F	8-23C 8-24D 8-24E	P1 P2 P3

	undercrossing and Fulton Ave. (PM 5.60 to PM 5.95)	Bicycle grate (1998/1999)	*treatment employs subject BMP at inlet	**control employs conventional grate inlet	

The LMPS was designed to evaluate the effectiveness of structural and non-structural BMPs in reducing litter in the Caltrans storm water system by comparing litter amounts at paired treatment and control catchments. It should be emphasized that the objective of this study is specifically to evaluate the stated BMPs in a freeway environment and that these data are specific to Los Angeles conditions. In addition, litter data appear to be inherently variable and the data presented herein apply to the project-specific environment and conditions.

BMP Effectiveness

Caltrans litter data from samples collected at outfalls after storm events and compiled for the rainy season were qualitatively and quantitatively evaluated to identify whether or not each of the study BMPs was demonstrated to be effective. Data collected at each outfall were normalized by area and flow, and this data was then evaluated using the statistical methods described in Section 7.1. The results are summarized as follows:

- Statistical tests indicate that increasing the frequency of street sweeping from monthly to weekly does not statistically reduce ($\alpha = 0.05$) the count or weight of litter observed at the outfalls or in the total system load. This is the case for weight regardless of whether the litter data are normalized by catchment area or flow. For count, the reduction is not significant for the area-normalized analysis, but is statistically significant for the flow-normalized analysis. Because the number of data points is substantially larger for the area-normalized analysis, the results of that analysis are considered more powerful. These results suggest that weekly sweeping is not more effective than monthly sweeping in reducing litter in runoff from freeways with standard inlet grates.
- Statistical tests indicate that increasing the frequency of litter pickup from monthly to weekly reduces the quantity of litter observed at the outfalls, with $\alpha = 0.05$. This is the case for all measuring parameters (weight, volume, and count) regardless of whether the litter data are normalized by watershed area or flow. The average annual reduction between the treatment and control outfalls during the two-year study period were 30% by weight, 33% by count and 41% by volume.
- Statistical tests have shown that the modified inlet grate reduces the quantity of litter observed at the outfalls, with $\alpha = 0.05$. This is the case for all measuring parameters (weight, volume, and count) regardless of whether the litter data are normalized by watershed area or flow. The average annual reduction between the treatment and control outfalls during the two-year study period was 26% by weight, 23% by count and 19% by volume.
- Statistical tests indicate that the standard Caltrans bicycle grate does not statistically reduce ($\alpha = 0.05$) the litter observed at the outfalls or in the total system load. The bicycle grate BMP was evaluated during the first year of the study, and it was removed and replaced with the LID for the second year.

- Results of inlet deposition monitoring indicate that the LID is effective in reducing dry weather deposition (see Figure 4-5). Additionally, an important finding from the field evaluation of the LID BMP is that the LID gates operated well in storm conditions. The statistical analysis did not confirm that the BMP is effective in reducing volume or weight regardless of whether the litter data are normalized by watershed area or flow and which method of paired analysis is used. For count, the reduction is significant for the outfall-discharged, area-normalized load, but is not significant for either the outfall-discharged, flow-normalized load or the total system load.
- Statistical analysis conducted to assess the effect of the litter BMPs on the concentration of chemical constituents (e.g. heavy metals, total dissolved solids, etc.) between treatment and control areas did not show a reduction in chemical constituent concentrations that could be attributed to BMP implementation.

Other Results

Although the major focus of the LMPS was to evaluate BMP effectiveness, the data collected during this pilot study provides extensive information that can be used to enhance knowledge related to litter on Caltrans highways. The following general observations and trends from the LMPS may be useful related to future projects designed to understand and/or control litter on Caltrans highways.

- The material collected in the outfall monitoring nets consisted of gross pollutants comprising litter and vegetative material. The majority of all material collected was found to be vegetation. Site averages for percent vegetative material monitored in the outfalls range from 75 to 87 percent by wet weight for the four sites. These results also suggest that any device designed to capture litter will capture a majority of vegetation.
- Litter collected during outfall monitoring consists of paper, plastic, wood, cigarette butts, styrofoam, metal, and glass. The distribution by category is presented in Figures 6-2 to 6-7. The size of litter pieces was consistent and small (typically less than 2 square centimeters), suggesting that the standard parallel bar inlet grate that has 35 mm (1½-inch) bar spacing is effective in keeping large pieces of litter out of the inlets.
- Annual air-dried litter loads during the two-year study period ranged from 3.1 kg/acre at Site 8 to 7.5 kg/acre at Site 1E. It should be noted that the data normalized by area assume a straight-line relationship between catchment size and litter load. It is not the intent of this data presentation to predict average litter loads in other areas but instead give a general indication of loads and the variation between the LMPS sites.
- Data from the LMPS indicate that smoking- and food-related litter account for 20-30% of the litter by weight and volume. Seventy-nine percent of items by weight and 71% by volume were assigned to the “other” category. The LMPS data also indicate that approximately 80% of the litter collected at the outfall is floatable (see Table 6-2).
- Analysis shows that the types of litter materials present in sweeper litter are similar to outfall litter, with higher proportions of glass, moldable plastics, and metals, and a lower proportion of paper and film plastic in sweeper litter (see Figures 4-6 to 4-8).

- Analysis shows that the types of materials present in litter collected from the freeway ROW are similar to outfall litter with higher proportions of chipboard/cardboard, glass, and wood, and a much lower proportion of cigarette butts in ROW litter (see Figures 4-6 to 4-8).
- No clear relationships between litter and rainfall intensity, peak flow, total flow, and antecedent dry period for monitored events at each outfall were identified.
- No correlation between litter quantity and chemical concentrations for any of the constituents monitored was observed.

The LMPS team identified a number of recommendations related to further studies and research to advance the state of the knowledge of litter in storm water. These recommendations are presented in Section 8.2.

1.1 BACKGROUND

Caltrans is currently conducting numerous research projects with the common goal of improving the quality of runoff discharged from Caltrans highway drainage facilities. The Litter Management Pilot Study (LMPS) is one of these programs and is a direct result of Attachment 1 of the Stipulation and Order regarding the 1997/1998 Drain Inlet Cleaning Program that stemmed from a lawsuit filed against Caltrans by the Natural Resources Defense Council (NRDC) in Caltrans District 7 (Los Angeles area). The focus of the LMPS is field testing and evaluation of litter management practices to assess their effectiveness in reducing litter that is discharged from Caltrans storm water conveyance systems. The LMPS has defined litter as manufactured material that can be retained by a ¼-inch mesh and specifically addresses the following litter management practices:

- Increase street sweeping frequency
- Increase litter pick-up frequency
- Employ structurally modified inlets

At the core of the LMPS is a two-year field study that was conducted during the 1998-1999 and 1999-2000 rain seasons, following the methodology presented in the May 18, 1998 Final Detailed Study Design and Plan, Caltrans Document No. CTSW-RT-98-057 (Study Plan). This Final Report describes study implementation, data, and results that were obtained during the two-year study. The following additional reports have been prepared during the LMPS:

- Literature Review in Support of the LMPS, Caltrans Document No. CTSW-RT-99-015, 1997.
- Interim Report – District 7 LMPS, Caltrans Document No. CTSW-RT-99-056, 1999.

Caltrans has assembled a team of university representatives and consultants to assist the Caltrans Environmental Program in the design and implementation of the LMPS, including:

- California State University Sacramento (CSUS), Office of Water Programs
- URS Greiner Woodward Clyde (URSGWC)
- University of California Los Angeles (UCLA), Civil and Environmental Engineering Department

URS Greiner Woodward Clyde (URSGWC) has provided consulting services related to the majority of LMPS activities associated with project scoping, design, technical implementation, field monitoring, data review and analysis. UCLA has provided laboratory testing and prototype development of the Litter Inlet Deflector (LID) Best Management Practice (BMP) that was evaluated during year 2 of the LMPS.

1.2 OBJECTIVES

The objective of the LMPS is to evaluate the effectiveness of structural and non-structural BMPs that could result in a reduction of litter that enters or discharges from Caltrans freeway storm drain systems. The structural BMPs focus on freeway drain inlet modifications. The non-structural BMPs that were evaluated are mechanical broom street sweeping and manual litter pick-up programs.

1.3 STUDY DESIGN

The methodology followed during LMPS implementation is outlined in the Study Plan. The methodology was based on a systematic approach to research, evaluation, and work plan development. A key component of this process has been the project review provided by the Technical Advisory Group (TAG). The TAG consists of representatives from NRDC, Caltrans, the Santa Monica Bay Restoration Project (SMBRP), URSGWC, and the City of Los Angeles. The TAG has provided review and feedback throughout the project, acting as a steering committee to maintain project compliance with mutually agreed upon objectives. TAG support has included review of project documents, teleconferences, and periodic TAG meetings.

The Study Plan describes the basis for the study design in three primary sections:

- Section 2 – Identification and Monitoring of Litter in Storm Drains;
- Section 3 – Selection of Test and Control Areas; and
- Section 4 – BMPs to be tested.

A general overview of each section of the Study Plan is provided below.

1.3.1 Study Plan Section 2 – Identification and Monitoring of Litter

The Study Plan describes the equipment and approach used in the LMPS for monitoring litter and select chemical water quality constituents in the discharge from the monitored outfalls. Chemical water quality constituents monitored for this study are listed in Table 5-2. A unique litter monitoring program (e.g., field and laboratory facilities and procedures, plus data analysis procedures) was developed specifically to support this study. This was necessary because no standard or accepted methods and equipment are available for sampling and analyzing litter from storm water. The monitoring program was developed through the following process:

- **Defined litter for the LMPS**. This study has defined litter in storm water as:
  - Manufactured items that can be retained by ¼-inch mesh made from paper, plastic, cardboard, etc.
  - Materials that are not of natural origin (i.e., does not include sand, soil, gravel, vegetation, etc.)

Litter was quantified by weight (24-hour air-dried), volume, and count.

- **Identified monitoring locations and the method for collecting litter samples at those locations.** The Study Plan identified outfalls as the most suitable monitoring locations for this study. Outfall monitoring was selected over inlet monitoring because inlet monitoring would require traffic control for each set-up and post-storm collection and may result in traffic control during wet weather, which could impair the safety of the motoring public. For the purpose of this study, "outfall" is defined as a point in the drainage system, downgradient of inlets, where a transition that can be monitored occurs, generally between the Caltrans drainage system and the receiving municipal system. The general litter monitoring method comprises installing monitoring equipment at each monitored outfall, setting monitoring equipment before each trigger storm to collect litter from discrete storm events, and collecting and analyzing litter from each event.

- **Designed a litter sample collection device**. During development of the study design, four monitoring concepts were evaluated. These included two devices designed to be installed inside the outfall pipe and two devices for monitoring outside the pipe. A nylon mesh bag attached to a transition collar was the design selected based on its simplistic design and adaptability to various outfall configurations. More detail regarding the litter monitoring device is presented in Section 2 of this report.
- **Developed methods for quantifying and categorizing the collected litter.** The Study Plan presents a litter analysis methodology and its basis for development. The overall objective of litter analysis for this study is to generate data to evaluate the effectiveness of structural and non-structural BMPs. This objective was used in conjunction with an evaluation of litter analysis methods used in other studies (Folen and Zagar, 1990; and Syrek, 1998) to develop an initial litter analysis methodology. The initial methodology included the following general components:
  - Air drying the samples
  - Specieating the samples by material type and size
  - Weighing the samples
  - Measuring volume for each specieated sample component
  - Identifying the highly floatable fraction of the sample
  - Documenting the likely prior usage of the individual litter components (e.g., food container, smoking related, other)

The Study Plan also describes the quality assurance and quality control protocols to be used for litter monitoring, including standard data verification procedures and a sample recovery protocol. The sample recovery protocol was established to track the transport of litter from inlet to outfall at the study sites. The method involves spiking the inlets prior to every trigger storm event with a known set of materials that are similar to litter collected during pilot monitoring. The spike items are marked with unique identifiers for each event so that recovery can be tracked during litter characterization. Spike recovery is further discussed in Section 6 of this report.

The Study Plan additionally describes the procedures to be used for chemical water quality monitoring. Calibrated flow measurement flumes and automatic sampling equipment were used to collect flow-weighted composite samples to enable the calculation of Event Mean Concentrations (EMC) for chemical water quality constituents. Appendix B of the Study Plan presents the LMPS Monitoring Plan, which provides additional detail on both litter and chemical water quality monitoring procedures. Monitoring protocols are outlined further in Section 4 of this report.

1.3.2 Study Plan Section 3 – Selection of Test and Control Areas

The Study Plan describes the process used to identify the four final study sites, each with three BMP pairs. Each pair includes two outfalls: an outfall that drains a treatment (enhanced BMP) catchment area and an outfall that drains a control (non-enhanced BMP) catchment area. Site selection was conducted in a tiered or phased approach using database management techniques to organize and query siting information. During the initial phase, a list of 25 preliminary study

areas was developed by applying exclusionary criteria in several stages to outfalls that were identified through the review of an existing District 7 drain inlet database and Caltrans drainage system "as-built" plans. The list of 25 preliminary study areas was reduced to 7 potential areas that had inlet configurations that were considered to be representative of other District 7 configurations, areas outside major proposed Caltrans construction projects, and areas outside Caltrans environmental studies. (This latter criterion was applied to be sure that this study would not interfere with, or be interfered by, other studies that Caltrans is conducting nearby.) Detailed field reconnaissance was conducted at the remaining seven preliminary site study areas to make final study area selections. As a result, four final study sites were identified and matched with BMPs as follows:

- Site 1E – Litter Pick-Up: Eastbound Interstate 105, Post Mile (PM) 12.30 to PM 12.87
- Site 1W – Street Sweeping: Westbound Interstate 105, PM 12.87 to 12.30
- Site 6 – Structural BMP, Modified Inlet Grate: Eastbound Freeway 60, PM 15.12 to 15.58
- Site 8 – Structural BMP, LID - 1999/2000 (year 2), Bicycle Grate - 1998/1999 (year 1), Eastbound and Westbound Freeway 60, PM 5.60 to PM 5.95

Site locations are identified in Figure 1-1. Detailed site maps are provided in Section 2 of this report. The rationale for siting particular BMPs at their respective sites is provided in the Study Plan.

1.3.3 Study Plan Section 4 – BMPs to be Tested

The Study Plan outlines BMP implementation strategies for each of the three litter management practices evaluated in this study. The implementation strategies for each BMP are summarized below.

1.3.3.1 Street Sweeping

A review of municipal and commercial street sweeping equipment and practices and Caltrans freeway sweeping operations was conducted to develop a BMP implementation strategy for the LMPS. Various aspects of street sweeping were evaluated during this investigation including: equipment types, operational frequency, area of sweeping, operational variables affecting sweeping efficiency, traffic control requirements, pilot study site location, and the identification of candidate subcontractors. Caltrans routine street sweeping frequencies are based on loading criteria outlined in the Caltrans Maintenance Manual. The manual states that schedules are based on loading rates of ½ to 1 cubic yard of debris per mile. Sweeping frequencies can also be

Legend

- Final Site Areas
- Interstate Freeway
- State Freeway

N

SCALE

3 0 3 6 9

(IN MILES)

1 inch = 6 miles

Caltrans

SITE AREA LOCATIONS
CALTRANS LMPS

FIGURE 1-1

FN: DIST7A	PM: DEM	CHECKED BY:	DATE: 3-20-00	PROJECT NO: 58-977001NJ.01

adjusted in response to local aesthetics and safety considerations. The objective of the LMPS street sweeping BMP evaluation is to study the effect of increased street sweeping frequency using mechanical broom sweepers on reducing the quantity of litter that enters the Caltrans storm drain system. Based on this objective, the following BMP implementation strategy was described in the Study Plan and was implemented for the LMPS:

- Sweeping frequency – Increase the frequency of street sweeping at enhanced BMP sites. Street sweeping was conducted on a weekly basis in the enhanced BMP area and once every 4 weeks in the control BMP area.
- Swept areas – Caltrans currently conducts sweeping on shoulders, the center median, and on and off ramps. Lane sweeping is only conducted during spills or emergencies due to traffic and safety impacts. BMPs implemented during the LMPS maintained the current Caltrans practice.
- Scheduling – A majority of District 7 street sweeping is conducted between 8:30 a.m. and 3:00 p.m. Work associated with the LMPS was conducted during daytime hours, subject to restrictions based on heavy traffic hours for site-specific areas.
- Sweeper speed – Street sweeping was performed at manufacturer's recommended speeds (5 mph).
- Control conditions – Caltrans standard maintenance operations were discontinued during the study period in both the enhanced BMP and the control areas. Caltrans maintenance personnel respond to emergency street sweeping activities resulting from accidents or other circumstances, and these incidents were tracked via weekly communication with District 7 maintenance crews.
- Sweeper settings – Manufacturer's recommended practices for operation variables related to broom strike, broom material, and rear-broom coning were followed during street sweeping.

1.3.3.2 Manual Litter Pick-Up

An investigation of industry practice and District 7 Caltrans operations related to manual litter pick-up was conducted to develop a BMP implementation strategy for the LMPS. Various aspects of litter pick-up were evaluated during this investigation including resources, frequency, area of pick-up, procedures used, traffic control requirements, pilot study site location, and the identification of candidate subcontractors. Based on this evaluation, the following implementation strategy was described in the Study Plan and was implemented for the LMPS:

- Pick-up frequency – Increase the frequency of manual litter pick-up at enhanced BMP sites. At the start of the LMPS, Caltrans District 7 required a minimum frequency of 12 pick-ups per year for Adopt-A-Highway (AAH) Program participants. In some areas, AAH participants voluntarily collect litter on a more frequent basis. Litter is collected by Caltrans or Special Programs People on a minimum monthly basis in areas not covered by the AAH program. Litter pick-up frequency for the LMPS was once-per-week in the enhanced BMP area and once- per-four-weeks in the control area. Note that during the course of the LMPS, the District 7 AAH minimum required frequency has increased to two pick-ups per month and 24 pick-ups per year.

- Implementation – Caltrans District 7 litter pick-up is currently conducted by AAH participants and Special Programs People in the right-of-way (ROW) beyond the right shoulder only. Due to safety concerns, Caltrans prohibits litter pick-up on the roadway, medians, or shoulders by non-Caltrans personnel. Caltrans maintenance crews collect litter and debris in these areas on an as-needed basis. BMP implementation for the LMPS was conducted by AAH subcontractors and was therefore conducted in ROW areas only (i.e., not on paved surfaces).
- Pick-up procedures – The LMPS used procedures similar to those currently used by AAH, Special Programs, and Caltrans District 7 for litter collection. Litter pick-up was conducted in the Caltrans ROW, between the edge of pavement for the right shoulder and the ROW fence. Litter pick-up was not conducted on the roadway or median. Litter was picked up using mechanical, manually-operated, lever-actuated tongs and was placed into collection bags.

1.3.3.3 Structural Modifications to Drainage Inlets

The objective of the inlet control BMP is to reduce the amount of litter entering the storm drain system. A review of existing Caltrans standard inlet structures was conducted, and five candidate BMP alternatives were developed. Because the predominance of drain inlets in District 7 are "grate inlet" type, the original BMP alternatives were designed for this configuration as opposed to other Caltrans standards, such as curb cut inlets or k-rail opening-type inlets. The original candidate BMP alternatives included:

- a low-flow inlet with perimeter grate having small openings to trap floating litter while allowing low flows to enter the inlet;
- a litter-basket drain insert;
- a low-flow perforated plate similar to the first alternative;
- a Caltrans standard bicycle grate; and
- a synthetic whisker barrier upgradient of the inlet to trap litter.

Each alternative was rated using an evaluation matrix. The matrix included the following criteria: ease of installation; installation and maintenance cost; safety; compatibility with existing maintenance activities; safety; reliability; versatility; and flood protection. Based on this evaluation, the bicycle grate retrofit and the perforated plate retrofit were originally selected for field testing during the LMPS.

1.3.4 Study Design Modifications

One important modification was made to the LMPS after year 1 of monitoring. An alternative structural BMP was developed that was designed to substantially reduce dry weather deposition into the inlet. This new structural BMP, called the LID, consists of replacing the open grated inlet with a curb inlet containing a LID. All parties (the LMPS team, NRDC, and TAG participants) concurred that the LID retrofit had much greater potential to prohibit litter from entering the storm drain system than the bicycle grate retrofit monitored during year 1. The LID

BMP was installed in place of the bicycle grate structural BMP at Site 8. The LID structural BMP is described in further detail in Section 3.

1.4 COMMENTS

The objective of this study is specifically to evaluate the stated BMPs in a freeway environment. This study represents first-of-its-kind research in Southern California related to BMP effectiveness for litter removal in storm water systems. The principal objective of this Final Report is to present a summary of study activities, data, and results. It is important to realize that the data and conclusions reported herein are specific to Southern California freeway conditions. Therefore, use of the information reported herein should be tempered by consideration of the following caveats:

- The methodologies and the data presented herein apply strictly to small urban freeway catchments (less than one acre) and to site-specific hydrology.
- Rainfall during the 1998/1999 storm season (year 1) was approximately 50% below average for the monitored period (October – April). Rainfall during the 1999/2000 storm season (year 2) was approximately 80% of the average precipitation for the monitored period (October – March).

In addition, litter data appear to be inherently variable, and the data presented herein apply to the project-specific environment and conditions.

Data included in this report are presented in a combination of English and Metric units. All laboratory data (chemical water quality and litter) are measured and reported in metric units (e.g., liters, grams, milligrams per liter, etc.). Hydrologic data and area measurements, however, are typically presented in english units (e.g., flow in cubic feet or watershed inches, rainfall in inches, and area in acres). English units are maintained for consistency with recorded field values. Site data loggers were set to record flow and rainfall in cubic feet and inches, respectively, so that data collected could be readily compared to data from the National Weather Service and other Southern California meteorology reporting services.

The LMPS employed four field study sites, each of which was used to test and evaluate a separate BMP. Each study site included three replicate testing pairs. Each pair included two outfalls: an outfall that discharges runoff from a treatment or enhanced BMP catchment area and an outfall that discharges runoff from a control or non-enhanced BMP catchment area. Of the three outfall pairs at each site, two pairs were used to monitor only litter constituents, and one pair was used to monitor both litter and chemical water quality parameters. This section provides a general description of each site and identifies monitored outfalls. This section additionally describes litter and chemical water quality monitoring equipment used for this study.

2.1 SITE LOCATIONS AND OUTFALL DESCRIPTIONS

The four LMPS study sites are described below (a summary is provided in Table 2-1). Outfall locations and pair designations are shown on Figures 2-1 through 2-4. Photos 2-1 to 2-4 show typical conditions at each site.

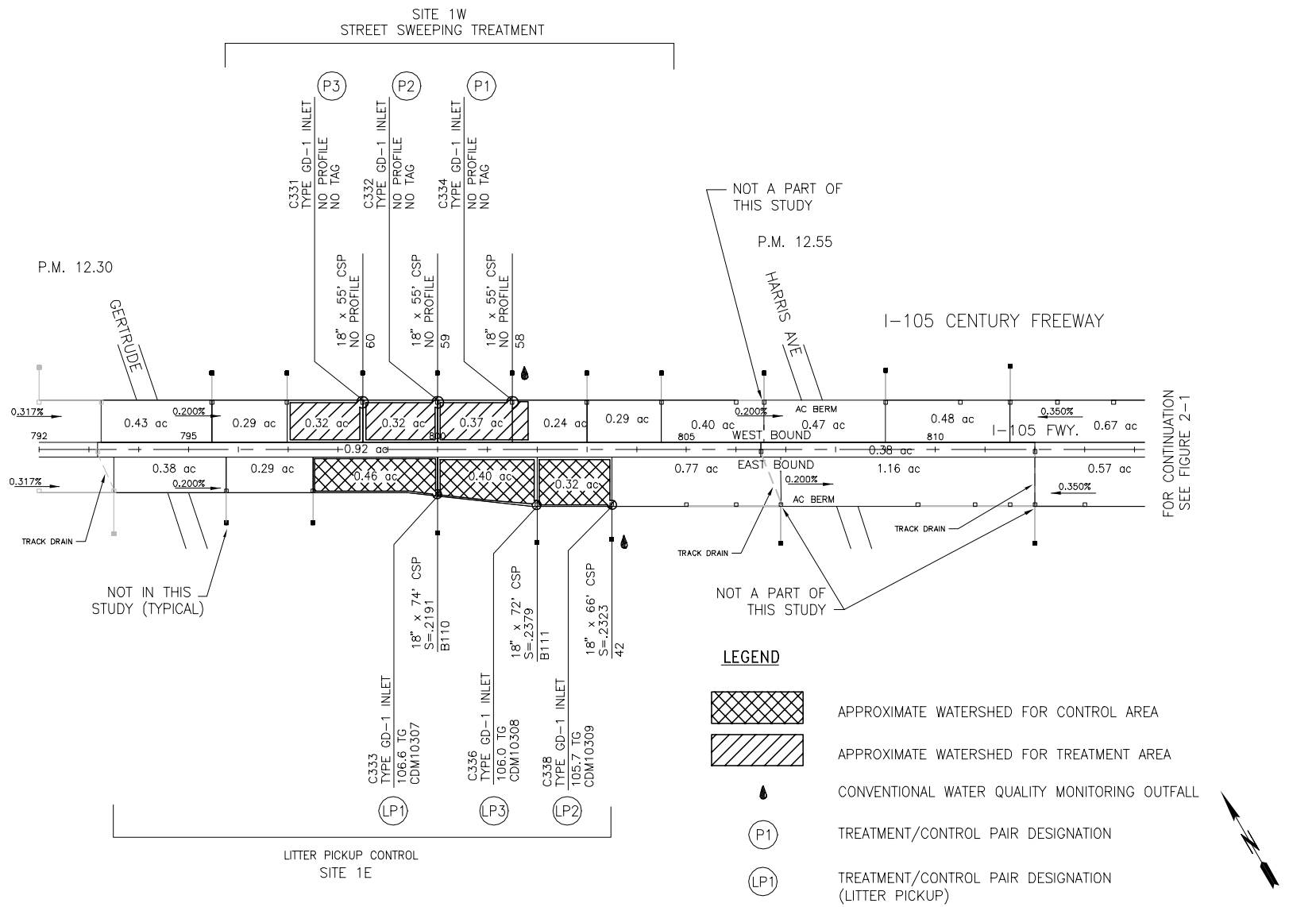
- **Site 1E (Litter Pick-Up)** — Site 1E (Figure 2-1) is located on the eastbound side of I-105 (the Century Freeway), between the Gertrude Avenue overpass (PM 12.30) and the Atlantic Boulevard overpass (PM 12.87) in Lynwood, California. The freeway in this area was constructed on fill slopes that are vegetated with small shrubs, with grass and bare earth at the toe of the slope. A vegetated earthen berm is present in the ROW along the edge of the shoulder pavement. The freeway consists of four travel lanes, a high occupancy vehicle (HOV) lane, and right and median shoulders. BMP implementation was monitored using three treatment/control pairs: LP1, LP2, and LP3. The outfalls (1-B110, 1-B111, and 1-42) used to monitor the litter pick-up control area are located in the western portion of the site, between the Gertrude Avenue and Harris Avenue overpasses. The outfalls used to monitor the litter pick-up treatment area (1-44, 1-46, and 1-47) are located in the eastern portion of the site, between the Harris Avenue and the Atlantic Boulevard overpasses.
- **Site 1W (Street Sweeping)** — Site 1W (Figure 2-2) is located on the westbound side of I-105 (the Century Freeway), between the Atlantic Boulevard overpass (PM 12.87) and the Gertrude Avenue overpass (PM 12.30) in Lynwood, California. The freeway in this area was constructed on fill slopes that are vegetated with small shrubs, with grass and bare earth at the toe of slope. A vegetated earthen berm is present in the ROW along the edge of the shoulder pavement. The freeway consists of four travel lanes, an HOV lane, and right and median shoulders. BMP implementation was monitored at three treatment/control pairs: P1, P2, and P3. The outfalls used to monitor the street sweeping control area (1-51, 1-50, and 1-52) are located in the eastern portion of the site, between the Atlantic Boulevard and Harris Avenue overpasses. The outfalls used to monitor the street sweeping treatment area (1-58, 1-59, and 1-60) are located in the western portion of the site, between the Harris Avenue and Gertrude Avenue overpasses.
- **Site 6 (Modified Inlet Grate)** – Site 6 (Figure 2-3) is located on the eastbound side of State Route 60 (the Pomona Freeway) between the Turnbull Canyon undercrossing (PM 15.12) and the Kwis Street pedestrian overcrossing (PM 15.58) in Hacienda Heights, California. The freeway in this area was constructed on fill slopes. A soundwall is present at the edge of the shoulder along the length of the site. Trees overhang the top of the soundwall at several locations.

Table 2-1
FIELD STUDY SITE INFORMATION

Study Site Number	Study Site Location	Subject BMP	Monitored "Treatment" Outfalls	Monitored "Control" Outfalls	Study Pair Designation
1E	I-105 Eastbound (Lynwood) between Gertrude Ave. and Atlantic Blvd. overpass (PM12.30 to PM12.87)	Manual litter pick-up	1-47 1-46 1-44 *treatment frequency pick-up once per week	1-B110 1-42 1-B111 **control frequency pick-up once per four weeks	LP1 LP2 LP3
1W	I-105 Westbound (Lynwood) between Atlantic Blvd. and Gertrude Ave. overpass (PM12.87 to PM12.30)	Street sweepers (mechanical brooms)	1-58 1-59 1-60 *treatment frequency sweep once per week	1-52 1-50 1-51 **control frequency sweep once per four weeks	P1 P2 P3
6	Freeway 60, Pomona freeway (Hacienda Heights) between Turnbull Canyon undercrossing and Kwis St. overcrossing (PM 16.12 to PM 15.58)	Modified inlet grate (option A – perforated steel plate)	6-20H 6-20F 6-20B *treatment employs perforated plate on inlets	6-20G 6-20E 6-20C **control employs standard grate inlet	P1 P2 P3
8	Freeway 60, Pomona freeway (Montebello and Monterey Park) between Garfield Ave. undercrossing and Fulton Ave. (PM 5.60 to PM 5.95)	LID (1999/2000) Bicycle grate (1998/1999)	8-B001 8-24B 8-24F *treatment employs the BMP at inlets	8-23C 8-24D 8-24E **control employs standard grate inlet	P1 P2 P3

The freeway consists of five travel lanes and a right shoulder. BMP implementation was monitored at three treatment/control pairs: P1, P2, and P3. Outfalls and catchment areas for these pairs are located sequentially from west to east along the freeway. Outfall locations and pair designations are shown on Figure 2-3.

- **Site 8 (LID – 1999/2000, Bicycle Grate – 1998/1999)** — Site 8 (Figure 2-4) is located on the eastbound and westbound sides of State Route 60 (the Pomona Freeway) between Garfield Avenue undercrossing (PM 5.60) and Fulton Avenue (PM 5.95) in Montebello and Monterey Park, California. The freeway in this area was constructed on fill slopes that are vegetated with large shrubs and trees, with grass at the toe of slope. A guardrail is present along the edge of the shoulder pavement. The freeway consists of four travel lanes and right and median shoulders. BMP implementation was monitored at three treatment/control pairs. P1 (Outfalls B001 and 23C) is located on the westbound side of the freeway, whereas P2 (Outfalls 24B and 24D) and P3 (Outfalls 24E and 24F) are located on the eastbound side of the freeway. Outfall locations and pair designations are shown on Figure 2-4.



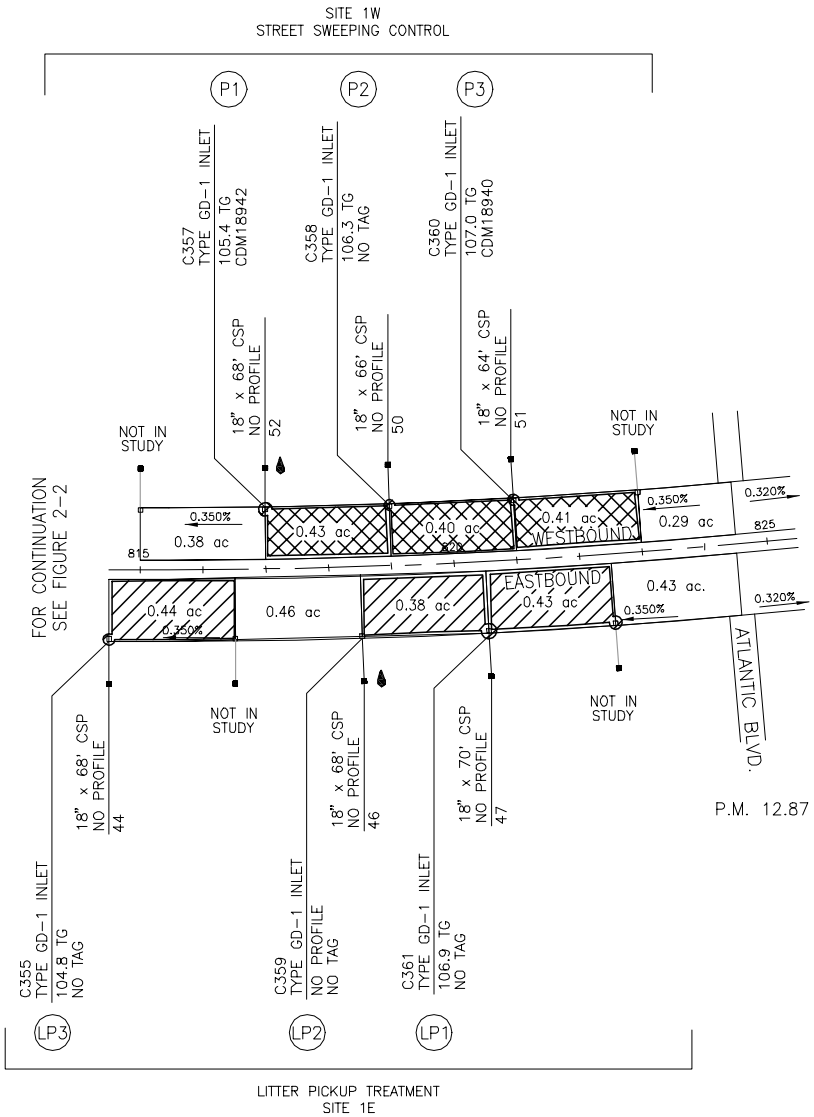
NOTE:
LMPS CATCHMENT AREAS ARE DERIVED FROM CALTRANS AS-BUILTS ADJUSTED AS APPROPRIATE FOLLOWING FIELD RECONNAISSANCE (JUNE 2-3, 1999). SCALED FREEWAY WIDTHS ON DRAWING MAY NOT REPRESENT ACTUAL CONDITIONS.

Caltrans

SITE 1
CALTRANS LMPS

FN: SITE1-1B	PM: DEM	CHECKED BY:	DATE: 5-12-00	PROJECT NO: 58-977001NJ.01

FIGURE 2-1



I-105 CENTURY FREEWAY

LEGEND

- APPROXIMATE WATERSHED FOR CONTROL AREA
- APPROXIMATE WATERSHED FOR TREATMENT AREA
- CONVENTIONAL WATER QUALITY MONITORING OUTFALL
- (P1) TREATMENT/CONTROL PAIR DESIGNATION
- (LP1) TREATMENT/CONTROL PAIR DESIGNATION (LITTER PICKUP)

0 300 600

APPROXIMATE GRAPHIC SCALE
(FEET)

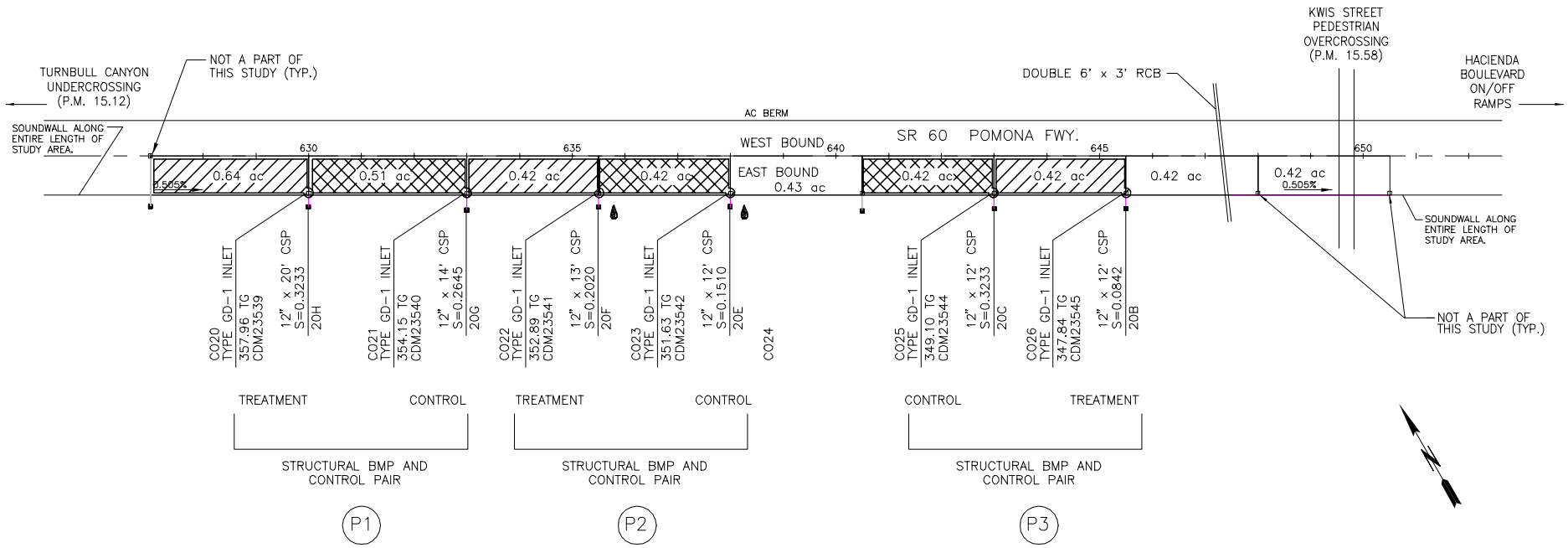
NOTE:
LMPS CATCHMENT AREAS ARE DERIVED FROM CALTRANS AS-BUILTS ADJUSTED AS APPROPRIATE FOLLOWING FIELD RECONNAISSANCE (JUNE 2-3, 1999). SCALED FREEWAY WIDTHS ON DRAWING MAY NOT REPRESENT ACTUAL CONDITIONS.

Caltrans

SITE 1
CALTRANS LMPS

FN: SITE1-02	PM: DEM	CHECKED BY:	DATE: 5-12-00	PROJECT NO: 58-977001NJ.01

FIGURE 2-2



STRUCTURAL BMP – MODIFIED INLET GRATE

LEGEND

- APPROXIMATE WATERSHED FOR CONTROL AREA
- APPROXIMATE WATERSHED FOR TREATMENT AREA
- CONVENTIONAL WATER QUALITY MONITORING OUTFALL
- (P1) TREATMENT/CONTROL PAIR DESIGNATION

0 300 600

APPROXIMATE GRAPHIC SCALE (FEET)

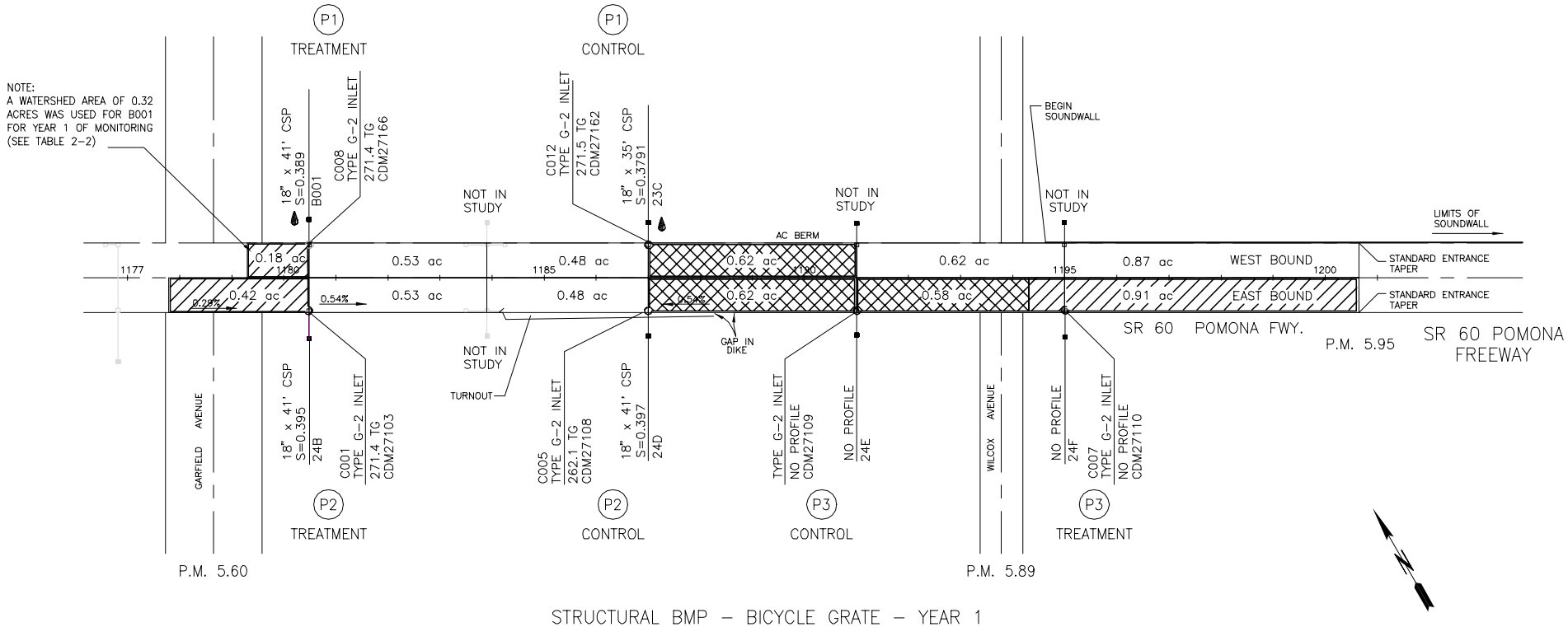
NOTE:
LMPS CATCHMENT AREAS ARE DERIVED FROM CALTRANS AS-BUILTS ADJUSTED AS APPROPRIATE FOLLOWING FIELD RECONNAISSANCE (JUNE 2-3, 1999). SCALED FREEWAY WIDTHS ON DRAWING MAY NOT REPRESENT ACTUAL CONDITIONS.

Caltrans

SITE 6
CALTRANS LMPS

FN: SITE6-1B	PM: DEM	CHECKED BY:	DATE: 5-12-00	PROJECT NO: 58-977001NJ.01

FIGURE 2-3



STRUCTURAL BMP – BICYCLE GRATE – YEAR 1
LITTER INLET DEFLECTOR (LID) – YEAR 2

LEGEND

- APPROXIMATE WATERSHED FOR CONTROL AREA
- APPROXIMATE WATERSHED FOR TREATMENT AREA
- CONVENTIONAL WATER QUALITY MONITORING OUTFALL
- (P1) TREATMENT/CONTROL PAIR DESIGNATION

0 300 600
APPROXIMATE GRAPHIC SCALE (FEET)

Caltrans

SITE 8
CALTRANS LMPS

FN: SITE8	PM: DEM	CHECKED BY:	DATE: 5-23-00	PROJECT NO: 58-977001NJ.01

FIGURE 2-4

Photo 2–1
Typical Freeway and Shoulder Conditions–Site 1E (Litter Pick-Up)

Photo 2–2
Typical Freeway and Shoulder Conditions–Site 1W (Street Sweeping)

Photo 2–3
Typical Freeway and Shoulder Conditions–Site 6 (Modified Inlet Grate)

Photo 2–4
Typical Freeway and Shoulder Conditions–Site 8 (LID-1999/2000; Bicycle Grate-1998/2000)

Table 2-2 presents estimated catchment areas and pair designations for outfalls at each site and designates which outfalls are monitored for chemical water quality constituents. Two sets of estimated catchment area values are presented in Table 2-2. One set represents the initial estimate, which was based on an interpretation of Caltrans as-built drawings. The second set represents adjusted values, which reflect the findings from the following: a focused field reconnaissance conducted on June 2–3, 1999, year 2 wet weather field observations, and final hydrologic data analysis.

During development of the Study Plan, catchment areas were estimated, based primarily on information shown on as-built engineering drawings. Additional field reconnaissance was conducted after year 1 of monitoring, because analysis of site hydrologic data for some catchment areas yielded runoff coefficients that were unusual for freeway pavement conditions. As a result, the LMPS team suspected that watershed sizes (i.e., the actual drainage areas) may be different from those originally estimated from the as-built drawings. Field reconnaissance was conducted to further define catchment sizes and to look for pavement conditions or other features that could explain unexpected runoff coefficients. Some catchment areas were adjusted as a result of field investigations and hydrologic data were re-analyzed, yielding more realistic runoff coefficients. Additional wet-weather field observations were conducted during year 2 of monitoring to confirm runoff patterns in Site 1 and Site 8 catchments. These observations were conducted during 4 events (1990-05, 1999-08, 1999-11, 1999-12). In general, adjusted catchment areas were confirmed by wet weather observations. Based on year 2 hydrologic data analysis and wet weather observations, the catchment area at B001 was adjusted to 0.18 acres, and the catchment areas at 24E and 24F were adjusted to 0.58 acres and 0.91 acres, respectively. Summaries of both dry and wet weather field investigation findings are presented in Appendix A.

2.2 MONITORING EQUIPMENT

As indicated above, some outfalls were monitored for litter-only, whereas others were monitored for both litter and chemical water quality constituents. Equipment installed at each type of monitoring outfall is described in the following subsections.

2.2.1 Litter Monitoring Equipment

The litter monitoring device used at all outfalls consists of a ¼-inch mesh bag that is attached to a metal collar at the outfall via a web strap. Metal collars were designed and fabricated to site-specific specifications (i.e., tailored for pipe diameter and outfall type). Two primary types of collars were installed; one type attached to an existing corrugated metal pipe at flared-end sections and one type attached to circular pipe headwalls. Litter bags with ¼-inch mesh were manufactured specifically for the study. Nylon belt straps were used to secure the litter mesh bags to the metal collars. Buckle straps were chosen for their ease of removal in case of emergency. For each of the 16 outfalls monitored for litter only, a chain-link protective enclosure was constructed to surround the outfall. A typical litter-only monitoring station is shown in Photos 2-5 and 2-6.

Table 2–2
ESTIMATED WATERSHED AREAS AND PAIR DESIGNATIONS FOR LMPS OUTFALLS

Site	Best Management Practice (BMP)	Outfall Pair		Outfall	Estimated Watershed Area (ac) Based on As-Builts Only	Final Estimated Watershed Area (ac)[1]
1 East	Litter Pick-up	LP1	Control	B-110	0.42	0.46
			Treatment	47	0.46	0.43
		LP2[2]	Control	42	0.34	0.32
			Treatment	46	0.46	0.38
		LP3	Control	B111	0.41	0.40
			Treatment	44	0.46	0.44
1 West	Street Sweeping	P1[2]	Control	52	0.38	0.43
			Treatment	58	0.29	0.32
		P2	Control	50	0.38	0.40
			Treatment	59	0.29	0.32
		P3	Control	51	0.38	0.41
			Treatment	60	0.29	0.32
6	Modified Inlet	P1	Control	20G	0.51	0.51
			Treatment	20H	0.51	0.64
		P2[2]	Control	20E	0.42	0.42
			Treatment	20F	0.42	0.42
		P3	Control	20C	0.42	0.42
			Treatment	20B	0.42	0.42
8	LID (1999/2000)	P1[2]	Control	23C	0.62	0.62
			Treatment	B001	0.57	0.32/0.18[3]
		P2	Control	24D	0.62	0.62
	Bicycle Grate (1998/1999)		Treatment	24B	0.57	0.42
		P3	Control	24E	0.62	0.58
			Treatment	24F	0.62	0.91

1 Final estimated watershed areas are based on previous estimates and revisions due to wet weather observations and final hydrologic analysis.

2 Outfalls monitored for chemical water quality constituents.

3 0.32 acres used in evaluation of year 1 bicycle grate retrofit. 0.18 acres used in evaluation of year 2 LID retrofit. Adjustment resulting from non-study related changes to pavement conditions at Site 8 prior to year 2 monitoring.

Photo 2–5
Typical Litter Monitoring Bag at Outfall

Photo 2–6
Litter Monitoring Station with Fence Enclosure

2.2.2 Chemical Water Quality Monitoring Equipment

Eight of the 24 study outfalls were monitored for chemical water quality constituents in addition to litter. These outfalls are shown on Figures 2-1 through 2-4. At these stations, samples were collected on a flow-weighted basis via automatic sampling equipment. The following equipment was installed at each of these sites: a custom H-flume with a bubbler flow-meter; a tipping-bucket rain gauge; an automatic sampler and data logger; and an equipment enclosure. A detailed list of components installed at each site is provided in Table 2-3. In addition to components listed in Table 2-3, sites were also outfitted with the litter monitoring equipment described in Section 2.2.1. The litter bags used at the chemical water quality monitoring outfalls were modified to include a Velcro™ grab-sampling port at the top of each bag. A typical chemical water quality monitoring station is shown in Photo 2–7. Equipment installed in an enclosure is shown in Photo 2–8.

2.3 EQUIPMENT INSTALLATION

Monitoring equipment was installed from October 13, 1998 to October 23, 1998. Site preparation activities preceded the actual installation of litter monitoring and water monitoring equipment. Site preparation and equipment installation activities are described below.

Site Preparation Work

The following site preparation work was conducted between September 21, 1998 to October 8, 1998:

- Removal and proper disposal of vegetation (small trees, shrubs, and weeds) at designated outfalls;
- Soil grading and contouring to level water-quality monitoring sites and provide for proper drain pipe discharge;
- Truncation of existing 12-inch corrugated metal pipe (CMP) at Site 6, Outfalls 20E and 20F;
- Installation of concrete slabs for flume foundations and equipment enclosures;
- Installation of equipment enclosures onto the concrete slabs at each chemical water quality monitoring location;
- Installation of rain gauge pole, solar panel pole, and solar panels at each chemical water quality monitoring location;
- Installation of 8-foot-high perimeter security fences each with 4-foot-wide walk gates at each chemical water quality monitoring location; and
- Installation of protective chain-link fence enclosures at 16 litter monitoring outfalls.

Table 2–3
CHEMICAL WATER QUALITY EQUIPMENT COMPONENTS

Equipment Manufacturer	Part No.	Quantity	Description
FLOW METER			
American Sigma	2672	8	Sigma 950 bubbler flow meter with graphics display
	2921	2	Vinyl bubble tubing, 1/8-inch ID x 100 feet
	2900	8	Bubble tube mounting plate with holes
	1414	16	Battery, gel electrolyte, 12 VDC, 6 amp-hr
	1602	8	Modem, 14,400 baud
	2666	8	Rain gauge input
	940	8	Multi-purpose full cable, 10 feet, 6 pin connector both ends
AUTOMATED SAMPLER			
American Sigma	8925	8	SIGMA 900 portable sampler controller with cover
	8976	8	Standard insulated base for SIGMA 900 sampler
	1414	16	Battery, gel electrolyte, 12 VDC, 6 amp-hr
	1118	24	Bottles, set of (8) 1.9 liter glass with caps (for standard base)
	1422	8	Retainer for (8) 1.9 liter glass bottles
	8584	8	Distributor with arm for 8 bottle standard base
	925	3	Teflon lined polyethylene tubing 3/8 inch x 100 feet
	2186	8	Connection kit for Teflon lined polyethylene tubing
	2071	8	Strainer for shallow depth applications, 316 stainless steel
RAIN GAUGE			
American Sigma	2149	8	Rain Gauge with 25 feet cable and base mounting plate
	0003	8	Junction box to connect rain gauge leads to flowmeter
TELEMETRY / MISC			
American Sigma	5120	8	Cellular phone option (with phone)
	1760	4	Charger, 5 station, 115 VAC for gel electrolyte
	0003	8	Solar power panel custom wired and sized with 75 foot cable
	3975	1	Insight and Vision Software on 3.5” Disk
ENCLOSURE			
American Sigma	6989	4	Weatherguard enclosure (full size, walk-in)
Hoffman Industrial	A-691	4	Industrial Enclosure
FLUME			
Corrosion Control	--	8	1.5-ft. Custom H-Flumes

Photo 2–7
Chemical Water Quality Monitoring Station

Photo 2–8
Enclosure with Automatic Sampler, Battery, Cell Phone, and Data Logger for Chemical Water Quality Monitoring

Access Gate Installation

Four access gates (4-foot-wide) were installed in the Caltrans ROW fence in accordance with Caltrans Standard Specifications Section 80, Fences, Caltrans Standard Plans A85, as part of the installation effort.

Removal and Disposal of Vegetation (Small Trees, Shrubs, and Weeds)

Site 6 required the removal of vegetation prior to installation of litter and water-quality monitoring equipment. Outfalls 20B, 20C, 20G, and 20H are litter monitoring outfalls, and each required clearing of vegetation and sediment surrounding the flared end outfalls. These outfalls required excavation to prepare the site, and the surrounding soil was contoured to minimize ponding of discharge at the mouth of the outfall.

Site 6 — Outfalls 20E and 20F are both litter and water-quality monitoring outfalls, and required some removal of vegetation consisting of shrubs, bushes, and small trees. Vegetation was cut back and removed as necessary to perform grading and leveling within the footprint required for protective perimeter fencing.

Installation of Solar Panel and Mounting Pole

A 12-foot galvanized steel pole (for solar panel mounting) embedded into 2 feet of concrete (10-foot finished height) was installed at Site 8 - Outfalls B001 and 23C, and Site 1 - Outfalls 52 and 58. For these four outfalls, solar panels were set on the embankment adjacent to the freeway shoulder.

The remaining 4 outfalls requiring solar panels, Site 6 - Outfalls 20E and 20F, and Site 1 - Outfalls 42 and 46, all face the southerly direction. These solar panels were set within the limits of the perimeter fenced area with directional settings aimed to capture the most sunlight. After each pole was set, solar panels were then mounted at the top of the poles, and wiring was routed back to the equipment enclosure encased in ¾-inch outdoor-rated conduit.

Installation of Perimeter Fence with Gate

At each of the eight water-quality monitoring outfall locations, a 6-foot-high galvanized chain-link fence and 4-foot-wide gates were installed. Installation was completed according to Caltrans Standard Specifications, Section 80 - Fences, and Caltrans Standard Plan A85.

Chain-Link Fence Enclosures — Litter Monitoring Outfalls

Sixteen chain-link protective enclosures with locking mechanisms were installed at designated outfalls. The chain-link enclosures were constructed with galvanized hardware, posts, and chain-link. The posts were placed at a minimum of 2 feet below grade and set in concrete footings.

For Site 8 — Outfalls 24B, 24D, 24E, and 24F, located in the City of Montebello, the enclosures were surface mounted on a concrete pad approximately 88 inches wide and 60 inches long. For

the remaining 12 sites with natural ground at drainage outfalls, crushed stone was placed at 3-inch-depth within the limits of the fenced enclosure.

Litter Monitoring Equipment Installation

All 16 litter metal collars were installed between September 28, 1998 and October 2, 1998. Litter mesh bags were strapped onto the metal collars for litter monitoring commencing on October 2, 1998.

Chemical Water Quality Monitoring Equipment

Equipment installation for the 8 chemical water quality monitoring sites was completed from October 13 to October 23, 1998. Custom designed H-flumes were also installed during this period. An American Sigma technical specialist field-tested and verified the water sampling equipment installation from October 27 to October 30, 1998.

BMPs related to three litter management practices were implemented in conjunction with the LMPS. These BMPs are: street sweeping, manual litter pick-up, and structural modifications to drainage inlets. Street sweeping and manual litter removal do not require structural modifications to the storm water conveyance system and are, therefore, referred to as "non-structural" BMPs. This section outlines BMP implementation for each of the three litter management methods. This section additionally discusses drain inlet cleaning conducted at study outfalls and tracking of Caltrans maintenance activities potentially affecting the LMPS.

3.1 INLET CLEANING

To provide a baseline "clean" condition for portions of the freeway drainage systems monitored in this study, each of the 24 inlet/outfall piping systems was cleaned prior to the start of BMP implementation. Cleaning was conducted by United Pumping from September 30, 1998 through October 2, 1998 using a wet jetting method from the outfall side of the drainage system. The wet jetting method generated co-mingled sediment/cleaning water residuals that were collected at the outfall by a vactor truck. The portions of freeway drainage systems monitored in this study consist of single inlets connected to a single outfall by a short section of corrugated metal pipe. Subsequent to cleaning, it was possible to look into the outfall pipes and visually see each corresponding inlet. Therefore, no additional investigative methods (e.g., subsurface video inspection) were necessary to verify that the systems were free of obstructions. A photo of a typical drainage system being cleaned is provided in Photo 3-1.

Inlet cleaning was also conducted at Sites 6 and 8 prior to the onset of the first rain event for year 2 monitoring. At Site 8, inlets and pipelines were cleaned prior to (September 16, 1999) and at the completion of (October 1, 1999) construction activities associated with the installation of the LID

Photo 3–1
Pipeline Cleaning Using Wet Jetting Method and Vactor Hose

structural retrofit. Cleaning involved removing inlet debris manually and placing debris in bags labeled by inlet/outfall number. Pipelines were then cleaned by dry methods by pulling a "train" of connected chimney brushes through the pipes (from inlet to outfall). A minimum of two passes were made through the pipes with the brush train. Inlet and pipe debris collected prior to construction was sent to the litter lab for analysis, representing the final set of data collected for the bicycle grate retrofit BMP. After construction, Site 8 inlets and pipes were cleaned, using the above manual methods to establish baseline clean conditions for evaluation of the LID BMP. Inlet debris collected after the construction period was not retained for analysis.

At Site 6, inlets were cleaned on October 26, 1999 as a result of a substantial amount of debris accumulation in study inlets (predominantly leaves and vegetation). Debris depth measurements performed in early October 1999 indicated that the buildup of debris was within 6 inches of the top of the grate at several inlets. Inlets were cleaned only to avoid full inlet conditions that could prohibit deposition or cause hydraulic or outfall monitoring problems. Debris from the six inlets was removed manually, placed in labeled bags, and sent to the litter lab for analysis. As a result of the substantial debris accumulation at Site 6, a LMPS cleanout criteria was established, such that all inlets at a site would be cleaned if any one inlet had accumulation depths less than one foot below the inlet grate.

At the conclusion of year 2 of monitoring, all study inlets and pipes were cleaned by dry methods described for Site 8 above. Debris was transported to the Santa Ana litter lab for analysis.

3.2 STREET SWEEPING - SITE 1W

3.2.1 BMP Implementation Strategy

The street sweeping BMP was conducted at Site 1W. Three replicate outfalls were located in the enhanced BMP (treatment) area. This consisted of a contiguous stretch of the I-105 freeway that extends from the Harris Avenue overpass to the Gertrude Avenue overpass (approximately ¼ mile long). Three replicate outfalls were located in the control area, a contiguous stretch of freeway from the Atlantic Boulevard overpass to the Harris Avenue overpass (also approximately ¼ mile long). The LMPS street sweeping BMP was implemented in these areas as follows:

- Street sweeping was conducted on a weekly basis in the enhanced BMP (treatment) area and once every 4 weeks in the control BMP area.
- Street sweeping was conducted by a contractor using a Mobil M-8A mechanical broom sweeper (Photo 3-2). Manufacturer's recommended practice for street sweeper operational parameters including broom strike, coning, and sweeper speed (5 miles per hour) were followed during the LMPS.
- Sweeping was conducted on the shoulder and median only. There are no on- or off-ramps in the study area, and travel lanes are not typically swept by Caltrans.

Photo 3–2
Mechanical Broom Sweeper

- Street sweeping activities that would normally be conducted by District 7 maintenance were discontinued in the treatment and control areas during the two-year study period. However, Caltrans maintenance personnel were still responsible for responding to emergency street sweeping activities resulting from accidents or other circumstances.
- Sweeping was conducted between 9am and 3pm but was not conducted during rain or any weather with reduced visibility.

Dates and corresponding sweeping locations (i.e., treatment vs. control) are listed in Table 3-1. An inspector accompanied the street sweeper (operated by a contractor) during all sweeping events to ensure that manufacturer's recommended practices were followed, as well as to ensure that sweeping was conducted in the appropriate location each week. Sweeping inspection was documented each week. A sample inspection form is provided in Appendix B.

3.3 MANUAL LITTER PICK-UP – SITE 1E

3.3.1 Manual Litter Pick-Up BMP Implementation Strategy

- The litter pick-up BMP was conducted at Site 1E, located on the eastbound side of the 105 Freeway in Lynwood, between the Gertrude Avenue overpass and the Atlantic Boulevard overpass. Three replicate outfalls were located in the enhanced BMP (treatment) area, a contiguous stretch of freeway that extends from the Harris Avenue overpass to the Atlantic Boulevard overpass (approximately ¼ mile long). Three replicate outfalls were located in the control area, a contiguous stretch of freeway that extends from the Gertrude Avenue overpass to the Harris Avenue overpass (also approximately ¼ mile long).

Table 3–1
Sites 1W and 1E
NON-STRUCTURAL BMP IMPLEMENTATION
October 1998 – March 2000

	Street Sweeping - Site 1W		Litter Pick-Up - Site 1E	
Week No.	Date	Implementation	Date	Implementation
1	10/7/98	Control (Atlantic to Gertrude)	10/6/98	Control (Gertrude to Atlantic)
2	10/15/98	Treatment (Harris to Gertrude)	10/13/98	Treatment(Harris to Atlantic)
3	10/22/98	Treatment (Harris to Gertrude)	10/20/98	Treatment(Harris to Atlantic)
4	10/29/98	Treatment (Harris to Gertrude)	10/27/98	Treatment(Harris to Atlantic)
5	11/5/98	Control (Atlantic to Gertrude)	11/3/98	Control (Gertrude to Atlantic)
6	11/12/98	Treatment (Harris to Gertrude)	11/10/98	Treatment(Harris to Atlantic)
7	11/19/98	Treatment (Harris to Gertrude)	11/17/98	Treatment(Harris to Atlantic)
8	11/25/98	Treatment (Harris to Gertrude)	11/24/98	Treatment(Harris to Atlantic)
9	12/2/98	Control (Atlantic to Gertrude)	12/2/98	Control (Gertrude to Atlantic)
10	12/11/98	Treatment (Harris to Gertrude)	12/8/98	Treatment(Harris to Atlantic)
11	12/17/98	Treatment (Harris to Gertrude)	12/15/98	Treatment(Harris to Atlantic)
12	12/23/98	Treatment (Harris to Gertrude)	12/22/98	Treatment(Harris to Atlantic)
13	12/29/98	Control (Atlantic to Gertrude)	12/29/98	Control (Gertrude to Atlantic)
14	1/7/99	Treatment (Harris to Gertrude)	1/5/99	Treatment(Harris to Atlantic)
15	1/14/99	Treatment (Harris to Gertrude)	1/12/99	Treatment(Harris to Atlantic)
16	1/20/99	Rain Cancellation	1/19/99	Treatment(Harris to Atlantic)
17	1/28/99	Control (Atlantic to Gertrude)	1/27/99	Treatment(Harris to Atlantic)
18	2/4/99	Treatment (Harris to Gertrude)	2/2/99	Control (Gertrude to Atlantic)
19	2/11/99	Treatment (Harris to Gertrude)	2/11/99	Treatment (Harris to Atlantic)
20	2/18/99	Treatment (Harris to Gertrude)	2/16/99	Treatment (Harris to Atlantic)
21	2/25/99	Control (Atlantic to Gertrude)	2/23/99	Treatment (Harris to Atlantic)
22	3/4/99	Treatment (Harris to Gertrude)	3/2/99	Control (Gertrude to Atlantic)
23	3/11/99	Treatment (Harris to Gertrude)	3/9/99	Treatment (Harris to Atlantic)
24	3/18/99	Treatment (Harris to Gertrude)	3/16/99	Treatment (Harris to Atlantic)
25	3/26/99	Control (Atlantic to Gertrude)	3/23/99	Treatment (Harris to Atlantic)
26	4/1/99	Treatment (Harris to Gertrude)	3/30/99	Control (Gertrude to Atlantic)
27	4/8/99	Treatment (Harris to Gertrude)	No Pick-up	Contractor Scheduling Error
28	4/15/99	Treatment (Harris to Gertrude)	4/14/99	Treatment (Harris to Atlantic)
29	4/22/99	Control (Atlantic to Gertrude)	4/21/99	Treatment (Harris to Atlantic)
30	4/29/99	Treatment (Harris to Gertrude)	4/27/99	Treatment (Harris to Atlantic)
31	5/6/99	Treatment (Harris to Gertrude)	5/4/99	Control (Gertrude to Atlantic)
32	5/14/99	Treatment (Harris to Gertrude)	5/11/99	Treatment (Harris to Atlantic)
33	5/20/99	Control (Atlantic to Gertrude)	5/18/99	Treatment (Harris to Atlantic)
34	5/27/99	Treatment (Harris to Gertrude)	5/25/99	Treatment (Harris to Atlantic)
35	6/30/99	Treatment (Harris to Gertrude)	6/01/99	Control (Gertrude to Atlantic)
36	6/10/99	Treatment (Harris to Gertrude)	6/08/99	Treatment(Harris to Atlantic)
37	6/17/99	Control (Atlantic to Gertrude)	6/15/99	Treatment(Harris to Atlantic)
38	6/24/99	Treatment (Harris to Gertrude)	6/22/99	Treatment(Harris to Atlantic)

Table 3–1 (Continued)
NON-STRUCTURAL BMP IMPLEMENTATION
October 1998 – March 2000

	Street Sweeping - Site 1W		Litter Pick-Up - Site 1E	
Week No.	Date	Implementation	Date	Implementation
39	7/1/99	Treatment (Harris to Gertrude)	6/29/99	Control (Gertrude to Atlantic)
40	7/8/99	Treatment (Harris to Gertrude)	7/13/99	Treatment(Harris to Atlantic)
41	7/15/99	Control (Atlantic to Gertrude)	7/13/99	Treatment(Harris to Atlantic)
42	7/22/99	Treatment (Harris to Gertrude)	7/20/99	Treatment(Harris to Atlantic)
43	7/30/99	Treatment (Harris to Gertrude)	7/27/99	Control (Gertrude to Atlantic)
44	8/6/99	Treatment (Harris to Gertrude)	8/3/99	Treatment(Harris to Atlantic)
45	8/13/99	Control (Atlantic to Gertrude)	8/10/99	Treatment(Harris to Atlantic)
46	8/20/99	Treatment (Harris to Gertrude)	8/17/99	Treatment(Harris to Atlantic)
47	8/27/99	Treatment (Harris to Gertrude)	8/24/99	Control (Gertrude to Atlantic)
48	9/3/99	Treatment (Harris to Gertrude)	8/31/99	Treatment(Harris to Atlantic)
49	9/10/99	Control (Atlantic to Gertrude)	9/7/99	Treatment(Harris to Atlantic)
50	9/17/99	Treatment (Harris to Gertrude)	9/14/99	Treatment(Harris to Atlantic)
51	9/24/99	Treatment (Harris to Gertrude)	9/21/99	Control (Gertrude to Atlantic)
52	10/1/99	Treatment (Harris to Gertrude)	9/28/99	Treatment (Harris to Atlantic)
53	10/8/99	Control (Atlantic to Gertrude)	10/5/99	Treatment (Harris to Atlantic)
54	10/15/99	Treatment (Harris to Gertrude)	10/12/99	Treatment (Harris to Atlantic)
55	10/22/99	Treatment (Harris to Gertrude)	10/19/99	Control (Gertrude to Harris)
56	10/29/99	Treatment (Harris to Gertrude)	10/26/99	Treatment (Harris to Atlantic)
57	11/4/99	Control (Atlantic to Gertrude)	11/2/99	Treatment (Harris to Atlantic)
58	11/12/99	Treatment (Harris to Gertrude)	11/9/99	Treatment (Harris to Atlantic)
59	11/18/99	Treatment (Harris to Gertrude)	11/16/99	Control (Gertrude to Harris)
60	11/24/99	Treatment (Harris to Gertrude)	11/23/99	Treatment (Harris to Atlantic)
61	12/2/99	Control (Atlantic to Gertrude)	11/30/99	Treatment (Harris to Atlantic)
62	12/9/99	Treatment (Harris to Gertrude)	12/7/99	Treatment (Harris to Atlantic)
63	12/16/99	Treatment (Harris to Gertrude)	12/14/99	Control (Gertrude to Atlantic)
64	12/23/99	Treatment (Harris to Gertrude)	12/21/99	Treatment (Harris to Atlantic)
65	12/29/99	Control (Atlantic to Gertrude)	12/28/99	Treatment (Harris to Atlantic)
66	1/6/00	Treatment (Harris to Gertrude)	1/4/00	Treatment (Harris to Atlantic)
67	1/13/00	Treatment (Harris to Gertrude)	1/11/00	Control (Gertrude to Atlantic)
68	1/20/00	Treatment (Harris to Gertrude)	1/18/00	Treatment (Harris to Atlantic)
69	1/27/00	Control (Atlantic to Gertrude)	1/26/00	Treatment (Harris to Atlantic)
70	2/3/00	Treatment (Harris to Gertrude)	2/1/00	Treatment (Harris to Atlantic)
71	2/11/00	Treatment (Harris to Gertrude)	2/8/00	Control (Gertrude to Atlantic)
72	2/18/00	Control (Atlantic to Gertrude)	2/15/00	Treatment (Harris to Atlantic)
73	2/24/00	Treatment (Harris to Gertrude)	2/22/00	Treatment (Harris to Atlantic)
74	3/02/00	Treatment (Harris to Gertrude)	2/29/00	Treatment (Harris to Atlantic)
75	3/10/00	Treatment (Harris to Gertrude)	3/07/00	Control (Gertrude to Atlantic)
76	3/16/00	Control (Atlantic to Gertrude)	3/14/00	Treatment (Harris to Atlantic)
77	3/23/00	Treatment (Harris to Gertrude)	3/21/00	Treatment (Harris to Atlantic)

Table 3–1 (Continued)
NON-STRUCTURAL BMP IMPLEMENTATION
October 1998 – March 2000

	Street Sweeping - Site 1W		Litter Pick-Up - Site 1E	
Week No.	Date	Implementation	Date	Implementation
78			3/28/00	Treatment (Harris to Atlantic)

The LMPS litter pick-up BMP was implemented in the above-described areas using the following strategy (as outlined in the Study Plan):

- Standard practice in District 7 was for litter pick-up to be conducted by one of the following labor resources (AAH program participants, Special Programs People, and Caltrans staff). District 7 requires AAH participants to conduct pick-up in 2-mile freeway segments. Information obtained during the literature review for the LMPS (Woodward Clyde, 1997) indicates that increased litter frequency may achieve a reduction in the amount of freeway litter available to be transported to drainage inlets. Therefore, increased frequency of pick-up was selected for evaluation. Litter pick-up was conducted once-per-week in the enhanced BMP area and once-per-four-weeks in the control area. Note that at the start of the LMPS, Caltrans District 7 AAH permits required litter pick-up 12 times per year and the required frequency has since been increased to 24 times per year (2 pick-ups per month).
- The litter pick-up BMP was conducted only in those portions of the freeway ROW that extend beyond the limits of paved shoulder areas. Due to safety concerns, Caltrans District 7 prohibits litter pick-up on the roadway, medians, or shoulders by non-Caltrans personnel. Caltrans maintenance crews collect litter and debris on the roadway and the shoulders on an as-needed basis.
- The litter pick-up BMP used litter collection practices similar to standard practices utilized by AAH contractors, Special Programs People, and Caltrans District 7 staff. Litter was picked up (using mechanical, manually-operated, lever-actuated tongs) and was placed into collection bags. Litter too small to be collected by tongs (e.g., a cigarette butt) was not picked up.

Dates and corresponding litter pick-up locations (i.e., treatment vs. control) are listed in Table 3-1. The litter pick-up BMP was initiated on October 6, 1998 with pick-up being conducted in both the enhanced BMP and the control areas. During the initial implementation, inspectors were present during pick-up to verify implementation location and observe methods used by the subcontractor, Adopt-a-Highway Maintenance Corporation (AAHMC). Throughout study implementation, the litter pick-up area was inspected on a weekly basis in conjunction with street sweeping inspection to confirm that litter pick-up had been conducted as required. Litter pick-up was typically conducted on Tuesdays, with litter pick-up inspection conducted on the following Thursdays. Litter pick-up inspection was documented each week on a non-structural BMP inspection form. A sample inspection form is provided in Appendix B.

3.4 STRUCTURAL CONTROLS

Three different structural controls were tested during the LMPS. These include a modified inlet grate tested at Site 6, a Caltrans standard bicycle grate tested at Site 8 during year 1, and a LID curb inlet tested at Site 8 during year 2. Each of the three structural retrofits is discussed further in subsections below.

3.4.1 Modified Inlet Grate

The modified inlet grate consists of a standard parallel bar grate, to which perforated metal plates have been added along the inflow perimeter of the inlet, as shown in Photo 3–3. Hole sizes in the metal plates are 0.25 inches in diameter. The perforated plates were installed by welding

Photo 3–3
Modified Inlet Grate–Site 6

them to the top of new parallel bar grates. The plates were designed to be approximately flush with the surrounding finished grade so that low flows would not be impeded. A 14-gauge perforated metal plate with a corresponding thickness of 0.08 inches was chosen.

During design of the inlet retrofit, a hydraulic analysis was performed to evaluate whether the modified inlet grates would impact inlet hydraulic capacity. Details of the hydraulic analysis are provided in "Technical Memorandum No. 2, Structural BMP Hydrology/Hydraulic Analysis and Pre-Construction Design." Results of the analysis indicated that the hydraulic capacity of all retrofitted inlets was sufficient without increasing the surface area of inlets.

Installation of structural retrofits involved replacing existing inlet grates at designated treatment locations with BMP grates. Installation work was completed on August 12, 1999. During installation, debris was manually removed from each inlet and placed in 50-gallon plastic bags. Debris was then sorted and evaluated to fine-tune the litter characterization protocol for the LMPS prior to the onset of the first storm season.

3.4.2 Bicycle Grate

The Caltrans standard bicycle grate (shown in Photo 3–4) is identical to existing parallel bar grates at Site 8 with the addition of cross bars, resulting in reduced grate openings. This retrofit was evaluated during year 1. Based on analysis of year 1 data and field observations, the project team including Caltrans, NRDC, and TAG members agreed to discontinue testing of the bicycle grate alternative. All parties agreed that the bicycle grate appeared to have little potential to reduce the quantity of litter entering drain inlets. Results of data analysis for BMP effectiveness are presented in Sections 7.1.4 and 7.1.5.

3.4.3 Litter Inlet Deflector

Based on field review of the structural retrofits and review of the LMPS data from year 1, Caltrans and NRDC agreed that the bicycle grate retrofit did not hold a great potential to reduce litter in the freeway drainage system. Testing of the bicycle grate retrofit was replaced by the

Photo 3–4
Bicycle Grate–Site 8

LID during year 2 of monitoring. The LID is designed to reduce dry weather litter deposition in drainage inlets. To assess dry deposition patterns, inlet deposition monitoring (see Section 4.3.1) was initiated at the LMPS sites in conjunction with evaluation of the LID retrofit. A schematic representation of the LID is provided in Figure 3-1. A photo of a typical LID is shown in Photo 3-5. This design was installed at inlets currently designated as treatment inlets at Site 8. The design consists of reconfiguring the current drop inlet to make it function as a curb inlet. The curb opening was fitted with a gate that acts as a "board-over" during dry weather conditions, thereby blocking litter that would be conveyed into the inlet opening by air transport (e.g., wind and/or vehicle-induced turbulence). Blocked litter would then be available to be picked up by Caltrans street sweepers during regular maintenance. Field tests were conducted to measure wind speed at the curb face, and the gates are designed not to open under traffic-related wind pressure alone.

The gate hangs from a hinge that uses a Teflon™-coated rod and bracket device, and is designed to open only during flow conditions to allow storm water into the inlet. The gate is additionally slotted to allow the passage of dry weather (nuisance) flows that would be insufficient to open the gate to enter the basin. Two observation ports are located on the structure's top, allowing visual identification of any litter within the new system. Access through the original grate is preserved in five locations to allow deposition monitoring at the inlets. The entire LID structure is designed to replace the existing dike in profile, resting well beneath the guardrail and offering no obstruction to passing vehicles.

During design of the LID, the watershed areas contributing runoff to each inlet to be retrofitted were calculated from as-builts and were also confirmed in the field. Using these areas, 25-year-storm flows for each outfall were calculated, thus the required flow capacity for each of the new structures was estimated. The hydraulics of the gates were analyzed and compared to typical curb inlets. The design of each LID was standardized, except for the length of the LID opening;

Figure 3-1
LID SCHEMATIC – Site 8

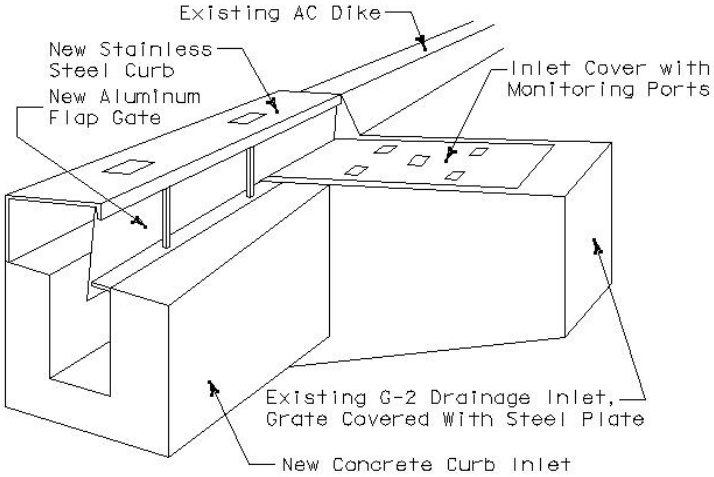


Photo 3-5
LID-Site 8

the greater the required flow capacity, the greater the structure's length. To further increase capacity and ensure that the gates open reliably, flow diverters were added to the design. These flow diverters consist of angled channels in the asphalt surfacing before the LID, designed to redirect passing storm water toward the hanging gate. Prototype testing of the LID design was conducted at the UCLA hydraulics lab. Initial testing was conducted on May 26, 1999. During this initial round of testing, the flume in the UCLA lab was modified to accommodate a reduced-size LID prototype. For ease of prototype construction, this prototype used an alternate hanger bearing suspension mechanism in lieu of the Teflon™-coated rod and bracket mechanism. The gate was tested using varying flow rates (and therefore depths) of water, up to 26 gallons per minute. A second LID prototype was then constructed that more closely met design specifications, matching units installed in the field. Additional flume testing using this prototype

and varying flow rates was conducted throughout year 2 of the LMPS. A report of laboratory test findings is provided in Appendix M. The flume channel was constructed to simulate the design pavement slope and scallop pattern at the inlet entrance.

Field construction of the LID BMPs was conducted between September 16, 1999 and October 15, 1999.

3.5 CALTRANS MAINTENANCE ACTIVITIES

Caltrans maintenance personnel were contacted throughout the LMPS study period to monitor activities conducted by Caltrans or accidents occurring in the study areas that could potentially affect the study. A standard maintenance contact form was used to interview road crew supervisors and landscape crew supervisors and to track activities such as Caltrans street sweeping, landscape maintenance, accidents, pavement repair, painting, or other activities that may affect chemical water quality. A copy of the maintenance contact form is provided in Appendix B. Unique events that occurred at study sites are discussed below. This information is based on information provided by Caltrans maintenance personnel or through other Caltrans sources.

Site 1W (Street Sweeping)

Caltrans conducted exploratory borings in the shoulder area at two locations at Site 1W on February 10, 1999. The purpose of the activity was to identify potential soil voids at bridge abutments at the Atlantic Boulevard and Harris Avenue overpasses. Caltrans completed concrete coring at both locations, followed by hand augering to 5.4 feet below grade. No voids were encountered and the boreholes were backfilled with concrete slurry. Water used for concrete coring was collected by a vacuum at the boring location and no runoff was generated. The Caltrans resident engineer indicated that no runoff from the slurry backfill was generated.

On Monday, November 1, 1999 the Lynwood Fire Department was dispatched to extinguish a fire on the westbound 105 freeway approximately 0.2 mile after the merging of the 105 and 710 freeways. This fire occurred immediately adjacent to, and around, site 1-52 and damaged an area approximately 70 feet by 40 feet, or approximately 280 square feet of ground cover. The fire was characterized in the Lynwood fire report as a “tree, brush, grass, crops fire” which notes that the fire was most likely caused by “heat, open flame, smoking materials.” The slope will be re-planted with permanent landscaping and measures taken as per Caltrans operating and planting procedures to ensure the continued stability of the slope.

The fire occurred at the top of slope in the vicinity of Outfall 1-52. Photo 3-6 shows the fire-damaged area and the solar panel pole for the monitoring station at Outfall 1-52. Caltrans re-seeded the area and laid down additional groundcover in order to stabilize soil and provide temporary repair of vegetation on the slope. On December 2, 1999 “mud-jacking” operations were

Photo 3-6
(Site 1W)
Fire Damage at Top of Slope Near Outfall 1-52 – Solar Panel Pole is Shown

performed in the vicinity of the project site. "Mud-jacking" refers to the injection of mud underneath the concrete slab of the freeway in order to correct and prevent any subsidence and 'dips' in the freeway surface that may have occurred. The causes for this subsidence can range from biotic effects (such as gophers and rodents) to seismic events. Caltrans indicated that this activity does not generate runoff and is not anticipated to effect chemical water quality or litter monitoring at the study sites.

Site 6 (Modified Inlet Gate)

Caltrans maintenance personnel indicated during the week of March 22, 1999 that asphalt work was ongoing in conjunction with the installation of closed circuit TV cable.

The guardrail along the 60 freeway in the approximate vicinity of the study site was repaired on Wednesday, November 17, 1999 in response to a vehicle accident occurring earlier in the week. The exact date of the accident and how many vehicles were involved are not known.

Site 8 (Bicycle Grate/LID)

A spill of loose oranges was reported by Caltrans maintenance personnel between November 11, 1998 and November 24, 1998.

Construction activities were initiated by a Caltrans contractor in early March 1999 in the vicinity of Outfall 24D to install a maintenance turnout associated with closed circuit TV installation. Approximately 400 feet of k-rail were placed at the edge of the shoulder upgradient and downgradient of 24D. Work was complete on the freeway surface prior to year 2 monitoring.

On Sunday, November 21, 1999 a moving road crew passed along the LMPS study area and the surrounding freeways, checking the surface of the freeway cement slab. These slabs were surveyed for damage and future maintenance, repair, and replacement needs and then counted so as to maintain current Caltrans records.

On Monday, November 29, 1999 through Thursday, December 9, 1999 the guardrails about and along State Route 60 were surveyed for damage, and repairs or plans to repair the structures were made as needed.

During the week of November 1, 1999 through November 5, 1999 a search for pot holes was made in the study area. The pot holes, when discovered, are typically filled with "bag-mix" asphalt. This is an asphalt that sets up quickly so that traffic can be restored immediately after the repair. Caltrans indicated that no major pot holes were encountered at the site.

4.1 MONITORING PROCEDURES FOR CHEMICAL WATER QUALITY AND LITTER SAMPLING

Numerous tasks were performed prior to, during, and after each storm event to successfully perform monitoring for the LMPS.

Litter monitoring required the following tasks prior to and after a storm event:

- photographing storm drain inlet conditions,
- litter bag replacement,
- spiking the storm drain inlets,
- record keeping and field notes, and
- field QA/QC.

Tasks related to chemical water quality monitoring included the following additional tasks:

- weather tracking,
- field equipment and sample bottle organization,
- sampling station set up,
- basic equipment maintenance,
- programming sampler operation,
- grab sample collection,
- sample collection, handling, and transfer,
- sampler bottle replacement,
- record keeping and field notes, and
- field quality assurance and quality control (QA/QC).

The following field Standard Operating Procedures (SOPs) were developed and implemented to assure these tasks were performed correctly and consistently during each monitored storm event:

- Pre-Event (Storm Water and Litter),
- Bottle Replacement (Storm Water Only),
- Grab Sampling (Storm Water Only), and
- Post-Event (Storm Water and Litter).

Each SOP contains detailed instructions (step-by-step) on how to perform the various tasks.

4.1.1 Pre-Event SOPs

Key criteria for event monitoring included the following:

- The storm event should produce a minimum of 0.20 inches of rainfall.
- The probability of precipitation should be 70 percent or greater.
- The event would generate sufficient runoff volume at each station to meet sample collection volume requirements.
- In addition, samples would be collected following at least 24 hours of dry weather (defined as a 24-hour period with no rainfall > 0.10 inches).

Initially, the LMPS used the following event monitoring criterion: an 80 percent probability of 0.1 inches or greater of rainfall with a 72-hour antecedent period. However, after the first storm

event during year 1 (November 8, 1998), the criterion was modified slightly. Based upon flow data from the first event, the criterion for minimum amount of rainfall predicted for an event was increased to 0.20 inches, because the sites were estimated to have depression storage that was approximately equal to the original 0.10-inch criterion. Additionally, the criterion for probability of precipitation was reduced from 80% to 70%, and the criterion for antecedent dry weather was reduced from 72 hours to 24 hours. These reductions were based upon an expectation that the 1998/99 rain season would follow a "La Nina" pattern—i.e., the number of storm events and the total precipitation would be below average in Southern California during the 1998/1999 rain season. Meteorologists predicted that the "La Nina" pattern would continue for the 1999/2000 rain season, so the revised criteria were followed during year 2 of monitoring.

Given these criteria for a monitoring event, the Storm Event Coordinator (SEC) tracked weather forecasts on a daily basis. The daily tracking included review of the probability of precipitation for each day of a 10-day forecast provided by a meteorologist. In cases when a 60% probability of precipitation was specified in the 10-day forecast, the SEC had frequent telephone briefings with the meteorologist. Typically, field crew staff were notified 3-4 days prior to a predicted event to alert them to a potential monitoring event. Once within the 72-hour window preceding the forecasted event, the meteorologist provided at least two Quantitative Precipitation Forecasts (QPFs) each day until the storm event had passed through the study area. The QPFs provided forecasts of rainfall volume and associated probabilities for 3-hour intervals over a rolling 24-hour period. The QPFs were used to determine the "trigger" volume for automatic sampler pacing at each chemical water quality monitoring station and to identify the best time frame for field crews to collect grab samples.

About 72 hours prior to an event predicted to have at least 0.2 inch rainfall with 70% or greater probability of precipitation, the SEC initiated preparation for the events. Specific field crews were designated, automatic sampler and grab sample bottles were labeled, and field boxes were checked for necessary supplies and equipment. Since photographs of the storm drain inlets and the surrounding area were required, it was beneficial for pre-event setup to be performed during daylight hours. Therefore, depending upon the time of day that precipitation was forecast to begin, field crews were typically mobilized 12 to 24 hours prior to the time of rainfall onset specified in the forecast.

During pre-event setups, two-person field crews performed the following tasks:

- Inspected the condition of sampling station equipment (flume, tubing, battery power level, etc.),
- Programmed the flowmeter and sampler for sample collection,
- Photographed storm drain inlet grates and adjacent road surface and ROW conditions, (initiated mid-way through the storm season),
- Replaced litter bags,
- Spiked the storm drain inlets, and
- Completed field activity forms.

While performing the pre-event setup, each field crew completed an "Automated Sampler Station Checklist" and a "Pre-Storm Event Litter Collection Field Data Form." Field forms are

provided in Appendix B. If any litter had accumulated in the bags during the time between "monitored" events, the bags were labeled and returned to the litter lab for characterization.

4.1.2 Grab Sampling SOPs

Several water quality analyses (e.g., oil & grease, total petroleum hydrocarbons-gasoline and diesel fractions, total coliform, fecal coliform) and physical measurements (e.g., temperature, pH, specific conductance) required collection of manual grab samples and/or field measurements.

For field QA/QC of each event, one of the eight stations was designated to prepare field equipment blanks for laboratory analysis, and another of the eight stations was designated to prepare field duplicates. The field crews also measured temperature, pH, and specific conductance in the field at the time of grab sampling and recorded those measurements on a "Grab Sampling Field Data Log" (Appendix B). The field crews completed the sample bottle labels, and then the sample bottles, including field equipment blanks and duplicates, were placed in coolers with ice and submitted to the laboratory for analysis.

4.1.3 Post-Event SOPs

During a storm event, the SEC frequently communicated with the meteorologist to track the predicted end of the storm event. The SEC mobilized field crews to retrieve bottles from the automatic samplers and the litter bags during daylight hours as soon as possible after conclusion of the storm event. The field crews removed the sample bottles from the automatic samplers, completed the bottle labels, and then placed the bottles in coolers with ice. The field crews also removed litter bags from the outfalls and labeled the bags to be delivered to the Litter Laboratory for characterization. A "clean" litter bag was placed on each outfall before the field crew left the site.

While performing post-event activities, each field crew completed an "Automated Sampler Station Checklist" and a "Post Storm Event Litter Collection Field Data Form" (Appendix B). Upon return to the field office/litter lab and before the bottles were submitted to the laboratory for compositing and analysis, the SEC verified the information on the "Automated Sampler Station Checklist" regarding the number of bottles filled and the fraction full for each bottle.

Data from the flowmeter data loggers were downloaded remotely via modem as soon as possible after the storm event concluded to allow for timely preparation of sample compositing schemes. Field crews also had data transfer units available to download data directly from the flowmeter data loggers if for some reason a modem connection to the flowmeter could not be established. Flow data and sampling history data from each station were used to prepare compositing schemes that were submitted to the laboratory. The preparation of compositing schemes was necessary, since it is very common for automatic samplers to only partially fill bottles or to fill less than the full set of eight bottles. Compositing schemes for each station were faxed to the laboratory as soon as they were completed.

4.2 STORM EVENT HYDROGRAPHS

During the 1998/1999 rain season (year 1), ten storm events were monitored at the LMPS sites. The first event, 1998-01 (November 8, 1999) was monitored only for litter constituents. The next nine events were monitored for both litter and chemical water quality constituents. During the 1999/2000 rain season (year 2), thirteen storm events were monitored at LMPS sites. Events 1999-03 and 1999-15A were monitored for litter only. Rainfall and flow data were recorded for all events. This section summarizes hydrologic data collected for each event and discusses the general approach used in analysis and QA/QC of the data. The following storms were monitored during the LMPS.

Storm Event	Date	Comment
1998-01	11/8/98	Litter only
1998-02	11/28/98	Chemical water quality and litter
1998-03	12/1/98	Chemical water quality and litter(1)
1998-05	1/25/99	Chemical water quality and litter
1998-06	2/9/99	Chemical water quality and litter
1998-09	3/15/99	Chemical water quality and litter
1998-10	3/20/99	Chemical water quality and litter(1)
1998-11	3/25/99	Chemical water quality and litter
1998-12	4/6/99	Chemical water quality and litter
1998-13	4/11/99	Chemical water quality and litter
1999-03	12/31/00	Litter only(2)
1999-05	1/25/00	Chemical water quality and litter
1999-06	1/30/00	Chemical water quality and litter
1999-08	2/10/00	Chemical water quality and litter
1999-09	2/12/00	Chemical water quality and litter
1999-10	2/13/00	Chemical water quality and litter(3)
1999-11	2/16/00	Chemical water quality and litter
1999-12	2/20/00	Chemical water quality and litter
1999-13	2/23/00	Chemical water quality and litter
1999-14	2/27/00	Chemical water quality and litter
1999-15A	3/03/00	Litter only
1999-15	3/05/00	Chemical water quality and litter
1999-16	3/08/00	Chemical water quality and litter

1 Precipitation at Site 6 did not meet Caltrans Storm Water Program definition of a precipitation event (LWA 1999).

2 Precipitation at Sites 1E and 1W did not meet the Caltrans Storm Water Program definition of a precipitation event (LWA 1999).

3 Event 1999-10 does not meet the 24-hour antecedent dry period criteria established for the LMPS.

The event numbers listed above identify only storms that were monitored. The numbers are not continuous due to “false-start” events. The term “false start” refers to events that were predicted by the contract meteorologist and/or the National Weather Service but were later downgraded

(immediately prior to the onset of the event) and were not actually monitored. The "pre-storm set-up" activities discussed in Section 4.1.1 were conducted, but the storms were never realized. Three "false-starts" occurred during the 1998/1999 rain season (year 1), and four "false-starts" occurred during the 1999/2000 rain season (year 2). A more detailed discussion for each "false-start" event is provided in Appendix C.

Throughout the LMPS, flow and rainfall monitoring equipment recorded minute-by-minute continuous rainfall and flow records at each station. After each storm, hydrologic information was reviewed for each station and hydrographs for each event were prepared. Figure 4-1 presents a sample hydrograph for Event No. 1998-01, Outfalls 1-42 and 1-46. Appendix D provides a detailed discussion of the process used to review the data and Appendix E presents storm event hydrographs for both years of monitoring.

4.2.1 QA/QC of the Raw Data

QA/QC of the raw data was performed to facilitate the identification of anomalies such as clogged rainfall gauges or spikes in the flow record unrelated to rainfall increases. The procedures applied to QA/QC of the raw data included the following steps:

1. Generation of hydrographs, hyetographs, and summaries for each storm at each outfall including: peak rainfall intensity, total precipitation, total flow volume, total depth of flow (watershed inches), peak flow rate, and the event's beginning and ending time and date.
2. Visual inspection of hydrographs and hyetographs to identify instances where flow rate, change in flow rate, or flow duration appeared to be outside expected ranges.
3. Comparison of rainfall observations (i.e., total depths and plots of cumulative rainfall as a function of time during the event) at each site (i.e., adjacent control and treatment outfalls and NWS data) to identify data anomalies.
4. Preparation and assessment of scatter plots by plotting runoff as a function of rainfall on an outfall basis over the period of record. Regression analysis was conducted on these plots to quantitatively identify potential outliers that might indicate additional anomalies in the data record. Data collected later in the study had the advantage of having a larger data set for comparison. This allowed individual events to be analyzed in light of the expected runoff coefficient for the outfall. Outliers were examined to identify specific anomalies in rainfall or flow as described in steps 5 and 6.
5. Updates of rainfall totals (i.e., rainfall totals from adjacent stations were used to estimate total rainfall for rain gauges that were not functioning correctly).
6. Review of flow records that contained anomalies to identify relationships to specific known equipment problems.
7. If data anomalies associated with outliers could not be corrected by methods in steps 5 and 6, data outliers were flagged and excluded from the final data set and further analysis.
8. Using the final data set to calculate runoff coefficients using final regression analysis and other hydrologic summary information.

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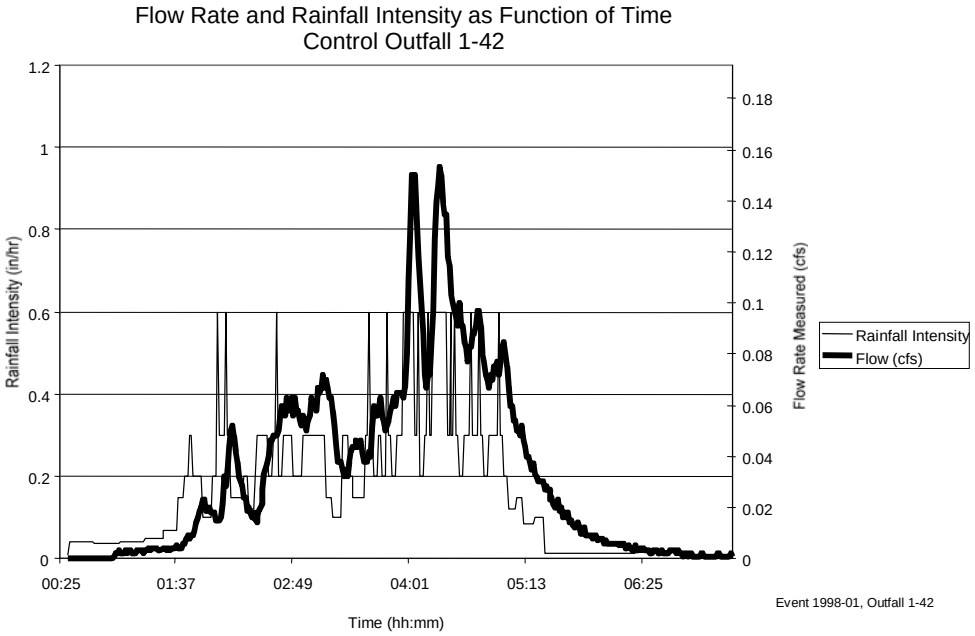
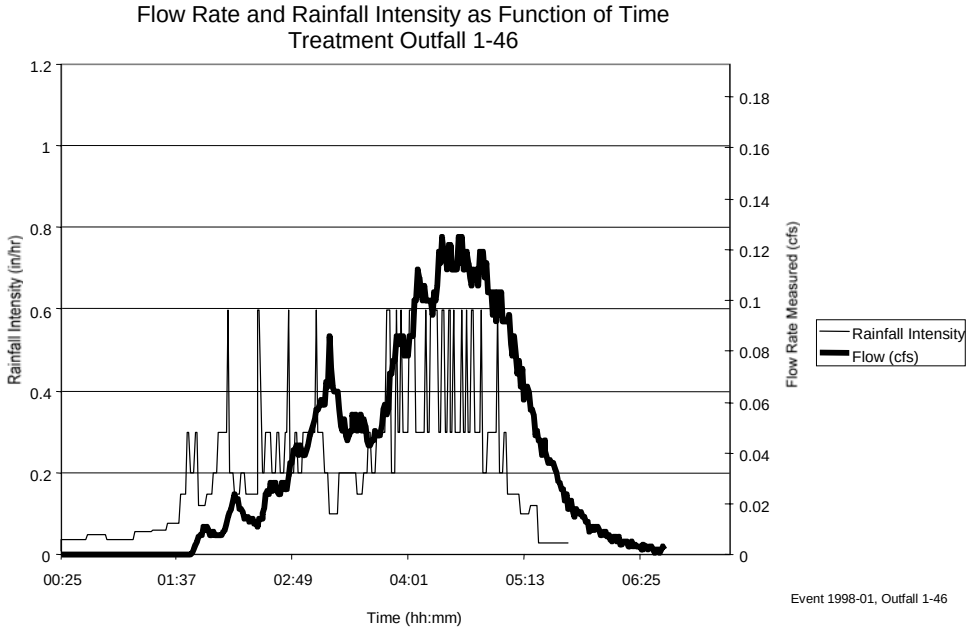
Figure 4-1
SITE 1 E (LITTER PICK-UP) – OUTFALLS 42 AND 46 — EVENT NO. 1998-01 11/08/98





A detailed discussion of the above QA/QC process for storm event hydrologic data is presented in Appendix D.

4.2.2 Field Investigation and Reevaluation of Watershed Areas and Freeway Surface Conditions

Results of interim regression analyses performed during the QA/QC process after year 1 of monitoring yielded unexpected runoff coefficients for freeway pavement conditions for some of the outfalls. The analysis was based on catchment areas for each outfall that were calculated from dimensions provided on as-built engineering drawings obtained from Caltrans. Because data analysis indicated unexpected coefficients, anomalies were suspected in the areas of the catchments (i.e., watersheds varied from the original interpretation of the as-builts). Therefore, field reconnaissance was conducted to further define catchment sizes and look for pavement conditions or other features that could explain unexpected runoff coefficients. Catchment areas were adjusted as a result of field investigations, and regression analyses were re-run for each site using combined data from both years of monitoring, yielding a better estimate of runoff coefficients. Comparative catchment sizes are shown in Table 4-1. Field investigation results are discussed further in Appendix A.

Adjusted final catchment areas and runoff coefficients calculated from combined year 1 and year 2 data are listed in Table 4-1. This table also lists the calculated areas for each catchment. Such calculations were based on assumed Rational Method runoff coefficients for each of the watersheds (e.g., it was assumed that impervious surfaces have a runoff coefficient of 0.8, and unpaved berms have a runoff coefficient of 0.2). Ideally, catchment areas estimated from field investigations and as-builts would match areas that are back-calculated from measured flow data and an assumed runoff coefficient. The absolute percent difference in areas listed in Table 4-1 ranges from 4% to 23%. The field survey indicated that losses on the freeway surface may be in excess of the approximately 10-20% typically found for “impervious” surfaces (see Appendix A). The remaining discrepancies in the assumed versus empirical runoff coefficients are most likely a result of multiple factors, such as joint and crack integrity, monitoring equipment limitations, and the assumption that the assumed runoff coefficient is correct for the catchment.

4.2.3 Catchment Hydrology Observations and Estimated Final Catchment Areas

During year 2 of monitoring, flow patterns were observed on the monitored catchments and at study inlets to verify some of the assumptions made in the hydrologic analysis conducted during year 1.

Wet weather field observations were conducted during four storm events during year 2 (i.e., Events 1999-05, 1999-08, 1999-11, and 1999-12). Generally, the observations of catchment hydrology were consistent with catchment area limits observed during the June 1999 dry weather field investigations. However, modifications to the freeway surface in the B001 catchment were observed during wet weather investigations. Prior to implementation of year 2 monitoring, an underground fiber-optics cable was installed along the shoulder at Site 8. This construction included installation of an asphalt trench patch and utility box immediately upgradient of the B001 inlet. The trench patch in this area is not flush with the surrounding grade of the shoulder pavement and has been observed to collect runoff during storm events. B001 catchment limits were not confirmed during wet weather observations because a large portion of the assumed catchment area consists of a relatively flat bridge deck that can not be safely accessed during wet weather. More details on wet weather observations are provided in Appendix A.

Table 4-1
RESULTS OF FINAL REGRESSION ANALYSIS OF RAINFALL/RUNOFF CURVES AFTER QA/QC OF DATA BASED ON REVISED WATERSHED AREAS

Site	Outfall	As-Built Area (ac)	Final Values		Assumed Rational Runoff Coefficient (0.8 for impervious surfaces, and 0.2 for pervious berm and vegetation)	Calculated Area (ac), Based on Assumed Rational Runoff Coefficient	Percent Difference in Final Catchment Area and Calculated Area (%)
			Final Catchment Area Based on Field Investigation (ac)	Runoff Coefficient Using Final Catchment Areas (Calculated) (C)			
1	42	0.34	0.32	0.70	0.75	0.30	7%
1	46	0.46	0.38	0.67	0.75	0.34	11%
1	52	0.38	0.43	0.68	0.75	0.39	9%
1	58	0.29	0.37	0.89	0.75	0.44	-16%
6	20e	0.42	0.42	0.62	0.80	0.33	23%
6	20f	0.42	0.42	0.69	0.80	0.36	14%
8	23c	0.62	0.62	0.77	0.80	0.60	4%
8	B001[(1)]	0.57	0.32 (0.18)	0.74	0.80	0.30 (0.17)	8%

[1] 0.32 acres used in evaluation of year 1 bicycle grate retrofit. 0.18 acres used in evaluation of year 2 LID retrofit. Adjustment resulting from non-study related changes to pavement conditions at Site 8 prior to year 2 monitoring.

Additional regression analysis was performed on year 2 hydrologic data for B001 to calculate the effective catchment area for year 2 of monitoring. The year 2 regression analysis modifies the catchment area for B001 to 0.18 acres for year 2. This effective watershed area is not inconsistent with field observations of the behavior of runoff in the watershed. Because upgradient catchment limits are uncertain, based on visual observations at this site, the analysis of hydrologic data was used to determine the year 2 catchment area.

Adjustments were also made to the watershed area for 1-58 based on field observations and the flow record for this outfall. Backflow was observed to occur from a section approximately 25 feet upstream of the inlet at 1-58. This additional drainage area of 0.05 acres brought the final catchment area to 0.37 acres, as seen in Table 4-1.

4.2.4 Event Overview

Ten storm events were monitored during the 1998/1999 rain season (year 1) and thirteen storm events were monitored during the 1999/2000 rain season (year 2). Summary hydrologic data for each event are listed in Table 4-2.

Table 4-2 provides comparative hydrologic data before and after QA/QC and indicates rain and flow values that were considered to be abnormal as a result of QA/QC analysis. Information from field personnel on equipment problems and the results of the analysis of rainfall totals (as discussed above) were examined in concert with the results from the statistical analysis of the

rainfall/runoff pairs to identify abnormalities. Data abnormalities and the action taken regarding each are further described in Table 4-3.

Table 4-2
SUMMARY OF HYDROLOGIC DATA FOR MONITORED STORM EVENTS

Site	Outfall	Total Meas. Rainfall (inch)	Rain After QA/QC (inch)	Rain Abnorm.	Total Meas. Flow (cf)	Flow Abnorm.	Total Flow After QA/QC (cf)	Total Flow After QA/QC (inch)	Begining Date of Monitoring Period	Begining Time of Monitoring Period	Ending Date of Monitoring Period	Ending Time of Monitoring Period	Duration (hh:mm)
Event 1998e01 - 11/08/1998													
1E	1-42	1.07	1.07	☐	826	☐	826	0.71	11/08/1998	0:31	11/08/1998	6:21	5:50
1E	1-46	1.1	1.1	☐	845	☐	845	0.61	11/08/1998	0:25	11/08/1998	5:41	5:16
1W	1-52	0.95	0.95	☐	806	☐	806	0.52	11/08/1998	0:29	11/08/1998	5:33	5:40
1W	1-58	1.04	1.04	☐	1130	☐	1130	0.84	11/08/1998	0:28	11/08/1998	5:25	4:57
6	6-20E	0.69	0.69	☐	685	☐	685	0.45	11/08/1998	1:46	11/08/1998	5:52	4:60
6	6-20F	0.67	0.67	☐	593	☐	593	0.39	11/08/1998	1:46	11/08/1998	5:56	4:10
8	8-23C	0.22	0.45	☑	329	☐	329	0.15	11/08/1998	1:28	11/08/1998	5:50	4:22
8	8-B001	0.45	0.45	☐	206	☐	206	0.18	11/08/1998	1:27	11/08/1998	6:10	4:43
Event 1998e02 - 11/28/1998													
1E	1-42	0.29	0.29	☐	182	☐	182	0.16	11/28/1998	3:24	11/28/1998	6:50	3:26
1E	1-46	0.27	0.27	☐	78	☐	78	0.04	11/28/1998	3:22	11/28/1998	6:50	3:28
1W	1-52	0.26	0.26	☐	139	☐	139	0.09	11/28/1998	3:19	11/28/1998	5:58	2:39
1W	1-58	0.29	0.29	☐	268	☐	268	0.2	11/28/1998	3:22	11/28/1998	6:47	3:25
6	6-20E	0.33	0.33	☐	218	☐	218	0.14	11/28/1998	3:43	11/28/1998	5:56	2:13
6	6-20F	0.32	0.32	☐	188	☐	188	0.12	11/28/1998	3:41	11/28/1998	5:52	2:11
8	8-23C	0.69	0.85	☑	505	☑	1194	0.53	11/28/1998	3:31	11/28/1998	14:34	11:03
8	8-B001	0.85	0.85	☐	886	☑	886	0.76	11/28/1998	3:28	11/28/1998	14:34	11:06
Event 1998e03 - 12/01/1998													
1E	1-42	0.17	0.17	☐	68	☐	68	0.06	12/01/1998	13:08	12/01/1998	17:50	4:42
1E	1-46	0.2	0.2	☐	39	☐	39	0.03	12/01/1998	13:06	12/01/1998	17:43	4:37
1W	1-52	0.2	0.2	☐	90	☐	90	0.06	12/01/1998	13:10	12/01/1998	17:49	4:39
1W	1-58	0.19	0.19	☐	117	☐	117	0.09	12/01/1998	13:10	12/01/1998	18:04	4:54
6	6-20E	0.09	0.09	☐	8	☐	8	0	12/01/1998	14:22	12/01/1998	16:19	1:57
6	6-20F	0.08	0.08	☐	4	☐	4	0	12/01/1998	14:31	12/01/1998	16:50	2:19
8	8-23C	0.25	0.25	☐	192	☐	192	0.09	12/01/1998	13:21	12/01/1998	17:07	3:46
8	8-B001	0.26	0.26	☐	404	☑	93	0.08	12/01/1998	13:20	12/01/1998	17:25	4:05

Table 4-2
SUMMARY OF HYDROLOGIC DATA FOR MONITORED STORM EVENTS

Site	Outfall	Total Meas. Rainfall (inch)	Rain After QA/QC (inch)	Rain Abnorm.	Total Meas. Flow (cf)	Flow Abnorm.	Total Flow After QA/QC (cf)	Total Flow After QA/QC (inch)	Begining Date of Monitoring Period	Begining Time of Monitoring Period	Ending Date of Monitoring Period	Ending Time of Monitoring Period	Duration (hh:mm)
Event 1998e05 - 01/25/1999													
1E	1-42	0.17	0.51	☑	359	☑	321	0.28	01/25/1999	0:46	01/25/1999	7:50	7:04
1E	1-46	0.52	0.52	☐	468	☐	468	0.34	01/25/1999	0:56	01/25/1999	7:51	6:55
1W	1-52	0.5	0.5	☐	370	☐	370	0.24	01/25/1999	0:46	01/25/1999	7:48	7:02
1W	1-58	0.51	0.51	☐	580	☐	580	0.43	01/25/1999	0:37	01/25/1999	7:51	7:14
6	6-20E	0.36	0.36	☐	271	☐	271	0.18	01/25/1999	1:49	01/25/1999	8:13	6:24
6	6-20F	0.36	0.36	☐	251	☐	251	0.16	01/25/1999	1:46	01/25/1999	8:18	6:32
8	8-23C	0.41	0.41	☐	400	☐	400	0.18	01/25/1999	1:26	01/25/1999	7:09	5:43
8	8-B001	0.37	0.37	☐	198	☐	198	0.17	01/25/1999	1:31	01/25/1999	7:02	5:31
Event 1998e06 - 02/09/1999													
1E	1-42	0.35	0.35	☐	223	☐	223	0.19	02/09/1999	11:02	02/09/1999	16:17	5:15
1E	1-46	0.35	0.35	☐	281	☐	281	0.2	02/09/1999	11:17	02/09/1999	16:20	5:03
1W	1-52	0.36	0.36	☐	233	☐	233	0.15	02/09/1999	11:07	02/09/1999	16:20	5:13
1W	1-58	0.37	0.37	☐	325	☐	325	0.24	02/09/1999	11:03	02/09/1999	16:18	5:15
6	6-20E	0.45	0.45	☐	446	☐	446	0.29	02/09/1999	10:40	02/09/1999	18:47	8:07
6	6-20F	0.42	0.42	☐	1033	☑	332	0.22	02/09/1999	11:33	02/09/1999	18:35	7:02
8	8-23C	-	0.29	☑	-	☑	223	0.1	02/09/1999	11:00	02/09/1999	18:04	7:04
8	8-B001	0.29	0.29	☐	173	☐	173	0.15	02/09/1999	11:00	02/09/1999	18:04	7:04
Event 1998e09 - 03/15/1999													
1E	1-42	0.58	0.58	☐	395	☐	395	0.34	03/15/1999	7:01	03/15/1999	10:48	3:47
1E	1-46	0.61	0.61	☐	423	☐	423	0.31	03/15/1999	7:01	03/15/1999	10:49	3:48
1W	1-52	0.59	0.59	☐	462	☐	462	0.3	03/15/1999	7:01	03/15/1999	10:47	3:46
1W	1-58	0.61	0.61	☐	602	☐	602	0.45	03/15/1999	7:02	03/15/1999	10:52	3:50
6	6-20E	0.5	0.5	☐	523	☐	523	0.34	03/15/1999	7:17	03/15/1999	11:21	4:04
6	6-20F	0.48	0.48	☐	1797	☑	395	0.26	03/15/1999	7:14	03/15/1999	11:20	4:06
8	8-23C	0.46	0.46	☐	525	☐	525	0.23	03/15/1999	7:18	03/15/1999	11:09	3:51
8	8-B001	0.46	0.46	☐	260	☐	260	0.22	03/15/1999	7:14	03/15/1999	11:04	3:50

T:\ENV\LJMLMPS.MDB: TABLE 4-2\09-MAR-00\SDG

Table 4-2
SUMMARY OF HYDROLOGIC DATA FOR MONITORED STORM EVENTS

Site	Outfall	Total Meas. Rainfall (inch)	Rain After QA/QC (inch)	Rain Abnorm.	Total Meas. Flow (cf)	Flow Abnorm.	Total Flow After QA/QC (cf)	Total Flow After QA/QC (inch)	Begining Date of Monitoring Period	Begining Time of Monitoring Period	Ending Date of Monitoring Period	Ending Time of Monitoring Period	Duration (hh:mm)
Event 1998e10 - 03/20/1999													
1E	1-42	0.18	0.18	☐	74	☑	74	0.06	03/20/1999	4:25	03/20/1999	8:23	3:58
1E	1-46	0.17	0.17	☐	30	☐	30	0.02	03/20/1999	4:31	03/20/1999	8:08	3:37
1W	1-52	0.17	0.17	☐	72	☐	72	0.05	03/20/1999	4:29	03/20/1999	8:20	3:51
1W	1-58	0.18	0.18	☐	125	☐	125	0.09	03/20/1999	4:28	03/20/1999	8:33	4:05
6	6-20E	0.08	0.08	☐	17	☐	17	0.01	03/20/1999	5:42	03/20/1999	9:30	3:48
6	6-20F	0.06	0.06	☐	0	☐	0	0	03/20/1999	5:42	03/20/1999	9:31	3:49
8	8-23C	0.21	0.21	☐	161	☐	161	0.07	03/20/1999	4:53	03/20/1999	9:25	4:32
8	8-B001	0.19	0.19	☐	62	☐	62	0.05	03/20/1999	4:48	03/20/1999	9:41	4:53
Event 1998e11 - 03/25/1999													
1E	1-42	0.58	0.58	☐	367	☐	367	0.32	03/25/1999	6:30	03/25/1999	18:29	11:59
1E	1-46	0.58	0.58	☐	387	☐	387	0.28	03/25/1999	6:30	03/25/1999	18:29	11:59
1W	1-52	0.55	0.55	☐	408	☐	408	0.26	03/25/1999	10:35	03/25/1999	17:41	7:06
1W	1-58	0.57	0.57	☐	484	☐	484	0.36	03/25/1999	10:29	03/25/1999	17:40	7:11
6	6-20E	0.14	0.14	☐	44	☐	44	0.03	03/25/1999	12:19	03/25/1999	17:23	5:04
6	6-20F	0.14	0.14	☐	26	☑	26	0.02	03/25/1999	12:12	03/25/1999	17:29	5:17
8	8-23C	0.2	0.2	☐	168	☐	168	0.07	03/25/1999	13:04	03/25/1999	16:54	3:50
8	8-B001	0.2	0.2	☐	64	☐	64	0.06	03/25/1999	11:32	03/25/1999	17:05	5:33
Event 1998e12 - 04/06/1999													
1E	1-42	0.41	0.41	☐	205	☐	205	0.18	04/06/1999	9:19	04/06/1999	14:44	5:25
1E	1-46	0.37	0.37	☐	207	☐	207	0.15	04/06/1999	9:06	04/06/1999	14:20	5:14
1W	1-52	0.28	0.28	☐	224	☐	224	0.14	04/06/1999	10:05	04/06/1999	14:11	4:06
1W	1-58	0.31	0.31	☐	264	☐	264	0.2	04/06/1999	9:49	04/06/1999	14:19	4:30
6	6-20E	0.79	0.79	☐	1129	☑	1129	0.74	04/06/1999	7:13	04/06/1999	15:43	8:30
6	6-20F	0.76	0.76	☐	501	☐	501	0.33	04/06/1999	7:08	04/06/1999	15:41	8:33
8	8-23C	-	0.98	☑	-	☑	1419	0.63	04/06/1999	10:40	04/07/1999	10:38	23:58
8	8-B001	0.98	0.98	☐	686	☐	686	0.59	04/06/1999	10:40	04/07/1999	10:38	23:58

T:\ENV\LJMLMPS.MDB: TABLE 4-2\09-MAR-00\SDG

Table 4-2
SUMMARY OF HYDROLOGIC DATA FOR MONITORED STORM EVENTS

Site	Outfall	Total Meas. Rainfall (inch)	Rain After QA/QC (inch)	Rain Abnorm.	Total Meas. Flow (cf)	Flow Abnorm.	Total Flow After QA/QC (cf)	Total Flow After QA/QC (inch)	Begining Date of Monitoring Period	Begining Time of Monitoring Period	Ending Date of Monitoring Period	Ending Time of Monitoring Period	Duration (hh:mm)
Event 1998e13 - 04/11/1999													
1E	1-42	1.44	1.44	☑	987	☑	1077	0.93	04/11/1999	13:13	04/12/1999	0:24	11:01
1E	1-46	1.52	1.52	☐	1450	☐	1450	1.05	04/11/1999	13:18	04/12/1999	0:10	10:52
1W	1-52	1.36	1.36	☐	1254	☐	1254	0.8	04/11/1999	13:14	04/12/1999	0:11	10:57
1W	1-58	1.43	1.43	☐	1478	☐	1478	1.1	04/11/1999	13:07	04/12/1999	0:50	11:43
6	6-20E	0.96	0.96	☐	1189	☐	1189	0.78	04/11/1999	12:39	04/12/1999	2:21	13:42
6	6-20F	0.94	0.94	☐	1477	☑	879	0.58	04/11/1999	12:39	04/12/1999	1:53	13:14
8	8-23C	0.79	1.09	☑	1491	☐	1491	0.66	04/11/1999	12:52	04/12/1999	1:31	12:39
8	8-B001	1.09	1.09	☐	710	☐	710	0.61	04/11/1999	12:48	04/12/1999	1:22	12:34
Event 1999e03 - 12/31/1999													
1E	1-42	-	0.04	☑	-	☑	0	0	12/31/1999	13:19	12/31/1999	14:10	0:51
1E	1-46	0.04	0.04	☐	2	☐	2	0	12/31/1999	13:16	12/31/1999	14:14	0:58
1W	1-52	0.04	0.04	☐	1	☐	1	0	12/31/1999	13:23	12/31/1999	13:52	0:29
1W	1-58	0.05	0.05	☐	30	☐	30	0.02	12/31/1999	13:17	12/31/1999	14:07	0:50
6	6-20E	0.16	0.16	☐	36	☐	36	0.02	12/31/1999	9:56	12/31/1999	16:41	6:45
6	6-20F	0.17	0.17	☐	45	☐	45	0.03	12/31/1999	9:55	12/31/1999	16:46	6:51
8	8-23C	0.24	0.24	☐	113	☐	113	0.05	12/31/1999	13:31	12/31/1999	17:50	4:19
8	8-B001	0.29	0.29	☐	-	☑	87	0.13	12/31/1999	13:29	12/31/1999	17:52	4:23
Event 1999e05 - 01/25/2000													
1E	1-42	0.57	0.57	☐	210	☑	210	0.18	01/25/2000	2:06	01/25/2000	20:50	18:44
1E	1-46	0.58	0.58	☐	159	☑	159	0.12	01/25/2000	2:16	01/25/2000	20:43	18:27
1W	1-52	0.52	0.52	☐	279	☐	279	0.18	01/25/2000	2:07	01/25/2000	20:42	18:35
1W	1-58	0.54	0.54	☐	501	☐	501	0.37	01/25/2000	2:07	01/25/2000	20:47	18:40
6	6-20E	0.78	0.78	☐	504	☐	504	0.33	01/24/2000	23:16	01/25/2000	21:13	21:57
6	6-20F	0.79	0.79	☐	584	☐	584	0.38	01/24/2000	23:19	01/25/2000	20:50	21:31
8	8-23C	0.34	0.55	☑	437	☐	437	0.19	01/25/2000	2:29	01/25/2000	20:52	18:23
8	8-B001	0.55	0.55	☐	77	☐	77	0.12	01/25/2000	2:28	01/25/2000	20:30	18:20

T:\ENV\LJMLMPS.MDB: TABLE 4-2\09-MAR-00\SDG

Table 4-2
SUMMARY OF HYDROLOGIC DATA FOR MONITORED STORM EVENTS

Site	Outfall	Total Meas. Rainfall (inch)	Rain After QA/QC (inch)	Rain Abnorm.	Total Meas. Flow (cf)	Flow Abnorm.	Total Flow After QA/QC (cf)	Total Flow After QA/QC (inch)	Begining Date of Monitoring Period	Begining Time of Monitoring Period	Ending Date of Monitoring Period	Ending Time of Monitoring Period	Duration (hh:mm)
Event 1999e06 - 01/30/2000													
1E	1-42	0.23	0.23	☐	71	☐	71	0.06	01/30/2000	19:14	01/31/2000	1:45	6:31
1E	1-46	0.22	0.22	☐	24	☐	24	0.02	01/30/2000	19:21	01/31/2000	1:36	6:15
1W	1-52	0.18	0.18	☐	79	☐	79	0.05	01/30/2000	19:30	01/31/2000	1:26	5:56
1W	1-58	0.20	0.2	☐	144	☐	144	0.11	01/30/2000	19:31	01/31/2000	1:29	5:58
6	6-20E	0.24	0.24	☐	113	☐	113	0.07	01/30/2000	20:02	01/31/2000	1:21	5:19
6	6-20F	0.24	0.24	☐	128	☐	128	0.08	01/30/2000	20:02	01/31/2000	1:15	5:14
8	8-23C	0.07	0.15	☑	27	☐	27	0.01	01/30/2000	20:02	01/31/2000	1:15	5:13
8	8-B001	0.15	0.15	☐	3	☐	3	0.01	01/30/2000	19:55	01/31/2000	1:23	5:28
Event 1999e08 - 02/10/2000													
1E	1-42	0.30	0.3	☐	186	☐	186	0.16	02/10/2000	13:56	02/10/2000	16:41	2:45
1E	1-46	0.32	0.32	☐	111	☐	111	0.08	02/10/2000	13:58	02/10/2000	16:44	2:46
1W	1-52	0.32	0.32	☐	212	☐	212	0.14	02/10/2000	13:56	02/10/2000	17:26	3:30
1W	1-58	0.32	0.32	☐	287	☐	287	0.21	02/10/2000	13:57	02/10/2000	16:42	2:45
6	6-20E	0.52	0.52	☐	376	☐	376	0.25	02/10/2000	13:57	02/10/2000	23:56	9:59
6	6-20F	0.51	0.51	☐	397	☐	397	0.26	02/10/2000	14:02	02/10/2000	23:55	9:53
8	8-23C	0.27	0.27	☐	230	☐	230	0.1	02/10/2000	13:18	02/10/2000	17:06	3:48
8	8-B001	0.19	0.19	☐	65	☐	65	0.1	02/10/2000	13:15	02/10/2000	17:18	4:03
Event 1999e09 - 02/12/2000													
1E	1-42	-	0.52	☑	-	☑	329	0.28	02/12/2000	0:55	02/12/2000	3:15	2:20
1E	1-46	0.53	0.53	☐	392	☐	392	0.28	02/12/2000	0:59	02/12/2000	3:22	2:23
1W	1-52	0.51	0.51	☐	523	☐	523	0.34	02/12/2000	0:56	02/12/2000	3:11	2:15
1W	1-58	0.51	0.51	☐	542	☐	542	0.4	02/12/2000	0:51	02/12/2000	3:12	2:21
6	6-20E	0.40	0.4	☐	342	☐	342	0.22	02/12/2000	1:15	02/12/2000	3:11	1:56
6	6-20F	0.40	0.4	☐	361	☐	361	0.24	02/12/2000	1:15	02/12/2000	3:40	2:25
8	8-23C	0.65	0.65	☐	878	☐	878	0.39	02/12/2000	0:39	02/12/2000	5:59	5:20
8	8-B001	0.62	0.62	☐	202	☐	202	0.31	02/12/2000	0:30	02/12/2000	5:38	5:08

T:\ENV\LJMLMPS.MDB: TABLE 4-2\09-MAR-00\SDG

Table 4-2
SUMMARY OF HYDROLOGIC DATA FOR MONITORED STORM EVENTS

Site	Outfall	Total Meas. Rainfall (inch)	Rain After QA/QC (inch)	Rain Abnorm.	Total Meas. Flow (cf)	Flow Abnorm.	Total Flow After QA/QC (cf)	Total Flow After QA/QC (inch)	Begining Date of Monitoring Period	Begining Time of Monitoring Period	Ending Date of Monitoring Period	Ending Time of Monitoring Period	Duration (hh:mm)
Event 1999e10 - 02/13/2000													
1E	1-42	0.35	0.35	☐	183	☐	183	0.16	02/13/2000	18:26	02/14/2000	11:08	16:42
1E	1-46	0.38	0.38	☐	131	☐	131	0.09	02/13/2000	18:22	02/14/2000	10:30	16:08
1W	1-52	0.28	0.28	☐	228	☐	228	0.15	02/13/2000	18:09	02/14/2000	10:25	16:16
1W	1-58	0.31	0.31	☐	346	☐	346	0.26	02/13/2000	18:22	02/14/2000	10:45	16:23
6	6-20E	0.32	0.32	☐	125	☐	125	0.08	02/13/2000	19:14	02/14/2000	11:53	16:39
6	6-20F	0.34	0.34	☐	89	☐	89	0.06	02/13/2000	18:48	02/14/2000	12:02	17:14
8	8-23C	0.20	0.33	☑	291	☐	291	0.04	02/13/2000	18:53	02/14/2000	12:32	17:39
8	8-B001	0.33	0.33	☐	53	☐	53	0.08	02/13/2000	18:53	02/14/2000	12:32	17:39
Event 1999e11 - 02/16/2000													
1E	1-42	0.54	0.54	☐	336	☐	336	0.29	02/16/2000	3:45	02/16/2000	20:02	16:17
1E	1-46	0.50	0.5	☐	306	☐	306	0.22	02/16/2000	3:52	02/16/2000	19:53	16:01
1W	1-52	0.48	0.48	☐	380	☐	380	0.24	02/16/2000	3:52	02/16/2000	19:50	15:58
1W	1-58	0.52	0.52	☐	533	☐	533	0.4	02/16/2000	3:43	02/16/2000	19:53	16:10
6	6-20E	0.72	0.72	☐	654	☐	654	0.43	02/16/2000	3:58	02/16/2000	20:47	16:49
6	6-20F	0.74	0.74	☐	672	☐	672	0.44	02/16/2000	3:46	02/16/2000	20:04	16:18
8	8-23C	0.74	0.74	☐	1117	☐	1117	0.5	02/16/2000	3:59	02/16/2000	19:56	15:57
8	8-B001	0.78	0.78	☐	323	☐	323	0.49	02/16/2000	3:57	02/16/2000	19:53	15:56
Event 1999e12 - 02/20/2000													
1E	1-42	-	2.33	☑	-	☑	1800	1.55	02/20/2000	5:40	02/21/2000	16:11	34:31
1E	1-46	2.43	2.43	☐	1961	☐	1961	1.42	02/20/2000	5:40	02/21/2000	16:22	34:42
1W	1-52	2.29	2.29	☐	2292	☐	2292	1.47	02/20/2000	5:39	02/21/2000	16:08	34:29
1W	1-58	2.26	2.26	☐	2548	☐	2548	1.9	02/20/2000	5:40	02/21/2000	15:59	34:19
6	6-20E	2.61	2.61	☐	2291	☐	2291	1.5	02/20/2000	6:14	02/21/2000	17:07	34:53
6	6-20F	2.57	2.57	☐	2509	☐	2509	1.65	02/20/2000	6:16	02/21/2000	17:03	34:47
8	8-23C	1.91	2.35	☑	4058	☐	4058	1.8	02/20/2000	6:05	02/21/2000	13:52	31:47
8	8-B001	2.35	2.35	☐	1113	☐	1113	1.7	02/20/2000	6:03	02/21/2000	14:25	32:22

T:\ENV\LJMLMPS.MDB: TABLE 4-2\09-MAR-00\SDG

Table 4-2
SUMMARY OF HYDROLOGIC DATA FOR MONITORED STORM EVENTS

Site	Outfall	Total Meas. Rainfall (inch)	Rain After QA/QC (inch)	Rain Abnorm.	Total Meas. Flow (cf)	Flow Abnorm.	Total Flow After QA/QC (cf)	Total Flow After QA/QC (inch)	Begining Date of Monitoring Period	Begining Time of Monitoring Period	Ending Date of Monitoring Period	Ending Time of Monitoring Period	Duration (hh:mm)
Event 1999e13 - 02/23/2000													
1E	1-42	1.16	1.16	☐	0	☑	849	0.73	02/23/2000	3:45	02/23/2000	14:17	10:32
1E	1-46	1.12	1.12	☐	1053	☐	1053	0.76	02/23/2000	3:46	02/23/2000	14:11	10:25
1W	1-52	1.05	1.05	☐	1073	☐	1073	0.69	02/23/2000	3:43	02/23/2000	14:03	10:20
1W	1-58	1.14	1.14	☐	1202	☐	1202	0.89	02/23/2000	3:45	02/23/2000	14:03	10:18
6	6-20E	1.23	1.23	☐	1321	☐	1321	0.87	02/23/2000	5:10	02/23/2000	14:32	09:22
6	6-20F	1.21	1.21	☐	1574	☑	1574	1.03	02/23/2000	4:29	02/23/2000	14:30	10:01
8	8-23C	1.15	1.49	☑	2356	☐	2356	1.05	02/23/2000	4:23	02/23/2000	14:11	09:48
8	8-B001	1.49	1.49	☐	549	☑	667	1.02	02/23/2000	4:25	02/23/2000	14:25	10:00
Event 1999e14 - 02/27/2000													
1E	1-42	0.16	0.16	☐	65	☐	65	0.06	02/27/2000	12:28	02/27/2000	14:21	01:53
1E	1-46	0.18	0.18	☐	63	☐	63	0.05	02/27/2000	12:28	02/27/2000	14:04	01:36
1W	1-52	0.18	0.18	☐	112	☐	112	0.07	02/27/2000	12:25	02/27/2000	14:22	01:57
1W	1-58	0.16	0.16	☐	118	☐	118	0.09	02/27/2000	12:27	02/27/2000	14:06	01:39
6	6-20E	0.19	0.19	☐	166	☐	166	0.11	02/27/2000	12:25	02/27/2000	14:50	02:25
6	6-20F	0.19	0.19	☐	167	☐	167	0.11	02/27/2000	12:24	02/27/2000	14:24	02:00
8	8-23C	0.26	0.19	☑	346	☐	346	0.15	02/27/2000	12:10	02/27/2000	14:17	02:07
8	8-B001	0.19	0.19	☐	83	☐	83	0.13	02/27/2000	12:10	02/27/2000	14:16	02:06
Event 1999e15 - 03/04/2000													
1E	1-42	1.79	1.79	☐	1398	☐	1398	1.2	03/04/2000	22:41	03/06/2000	4:58	30:17
1E	1-46	1.76	1.76	☐	1517	☐	1517	1.1	03/04/2000	22:46	03/06/2000	4:56	30:10
1W	1-52	1.58	1.58	☐	1713	☐	1713	1.1	03/04/2000	22:39	03/06/2000	5:46	31:07
1W	1-58	1.72	1.72	☐	2199	☑	2199	1.64	03/04/2000	22:43	03/06/2000	4:56	30:13
6	6-20E	1.56	1.56	☐	1187	☐	1187	0.78	03/04/2000	17:53	03/06/2000	3:04	33:11
6	6-20F	1.55	1.55	☐	1334	☐	1334	0.88	03/04/2000	17:54	03/06/2000	3:01	33:07
8	8-23C	0.96	1.59	☑	2129	☐	2129	0.95	03/04/2000	22:23	03/05/2000	22:39	24:16
8	8-B001	1.59	1.59	☐	679	☐	679	1.04	03/04/2000	19:04	03/05/2000	21:55	26:51

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Table 4-2
SUMMARY OF HYDROLOGIC DATA FOR MONITORED STORM EVENTS

Site	Outfall	Total Meas. Rainfall (inch)	Rain After QA/QC (inch)	Rain Abnorm.	Total Meas. Flow (cf)	Flow Abnorm.	Total Flow After QA/QC (cf)	Total Flow After QA/QC (inch)	Begining Date of Monitoring Period	Begining Time of Monitoring Period	Ending Date of Monitoring Period	Ending Time of Monitoring Period	Duration (hh:mm)
Event 1999e15a - 03/03/2000													
1E	1-42	0.35	0.35	☐	167	☐	167	0.14	03/03/2000	18:19	03/03/2000	21:57	3:38
1E	1-46	0.36	0.36	☐	209	☐	209	0.15	03/03/2000	18:20	03/03/2000	22:25	4:05
1W	1-52	0.34	0.34	☐	255	☐	255	0.16	03/03/2000	18:17	03/03/2000	22:21	4:04
1W	1-58	0.33	0.33	☐	344	☐	344	0.26	03/03/2000	18:18	03/03/2000	22:23	4:05
6	6-20E	0.54	0.54	☐	463	☐	463	0.3	03/03/2000	19:55	03/03/2000	22:41	2:46
6	6-20F	0.53	0.53	☐	501	☐	501	0.33	03/03/2000	19:56	03/03/2000	22:42	2:46
8	8-23C	0.45	0.45	☐	566	☐	566	0.25	03/03/2000	20:03	03/03/2000	22:34	2:31
8	8-B001	0.50	0.5	☐	134	☐	134	0.21	03/03/2000	20:00	03/03/2000	22:32	2:32
Event 1999e16 - 03/08/2000													
1E	1-42	0.86	0.86	☐	510	☐	510	0.44	03/08/2000	1:54	03/08/2000	10:47	08:53
1E	1-46	0.94	0.94	☐	796	☐	796	0.58	03/08/2000	2:01	03/08/2000	10:44	08:43
1W	1-52	0.80	0.8	☐	860	☐	860	0.55	03/08/2000	2:26	03/08/2000	10:39	08:13
1W	1-58	0.81	0.81	☐	927	☐	927	0.69	03/08/2000	0:26	03/08/2000	10:42	10:16
6	6-20E	1.22	1.22	☐	1296	☐	1296	0.85	03/08/2000	2:36	03/08/2000	11:28	08:52
6	6-20F	1.23	1.23	☐	1398	☐	1398	0.92	03/08/2000	2:32	03/08/2000	12:53	10:21
8	8-23C	0.42	0.86	☑	295	☑	1211	0.54	03/07/2000	23:56	03/08/2000	11:05	11:09
8	8-B001	0.86	0.86	☐	267	☐	267	0.41	03/07/2000	23:52	03/08/2000	11:14	11:22

Table 4-3
DESCRIPTION OF HYDROLOGIC DATA ABNORMALITIES AND ADJUSTMENTS

Event Number	Date	Site	Outfall	Type of Abnormality	Recorded Value (inches or watershed inches)	Action Taken During Analysis of Rainfall/Runoff Relationships	Description or Abnormality
1998e01	11/8/98	8	23c	Rain	0.22 in	Rainfall total set to value recorded at outfall B001, 0.45 in.	Rainfall total is appreciably lower than recorded value at B001. Vegetative mater present in rain gauge.
1998e02	11/28/98	8	B001	Statistical Outlier	0.76 in (886 cf) of Runoff	No action taken, point was not corrected. The storm was extremely peaky and had an appreciable intensity, these could be major factors contributing to the observations for this storm at Site 8.	Identified as a possible outlier based on a high studentized residual of 3.757. Trace rain followed the event. Flow is much higher than expected for similar magnitude events for this outfall.
1998e02	11/28/98	8	23c	Flow and Rain	0.69 in of Rainfall and 0.22 (505 cf) in of Runoff	Rainfall adjusted to 0.85 inches and flow adjusted to 0. 53 inches (1194 cf) based on rainfall at B001 for this event and the runoff coefficient and depression storage observed for other events at this outfall. The storm was extremely peaky and had an appreciable intensity, these could be major factors contributing to the observations for this storm at Site 8. The rain gauge may have not functioned well under the severe wind/rain conditions present.	Rainfall total does not agree with other outfall at site and total for Montbello NWS Rain Gauge rain gauge, which recorded 1.00 in during the 24 hour period from 11/27 at 16:00 to 11/28 at 16:00. The flow total is quite low compared to the amount expected. 0.22 watershed inches is the runoff expected from a storm of magnitude less than 0.5 in.
1998e03	12/1/98	8	B001	Flow	0.20 in (404 cf)	Value was corrected to 0.08 inch (93 cf) based on runoff coefficient and depression storage observed for other events at this outfall. The flow abnormality was most likely due to an equipment problem.	Flow recorded was higher than expected. Bubbler was clogged with sediment during set-up. The tube was cleared prior to event, but problem appears to have continued during event.
1998e05	1/25/99	1	42	Rain, Flow, Start Time	0.17 in Rainfall and 0.31 in (359 cf)	Rainfall total set to average value recorded at other three outfalls at Site 1, 0.51 inches (321 cf). Runoff was recalculated based on adjusted start time.	Rainfall total is much less than other gauges at site 1 for this event. The rain gauge was clogged during event due to bird droppings. As a result of the clogged rain gauge, the flow start time was not accurate.

Table 4-3 (Continued)
DESCRIPTION OF HYDROLOGIC DATA ABNORMALITIES AND ADJUSTMENTS

Event Number	Date	Site	Outfall	Type of Abnormality	Recorded Value (inches or watershed inches)	Action Taken During Analysis of Rainfall/Runoff Relationships	Description or Abnormality
1998e06	2/9/99	6	20f	Flow	0.68 in (1033 cf)	Value was corrected to 0.22 inch (332 cf) based on runoff coefficient and depression storage observed for other events at this outfall.	Flow total was higher than expected from other events. Unknown measurement error. Possible sporadic equipment problem or clogging of bubbler tube. Runoff coefficient for event was greater than unity (1.62).
1998e06	2/9/99	8	23c	Flow and Rainfall	-	For total flow and rainfall calculations, rainfall was taken from 8-B001 and flow was estimated from runoff coefficient and rainfall. After QA values were set to 0.29 inches of rainfall and 0.10 inches (223 cf) of runoff.	Data record not available.
1998e09	3/15/99	6	20f	Flow	1.18 in (1797 cf)	Value was corrected to 0.26 inch (395 cf) based on runoff coefficient and depression storage observed for other events at this outfall.	Flow total was higher than expected from previous events. Unknown measurement error. Possible sporadic equipment problem or clogging of bubbler tube. Runoff coefficient for event is greater than unity (2.46).
1998e10	3/20/99	1	42	Spike in flow record	0.06 (74 cf)	Spike removed from record and measured value was recalculated from field data. Value shown is after removal of spike from record.	Flow record spikes with no corresponding sudden change in rainfall rate. The measurement was in error
1998e11	3/25/99	6	20f	Spike in flow record	0.02 in (26 cf)	Spike removed from record and measured value was recalculated from field data. Value shown is after removal of spike from record.	Flow total was higher than expected from other events. Flow reading jumped abruptly upward during modem call-in.
1998e12	4/8/99	6	20e	Statistical Outlier, Flow	0.74 (1129 cf)	No action taken, point remains in QA data set.	After QA, identified as a possible outlier based on a high studentized residual of 3.145.
1998e12	4/8/99	8	23c	Flow and Rainfall	-	For total flow and rainfall calculations, rainfall was taken from 8-B001 and flow was estimated from runoff coefficient and rainfall. After QA values were set to 0.98 inches of rainfall and 0.63 inches (1419 cf) of runoff.	Data record not available.

Table 4-3 (Continued)
DESCRIPTION OF HYDROLOGIC DATA ABNORMALITIES AND ADJUSTMENTS

Event Number	Date	Site	Outfall	Type of Abnormality	Recorded Value (inches or watershed inches)	Action Taken During Analysis of Rainfall/Runoff Relationships	Description or Abnormality
1998e13	4/11/99	1	42	Flow, Start and Stop Time	0.85 (987 cf)	Flow was adjusted to 0.93 inch (1077 cf) watershed inches based on start and stop time for 1-46 and flow measured at 1-42.	An apparently clogged rain gauge was at fault causing the storm start time to be in error. A start time from adjacent gauges was used and flow was recalculated.
1998e13	4/11/99	6	20F	Flow, Statistical Outlier	0.97 in (1477 cf)	Value was corrected to 0.58 inch (879 cf) based on runoff coefficient and depression storage observed for other events at this outfall.	Runoff coefficient for event was greater than unity. Event was identified during QA as a possible outlier based on a high studentized residual of 3.145.
1998e13	4/11/99	8	23c	Rain	0.79 in	Rainfall total set to value recorded at outfall B001, 1.09 in.	Rainfall total lower than expected. Possible clogging/partial obstruction of rain gauge, although not reported in the field. Total rainfall recorded at Montebello NWS rain gauge was 1.64 in from 17:00 4/10 to 17:00 4/12. Using rainfall total from outfall B001 (1.09 in) puts the event close to the rainfall/runoff curve from other events.
1999e03	12/31/99	1	42	Rain, Flow	-	For total flow and rainfall calculations, rainfall was taken from average of other stations at Site 1 and flow was estimated from runoff coefficient and depression storage observed for other events at this outfall. Values were set to 0.04 inches of rainfall and 0.00 inches of runoff.	Data record not available.
1999e03	12/31/99	8	B001	Flow	-	Flow was estimated from runoff coefficient, and depression storage observed for other events at this outfall. The value was set to 0.13 inches (87 cf) of runoff.	Flow data record not available due to a dislodged bubbler tube.
1999e05	1/25/00	1	42	Flow	0.18 in (210 cf)	No action taken, point remains in QA data set.	After QA, identified as a possible outlier based on a high studentized residual of –4.776. Measurement abnormality is most likely due to the long duration low intensity of the event.

Table 4-3 (Continued)
DESCRIPTION OF HYDROLOGIC DATA ABNORMALITIES AND ADJUSTMENTS

Event Number	Date	Site	Outfall	Type of Abnormality	Recorded Value (inches or watershed inches)	Action Taken During Analysis of Rainfall/Runoff Relationships	Description or Abnormality
1999e05	1/25/00	1	46	Flow	0.12 in (159 cf)	No action taken, point remains in QA data set.	After QA, identified as a possible outlier based on a high studentized residual of –3.040. Measurement abnormality is most likely due to the long duration low intensity of the event.
1999e05	1/25/00	8	23c	Rain	0.34 in	Rainfall total set to value recorded at outfall B001, 0.55 in.	Rainfall total lower than expected. Possible obstruction of rain gauge or rain shadow from vegetation.
1999e06	1/30/00	8	23c	Rain	0.07 in	Rainfall total set to value recorded at outfall B001, 0.15 in.	Rainfall total lower than expected. Possible obstruction of rain gauge or rain shadow from vegetation.
1999e09	2/12/00	1	42	Rain, Flow	-	For total flow and rainfall calculations, rainfall was taken from average of other stations at Site 1 and flow was estimated from runoff coefficient and depression storage observed for other events at this outfall. Values were set to 0.52 inches of rainfall and 0.28 inches (329 cf) of runoff.	Data record not available.
1999e10	2/13/00	8	23c	Rain	0.20 in	Rainfall total set to value recorded at outfall B001, 0.33 in.	Rainfall total lower than expected. Possible obstruction of rain gauge or rain shadow from vegetation.
1999e12	2/20/00	1	42	Rain, Flow	-	For total flow and rainfall calculations, rainfall was taken from average of other stations at Site 1 and flow was estimated from runoff coefficient and depression storage observed for other events at this outfall. Values were set to 2.33 inches of rainfall and 1.55 inches (1800 cf) of runoff.	Data record not available.

Table 4-3 (Continued)
DESCRIPTION OF HYDROLOGIC DATA ABNORMALITIES AND ADJUSTMENTS

Event Number	Date	Site	Outfall	Type of Abnormality	Recorded Value (inches or watershed inches)	Action Taken During Analysis of Rainfall/Runoff Relationships	Description or Abnormality
1999e12	2/20/00	8	23c	Rain, Statistical Outlier	1.91 in	Rainfall total set to value recorded at outfall B001, 2.35 in.	Rainfall total lower than expected. Possible obstruction of rain gauge or rain shadow from vegetation. After QA, marginally identified as a possible outlier based on a studentized residual of 2.837.
1999e13	2/23/00	1	42	Flow	0 in	Flow was estimated from runoff coefficient, and depression storage observed for other events at this outfall. The value was set to 0.73 inches (849 cf) of runoff.	No flow data recorded. Bubbler on flow meter failed.
1999e13	2/23/00	6	20F	Statistical Outlier, Flow	1.03 in (1574 cf)	No action taken, point remains in QA data set.	After QA, identified as a possible outlier based on a high studentized residual of 4.631.
1999e13	2/23/00	8	B001	Flow	0.84 in (549 cf)	Flow was estimated from runoff coefficient, and depression storage observed for other events at this outfall. The value was set to 1.02 inches (667 cf) of runoff.	Runoff lower than expected from other events. Hydrograph of flow indicated that flow record was not responsive to rainfall intensity.
1999e13	2/23/00	8	23c	Rain	1.15 in	Rainfall total set to value recorded at outfall B001, 1.49 in.	Rainfall total lower than expected. Possible obstruction of rain gauge or rain shadow from vegetation.
1999e14	2/27/00	8	23c	Rain	0.26 in	Rainfall total set to value recorded at outfall B001, 0.19 in.	Rainfall total higher than expected. Possible obstruction of rain gauge or additional rain falling from vegetation during wind and low intensity rainfall.
1999e15	3/4/00	1	58	Statistical Outlier, Flow	1.89 in (2199 cf)	No action taken, point remains in QA data set.	After QA, identified as a possible outlier based on a high studentized residual of 5.990.
1999e15	3/4/00	8	23c	Rain, Statistical Outlier	0.96 in	Rainfall total set to value recorded at outfall B001, 1.59 in.	Rainfall total lower than expected. Possible obstruction of rain gauge or rain shadow from vegetation. After QA, identified as a possible outlier based on a high studentized residual of -2.965.

Table 4-3 (Continued)
DESCRIPTION OF HYDROLOGIC DATA ABNORMALITIES AND ADJUSTMENTS

Event Number	Date	Site	Outfall	Type of Abnormality	Recorded Value (inches or watershed inches)	Action Taken During Analysis of Rainfall/Runoff Relationships	Description or Abnormality
1999e16	3/8/00	8	23c	Rain, Flow	0.42 in of Rainfall and 0.13 in (293 cf) of Runoff	For total flow and rainfall calculations, rainfall was taken from B001 and flow was estimated from runoff coefficient and depression storage observed for other events at this outfall. Values were set to 0.86 inches of rainfall and 0.54 inches (1211 cf) of runoff.	Rainfall total lower than expected. Possible obstruction of rain gauge or rain shadow from vegetation. Runoff much lower than expected from other events with a runoff coefficient of 0.15 after rainfall was corrected. Hydrograph of flow indicated that flow record was not responsive to rainfall intensity.

4.2.5 Total Seasonal Rainfall and Flow Data

Rainfall gauges and flow meters remained active during rainfall events and in between successive events. This provided a total seasonal data record for both rainfall and flow. Table 4-4 shows the total rainfall for four National Weather Service stations in proximity to the monitored sites and rainfall totals by month of the monitoring period. The seasonal rainfall record, as adjusted based on QA/QC (Appendix D), was used along with the analysis of the relationship between flow and rainfall during chemical water quality monitoring events to predict the total volume of runoff for each of the chemical water quality sites. Although flow data were collected during inter-event periods, the minute-by-minute flow record contained abnormalities related to flow readings that were outside Caltrans storm criteria. Therefore, the calculated flow total was considered to better estimate actual flow conditions.

4.3 OTHER MONITORING ACTIVITIES

During the course of the LMPS, several monitoring activities were initiated to supplement the monitoring activities prescribed in the Study Plan. These monitoring activities comprise inlet deposition monitoring, characterization of street sweeping debris, and characterization of litter pick-up debris. Details and results of these activities are discussed in subsections below.

4.3.1 Inlet Deposition Monitoring

Inlet deposition monitoring was initiated at the 24 LMPS study inlets in June 1999. This supplementary monitoring consisted of observing deposition within drain inlets. The purpose of the effort was to obtain field insights regarding the amount of litter that enters a drain inlet as a result of transport by wind and vehicle-induced turbulence. Inlet deposition monitoring was conducted once every four weeks during June, July, and August 1999. Between September 1999 and April 2000, inlet deposition monitoring was conducted every other week. Deposition monitoring consists of taking debris depth measurements (i.e., as a way to estimate the volume of litter contained inside the chambers of the drain inlet structures) and making visual observations at each inlet. Depth measurements were taken at twelve points marked on each grate. Depth measurements taken during each monitoring event were then compared to base inlet depths at each measurement point location. Field procedures for inlet deposition monitoring are provided in Appendix F.

The inlet debris volume data are presented for each site in Figures 4-2 to 4-5. The data indicate that the volume of debris in the inlets gradually increased through the summer. Additionally, between January 11, 2000 and February 8, 2000, the volumes of debris continued to generally accumulate even though 3 monitored storms occurred during this period. Five monitored storms occurred during the 2-week period between February 8, 2000 and February 22, 2000, and a substantial reduction in inlet debris volume was measured during this period. This trend is supported by field observations during Event 1999-12 on February 21, 2000, where high flows appeared to “scour” debris in drain inlets at Site 1.

Table 4-4
SEASONAL RAINFALL AND TOTAL FLOW

	1998		1999						1999		2000				
	Nov.	Dec.	Jan.	Feb.	Mar.	April	Seasonal Total Rainfall[3]	Seasonal Total Flow[1]	Nov.	Dec.	Jan.	Feb.	Mar.	Seasonal Total Rainfall[4]	Seasonal Total Flow[1]
Station	Rainfall (in)						(in)	(cf)	Rainfall (in)					(in)	(cf)
Site 1W/1E – Lynnwood (NWS – LAX is 12 miles northwest and NWS – Torrance 12 miles southwest.															
NWS – LAX (045114)	1.89	0.74	1.19	0.5	2.28	2.26	8.86		0.36	0.00	0.85	4.75	2.39	8.35	
NWS – Torrance (048973)	1.12	0.48	1.22	0.45	2.17 4 days missing	2.33	7.77		0.36 4 days missing	0.00 3 days missing	0.75 8 days missing	3.78 4 days missing	2.36 8 days missing	7.25	
NWS – Long Beach (045085)	1.40	0.57	1.46	0.41	1.81	2.31	7.96		0.17 1 days missing	0.00	0.59	2.85	1.70	5.31	
1-42	1.36	0.82	1.11	0.36	1.36	2.55	7.56	6485	0.33	0.01	0.81	5.56[2]	3.05	9.76	7877
1-46	1.42	0.99	1.64	0.36	1.37	2.43	8.21	7370	0.34	0.04	0.83	5.78	3.09	10.08	8953
1-52	1.23	0.97	1.58	0.37	1.35	2.25	7.75	8465	0.34	0.05	0.74	5.41	2.75	9.29	10282
1-58	1.35	1.01	1.69	0.51	1.39	2.43	8.38	11255	0.39	0.06	0.78	5.50	2.89	9.62	12921
NWS -Montebello (045790)	1.65	0.6 1 day missing	2.05 4 days missing	0.64	0.75 12 days missing	2.88 4 days missing	8.57		0.25 8 days missing	0.00 6 days missing	0.06 11 days missing	4.59 11 days missing	2.51 10 days missing	7.41	
Site 6 – Hacienda Heights (NWS – Montebello, above, is 6 miles east)															
6-20e	1.02	0.60	1.52	0.90	0.75	2.65	7.43	6948	0.11	0.17	1.10	6.30	3.38	11.06	10417
6-20f	1.00	0.58	1.52	0.89	0.71	2.57	7.27	7732	0.11	0.17	1.11	6.26	3.33	10.98	11593
Site 8 – Montebello (NWS – Montebello is 4 miles west)															
8-23c	1.30[2]	0.49	1.72	0.61	0.89	1.97[2]	6.98	12113	0.22	0.30	0.45	6.28[2]	2.97[2]	10.22	17841
8-b001	1.30	0.51	1.74	0.61	0.87	1.97	7.00	5695	0.11	0.25	0.76	6.28	2.97	10.37	4722

NWS = National Weather Service, distances to NWS gauges are approximate.

1. Seasonal flow estimated from average rainfall at all rain gauges at site and the runoff coefficient determined from both years of rainfall and runoff event data. Depression storage is not included in the estimate.
2. Value has been approximated based on information from adjacent rain gauges for periods where rain gauge was not functioning properly.
3. Average seasonal rainfall totals (October-April) for the LA area are as follows: NWS-LAX 11.67 inch; NWS-Torrance 13.00 inch; NWS-Long Beach 11.76 inch; NWS-Montebello 16.21inch; NWS-Civic Center 14.14 inch.
4. Average seasonal rainfall totals (October-March) for the LA area are as follows: NWS-LAX 10.89 inch; NWS-Torrance 12.13 inch; NWS-Long Beach 11.02 inch; NWS-Montebello 15.19 inch; NWS-Civic Center 13.08 inch.

Figure 4-2
Inlet Material Volumes Based on Inlet Deposition Monitoring at Site 1E - Litter Pick-up

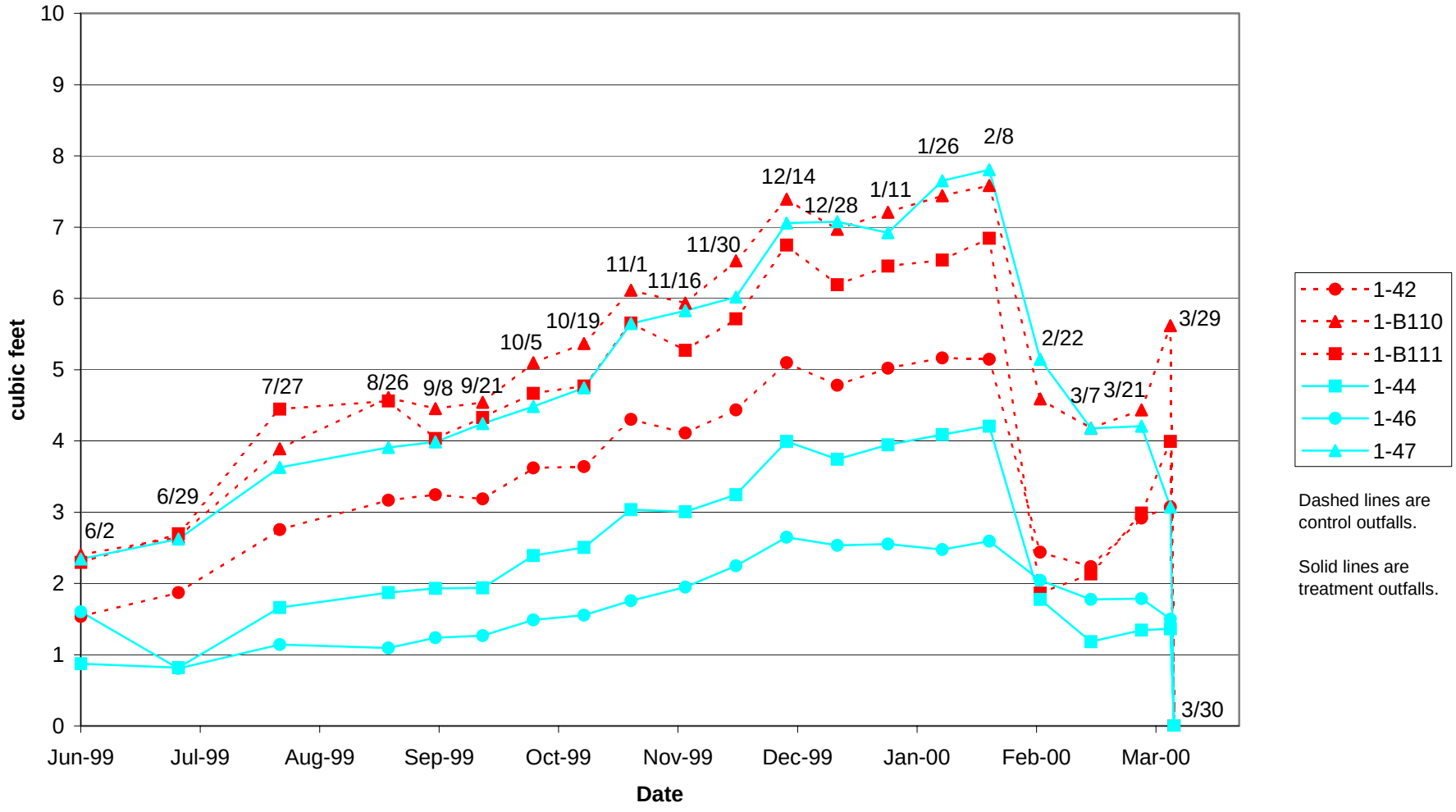


Figure 4-3
Inlet Material Volumes Based on Inlet Deposition Measurements at Site 1W - Street Sweeping

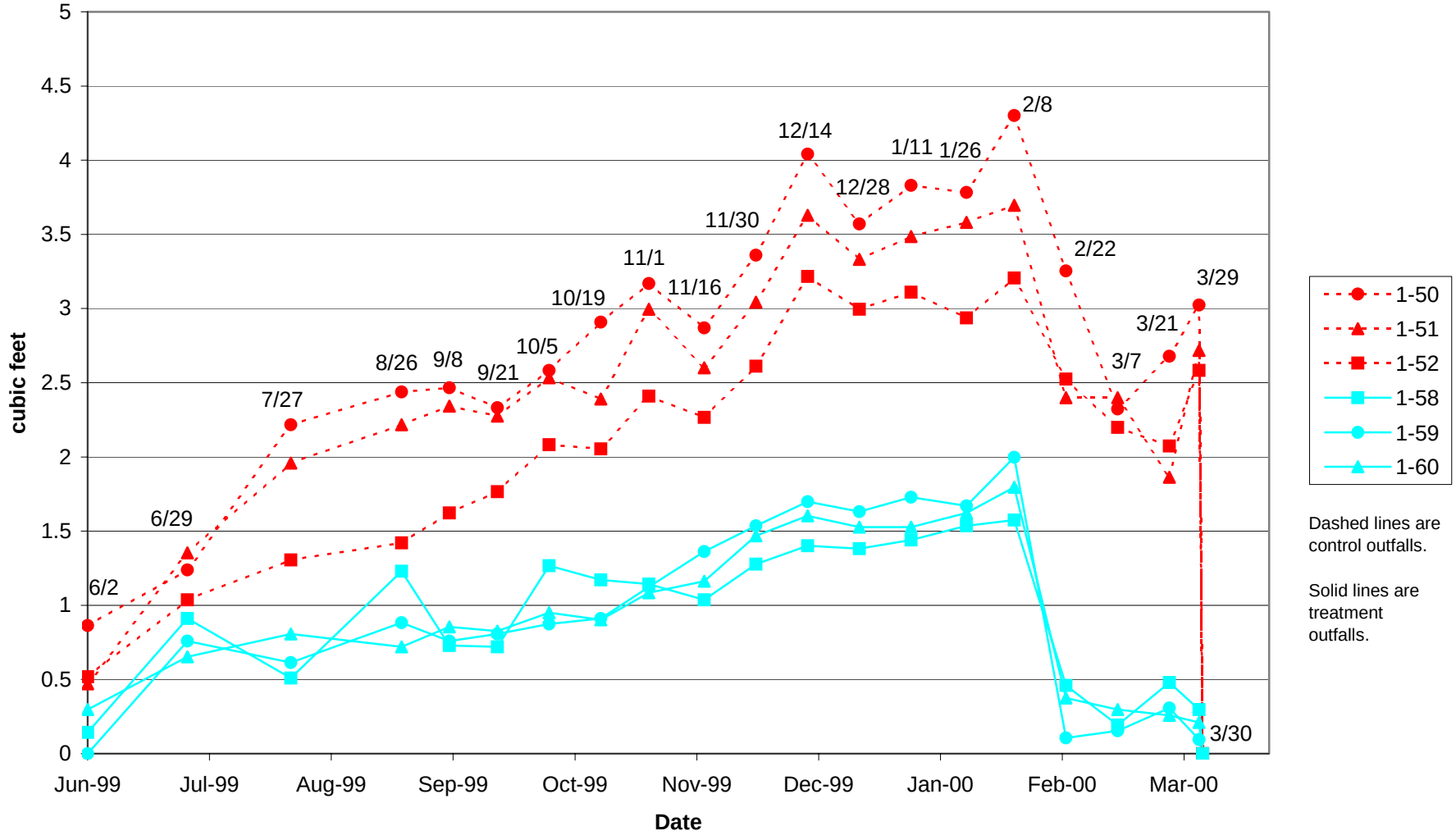


Figure 4-4
Inlet Material Volumes Based on Inlet Deposition Measurements at Site 6 - Modified Inlet

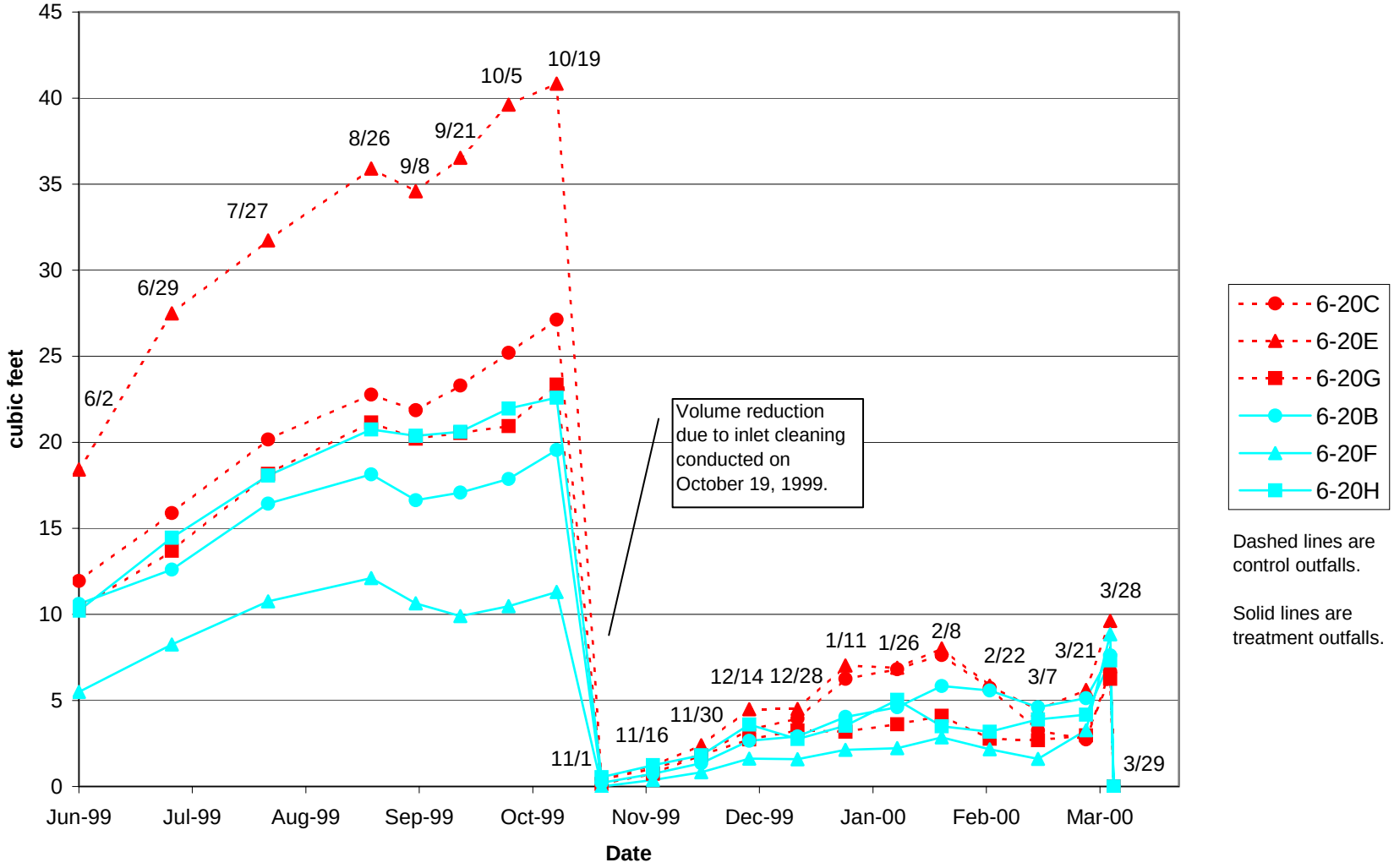
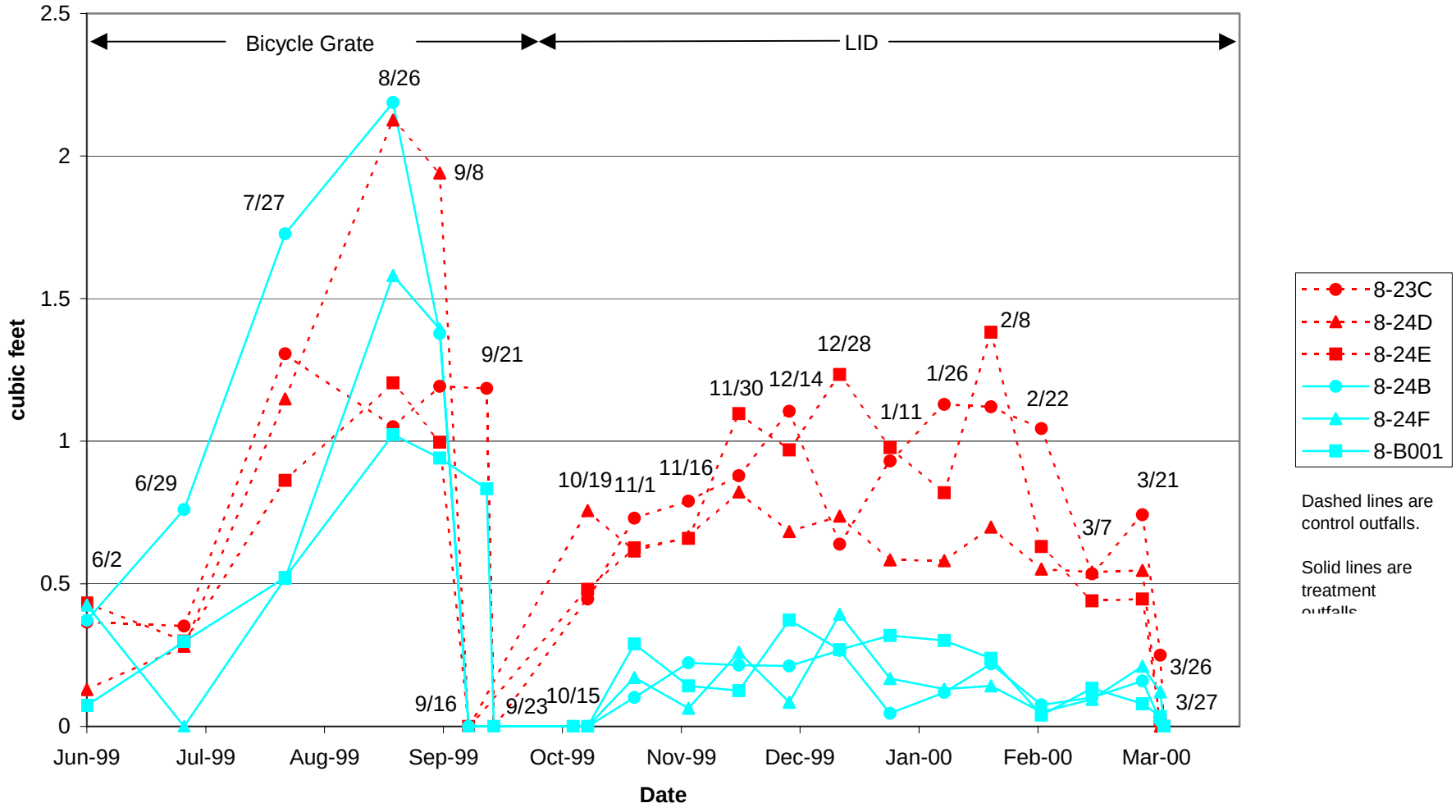


Figure 4-5
Inlet Material Volumes Based on Inlet Deposition Measurements at Site 8 - Bicycle Grate (Year 1) and LID (Year 2)



Figures 4-2 and 4-4 do not reveal clear trends with respect to BMPs reducing inlet material volume at Site 1E (litter pick-up) or Site 6 (modified inlet grate). Figure 4-3 shows a pattern of reduced volumes of inlet material for street sweeping treatment inlets compared to street sweeping control inlets at Site 1W. A similar pattern of reduced inlet material volumes is apparent for LID treatment inlets compared to control inlets at Site 8. However, these inlet material volume trends are not supported by litter monitoring results at the outfall. The trends are not demonstrated in either the cumulative litter monitoring results (Section 7.1.2) or the results of statistical testing for BMP effectiveness (Sections 7.1.4 and 7.1.5).

4.3.2 Street Sweeper Debris Characterization

In addition to the monitoring activities prescribed in the Study Plan, weight and volume measurements of sweeper debris were also taken. On several occasions, samples of sweeper debris were also collected for analysis in the litter lab. The purpose of these activities was to assess whether the litter collected by street sweepers was similar to the litter collected by the net bags at the ends of the drainage system outfalls, with respect to their composition and visual appearance.

Weight and volume measurements of sweeper debris were made on a weekly basis after the sweeper had finished both median and shoulder sweeping in the study area. Debris weight was measured by subtracting the tare weight of the sweeper (measured at truck scales upon exiting the transfer station) from the gross weight of the sweeper (taken upon entering the transfer station). Net weights of debris were found to be very small compared to the sweeper weight. Therefore, these weight data are not considered representative. Volume data are discussed below.

From March to October 1999, debris was collected from street sweeping operations (at Site 1) and then separated and analyzed. The volume of all of the material collected was estimated in the field. Volumes were measured after the debris was dumped from the hopper onto the ground. The following methods were used to measure debris volume: (1) shoveling debris into a 5-gallon bucket or (2) placing a calibrated wooden frame around the debris and taking width and length measurements for a standard depth (6 inches). Photo 4–1 depicts the calibrated frame technique. A sample of the material was then sieved to remove sediments, and the litter that was retained was taken to the litter lab for categorization.

Photo 4-1

Calibration Frame Used to Measure Volume of Sweeper Debris

Street sweeper debris was sorted and categorized 25 times from the westbound side of Site 1. The collected material was either collected during weekly sweeping (at the treatment site only) or during sweeping conducted every four weeks (from the treatment and control sites combined) and was analyzed in the litter lab. The analysis gave an indication of the types of litter that street sweepers collect on highways. These litter categories were then compared with the litter collected in the net bags at the ends of the drainage outfalls.

Figures 4-6 to 4-8 show the percent composition of street sweeping litter compared to litter monitored in the drainage system and litter collected from the ROW for each category by weight, volume, and count. Figures 4-6 to 4-8 show that the types of materials collected by freeway street sweepers is quite similar to the litter collected by the net bags at drainage system outfalls, except for some differences in the proportions of glass, moldable plastics, metal, paper, film plastic, styrofoam, and wood.

The percent composition of glass in sweeper debris ranges from 1 to 11 percent but was less than one percent in drainage system litter for the three measurement parameters (air-dried weight, volume, and count). Metal in sweeper debris ranged from 7 to 19 percent and 5 to 13 percent in drainage system litter. Moldable plastic in sweeper debris ranged from 27 to 38 percent but only 11 to 21 percent in drainage system litter. Paper and film plastic in sweeper debris ranged from 2 to 4 percent and 1 to 2 percent, respectively, whereas paper and film plastic ranged from 9 to 14 percent and 7 to 12 percent, respectively, in outfall litter.

The exceptions of higher proportions of moldable plastic and metal may be partly explained by considering the sweepers' ability to remove items such as drink bottles, cans, and vehicle parts that cannot fit through grates into drain inlets (typically 35mm/1 ½-inch bar-spacing) but can be removed by sweepers. Figure 4-8 also shows the very high proportion of the number of cigarette butts, which is consistent with the net bag monitoring results from the drainage system.

Figure 4-6
Drainage System, Street Sweeper, and ROW Litter Composition by Air-Dried Weight

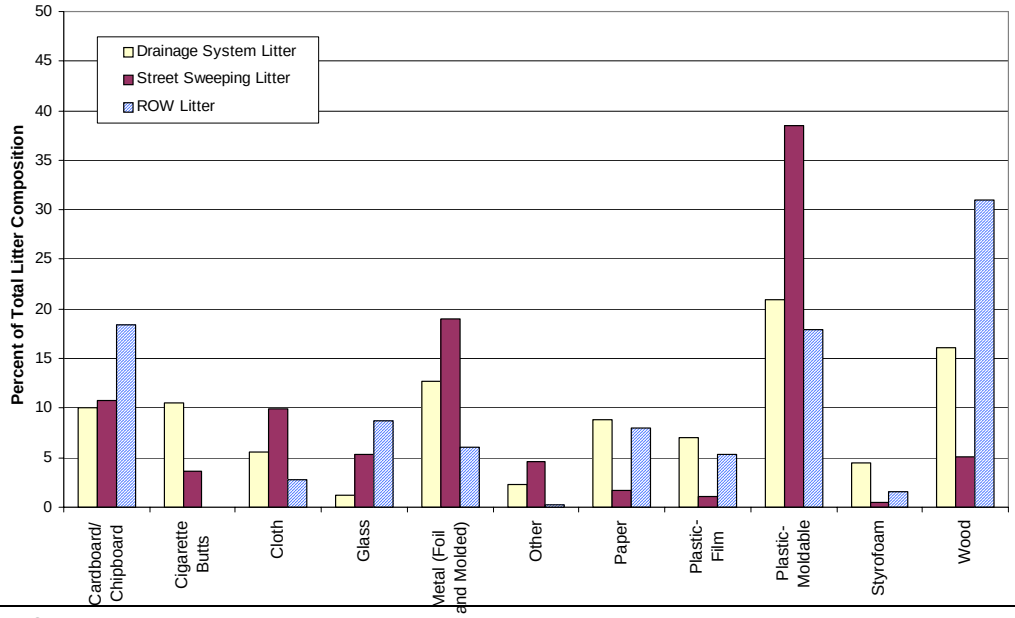


Figure 4-7
Drainage System, Street Sweeper, and ROW Litter Composition by Volume

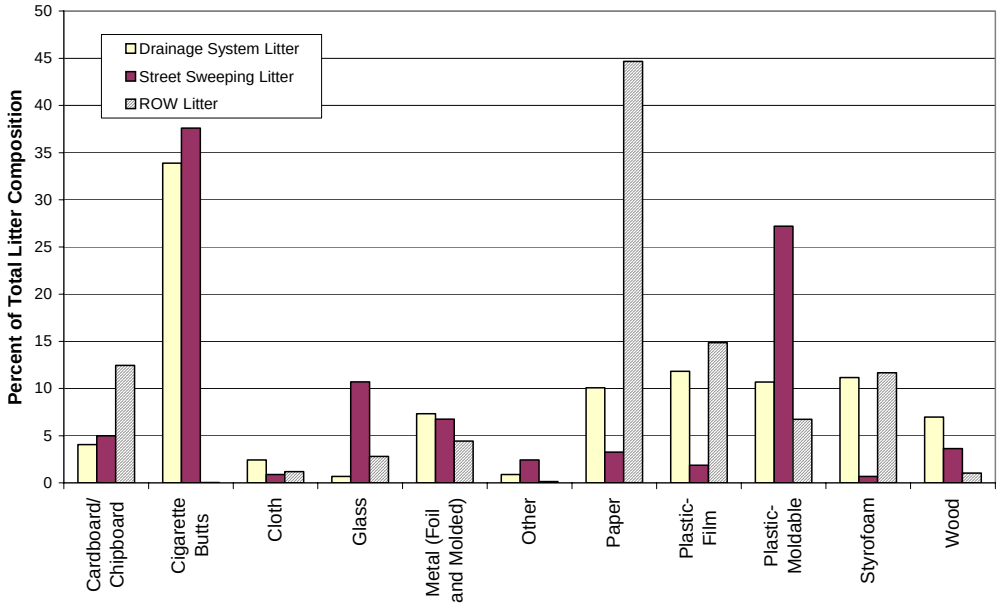
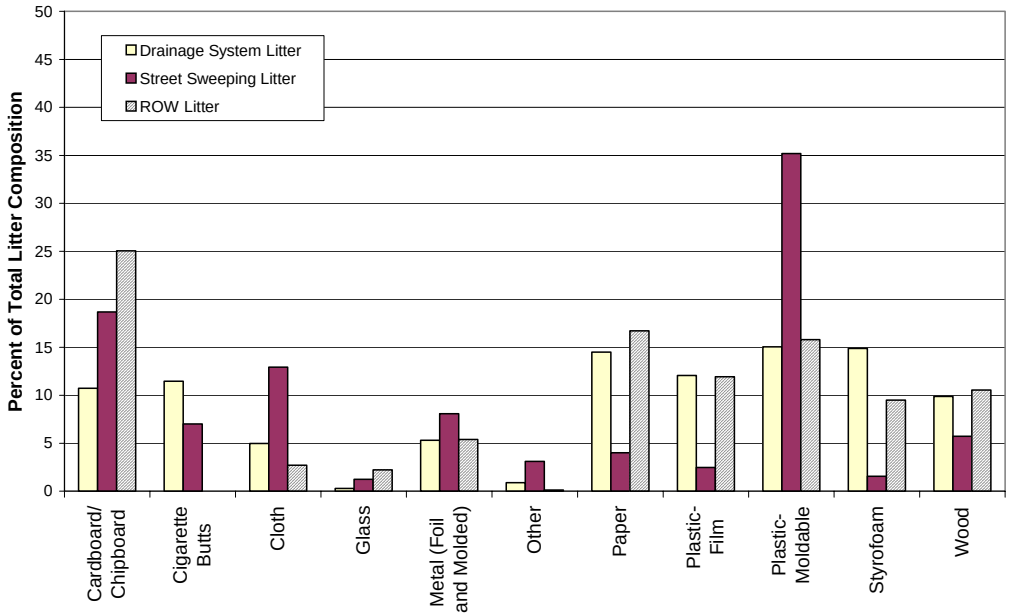


Figure 4-8
Drainage System, Street Sweeper, and ROW Litter Composition by Count



Differences in visual appearance between outfall litter and sweeper debris were evaluated by comparing laboratory observations regarding the general size and condition of items characterized. In general, items collected by the sweeper contained larger-sized items compared to outfall items. This difference is demonstrated in Photos 4-2 and 4-3.

4.3.3 Litter Pick-Up Debris Characterization

Throughout the LMPS, the litter pick-up subcontractor recorded the number of 20-gallon trash bags collected from the study area each week. Based on this accounting, 189 bags of litter were collected during 52 weekly pick-ups.

In addition to street sweeping debris characterization, ROW litter collected during implementation of the litter pick-up BMP was characterized. Litter from ROW pick-up was characterized during a 6-week period from September and October 1999. The purpose of characterization was to investigate whether litter during AAH litter pick-up was similar to litter retained in the net bags at the drainage outfalls, with respect to litter composition and size. The 6-week collection period provides a snap-shot of ROW litter that is expected to be similar to ROW litter collected throughout the study.

The litter pick-up collection and characterization methodologies are described below:

- As described in Section 3.3.1, litter pick-up is conducted on a weekly basis in the Site 1E treatment area ROW (Harris Avenue to Atlantic Boulevard on the I-105 freeway) and once every four weeks in the Site 1E control area ROW (Gertrude Avenue to Harris Avenue).
- The litter pick-up BMP uses litter collection practices similar to standard practices utilized by AAH contractors, Special Programs People, and Caltrans District 7 staff. Therefore, litter was picked up using mechanical, lever-actuated tongs and placed into collection bags; litter too small (e.g., cigarette butts) for pick-up was not collected.
- Standard practice for the LMPS was for the AAH contractor to place the collected litter in standard Caltrans District 7 AAH program trash bags and dispose of debris off-site as municipal solid waste.
- The AAH contractor was instructed to leave the trash bags on-site after collection in the appropriate treatment or control area. The bags were then retrieved from the site within a day of collection, each bag was properly labeled with date and collection area, and the bags were transported to the Santa Ana litter lab for characterization.
- Litter was characterized in accordance with the LMPS protocol. Additionally, the proportion of the ROW litter that could fit through a typical inlet grate was estimated.

Analysis of litter pick-up characterization data gives an indication of the types of litter present in the freeway ROW and collected by AAH programs. These litter categories were then compared with the litter monitored in the drainage outfalls.

Photo 4-2

Typical Litter in Sweeper Debris Collected From Site 1W, Harris to Gertrude, on 4/1/99

Photo 4-3

Typical Litter in Outfall Debris from Outfall 1-58, Event 1998-11, 3/25/99

Figures 4-6 to 4-8 show a plot of the proportions of litter categories for the ROW litter compared to drainage system and street sweeping litter. The material collected by the AAH contractor is similar to the litter retained in the net bags at the drainage systems, but the proportions of constituents differ. The data indicate that there are higher proportions of chipboard/cardboard, glass, and wood in the ROW litter compared to outfall litter, and much lower proportions of cigarette butts. The percent composition of cardboard/chipboard ranged from 12 to 25 percent in ROW litter and from 5 to 10 percent in drainage litter depending on measurement parameter (air-dried weight, volume, or count). For glass, the ROW percent composition ranged from 2 to 9 percent and drainage systems litter was 1 percent or less. For wood, the ROW percent composition ranged from 1 to 31 percent and the drainage system percent composition was 7 to 16 percent. For cigarette butts, the drainage system percent composition ranged from 10 to 34 percent and ROW litter contained no cigarette butts.

One explanation for this trend may be the size of the material collected during litter pick-up. In accordance with standard District 7 AAH litter collection practices, the AAH contractor did not remove individual cigarette butts, and this could explain why there is such as low proportion compared to the litter in the drainage system. Large litter items, such as wood from broken pallets, glass bottles, and large cardboard pieces, can be picked up by AAH contractors but would be unlikely to find their way into the drain system because of their size.

The size analysis involved placing the litter items from the ROW onto a typical inlet grate in the lab and measuring what proportion of material could fit through the grate. This analysis showed that approximately 90% of the litter collected from the ROW was too large to fit into a typical inlet grate.

4.3.4 LID Observations

Observations were made of the three LID BMPs during monitored storm events to assess BMP performance during wet weather. The hydraulic characteristics of the gates at each of the three treatment inlets (B001, 24B, and 24F) appeared to be satisfactory under all storm conditions observed. During low-flow periods, the vertical slots in the gate were sufficient to convey flow to the inlet without bypass. During higher flows (e.g., Event 1999-12), the gates opened to allow flows to enter the inlets, again without bypass. The flow diverters (angled asphalt channels) worked well to direct flow to the curb inlets. The current LID design includes vertical supports between the gate panels. These vertical supports tend to trap and collect debris, at times prying the gate open. More details regarding LID observations are provided in Appendix A.

5.1 SAMPLE ANALYSIS

A monitoring objective of the Caltrans LMPS was to obtain chemical water quality data from each of the eight stations for up to 18 storm events, or a total of 144 station events. During year 1 of monitoring, results for 90% of the targeted storm event chemical water quality constituents were obtained. During year 2 of monitoring, results for 87% (as of Event 1999-11) of the targeted constituents were obtained. Samples were not obtained for the remaining constituents because either lower than forecast rain volumes were observed or monitoring equipment malfunctioned. See Table G-2 in Appendix G for a breakdown of the constituents that were not analyzed.

5.1.1 Chemical Water Quality Parameters and Analytical Methods

The chemical water quality parameters and the associated sampling method, analytical method number, target detection limit, and holding time selected for the LMPS are shown in Table 5-1.

5.1.2 Sample Compositing

For each monitored storm event, the analytical laboratory prepared composite samples for each of the eight chemical water quality monitoring stations using aliquots from each of the automatic sampler bottles containing storm water runoff. The aliquot volume was determined by utilizing the sampling history recorded by the data logger, cumulative flow, and the representative proportion of flow captured for the event in each bottle.

Each automatic sampler was configured to contain eight 1900 ml bottles. The samplers were programmed to deliver three 600 ml samples to each of the eight bottles on a flow-weighted basis. Therefore, ideally, at the end of a storm event, each sampler would contain eight bottles, each holding exactly 1800 ml of storm water runoff. The entire set of bottles would then represent the entire duration of the storm event. However, for several reasons, partially-filled bottles are fairly common when using automatic samplers. Partially-filled bottles may occur because the flow is too low or there is a partial blockage of the intake tube such that the sampler cannot draw 600 ml when it is triggered. The calibration of the automatic sampler can degrade over time, such that the sampler does not draw exactly 600 ml (for example, a sampler may only draw 575 ml when triggered). Also, if the actual precipitation is less than forecast, the last bottle holding storm water sample may only have received one or two of the three samples programmed for each bottle.

To prepare a composite sample representative of the monitored event, the aliquots taken from each bottle had to be in proportion to the fraction of the cumulative flow represented by the sample in each bottle. Since each sample bottle did not always contain 1800 ml of storm water runoff, the composite sample could not be comprised of equal aliquots from each bottle. A worksheet was developed to compute the fraction of the cumulative flow represented by each bottle. This fraction was then used to determine the volume of the aliquot to be taken from each sample bottle when preparing the composite sample.

Table 5-1
CHEMICAL WATER QUALITY PARAMETERS AND ANALYTICAL METHODS

Parameter	Sampling Method	Method Number	Target Detection Limit	Holding Times
Metals (Total and Dissolved)				
Cadmium	Flow-weighted Automatic Sampling	EPA 6020	0.2 µg/L	6 months
Chromium	Flow-weighted Automatic Sampling	EPA 6020	1.0 µg/L	6 months
Copper	Flow-weighted Automatic Sampling	EPA 6020	1.0 µg/L	6 months
Lead	Flow-weighted Automatic Sampling	EPA 6020	1.0 µg/L	6 months
Nickel	Flow-weighted Automatic Sampling	EPA 6020	1.0 µg/L	6 months
Zinc	Flow-weighted Automatic Sampling	EPA 6020	1.0 µg/L	6 months
Nutrients				
Orthophosphate	Flow-weighted Automatic Sampling	EPA 365.3	0.05 mg/L	48 hours
Phosphorus - Total	Flow-weighted Automatic Sampling	EPA 365.3	0.05 mg/L	28 days
Total Kjeldahl Nitrogen (TKN)	Flow-weighted Automatic Sampling	EPA 351.3	0.3 mg/L	28 days
Nitrate-N	Flow-weighted Automatic Sampling	EPA 300.0	0.1 mg/L	48 hours
Other				
Coliform - Total	Manual Grab Sampling	SM 9221C	- -	6 hours
Coliform - Fecal	Manual Grab Sampling	SM 9221E	- -	6 hours
Hardness	Flow-weighted Automatic Sampling	EPA 130.2	1.0 mg/L	6 months
Oil and Grease	Manual Grab Sampling	EPA 413.1	1 mg/L	28 days
Temperature	Manual Grab Sampling	Field Test	—	—
pH	Manual Grab Sampling	Field Test and EPA 150.1	0.01	24 hours
Specific Conductance	Manual Grab Sampling	Field Test and EPA 120.1	1µhos/cm	NA
Total Petroleum Hydrocarbon (TPH) - Diesel fraction	Manual Grab Sampling	8015M	1000 µg/L	14 days
TPH - Gasoline fraction	Manual Grab Sampling	8015M	500 µg/L	14 days
Total Organic Carbon (TOC)	Flow-weighted Automatic Sampling	EPA 415.2	0.05 mg/L	28 days
Total Suspended Solids (TSS)	Flow-weighted Automatic Sampling	EPA 160.2	1.0 mg/L	7 days
Volatile Solids	Flow-weighted Automatic Sampling	EPA 160.4	1 ppm	7 days

5.1.3 Prioritization of Analytical Parameters

The chemical water quality parameters were prioritized for circumstances in which the volume of composite sample for a monitoring station was insufficient to conduct all of the analyses. This was particularly likely for those storm events where the actual precipitation was substantially less than the forecast precipitation amount which had been used to determine the

sampler pacing volume. Of the 147 composite chemical water quality station events for both years of monitoring, all of the analyses were conducted for all but 13 station events. The prioritization was developed based on discussion with Larry Walker and Associates (LWA), under contract with Caltrans to develop monitoring and analytical procedures for Caltrans chemical water quality studies. The general prioritization is presented in Table 5-2.

However, depending upon the minimum volume required to conduct an analysis and the amount of composite sample remaining, the "next" analysis in priority may be omitted, and a subsequent analysis in priority may be conducted. For example, if the total volume of composite sample was 700 ml, the following analyses would be conducted: Metals (100 ml), TSS (200 ml), Volatile Solids (200 ml), TOC (100 ml), pH and specific conductance (50 ml), and Nitrate (25 ml). In this example, the analysis for Total Phosphorus was skipped because it would have required 100 ml and only 50 ml of composite sample would be available. Therefore, the analysis for Nitrate would be specified, because it would require only 25 ml.

Table 5-2
PRIORITIZATION OF CHEMICAL WATER QUALITY PARAMETERS

Analytical Parameter in Order of Priority	Minimum Volume of Sample to Conduct Analysis (ml)
1) Metals - Total and Dissolved	100
2) TSS	200
3) Volatile Solids	200
4) TOC	100
5) pH and specific conductance	50
6) Total Phosphorus	100
7) Nitrate	25
8) Orthophosphate	100
9) TKN	300
10) Hardness	100

5.1.4 QA/QC

Several types of quality assurance and quality control (QA/QC) were applied to the chemical water quality data. First, data validation was performed in accordance with U.S. Environmental Protection Agency (EPA) and Caltrans Storm Water Program protocols on data from each storm event throughout both years of monitoring. Secondly, lab data that were submitted electronically (in Access format) were compared to hard copy reports to ensure that information in both data sets was consistent. This was accomplished by generating database reports in the format of the hard copy reports and comparing sets for approximately 12% of outfalls (one random outfall per storm event).

Chemical water quality data were reviewed for the following QA/QC elements of precision, accuracy, reporting limits, and contamination in accordance with the LWA protocols.

- Holding time
- Detection limits
- Blanks
- Surrogates
- Matrix spike/matrix spike duplicates
- Laboratory control samples
- Total vs. dissolved metals
- Field duplicates

Holding Times

Analytical methods adhered to sample holding times that were established for this study. The term "holding time" refers to the maximum amount of time after collection that a sample may be held prior to sample preparation and/or analysis. Although holding times were almost always met, on two occasions several samples were analyzed for nitrate out of holding time in year 1 due to sample compositing delays. These are presented in Table 5-3. All of the exceedances were less than 20 hours, and nitrate was detected in all of the affected samples at levels that were comparable to unaffected samples. In addition, all samples were analyzed by the laboratory within 48 hours of receipt. Therefore, no qualification was judged to be necessary.

Table 5-3
NITRATE HOLDING TIMES IN EXCESS OF 48 HOURS

Storm Event	Sample ID	Sample Start Date and Time	Sample Analysis Date and Time	Holding Time Exceeded by:
1998-02	1-58	11/28/98 4:07	11/30/98 19:42	15 hrs 35 mins
	1-46	11/28/98 4:23	11/30/98 20:28	16 hrs 5 mins
	1-42	11/28/98 4:10	11/30/98 21:13	17 hrs 3 mins
	1-52	11/28/98 4:31	11/30/98 21:59	17 hrs 28 mins
	8-23C	11/28/98 4:39	11/30/98 22:44	18 hrs 5 mins
	8-B001	11/28/98 4:36	11/30/98 23:29	18 hrs 53 mins
	6-20F	11/28/98 4:59	12/1/98 00:15	19 hrs 14 mins
	6-20E	11/28/98 5:01	12/1/98 1:00	19 hrs 59 mins
1998-03	1-58	12/1/98 13:45	12/4/98 00:09	10 hrs 24 mins
	8-23C	12/1/98 15:07	12/4/98 00:39	9 hrs 32 mins
	8-B001	12/1/98 14:15	12/4/98 1:10	10 hrs 55 mins

Detection Limits

Actual laboratory detection limits were compared to the detection limits specified in the Study Plan to determine compliance. During year 1, Study Plan detection limits were met for all analytes except two:

- TKN - 0.5 mg/L was used instead of 0.3 mg/L (storm event 3 only)
- Zinc - 5 μg/L instead of 1 μg/L

However, in all cases, samples had detected concentrations of these analytes. During year 2, Study Plan detection limits were met for all analytes except two:

- Hardness - 2 mg/L instead of 1 mg/L
- Nitrate - 0.5 mg/L was used instead of 0.1 mg/L for several station events

However, in all cases samples had detected concentrations of these analytes. In addition, nitrate detection limits were raised only in cases where dilution was required to quantify the nitrate present.

Blanks

Method blanks, consisting of deionized water (DI), were carried through each step of the analysis with the samples and were analyzed with each analytical parameter. For year 1, in four cases (zinc in 1998-06, cadmium in 1998-09, lead in 1998-11, and chromium in 1998-12) concentrations of metals above the detection limit, but below the reporting limit, were observed in the method blanks. All samples with concentrations less than five times the concentration found in the associated method blank were qualified as undetected (**U)**. For year 2, all method blanks had undetected analyte concentrations.

Equipment blanks were collected for storm events 1998-03, 1998-05, 1998-09, 1998-10, 1998-11, 1998-12, and 1998-13 and were analyzed for pH, specific conductance, hydrocarbons, coliforms, and fecal coliforms. Three of the equipment blanks had detected concentrations of oil and grease ranging from 1 to 2 mg/l. All samples with concentrations less than five times the concentration found in the associated equipment blank were qualified as undetected (**U)**.

Equipment blanks were collected and analyzed from the automated sampler tubing prior to year 2 monitoring at each of the eight monitoring stations. Teflon™ sample collection tubing was replaced at each sampler, prior to collecting samples using laboratory grade DI water. However, rubber tubing located inside the sampler pump was not replaced due to the additional work required to replace internal tubing. Tubing was flushed with DI water several times before collection of equipment blanks. Analytes were detected above the reporting limit in all samples. Table 5-4 compares the range of results found to the reporting limit and the range of expected EMCs based on year 1 data. Detected analytes in equipment blanks were most likely the result of residual constituents inside rubber sampler tubing. In each case, the expected EMC was at least one order of magnitude higher than the concentration detected in the equipment blanks. Therefore, data are not expected to be affected by on the low detections observed in the field blanks.

Table 5-4
AUTOMATED SAMPLER TUBING EQUIPMENT BLANK RESULTS COMPARED TO YEAR 1 EMCs

Analyte	Units	Reporting Limit	Range of Equipment Blank Results	Range of Expected EMCs Based on Year 1 Data
Ortho-phosphate	mg/l	0.03	0.04-0.06	0.11-0.22
Total phosphorus	mg/l	0.03	0.04-0.09	0.22-0.71
Copper (dissolved)	µg/l	1.0	1.19-4.49	13-41
Zinc (dissolved)	µg/l	1.0	3.37-14.8	42-70

Equipment blanks were collected for storm events 1999-05, 1999-08, 1999-09, 1999-10, 1999-11, 1999-12, 1999-13, 1999-14, 1999-15, and 1999-16 and were analyzed for pH, specific conductance, hydrocarbons, coliforms, and fecal coliforms. Oil and grease (1 mg/L) and TPH-diesel (16 mg/L) were detected in the 1999-05 equipment blank. Oil and grease (16 mg/L) was detected in the 1999-16 equipment blank. All samples with concentrations less than five times the concentration found in the associated blank were qualified as undetected **U**. All other equipment blanks had undetected hydrocarbon concentrations.

Surrogates

Surrogates were spiked into blanks, samples, quality control samples, and standards for organic analyses to evaluate accuracy on a sample-specific basis. All surrogate recoveries were within the associated control limits for both years 1 and 2.

Matrix Spike/Matrix Spike Duplicates (MS/MSD)

MS/MSD samples were analyzed to evaluate matrix interference for an analytical batch and to assess accuracy and precision. Several MS/MSD recoveries were determined to be outside control limits for the metals analyses. Results are summarized in Table 5-5. There may be several explanations for these irregularities including the following: matrix interference, matrix heterogeneity, inclusion of non-project samples in the analyses, and use of lower-than-recommended concentrations in the spikes (less than four times the sample concentration). Non-project samples were selected for MS/MSD analysis from the same laboratory batch as LMPS samples but were from other environmental projects.

Use of the MS/MSD recoveries for non-project samples would not be an appropriate measure of how well the project data met the target success rates, because the concentrations of pollutants in the non-project samples are unknown and therefore cannot be directly compared to the monitored samples. If these samples are eliminated from consideration, the success rates increase from 85% and 79% to 85% and 82% respectively for MS and MSD recoveries in year 1. This represents a substantial improvement for matrix spike duplicates but is still below the target success rate.

Table 5-5
MS/MSD RECOVERIES OUTSIDE CONTROL LIMITS

QC Batch	Sample ID	Analyte	MS % Rec.	MSD % Rec.	RPD	Comments	Qualification
Control Limits			75-125	75-125	<20		
981201lcs2	98-11-0790-1	Zinc	85	63	21	NPS	no qual
981130lcs5	8-B001	Zinc	58	53	5	spike <4x sample	no qual
981204lcs4	98-12-0105-7	Copper	84	73	9	NPS	no qual
980127lcs3	Site 1-52	Cadmium	71	76	7		no qual
		Copper	71	81	11		no qual
		Zinc	45	61	18	spike <4x sample	no qual
990211lcs6	1-58	Zinc	78	71	8	spike <4x sample	no qual
990318	1-46	Copper	76	150	49	spike <4x sample	no qual
		Nickel	97	591	139	heterogeneous	no qual
		Zinc	62	149	47	spike <4x sample	no qual
990326lcs5	1-42	Zinc	119	136	6	spike <4x sample	no qual
990322	1-58	Cadmium	71	72	2		J or UJ
		Nickel	74	76	3		no qual
		Zinc	38	52	9	spike <4x sample	no qual
990323	99-03-0675-25	Zinc	70	66	3	NPS	no qual
990408lcs1	1-42	Zinc	90	67	13	spike <4x sample	no qual
990413lcs1	1-46	Zinc	44	1	46	spike <4x sample	no qual
000127lcs3	1-46	Zinc	96	163	25	sample = spike	J or no qual
000127lcs5	1-58	Zinc	59	47	3	sample = 3x spike	no qual
000221lcs6	6-20E	Lead	134	135	0	sample =4x spike	no qual
000218lcs7	1-42 Dup	Zinc	68	47	11	sample = spike	no qual
000221lcs5	00-02-0563-3	Zinc	68	69	1	NPS	no qual
000223lcs5	1-58	Zinc	340	250	26	spike < 4x sample	J or no qual
000223lcs6	8-B001	Cadmium	62	64	3	spike >> sample	J or UJ
		Chromium	66	68	2	spike >> sample	J or UJ
		Nickel	62	64	3	spike >> sample	J or UJ
		Zinc	10	8	1	sample > 4x spike	no qual
000228lcs5	1-58 Dup	Zinc	51	68	11	sample = spike	no qual
000228lcs7	1-52	Zinc	71	71	0	sample = spike	no qual
000310lcs9	1-42	Zinc	58	61	2	sample = spike	no qual

NPS – non-project sample (a random environmental sample analyzed in the same laboratory batch as LMPS samples).

Another consideration of these samples is the spike concentrations. Unless the spike concentration is at least 4 times the sample concentration, then the expected MS/MSD recovery ranges would be quite different than the 75% - 125% recovery range specified in the USEPA Guidelines. This is a direct result of the combination of how the recoveries are calculated and the expected variation in laboratory precision under normal circumstances. MS/MSD recoveries are calculated by subtracting the original sample result from the spiked sample concentration and dividing the remainder by the spike concentration to determine the percent of spike recovered.

Given that laboratory precision is generally within ± 25%, expected MS/MSD recoveries would vary depending on the relationship of sample concentration to spike concentration, as shown in Table 5-6.

Table 5-6
EXPECTED MS/MSD RECOVERIES BASED ON MS/MSD CONCENTRATIONS

If the spike concentration equals:	Expected spike recovery range equals:
50% of the sample concentration	25% - 175%
100% of the sample concentration	50% - 150%
200% of the sample concentration	63% - 138%
400% of the sample concentration	69% - 131%

It is also relevant to point out that the laboratory did not know the concentration of the sample before introducing the spike and therefore may have underestimated the concentration required.

If this phenomenon is taken into account and if exceedances within the range of expected values are counted as successes, then the success rates would climb to 95% and 93%, respectively, for year 1. Non-project samples were of necessity, eliminated from consideration because we do not know what the original sample concentrations were.

MS/MSD recoveries had a success rate of 91% and 91%, respectively, in year 2.

Laboratory Control Samples (LCS)

LCS are well-characterized, laboratory-generated samples used to monitor the laboratory's day-to-day performance for analyses and assess the accuracy of the analytical process independent of matrix effects. All LCS recoveries were within control limits for years 1 and 2.

Total vs. Dissolved Metals

For year 1, in very few instances, dissolved metals concentrations exceeded total metals concentrations. Five observations out of a total of 402 observations over the course of year 1 of monitoring exhibited this discrepancy. In other words, 99% of the individual metals observations had a total concentration exceeding the associated dissolved concentration. Clearly the dissolved fraction of metals should not exceed the total concentration of metals. The discrepancy during the 1% of occasions during year 1 is expected to be due to inadequate sample homogenization.

In no case during year 2 did dissolved concentrations exceed total concentrations.

Duplicates

Lab duplicates were analyzed to evaluate analytical precision in each batch. All relative percent differences (RPDs) were within control limits.

Field duplicate samples were collected and analyzed for pH, specific conductance, coliforms, and fecal coliforms. The results and calculated RPDs are summarized in Table 5-7. In general, agreement between the duplicates is reasonable for pH and specific conductance. However, the RPDs for the coliforms and fecal coliforms analyses were larger. This is not particularly surprising, and these discrepancies are not expected to invalidate the data. In addition, one conductance RPD was quite high (100%). However, the values were close to the detection limit, and this discrepancy is therefore not expected to invalidate the data.

Quality Control Summary

The data from the water quality analyses sampling were reviewed to evaluate their usability for project decisions. The success rates of the quality control measures are summarized below.

For year 1, all QA/QC checks met or exceeded the target of 85%, except for MS/MSD for metals (see Table 5-8). This could be due to matrix interference and is discussed in the MS/MSD subsection. For year 2, all QA/QC checks exceeded the target of 85% (see Table 5-9). Overall, the accuracy and precision of the data were found to be adequate to allow use of these data in project decisions.

5.2 DATA MANAGEMENT

The chemical water quality data were submitted by Calscience Environmental Laboratories (CEL) in a Microsoft Access database format compatible with the Caltrans data reporting protocols (LWA, 1999). In order to perform data summaries, after data validation had been completed, selected columns from the spreadsheet were imported to a database contained on the accompanying CD-ROM. Queries were designed in the database to meet the data summary needs.

5.3 DATA ANALYSIS

Chemical water quality data were analyzed to calculate event mean concentrations and seasonal mass quantities for each constituent. In addition, observations have been made that compare study data to other appropriate studies. Each of these three objectives is described in subsections below.

5.3.1 Event Mean Concentrations

Analytical results provided by CEL were compiled, and descriptive statistics were generated to estimate the mean of the measured EMCs of each of the 27 pollutants sampled for each of the stations over the sampling period. As an example, Table 5–10 shows the measured EMCs for total nickel at each station for each of the events in which total nickel was analyzed. At the bottom of the table, the estimated station mean, median, and coefficient of variation (COV) of the mean are given. Null data are explained in Table G-2 in Appendix G. Similar tables have been compiled for the other parameters analyzed. They are provided in Appendix G.

Table 5-7
SUMMARY OF FIELD DUPLICATE RESULTS FOR GRAB SAMPLES

Storm Event	Sample ID	PH [pH units]	Conductance [umhos/cm]	Coliforms [MPN/100 ml]	Fecal Coliforms [MPN/100 ml]
1998-09	1-42	7.50	80	40	23
	1-42D	7.41	83	500	110
RPD		1.2	3.7	170	130
1998-10	8-23C	7.28	207	300	170
	8-23D	7.60	200	2300	1300
RPD		4.3	3.4	150	150
1998-11	6-20F	7.24	138	1700	500
	6D-20F	7.18	139	800	500
		0.83	0.72	72	0
1998-13	1-58	7.70	99	NA	NA
	1D-58	7.67	102	NA	NA
RPD		0.39	3.0	--	--
1999-05	1-58	7.69	321	3000	80
	1D-58	7.57	321	3000	300
RPD		1.6	0	0	116
1999-08	1-42	7.10	129	17000	<20
	1-42 Dup	7.14	129	3000	<20
RPD		0.56	0	140	--
1999-09	8-23C	4.8	9	<20	<20
	8-23C D	5.76	3	<20	<20
RPD		18.2	100	--	--
1999-10	6-20F	7.87	371	13000	1100
	6D-20F	7.84	377	3000	230
RPD		0.38	1.6	125	131
1999-11	1-52	8.57	237	1700	<20
	1D-52	8.6	237	1100	800
RPD		0.35	0	43	--
1999-12	8-B001	7.95	103	3500	20
	8D-B001	7.92	103	2200	20
RPD		0.38	0	46	0
1999-13	1-46	8.85	102	2300	800
	1D-46	8.88	102	1300	300
RPD		0.34	0	56	91
1999-14	6-20E	8.12	156	500	40
	6D-20E	8.13	155	300	80
RPD		0.12	0.64	50	67
1999-15	8-23C	7.82	64	40	<20
	8D-23C	7.75	65	90	<20
RPD		0.90	1.6	77	--
1999-16	1-52	8.71	153	3500	500
	1-52 Dup	8.67	151	500	40
RPD		0.46	1.3	150	170

NA - not analyzed

Table 5-7
SUMMARY OF FIELD DUPLICATE RESULTS FOR GRAB SAMPLES

Storm Event	Sample ID	PH [pH units]	Conductance [umhos/cm]	Coliforms [MPN/100 ml]	Fecal Coliforms [MPN/100 ml]
1998-09	1-42	7.50	80	40	23
	1-42D	7.41	83	500	110
RPD		1.2	3.7	170	130
1998-10	8-23C	7.28	207	300	170
	8-23D	7.60	200	2300	1300
RPD		4.3	3.4	150	150
1998-11	6-20F	7.24	138	1700	500
	6D-20F	7.18	139	800	500
		0.83	0.72	72	0
1998-13	1-58	7.70	99	NA	NA
	1D-58	7.67	102	NA	NA
RPD		0.39	3.0	--	--
1999-05	1-58	7.69	321	3000	80
	1D-58	7.57	321	3000	300
RPD		1.6	0	0	116
1999-08	1-42	7.10	129	17000	<20
	1-42 Dup	7.14	129	3000	<20
RPD		0.56	0	140	--
1999-09	8-23C	4.8	9	<20	<20
	8-23C D	5.76	3	<20	<20
RPD		18.2	100	--	--
1999-10	6-20F	7.87	371	13000	1100
	6D-20F	7.84	377	3000	230
RPD		0.38	1.6	125	131
1999-11	1-52	8.57	237	1700	<20
	1D-52	8.6	237	1100	800
RPD		0.35	0	43	--
1999-12	8-B001	7.95	103	3500	20
	8D-B001	7.92	103	2200	20
RPD		0.38	0	46	0
1999-13	1-46	8.85	102	2300	800
	1D-46	8.88	102	1300	300
RPD		0.34	0	56	91
1999-14	6-20E	8.12	156	500	40
	6D-20E	8.13	155	300	80
RPD		0.12	0.64	50	67
1999-15	8-23C	7.82	64	40	<20
	8D-23C	7.75	65	90	<20
RPD		0.90	1.6	77	--
1999-16	1-52	8.71	153	3500	500
	1-52 Dup	8.67	151	500	40
RPD		0.46	1.3	150	170

NA - not analyzed

Table 5-8
RESULTS OF QA/QC ANALYSIS FOR YEAR 1

Category	QA/QC Check	Number of Observations	Observations Outside of Objectives	Success Rate
Conventionals, Nutrients, and Miscellaneous	Field Blanks	14	0	100%
	Method Blanks	44	0	100%
	Field Duplicates	8	0	100%
	Lab Duplicates	56	0	100%
	Matrix Spikes	36	0	100%
	Matrix Spike Duplicates	36	0	100%
	Laboratory Control Samples	36	0	100%
Metals	Method Blanks	72	4	94%
	Matrix Spikes	66	17	74%
	Matrix Spike Duplicates	66	22	67%
	Laboratory Control Samples	72	0	100%
Organics	Field Blanks	21	3	86%
	Method Blanks	25	0	100%
	Lab Duplicates	8	0	100%
	Matrix Spikes	9	0	100%
	Matrix Spike Duplicates	9	0	100%
	Laboratory Control Samples	17	0	100%
	Surrogate Spikes	165	0	100%

Table 5-9
RESULTS OF QA/QC ANALYSIS FOR YEAR 2

Category	QA/QC Check	Number of Observations	Observations Outside of Objectives	Success Rate
Conventionals, Nutrients, and Miscellaneous	Field Blanks	20	1	100%
	Method Blanks	55	0	100%
	Field Duplicates	20	0	100%
	Lab Duplicates	64	0	100%
	Matrix Spikes	33	0	100%
	Matrix Spike Duplicates	33	0	100%
	Laboratory Control Samples	33	0	100%
Metals	Method Blanks	180	0	100%
	Matrix Spikes	138	12	91%
	Matrix Spike Duplicates	138	13	91%
	Laboratory Control Samples	138	0	100%
Organics	Field Blanks	29	3	90%
	Method Blanks	42	0	100%
	Lab Duplicates	10	0	100%
	Matrix Spikes	11	0	100%
	Matrix Spike Duplicates	11	0	100%
	Laboratory Control Samples	28	0	100%

	Surrogate Spikes	181	0	100%

Table 5–10
EVENT MEAN CONCENTRATIONS AND STATION MEANS FOR TOTAL NICKEL

Nickel, Total ug/l

	Storm Event Date		1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	ND	ND	ND	ND	ND	ND	ND	ND
	1998-03	12/01/98	ND	0.6	0.5	2.3	*****	*****	0.8	0.6
	1998-05	01/25/99	0.3	0.4	ND	ND	0.3	0.5	0.4	ND
	1998-06	02/09/99	ND	ND	ND	ND	1.5	0.5	0.3	*****
	1998-09	03/15/99	ND	ND	*****	ND	ND	ND	ND	ND
	1998-10	03/20/99	ND	ND	*****	0.2	ND	ND	ND	ND
	1998-11	03/25/99	ND	ND	ND	ND	1.0	ND	0.2	*****
	1998-12	04/06/99	ND	ND	ND	ND	ND	ND	ND	ND
	1998-13	04/11/99	ND	ND	ND	ND	ND	ND	ND	ND
	COV*		*****	*****	*****	*****	4.15	*****	0.76	*****
	Mean*		*****	*****	*****	*****	0.6	*****	0.4	*****
	Median*		*****	*****	*****	*****	0.1	*****	0.3	*****
1999	1999-05	01/25/00	ND	0.31	ND	0.47	0.33	0.39	ND	ND
	1999-06	01/30/00	ND	ND	ND	0	ND	ND	ND	*****
	1999-08	02/10/00	0	ND	ND	0	ND	0	ND	0
	1999-09	02/12/00	*****	*****	ND	ND	ND	ND	ND	ND
	1999-10	02/13/00	ND	*****	ND	ND	0	0	ND	0
	1999-11	02/16/00	ND	ND	ND	ND	ND	0	ND	ND
	1999-12	02/20/00	*****	ND	ND	ND	ND	ND	ND	ND
	1999-13	02/23/00	*****	ND	ND	ND	ND	0	ND	ND
	1999-14	02/27/00	ND	ND	ND	ND	ND	0	*****	ND
	1999-15	03/04/00	ND	ND	ND	ND	ND	ND	ND	ND
	1999-16	03/08/00	ND	ND	ND	ND	ND	ND	ND	ND
	COV*		*****	*****	*****	1.08	*****	0.60	*****	*****
	Mean*		*****	*****	*****	0	*****	0	*****	*****
	Median*		*****	*****	*****	0	*****	0	*****	*****
Combined	COV*		*****	1.15	*****	11.37	4.97	0.69	1.24	0.60
	Mean*		*****	0	*****	0	0	0	0	0
	Median*		*****	0	*****	0	0	0	0	0

* Parameters based on an assumed log-normal distribution; will differ from estimations based on other distributions

***** Insufficient data to calculated population statistics

The station mean is an estimate of the average concentration of a pollutant that can be expected at a sampling station during a storm event and is useful for the comparison of runoff characteristics between sites. Since a flow-weighted sampling approach was used in this project, the reported lab results are equivalent to the measured estimate of EMC values for each event, and therefore, could be used directly to estimate station means. For this analysis, the station means were estimated assuming that their distribution was best described by the log-normal distribution. Therefore, the log-transformed data were utilized to estimate population statistics and they will differ from arithmetic means.

Log Conversion and Statistical Parameter Calculations

In the 1990 Federal Highway Administration (FHWA) runoff study summarized in *Pollutant Loadings and Impacts from Highway Stormwater Runoff*, Driscoll et al. concluded that estimating statistical parameters from storm water pollutant data based on the assumption that the EMC population is lognormally distributed was appropriate for the data set that they examined. As their study is one of the more comprehensive studies done for highway runoff to

date, this approach was followed for this project. This approach involves converting the data to log form (taking the natural log EMC values) and calculating new statistical parameters based on the relationship between central tendency and error that exist for log-converted data.

The formulas used for generation of statistical summary parameters are shown below:

$$\text{Let} \quad y_i = \text{Ln}\left(\text{Station} \quad EMC_i\right)$$

$$\bar{y} = \frac{\sum y_i}{n}$$

$$S_{y^2} = \frac{\sum \left(y_i - \bar{y}\right)^2}{n-1}$$

$$\text{Then, median EMC} \approx \exp\left(\bar{y}\right)$$

$$\text{Coefficient of variation of EMC, COV} = \sqrt{\left[\exp\left(S_{y^2}\right) - 1\right]}$$

$$\text{Mean EMC} = \text{median} \times \exp\left(S_{y^2}/2\right)$$

Non-Detects

In order to calculate the station mean, median, and coefficient of variation of the mean for constituent EMCs, non-detect values (below the detection limit) must be assigned an appropriate value.

Several approaches have historically been used to estimate concentrations of constituents that are reported by the laboratory as less than the detection limit. In the past, researchers have used the detection limit value or one-half the detection limit value. The LMPS used a robust method to deal with the non-detect values. Helsel and Hirsch (1992) evaluated several methods for handling non-detect data including substitution, distributional, and robust methods. They concluded that robust methods consistently produced smaller errors when estimating summary statistics, even when multiple reporting limits were present in the data set. Robust methods combine observed data above the laboratory reporting limit with extrapolated values for below-limit values. The method discussed by Helsel and Hirsch (1992, p. 364) for data containing multiple detection limits is selected for this analysis. This method uses a maximum likelihood estimation method for estimation of percentiles and the robust probability plot method for estimating the mean and standard deviation. The extrapolated values will be randomly assigned to the non-detect samples. These values will not be considered to be actual values at the specific sample locations. However, because of the random assignment, they can be used collectively to estimate the statistical parameters (such as the mean and variance) of the EMCs.

The robust method requires a minimum of two detect values. If a data set contains no detect values or only one detect value (and one or more nondetects), the robust method cannot be used, and no statistical analysis is feasible. In this case, for purposes of statistical summaries, all parameters (mean, median, and coefficient of variation) were identified with a qualifier “ND”. For the box and whisker plots, all data points (including a single detect value, if present) were

assigned a value of zero so that the plots simply show lines at the zero value indicating that all values (or all except one value) are non-detects.

For this data set, two parameters were analyzed as described above due to a substantial number of non-detects, cadmium and lead. TPH-gasoline had no detections at any of the eight stations for any of the storm events, therefore, no population statistics were calculated.

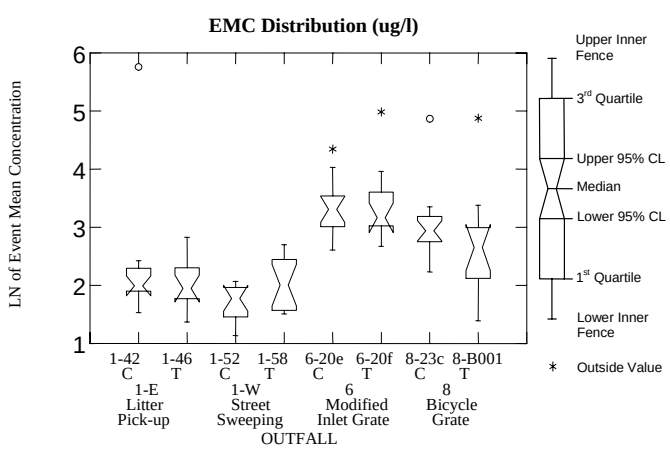
Box and Whisker Plots

Box and whisker plots, which are a graphical tool for summarizing estimated population statistics, were generated for each parameter at each station. They provide a visual indication of the spread in the data. Figure 5-1 shows a box and whisker plot for total nickel. Since the means were calculated on log transformed data, these diagrams were plotted on a log scale using log-transformed data. The waist-like constriction in the middle zone of the box is the mean of the log-transformed data (which when transformed is an estimate of the median concentration). The 95% confidence interval about the median of the log-transformed data is indicated by the section of the box that is less than full width. The first and third quartiles delimit the range in which the central 50% of values lie (i.e., 25% of the values lie below the first quartile and 25% of the values lie above the third quartile). The whiskers on the plots show the range of values that lie within the inner fences which are defined by the following equations:

Lower inner fence = value of the first quartile - (1.5 * (median - value of 1st quartile))

Upper inner fence = value of the third quartile + (1.5 * (value of the third quartile - median))

Figure 5–1
BOX AND WHISKER PLOT – TOTAL NICKEL (µg/l)



In some cases, in the box and whisker plots, the 95% confidence limit is either in excess of the third quartile or less than the first quartile. In many instances, these cases correspond to a distribution of values that are either very skewed, poorly represented by a normal distribution, low in number, and/or widely scattered.

Box and whisker plots for all of the parameters are provided in Appendix G.

5.3.2 Seasonal Mass Quantities

Seasonal mass quantities were calculated for each chemical water quality constituent at each BMP control monitoring location. These quantities were calculated by multiplying the estimated seasonal outfall flow volume by the station mean EMCs and station mean concentration of each constituent over the course of the two-year study (presented in Tables in Appendix G). Table 5-11 presents seasonal mass quantities for the study. The range of seasonal quantities based on the upper and lower 95% confidence limits about the mean are also presented. Seasonal flows are presented in Table 4-4 for each outfall by year for comparison purposes.

5.3.3 Data Observations

The mean concentrations of total copper, total and dissolved lead, total zinc, and total suspended solids were higher at LMPS Station 6-20e than at the other LMPS stations (see Table 5-12). The results suggest the metals at this location were generally associated with the total suspended solids that were present. The other stations had lower concentrations.

Table 5-11
SEASONAL MASS QUANTITIES
FOR CALTRANS LMPS CONTROL OUTFALLS

Site 1-E	Area (Ha)	Loads 1998 - 1999			Loads 1999 - 2000		
Station 1-42	0.13	Flow (liters/yr)	183625		Flow (liters/yr)	223056	
PARAMETER	Units	LL (95%) Load	Mean Load kg/Ha/yr	UL (95%) Load	LL (95%) Load	Mean Load kg/Ha/yr	UL (95%) Load
Total Organic Carbon	mg/l	23	30	44	28	37	53
Total Volatile Solids	mg/l	47	63	95	57	77	115
Hardness as CaCO3	mg/l	61	73	93	74	89	113
Total Suspended Solids	mg/l	44	61	98	53	74	119
Nitrate Nitrogen	mg/l	2	2	3	2	3	4
Total Kjedhal Nitrogen	mg/l	3	3	4	3	4	5
Total Phosphorus	mg/l	0.34	0.42	0.56	0.41	0.51	0.68
Ortho-Phosphorus	mg/l	0.15	0.18	0.24	0.18	0.22	0.29
Chromium, Dissolved	ug/l	0.004	0.005	0.006	0.005	0.006	0.007
Chromium, Total	ug/l	0.008	0.009	0.012	0.009	0.011	0.015
Cadmium, Dissolved	ug/l	****	****	****	****	****	****
Cadmium, Total	ug/l	0.001	0.001	0.002	0.001	0.001	0.002
Copper, Dissolved	ug/l	0.019	0.024	0.031	0.023	0.029	0.037
Copper, Total	ug/l	0.039	0.047	0.057	0.048	0.057	0.069
Lead, Dissolved	ug/l	0.002	0.002	0.003	0.002	0.003	0.003
Lead, Total	ug/l	0.021	0.026	0.034	0.026	0.032	0.041
Nickel, Dissolved	ug/l	0.005	0.006	0.008	0.006	0.007	0.009
Nickel, Total	ug/l	0.013	0.020	0.043	0.016	0.025	0.052
Zinc, Dissolved	ug/l	0.051	0.085	0.198	0.062	0.104	0.241
Zinc, Total	ug/l	0.19	0.23	0.30	0.23	0.28	0.37
Oil & Grease	mg/l	14	22	47	16	26	57
TPH (Diesel)	mg/l	10	22	93	12	26	113
TPH (Gasoline)	mg/l	****	****	****	****	****	****

****Data were insufficient to calculate a station mean due to fewer than three events with detected values.

Site 1-W	Area (Ha)	Loads 1998 - 1999			Loads 1999 - 2000		
Station 1-52	0.17	Flow (liters/yr)	239697		Flow (liters/yr)	291168	
PARAMETER	Units	LL (95%) Load	Mean Load kg/Ha/yr	UL (95%) Load	LL (95%) Load	Mean Load kg/Ha/yr	UL (95%) Load
Total Organic Carbon	mg/l	19	25	36	23	30	44
Total Volatile Solids	mg/l	41	56	87	49	68	106
Hardness as CaCO3	mg/l	42	46	50	51	56	61
Total Suspended Solids	mg/l	24	36	65	29	44	79
Nitrate Nitrogen	mg/l	2	2	3	2	3	4
Total Kjedhal Nitrogen	mg/l	2	2	3	2	3	3
Total Phosphorus	mg/l	0.27	0.34	0.47	0.33	0.42	0.57
Ortho-Phosphorus	mg/l	0.15	0.19	0.26	0.19	0.23	0.32
Chromium, Dissolved	ug/l	0.003	0.004	0.004	0.004	0.005	0.005
Chromium, Total	ug/l	0.006	0.007	0.009	0.007	0.008	0.011
Cadmium, Dissolved	ug/l	****	****	****	****	****	****
Cadmium, Total	ug/l	0.001	0.001	0.002	0.001	0.001	0.002
Copper, Dissolved	ug/l	0.014	0.017	0.023	0.017	0.021	0.028
Copper, Total	ug/l	0.030	0.034	0.040	0.036	0.042	0.049
Lead, Dissolved	ug/l	0.002	0.002	0.002	0.002	0.002	0.003
Lead, Total	ug/l	0.017	0.020	0.025	0.020	0.024	0.030
Nickel, Dissolved	ug/l	0.003	0.004	0.005	0.003	0.004	0.006
Nickel, Total	ug/l	0.005	0.007	0.009	0.007	0.008	0.011
Zinc, Dissolved	ug/l	0.031	0.055	0.150	0.038	0.067	0.182
Zinc, Total	ug/l	0.13	0.17	0.22	0.16	0.20	0.26
Oil & Grease	mg/l	16	30	86	20	36	105
TPH (Diesel)	mg/l	5	10	31	7	13	38
TPH (Gasoline)	mg/l	****	****	****	****	****	****

Table 5-11 (continued)
SEASONAL MASS QUANTITIES
FOR CALTRANS LMPS CONTROL OUTFALLS

Site 6	Area (Ha)	Loads 1998 - 1999			Loads 1999 - 2000		
Station 6-20E	0.17	Flow (liters/yr)	196735		Flow (liters/yr)	294969	
PARAMETER	Units	LL (95%) Load	Mean Load kg/Ha/yr	UL (95%) Load	LL (95%) Load	Mean Load kg/Ha/yr	UL (95%) Load
Total Organic Carbon	mg/l	16	26	39	23	39	58
Total Volatile Solids	mg/l	62	137	132	93	205	198
Hardness as CaCO3	mg/l	89	155	175	134	233	263
Total Suspended Solids	mg/l	232	466	559	348	699	838
Nitrate Nitrogen	mg/l	1	2	2	2	2	4
Total Kjedhal Nitrogen	mg/l	2	4	5	3	5	7
Total Phosphorus	mg/l	0.74	1.08	4.35	1.10	1.61	6.52
Ortho-Phosphorus	mg/l	0.11	0.17	0.23	0.17	0.26	0.34
Chromium, Dissolved	ug/l	0.002	0.003	0.003	0.004	0.005	0.005
Chromium, Total	ug/l	0.015	0.033	0.065	0.023	0.049	0.098
Cadmium, Dissolved	ug/l	****	****	****	****	****	****
Cadmium, Total	ug/l	0.002	0.004	0.007	0.003	0.006	0.011
Copper, Dissolved	ug/l	0.019	0.034	0.039	0.028	0.051	0.059
Copper, Total	ug/l	0.101	0.174	0.202	0.151	0.261	0.304
Lead, Dissolved	ug/l	0.009	0.016	0.019	0.013	0.025	0.028
Lead, Total	ug/l	0.321	0.680	0.810	0.482	1.020	1.215
Nickel, Dissolved	ug/l	0.003	0.005	0.006	0.004	0.008	0.009
Nickel, Total	ug/l	0.014	0.031	0.060	0.021	0.046	0.090
Zinc, Dissolved	ug/l	0.023	0.069	0.480	0.034	0.103	0.719
Zinc, Total	ug/l	0.31	0.48	0.57	0.46	0.72	0.85
Oil & Grease	mg/l	18	44	118	27	66	177
TPH (Diesel)	mg/l	7	16	78	10	24	116
TPH (Gasoline)	mg/l	****	****	****	****	****	****

Site 8	Area (Ha)	Loads 1998 - 1999			Loads 1999 - 2000		
Station 8-23C	0.25	Flow (liters/yr)	343015		Flow (liters/yr)	505199	
PARAMETER	Units	LL (95%) Load	Mean Load kg/Ha/yr	UL (95%) Load	LL (95%) Load	Mean Load kg/Ha/yr	UL (95%) Load
Total Organic Carbon	mg/l	20	26	36	29	38	53
Total Volatile Solids	mg/l	67	88	129	98	130	190
Hardness as CaCO3	mg/l	85	109	151	125	161	223
Total Suspended Solids	mg/l	63	357	811	93	525	1195
Nitrate Nitrogen	mg/l	2	2	3	2	3	4
Total Kjedhal Nitrogen	mg/l	3	4	6	5	6	9
Total Phosphorus	mg/l	0.48	0.61	0.83	0.71	0.90	1.22
Ortho-Phosphorus	mg/l	0.21	0.26	0.35	0.30	0.38	0.52
Chromium, Dissolved	ug/l	0.003	0.003	0.004	0.004	0.004	0.005
Chromium, Total	ug/l	0.019	0.027	0.044	0.028	0.039	0.065
Cadmium, Dissolved	ug/l	0.000	0.000	0.001	0.000	0.0005	0.001
Cadmium, Total	ug/l	0.002	0.003	0.004	0.003	0.004	0.006
Copper, Dissolved	ug/l	0.022	0.028	0.037	0.032	0.041	0.055
Copper, Total	ug/l	0.100	0.123	0.158	0.147	0.181	0.233
Lead, Dissolved	ug/l	0.006	0.009	0.015	0.009	0.013	0.022
Lead, Total	ug/l	0.316	0.409	0.574	0.466	0.602	0.846
Nickel, Dissolved	ug/l	0.004	0.005	0.008	0.006	0.008	0.011
Nickel, Total	ug/l	0.022	0.033	0.064	0.032	0.049	0.094
Zinc, Dissolved	ug/l	0.038	0.055	0.173	0.055	0.080	0.254
Zinc, Total	ug/l	0.33	0.39	0.50	0.49	0.57	0.73
Oil & Grease	mg/l	23	38	88	34	56	129
TPH (Diesel)	mg/l	10	16	32	15	24	47
TPH (Gasoline)	mg/l	****	****	****	****	****	****

****Data were insufficient to calculate a station mean due to fewer than three events with detected values.

Table 5-12
CALTRANS LMPS STATION MEANS
FROM COMBINED YEARS OF MONITORING

Parameter	Units	1-42	1-52	6-20e	8-23c
Cadmium, Dissolved	ug/l	—	—	0.27	0.23
Cadmium, Total	ug/l	0.76	0.63	3.21	2.06
Copper, Dissolved	ug/l	16.6	12.6	29.7	20.2
Copper, Total	ug/l	32.9	24.9	150	89.7
Lead, Dissolved	ug/l	1.66	1.31	14.19	6.56
Lead, Total	ug/l	18.5	14.4	588	299
Nickel, Dissolved	ug/l	4.0	2.6	5.2	3.3
Nickel, Total	ug/l	14.5	4.9	26.7	24.5
Nitrate Nitrogen	mg/l	1.8	1.6	1.4	1.1
Total Kjedhal Nitrogen	mg/l	2.3	1.6	3.1	3.2
Total Phosphorus	mg/l	0.3	0.3	0.9	0.5
Total Suspended Solids	mg/l	43	26	403	262
Zinc, Dissolved	ug/l	60	40	59	40
Zinc, Total	ug/l	164	121	417	284

6.1 CHARACTERIZATION PROTOCOLS

Litter characterization for the LMPS was conducted at a specially designed litter lab located at URSGWC's Santa Ana, California office. Characterization was conducted in accordance with a protocol developed for the LMPS that evolved during the early stages of the study. The laboratory analysis protocol and corresponding data analysis sheets are provided in Appendix H. The general protocol is discussed below.

Preparation

All litter samples/bags collected from the outfall locations are returned to the litter lab for analysis. The litter bags contain all material retained by the ¼-inch mesh openings. This material is termed gross pollutants and consists of both vegetation and litter. The weight and volume of the litter bag contents were measured at the start of the characterization process. The contents of the litter bags were then emptied into a sorting tub, and the vegetation was sorted from the litter material. The weight and volume of vegetative material was recorded on the data sheet and then disposed. The protocol included identification of potentially toxic materials during the initial sorting phase so they could be handled appropriately. It should be noted that no such materials were found in debris analyzed during the LMPS.

The litter material was then sifted through to recover any spike material. Recovered spike material was weighed as a composite and the weight was recorded on the data sheet. The spike materials were then sorted and segregated into different material categories (i.e., cigarette butts, styrofoam, fabric, etc.). Both the color and category of the recovered spike material were recorded on the data sheet.

The remaining litter material was placed on a drying screen and was allowed to dry for a minimum of 24 hours. The time that air-drying begins was recorded on the data sheet. The amount of time (in days) that had passed between the previous storm for which litter collection took place and the storm for which the litter analysis being conducted was recorded on the data sheet. The litter on the drying screen was photographed and identified by site/outfall number, storm number, and event number (see Photo 6-1). Drying screen photos collected during the LMPS are provided electronically in a photo database on the accompanying CD-ROM located at the end of this report.

Litter Characterization

Once the litter material had air dried, it was sorted into 12 different categories to investigate the source of the material. These categories included:

- cardboard/chipboard
- cigarette butts
- cloth
- glass
- metal
- paper
- plastic film
- plastic moldables
- styrofoam
- wood debris
- accident related
- other

Photo 6-1
Typical Litter on a Drying Screen

The litter material was further segregated according to usage (e.g., smoking-related, food-related, or general unknown) as specified on the data sheets. The segregated material was weighed on electronic scales, and the weight was recorded on a data sheet. The volume of each category of segregated litter material was then estimated and recorded. Each individual item was counted and total numbers were recorded on the data sheet.

An additional component of analysis was added for year 2 of monitoring. Sub-samples from each of the litter categories were oven-dried. This analysis was performed to investigate the moisture content of the air-dried litter. The procedure involved placing sub-samples of litter into an oven set at approximately 60 degrees Celsius for 24 hours. The weights of the sample before and after the oven drying were used to estimate a wet to dry ratio for the air-dried litter.

After the oven drying analysis was complete, the oven dried samples were returned to the segregated litter material and all litter from a given event was then placed within a tub full of water and was allowed to sit for at least 30 seconds. The floatable litter was separated from the non-floatable litter and was discarded. The non-floatable litter was then allowed to dry in the drying screens for 24 hours. After the 24-hour drying time, the non-floatable litter was weighed and the weight was recorded on the data sheet.

At the end of the characterization process, data from all completed data sheets were entered into a computer database. These data are presented on the accompanying CD-ROM (located at the end of the report).

6.2 DATA MANAGEMENT

Data management consisted of four procedures covering database setup, data entry, data QA/QC, and data queries.

6.2.1 Database Setup

The litter characterization data are stored in a Microsoft Access database designed to store site and event information and link the site and event information with collected data. The database contains the reference tables "Site Reference" and "Event Reference" and data tables, "Total Litter," "Non-Floatable," "Bag Totals," and "Spike Data." The Site Reference table contains descriptive information about each site, including the site number, outfall number, BMP, type (treatment or control), pair designation, as-built watershed area, inlet dimensions, and whether the site is also a chemical water quality outfall. Outfall number is the primary key in the Site Reference table, and links the site reference table to the data tables. The Event Reference table contains descriptive information about the events, including event ID, type of event, event start date, spike color associated with the event, and event sequence. The event ID field is the primary key in the Event Reference table, and links the Event Reference table to the data tables. The Total Litter Event 1 table contains the total dry weight, volume, and count of litter within the litter usage designations in each litter category at each site for event 1998e01. The All Event Total Litter data table contains the total dry weight, volume, and count of litter within the litter usage designations in each litter category at each site for each of events 1998i01 through 1999e16. (The litter characterization protocol was changed after event 1; therefore the total litter for event 1998e01 has a slightly different format than events 1998i01 through 1999e16). The Bag Totals data table contains the total bag weights, total vegetation wet weights, and total spike wet weights collected at each outfall during each event, including event 1998e01. The Spike Data table contains the color, category, and number of spike items collected at each outfall during each event, including event 1998e01.

6.2.2 Data Entry

Litter characterization data forms were completed at the litter lab and submitted for data entry. Litter lab personnel inspected the forms for consistency before turning them over to word processors. All data entry was performed in Microsoft Access. Data were entered in blank templates of the data tables. A separate set of data tables was created for each event. Data entry was performed in an "active" file created for use by the word processors. Double data entry was performed, using separate tables for each word processor. The data tables for each event were combined in single data tables in the master database after all monitoring had been completed and after quality assurance/quality control of data for each event had been performed.

6.2.3 Data Quality Assurance/Quality Control (QA/QC)

QA/QC of litter data was performed at both the reporting and data entry stages. Before litter characterization data were entered into the database, data sheets were reviewed for completeness and consistency by the litter lab supervisor. QA/QC of data entry was performed by a double-data entry process. All litter lab data was entered twice by separate data processors into separate data tables. A query was then performed to compare both data sets and identify records that did not match. These records were corrected to prepare a final data set.

6.2.3.1 Data Queries

Data queries were performed in Access to sort data, arrange the data in a format suitable for making charts, performing summary calculations, and presenting data. The use of data queries from single data tables prevents multiple versions of the data set. When data was exported to Excel for charts or other analysis, an active link was maintained with the original data tables in Access to ensure that multiple versions of the data set were not created.

6.3 LITTER AND VEGETATIVE MATERIAL CHARACTERISTICS

This section presents monitored litter and vegetative material characteristics from sampling gross pollutants found in storm water flowing through Caltrans' freeway storm drain system. Storm water gross pollutant samples were collected from the 24 LMPS outfalls. Samples were collected during year 1 of monitoring after ten storm events and in-between storm events on eight occasions from October 1998 to April 1999. Samples were collected during year 2 of monitoring after thirteen storm events and in-between storm events on one occasion from October 1999 to March 2000.

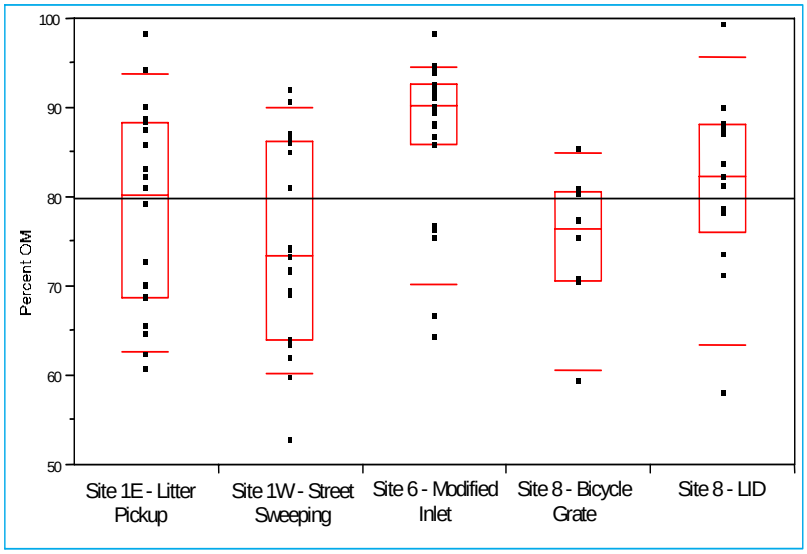
The litter samples were sorted and characterized by specific categories according to the type of material and sorted using three parameters; weight, volume, and the number of items. The categories selected were based on typical litter such as: cigarette butts, paper products, food wrappers, and wood pieces. Litter data were compiled at the end of the storm season, and the total amounts for the season are presented here. Individual storm event data are available, but not discussed here.

6.3.1 Wet Weight of Material

The first steps in litter analysis for the LMPS were (1) to weigh total material retained by the litter monitoring bags at each outfall (gross pollutants), (2) separate the litter from vegetative material and spikes placed in the inlets prior to storm events, and (3) weigh the vegetative and spike portions. These measurements were then used to calculate the percent vegetative material in the material collected from the outfalls. The weight of spikes were removed from the total weight and the vegetation weight to prevent them from influencing the percent vegetative material. Figure 6-1 shows the distribution of the percent vegetative material in trigger event outfall samples for each BMP site over the entire study. The plotted data points represent the combined site total percent vegetative material per event (i.e., weights were combined from all outfalls to get a single percent vegetative material for each site for each event). Site averages for percent vegetative material monitored in the outfalls range from 75 to 87 percent.

There are few studies worldwide with which to compare these results, with the exception of Australian and South African research. The composition data in this study appear to be similar to those for Australia urban watersheds (eg. Nielsen and Carleton, 1989, and Allison et al., 1998), with typically 60-90% vegetation found in Australian urban storm water (by weight). However, this study shows different compositions than South African research (as summarized by Armitage et al., 1998), which suggests that debris in South African urban storm water mainly consists of litter with little vegetation reported.

Figure 6-1
PERCENT VEGETATIVE MATERIAL BY WET WEIGHT



Site	Site 1E - Litter Pick-up	Site 1W - Street Sweeping	Site 6 – Modified Inlet	Site 8 - Bicycle Grate	Site 8 - LID
Mean	78.25	74.62	87.25	74.96	81.64
Std Dev	11.35	11.36	8.99	7.31	10.19
Min	60.79	52.84	64.51	59.54	58.17
Median	80.22	73.43	90.25	76.53	82.40
Max	98.33	92.19	98.37	85.52	99.47
N	20	21	23	10	13

The sites show relatively similar proportions of litter to vegetation except for Site 6. The average percent vegetative material at Sites 1E, 1W, and 8 range from 75 to 82 percent. The average percent vegetation at Site 6 was 87 percent. This may be due to the ROW conditions at each of the sites. At Sites 1E, 1W, and 8, the ROW is a vegetated strip that could retain leaves and debris as they fall. Site 6, however, has a vertical sound wall that borders the freeway such that all plant debris from the trees above and from vines that are growing on the wall will accumulate on the freeway surface. This likely accounts for the high proportion of vegetation at this site.

6.3.2 Air-Dried Weight of Litter

The air-dried weights of litter items collected from all sites and from all events and inlet cleaning are presented in Figure 6-2. The plots show that approximately one-third of the material is plastic (including plastic film, moldable plastic, and styrofoam) and the remainder of the material is approximately equal proportions of paper, cardboard/ chipboard, cigarette butts, wood, and miscellaneous items (metal, cloth, and glass etc.).

Common plastic items that were recovered include soft drink caps, broken pieces of vehicle lights, molded plastic containers (eg. soft drink bottles and oil containers), as well as plastic film and styrofoam. The average RPD for air-dried weight for the laboratory duplicates analysis (See Appendix H) is five percent.

6.3.3 Volumes of Litter

Sorting each of the classifications by their volume shows similar trends in the dry weight analyses, with a few exceptions as shown in Figure 6-3. Figure 6-3 shows there is a relatively even proportion of materials from most categories used, with plastic-moldable being the largest component by volume, with the exception of only small amounts of cloth, glass, metal, wood, and others.

The results show that approximately one-third of the litter are plastics and approximately 14% are paper, by volume. The increased proportion of paper and reduced proportion of wood by volume may be attributed to the differences in their densities. Another observation is the increased proportion of styrofoam compared to weight, due to its low density, and the reverse trend for the dense moldable plastics. The average RPD for litter volume for the laboratory duplicates analysis is 12 percent (see Appendix H).

6.3.4 Numbers of Items

Sorting the litter samples by count revealed a different composition compared to the weight and volume analyses. Figure 6-4 shows that cigarette butts are the largest single component of all litter items.

Following cigarette butts, plastic items account for a third of all items collected (including plastic film, moldable, and styrofoam). Another approximately 10% of the number of items were paper, and the remainder of the material accounted for smaller proportions. The average RPD for litter count for the laboratory duplicates analysis (see Appendix H) is two percent.

Additional pie charts are provided in Appendix I that show category breakdown for total seasonal litter at each site for air-dried weight, volume, and count. These plots provide a breakdown of litter categories for combined treatment vs. control outfalls.

6.3.5 Categories by Sources

To investigate the sources of the monitored litter items a number of usage categories were established. However, during the analysis it became evident that identification of particular items was often difficult. This difficulty limited the proportion of items that could be classified.

The sources of material are grouped into food-related (candy wrappers, ketchup packets, etc.), smoking-related (butts, packs, and cellophane wrappers), and other items. The relative proportions according to air-dried weight, volume, and the number of items are shown in Figures 6-5 through 6-7 for all events. The proportions remained consistent for both years of monitoring as shown in Figure 6-8. Figure 6-8 shows the usage distribution by year by air-dried weight. The distribution is consistent for other parameters as well, although not shown graphically.

Figure 6-2
LITTER CATEGORY DISTRIBUTION BY AIR-DRIED WEIGHT FOR ALL EVENTS COMBINED

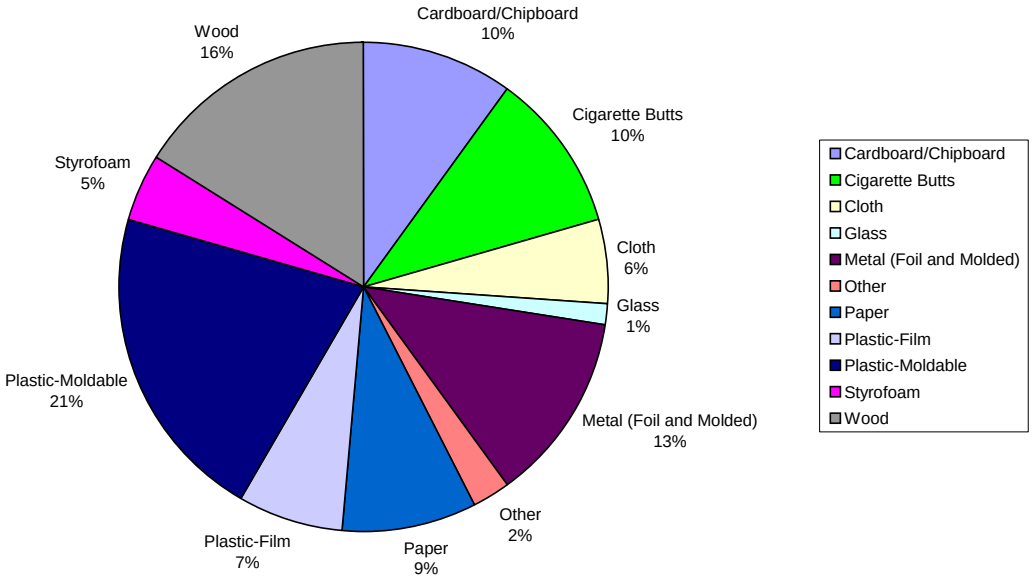


Figure 6-3
LITTER CATEGORY DISTRIBUTION BY VOLUME FOR ALL EVENTS COMBINED

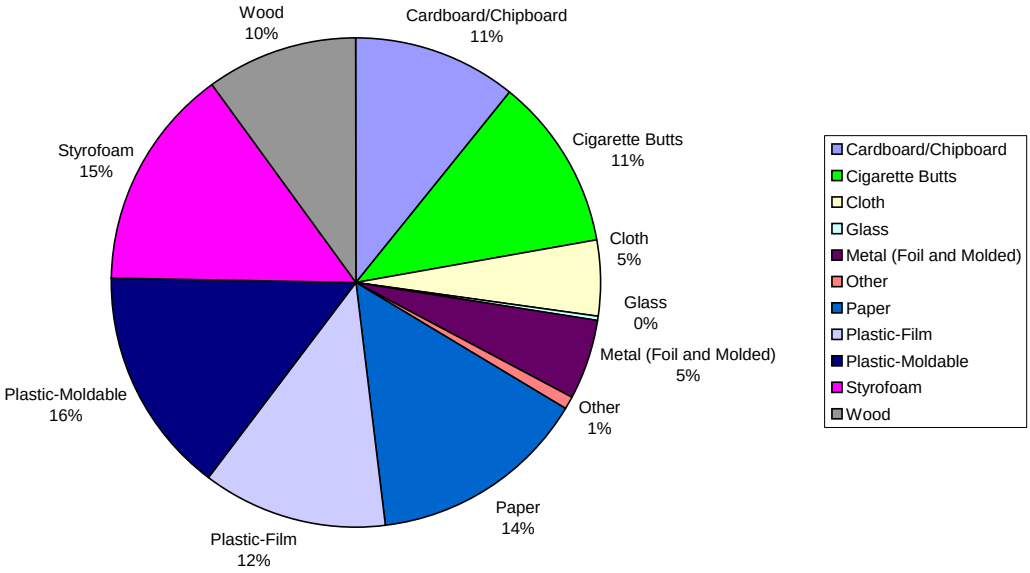
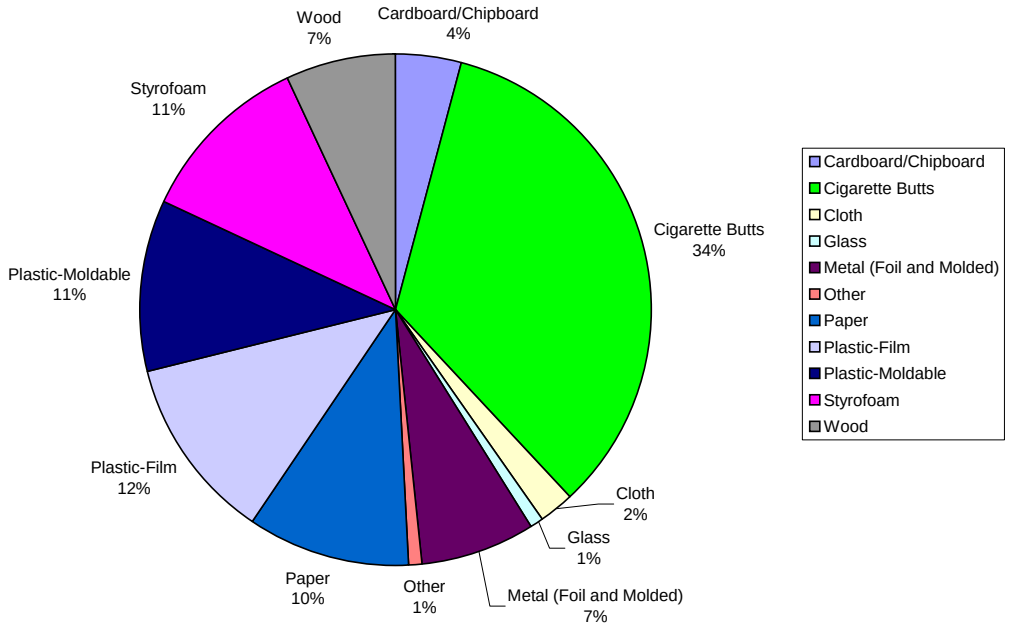


Figure 6-4
LITTER CATEGORY DISTRIBUTION BY COUNT FOR ALL EVENTS COMBINED



6.3.6 Oven-Dried Weights

There was an addition to the lab procedures during year 2 of monitoring. Further analysis was conducted to evaluate the moisture content of air-dried litter. This analysis provides an estimate of moisture content for each litter category.

An 'air-dried weight' to 'oven-dried weight' moisture content was determined for every analysis event. A sample was collected from the air-dried litter trays at the end of each analysis day from each category of the sorted material. This sample was then placed into an oven tray, weighed, and then placed in an oven for 24 hours at 60 degrees Celsius. On removal, the dry sample was weighed again and, after subtracting the tray weight, was compared to the air-dried weight (the weight before it went into the oven).

The formula for determining the percent moisture content of a sample is:

$$\mathrm{MC} = \frac{\left(\left(\text{sample air - dried weight}\right) - \left(\text{sample oven - dried weight}\right)\right)}{\left(\text{sample oven - dried weight}\right)} \times 100$$

Moisture contents were then calculated for each event for each category by averaging moisture contents for all analysis days for a given event. These values, along with overall averages for each category, are presented in Table 6-1.

Figure 6-5
LITTER USAGE DISTRIBUTION BY AIR-DRIED WEIGHT FOR ALL EVENTS

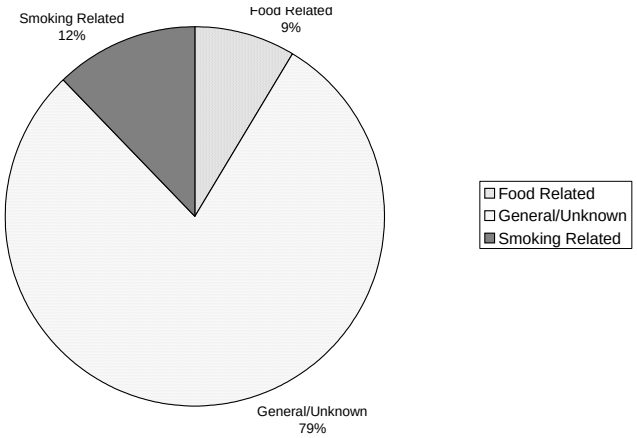
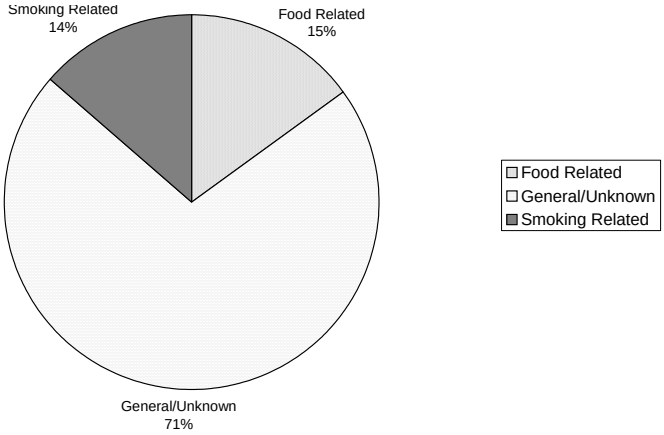


Figure 6-6
LITTER USAGE DISTRIBUTION BY VOLUME FOR ALL EVENTS



The moisture content of litter from storm events generally ranged from two percent to twenty-three percent (all categories combined), with the exception of events, 1999-08 and 1999-10, that had a combined litter moisture content of 38% and 82%, and 1999-12 that had a combined moisture content of 23%. However, Event 1999-10 did not have a 24-hour antecedent dry period which may have contributed to the high moisture content of litter from this event. Average moisture contents of individual litter categories ranged from zero percent to thirty-six percent. The categories of glass, metal, plastic-moldable, and styrofoam has the lowest moisture contents, ranging from zero percent for glass, to seven percent for styrofoam. The categories of wood,

plastic film, and cigarette butts had the highest moisture contents, ranging from twenty-one percent for wood and plastic film to thirty-six percent for cigarette butts.

Figure 6-7
LITTER USAGE DISTRIBUTION BY COUNT FOR ALL EVENTS

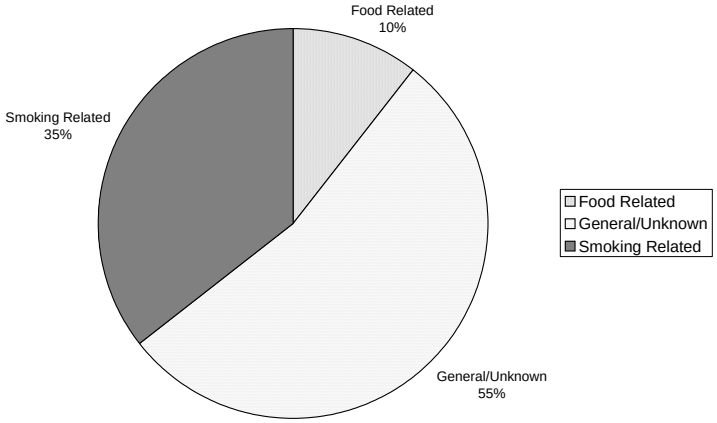


Figure 6-8
USAGE DISTRIBUTION BY AIR-DRIED WEIGHT BY YEAR

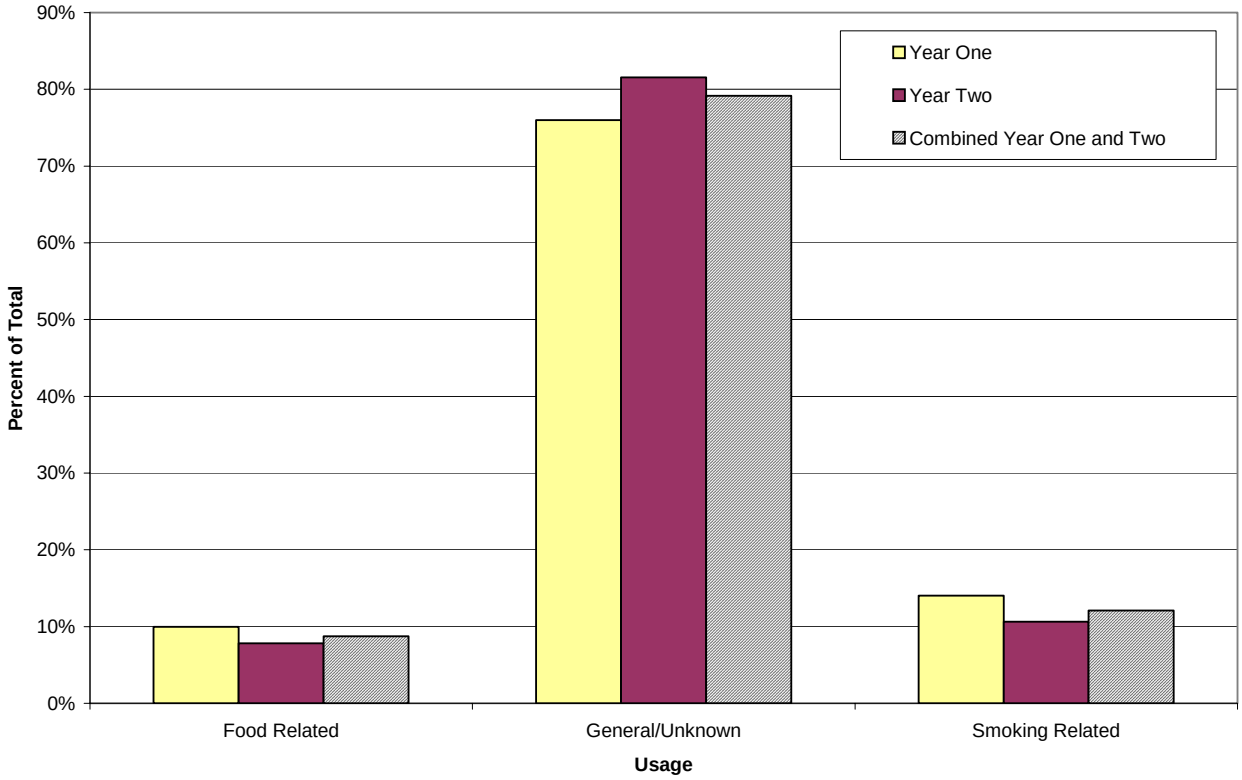


Table 6-1
MOISTURE CONTENTS OF LITTER AND VEGETATIVE MATERIAL[1]

Litter Category	Litter Event																
	Cleanout6*	1999e03	1999e05	1999e06	1999e08	1999e09	1999e10	1999e11	1999e12	1999e13	1999e14	1999e15A	1999e15	1999e16	Final Outfall Cleanout	Final Inlet Cleanout	Average[2]
Cardboard/Chipboard	3%	3%	6%	4%	47%	28%	NA	6%	40%	7%	11%	7%	29%	6%	26%	9%	17%
Cigarette Butts	2%	3%	27%	4%	81%	64%	162%	25%	57%	33%	8%	10%	44%	7%	38%	8%	36%
Cloth	1%	1%	3%	2%	31%	14%	NA	2%	21%	7%	5%	2%	10%	10%	1%	2%	10%
Glass	0%	NA	2%	1%	0%	1%	NA	0%	0%	0%	2%	0%	1%	0%	0%	0%	0%
Metal (Foil and Molded)	1%	1%	2%	1%	15%	12%	NA	1%	5%	2%	4%	4%	1%	0%	1%	0%	2%
Other	NA	NA	NA	5%	NA	4%	NA	9%	8%	2%	0%	1%	1%	1%	3%	1%	2%
Paper	3%	2%	4%	3%	43%	31%	120%	10%	39%	6%	5%	4%	23%	2%	3%	3%	16%
Plastic-Film	1%	4%	4%	3%	19%	13%	8%	2%	16%	8%	6%	5%	13%	5%	4%	68%	21%
Plastic-Moldable	0%	0%	0%	1%	7%	2%	NA	0%	2%	1%	1%	0%	1%	1%	2%	1%	2%
Styrofoam	1%	1%	1%	1%	11%	11%	19%	1%	21%	16%	2%	1%	19%	1%	13%	1%	7%
Wood	6%	7%	11%	7%	50%	20%	59%	14%	25%	32%	17%	13%	31%	15%	29%	15%	21%
Total of Litter Categories	2%	3%	7%	3%	38%	19%	82%	7%	23%	12%	6%	6%	16%	6%	10%	4%	12%
Vegetative Material	NM	36%	49%	147%	39%	26%	81%	34%	42%	35%	44%	46%	31%	58%	5%	28%	

Notes:

* Mid season cleanout of Site 6 on October 19, 1999

[1] Moisture contents based on oven drying analysis for representative litter samples for each event.

[2] Weighted average based on event-by-event air-dried weights by category.

NA = Not applicable because no litter was recovered in the category during the event.

NM = Not measured.

6.3.7 Floatable Portion of Litter

An estimate of the floatable portion of the litter collected at the outfalls was made by placing samples of the litter into large containers of water, manually stirring, waiting 30 seconds, and measuring the portions that float and those that sink. Table 6-2 shows the percent of floatable litter by event for all events and a total percent floatable for all year one and two events.

Findings indicate that a large portion (approximately 80% of litter collected for each year) of litter collected during the study was floatable, using the methodology selected for the LMPS. Allison et. al. found that 20% of storm water litter floats, based on collecting the floatable portion of debris in a CDS unit from 10 storms. One explanation for the difference in the findings of the studies may be attributable to the difference in residence time of the litter in both studies. The percentage of litter collected in storm water that is floatable may depend on how long the litter has been entrained in the system (i.e. if the litter has had a longer period of time to become more saturated). The CDS unit monitored by Allison et al. treated storm water from a 50 hectare (124 acre) urban catchment that contained 192 drainage inlets. The much lower percentage of floatables found by Allision et. al. may be a result of a longer litter residence time and turbulence associated with storm water flowing through an extensive piping system containing multiple bends etc. LMPS findings may reflect the short residence time of litter in the smaller LMPS drainage systems. Allison et. al. indicated that based on their findings, BMPS should be designed for floating and sinking gross pollutants because of the low percentage of floatables found in that study. The LMPS findings would indicate that a large portion of freeway litter collected after a short residence time in the drainage system is floatable.

6.3.8 Litter Spike Recovery

Spike materials were placed in the drain inlet upstream of each outfall during pre-storm preparation for events. A standard set of materials was used in each spike, and the set of materials was painted a different color for each event. The standard spike materials were:

- 4 gum wrappers
- 3 styrofoam popcorn
- 5 cigarette butts
- 2 tongue depressors
- 2 popsicle sticks
- 2 metal cans
- 2 fabric scraps
- 1 plastic lid
- 1 poker chip

Table 6-3 shows the event and date associated with each spike color. The event number and date represent the first opportunity for recovery of the associated spike color because the spike material was placed during pre-storm preparation for the associated event. Spike material placed for earlier events was also recovered from in-between event litter bags collected during pre-storm preparation for later events.

Table 6-4 displays the pattern of spike recovery for each storm event. The majority of the spike material in each color is recovered within the first two events after placement. However, spikes from the early part of the 1998/1999 rainy season were recovered as late as February 2000, during the most intense storm during the study period. Additionally, some spikes were not recovered at all during storm events and remained in the drainage system until the inlets were manually cleaned. Five percent of the total number of spike items that were placed in the inlets

during both seasons were recovered during cleanouts (including the October 1999 cleanouts conducted at Sites 6 and 8 and the final inlet cleanout).

Table 6–2
PERCENT FLOATABLE LITTER BY VOLUME

Year One Event	Date	Percent Floatable	Year Two Event	Date	Percent Floatable
1998i01	11/7/98	97%	Cleanout6*	10/28/99	84%
1998i02	11/27/98	93%	1999e03	12/31/99	74%
1998e02	11/28/98	83%	1999e05	1/25/00	82%
1998e03	12/1/98	84%	1999e06	1/30/00	86%
1998i05	1/23/99	85%	1999e08	2/10/00	80%
1998e05	1/25/99	84%	1999e09	2/12/00	94%
1998i06	2/7/99	77%	1999e10	2/13/00	71%
1998e06	2/9/99	86%	1999e11	2/16/00	76%
1998i09	3/14/99	58%	1999e12	2/20/00	79%
1998e09	3/15/99	79%	1999e13	2/23/00	68%
1998e10	3/20/99	76%	1999e14	2/27/00	77%
1998e11	3/25/99	76%	1999e15A	3/3/00	81%
1998i12	4/5/99	85%	1999e15	3/4/00	79%
1998e12	4/6/99	77%	1999e16	3/8/00	76%
1998i13	4/10/99	55%	Final Outfall Cleanout	3/23/00	50%
1998e13	4/11/99	63%	Final Inlet Cleanout	3/26/00	72%
1998d01	6/7/99	67%			
Bicycle Grate Closeout	9/27/99	67%			
TOTAL[1]		78%			80%

[1] Seasonal total: calculated by comparing the total volume and total non-floatable volume summed over all events for the season (listed above).

*Midseason cleanout of Site 6 on October 19, 1999

Table 6-5 shows the total percent recovery of each spike color at each outfall throughout the entire study. Table 6-5 also shows the average total recovery of each spike color for each site. Table 6-5 is useful in comparing relative spike recovery at the four sites.

Outfalls at Site 1W and Site 8 experienced the highest spike recovery. The Site 1W average recovery of spike colors placed during year 1 and year 2 of monitoring were 87 percent and 83 percent, respectively. The Site 8 average recovery of spike colors placed during year 1 and year 2 of monitoring were 83 percent and 86 percent, respectively. Outfalls at Site 6 had the lowest spike recovery, with average site recoveries of spike colors placed during year 1 and year 2 of monitoring of 59 percent and 76 percent, respectively. The Site 1E average recovery of spike colors placed during year 1 and year 2 of monitoring were 73 percent and 74 percent, respectively.

Table 6–3
SPIKE COLORS BY EVENT

Spike Color	Date Spiked	Associated Storm Event	Storm Event Date
red	11/7/98	1998e01	11/8/98
blue	11/27/98	1998e02	11/28/98
yellow	11/30/98	1998e03	12/1/98
brown	12/4/98	1998e04 (false start)	12/5/98
pink	1/24/99	1998e05	1/25/99
orange	2/8/99	1998e06	2/9/99
green	2/18/99	1998e07 (false start)	2/19/99
no spike	no spike	1998e08 (false start)	3/5/99
no spike	no spike	1998e09	3/15/99
purple	3/19/99	1998e10	3/20/99
aqua green	3/24/99	1998e11	3/25/99
maroon/fuschia	4/5/99	1998e12	4/6/99
no spike	no spike	1998e13	4/11/99
blue dot hot pink	11/13/99	1999e01 (false start)	11/14/99
no spike	no spike	1999e02 (false start)	12/9/99
no spike	no spike	1999e03	12/31/99
blue dot yellow	1/13/00	1999e04 (false start)	1/14/00
no spike	no spike	1999e05	1/25/00
blue dot blue	1/29/00	1999e06	1/30/00
blue dot red	2/4/00	1999e07 (false start)	2/5/00
no spike	no spike	1999e08	2/10/00
blue dot orange	2/11/00	1999e09	2/12/00
blue dot green	2/12/00	1999e10	2/13/00
blue dot brown	2/15/00	1999e11	2/16/00
blue dot purple	2/19/00	1999e12	2/20/00
blue dot gold	2/22/00	1999e13	2/23/00
blue dot silver	2/26/00	1999e14	2/27/00
no spike	no spike	1999e15A	3/3/00
blue dot light pink	3/3/00	1999e15	3/4/00
blue dot black	3/7/00	1999e16	3/8/00

Table 6-4
NUMBER OF SPIKE ITEMS RECOVERED BY DATE RECOVERED AND ASSOCIATED EVENT

Date Spiked	Total Number of Spike Items Recovered*	1998e01, 11/8/98	1998i02, 11/27/98	1998e02, 11/28/98	1998e03, 12/1/98	1998i05, 1/23/99	1998e05, 1/25/99	1998i06, 2/7/99	1998e06, 2/9/99	1998i09, 3/14/99	1998e09, 3/15/99	1998e10, 3/20/99	1998e11, 3/25/99	1998i12, 4/5/99	1998e12, 4/6/99	1998i13, 4/10/99	1998e13, 4/11/99	Bicycle Grate Closeout at Site 8, 9/27/99	Site 6 Cleanout, 10/28/99	1999e03, 12/31/99	1999e05, 1/25/00	1999e06, 1/30/00	1999e08, 2/10/99	1999e09, 2/12/00	1999e10, 2/13/00	1999e11, 2/16/00	1999e12, 2/20/00	1999e13, 2/23/00	1999e14, 2/27/00	1999e15A, 3/3/00	1999e15, 3/4/00	1999e16, 3/8/00	Final Outfall Cleanout, 3/23/00	Final Cage Cleanout, 3/23/00
11/7/98	401	363	1	20		3	1							1			1		8								1							
11/27/98	349			325		20		1																										
11/30/98	412				145	237	12	5			1				1												1							
12/4/98	425					395	21	4	1					2																				
1/24/99	437						209	169	32		10		1			1	1		10									1						
2/8/99	422								374	3	18		2	5			2	3	6								3							
2/18/99	434									21	307		21	11	7		7	3	22								8						1	
3/19/99	419											82	141	69	78		16		13								7							
3/24/99	369												193	81	69	1	7																	
4/5/99	403														337		26		15														1	
11/13/99	323																			80	14		51	19			78	13			1	5		
1/13/00	392																				110	1	130	48		2	41	6				3	1	1
1/29/00	446																					61	243	55		18	29	1			1	6		
2/4/00	432																						292	61			44	1				5		
2/11/00	474																							355		7	78	5			1	2	2	
2/12/00	422																								52	173	151	9	1	2	1	8		3
2/15/00	374																									168	171	4	1		1	7	1	1
2/19/00	369																										341	1	1		3	5	1	
2/22/00	449																											392	3	5	5	9	2	
2/26/00	477																												209	171	52	12		
3/3/00	485																														390	27	1	1
3/7/00	461																															416	1	
various	13																										11					1		

Notes:
Shaded boxes indicate spike items recovered during the first litter bag collection following the date spiked.
*Total number of items available for recovery is 528 (22 items per outfall in 24 outfalls).
**13 metal cans were recovered with only the blue dot portion of the spike visible.

Table 6-5
PERCENT OF TOTAL SPIKE MATERIAL RECOVERED AT EACH OUTFALL BY COLOR

		Site 1E - Litter Pick-up						
		Control Outfalls			Treatment Outfalls			
	Spike Color	1-42	1-B110	1-B111	1-44	1-46	1-47	Site Average by Color
Year 1 Spike Colors	Red	91%	95%	82%	82%	91%	68%	85%
	Blue	55%	77%	64%	59%	68%	55%	63%
	Yellow	91%	95%	82%	59%	95%	59%	80%
	Brown	100%	82%	86%	86%	64%	45%	77%
	Pink	77%	77%	86%	64%	100%	9%	69%
	Orange	59%	91%	73%	64%	91%	77%	76%
	Green	73%	59%	100%	27%	100%	45%	67%
	Purple	95%	86%	59%	64%	100%	82%	81%
	aqua green	95%	100%	41%	36%	27%	82%	64%
	Maroon/fuschia	77%	0%	68%	86%	100%	100%	72%
	Year 1 Average Recovery	81%	76%	74%	63%	84%	62%	73%
Year 2 Spike Colors	blue dot hot pink	41%	59%	55%	68%	86%	45%	59%
	blue dot yellow	73%	68%	59%	73%	73%	55%	67%
	blue dot blue	86%	91%	68%	73%	77%	59%	76%
	blue dot red	86%	82%	77%	68%	86%	68%	78%
	blue dot orange	100%	91%	86%	45%	91%	82%	83%
	blue dot green	91%	64%	59%	82%	86%	64%	74%
	blue dot brown	77%	68%	64%	64%	82%	50%	67%
	blue dot purple	68%	73%	59%	50%	73%	9%	55%
	blue dot gold	64%	82%	82%	91%	82%	64%	77%
	blue dot silver	100%	91%	91%	86%	95%	86%	92%
	blue dot light pink	77%	100%	86%	91%	86%	55%	83%
	blue dot black	68%	91%	82%	68%	100%	45%	76%
	Year 2 Average Recovery	78%	80%	72%	72%	85%	57%	74%
	Average Recovery of Spikes from Both Years	79%	78%	73%	68%	84%	59%	74%

**During some events, metal cans were recovered with only the blue dot portion of the spike visible.

Table 6-5 (continued)
PERCENT OF TOTAL SPIKE MATERIAL RECOVERED AT EACH OUTFALL BY COLOR

		Site 1W - Street Sweeping						
		Control Outfalls			Treatment Outfalls			
	Spike Color	1-50	1-51	1-52	1-58	1-59	1-60	Site Average by Color
Year 1 Spike Colors	Red	82%	91%	95%	95%	86%	77%	88%
	Blue	91%	86%	95%	86%	64%	64%	81%
	Yellow	95%	100%	100%	82%	86%	86%	92%
	Brown	91%	100%	91%	95%	100%	82%	93%
	Pink	59%	82%	100%	82%	86%	73%	80%
	Orange	95%	77%	86%	100%	100%	95%	92%
	Green	95%	100%	100%	91%	100%	91%	96%
	Purple	73%	73%	86%	100%	86%	86%	84%
	Aqua green	91%	45%	95%	95%	64%	86%	80%
	Maroon/fuschia	82%	100%	77%	82%	77%	100%	86%
	Year 1Average Recovery	85%	85%	93%	91%	85%	84%	87%
Year 2 Spike Colors	Blue dot hot pink	55%	55%	73%	77%	59%	55%	62%
	Blue dot yellow	95%	82%	91%	68%	64%	91%	82%
	Blue dot blue	95%	100%	68%	77%	100%	86%	88%
	Blue dot red	77%	95%	91%	64%	91%	82%	83%
	Blue dot orange	100%	95%	95%	100%	86%	86%	94%
	Blue dot green	82%	86%	59%	82%	100%	64%	79%
	Blue dot brown	68%	86%	73%	77%	73%	91%	78%
	Blue dot purple	73%	77%	64%	73%	55%	82%	70%
	blue dot gold	100%	100%	82%	82%	86%	91%	90%
	blue dot silver	95%	95%	68%	86%	100%	82%	88%
	blue dot light pink	100%	82%	91%	100%	95%	82%	92%
	blue dot black	95%	100%	86%	91%	86%	95%	92%
	Year 2 Average Recovery	86%	88%	78%	81%	83%	82%	83%
	Average Recovery of Spikes from Both Years	86%	87%	85%	86%	84%	83%	85%

**During some events, metal cans were recovered with only the blue dot portion of the spike visible.

Table 6-5 (continued)
PERCENT OF TOTAL SPIKE MATERIAL RECOVERED AT EACH OUTFALL BY COLOR

		Site 6 - Modified Inlet						
		Control Outfalls			Treatment Outfalls			
	Spike Color	6-20C	6-20E	6-20G	6-20B	6-20F	6-20H	Site Average by Color
Year 1 Spike Colors	Red	32%	18%	91%	36%	64%	41%	47%
	Blue	41%	91%	82%	64%	45%	64%	64%
	Yellow	68%	59%	45%	14%	59%	41%	48%
	Brown	77%	68%	82%	50%	32%	50%	60%
	Pink	50%	100%	100%	27%	77%	100%	76%
	Orange	45%	86%	82%	55%	9%	50%	55%
	Green	55%	32%	77%	36%	50%	59%	52%
	Purple	55%	64%	68%	23%	100%	68%	63%
	Aqua green	32%	50%	95%	59%	82%	55%	62%
	Maroon/fuschia	18%	55%	73%	100%	100%	36%	64%
	Year 1 Average Recovery	85%	62%	80%	46%	62%	56%	59%
Year 2 Spike Colors	Blue dot hot pink	27%	9%	64%	64%	50%	45%	43%
	Blue dot yellow	59%	50%	82%	59%	41%	45%	56%
	Blue dot blue	82%	91%	95%	77%	91%	60%	83%
	Blue dot red	68%	68%	82%	95%	77%	55%	74%
	Blue dot orange	91%	100%	100%	82%	91%	91%	92%
	Blue dot green	73%	55%	91%	82%	86%	73%	77%
	Blue dot brown	64%	73%	68%	73%	68%	45%	65%
	Blue dot purple	73%	77%	73%	68%	82%	73%	74%
	Blue dot gold	91%	77%	95%	73%	91%	82%	85%
	Blue dot silver	95%	100%	100%	86%	68%	86%	89%
	Blue dot light pink	100%	100%	82%	100%	77%	91%	92%
	Blue dot black	73%	68%	95%	95%	95%	95%	87%
	Year 2 Average Recovery	86%	72%	86%	80%	77%	70%	76%
	Average Recovery of Spikes from Both Years	62%	68%	83%	65%	70%	64%	69%

**During some events, metal cans were recovered with only the blue dot portion of the spike visible.

Table 6-5 (continued)
PERCENT OF TOTAL SPIKE MATERIAL RECOVERED AT EACH OUTFALL BY COLOR

		Site 8 - Bicycle Grate (1998/1999) and LID (1999/2000)						
		Control Outfalls			Treatment Outfalls			
	Spike Color	8-23C	8-24D	8-24E	8-24B	8-24F	8-B001	Site Average by Color
Year 1 Spike Colors	Red	91%	73%	86%	68%	100%	86%	84%
	Blue	82%	23%	59%	32%	64%	77%	56%
	Yellow	86%	95%	100%	91%	91%	86%	92%
	Brown	91%	91%	95%	91%	91%	91%	92%
	Pink	95%	100%	86%	100%	95%	86%	94%
	Orange	100%	91%	100%	95%	95%	95%	96%
	Green	100%	100%	100%	86%	82%	100%	95%
	Purple	95%	100%	82%	91%	82%	45%	83%
	aqua green	95%	100%	14%	64%	100%	50%	70%
	maroon/fuschia	100%	86%	91%	68%	18%	18%	64%
	Year 1 Average Recovery	94%	86%	81%	79%	82%	74%	83%
Year 2 Spike Colors	blue dot hot pink	82%	100%	77%	91%	100%	32%	80%
	blue dot yellow	95%	86%	91%	95%	95%	91%	92%
	blue dot blue	100%	82%	82%	100%	86%	86%	89%
	blue dot red	91%	91%	95%	91%	86%	95%	92%
	blue dot orange	64%	100%	82%	91%	91%	100%	88%
	blue dot green	77%	95%	82%	86%	91%	100%	89%
	blue dot brown	86%	59%	77%	77%	77%	59%	73%
	blue dot purple	73%	95%	82%	82%	73%	73%	80%
	blue dot gold	82%	91%	82%	82%	86%	100%	87%
	blue dot silver	91%	73%	95%	91%	100%	91%	90%
	blue dot light pink	86%	95%	95%	95%	95%	82%	92%
	blue dot black	95%	95%	100%	77%	95%	100%	94%
	Year 2 Average Recovery	85%	88%	84%	90%	90%	81%	86%
	Average Recovery of Spikes from Both Years	89%	87%	84%	84%	86%	79%	85%

**During some events, metal cans were recovered with only the blue dot portion of the spike visible.

Insight related to spike recovery percentages was gained during final inlet cleaning laboratory analysis. Litter lab technicians indicated that spike materials had degraded substantially so that the original form, material, and markings were at times unrecognizable, particularly for cigarette butts, gum wrappers, and fabric. This may partially explain lower than anticipated spike recovery results. In particular, the lowest overall spike recovery results at Site 6 may be explained by a higher potential for material degradation due to the high vegetation content (87 percent average per monitored event). This is unlikely to affect results related to the BMPs tested during the LMPS because there is no reason to suspect that the rate of degradation would be different in treatment vs. control inlets.

Table 6-6 shows the recovery of spike items by type for the LMPS monitoring period. Recovery of each type of spike item ranged from 56% recovery of placed cigarette butts over the study to 93% recovery of both metal cans and plastic lids.

6.4 EVENT LITTER DATA

This section contains a summary of the event by event litter loads and storm-related characteristics from the control outfalls at each site during the two seasons of monitoring. The data are useful to compare the litter rates between individual storm events, BMP sites, and seasons.

Table 6-7 presents the amount of litter monitored during each trigger storm (for air-dried weight, volume, and count) from the sum of the three control outfalls and the sum of the three treatment outfalls at each site (normalized by area). It should be noted that normalization by this method assumes a straight-line relationship between catchment size and litter load. Data were also normalized by flow for the purpose of evaluating BMP effectiveness. In addition to the storm event litter, rainfall volumes, maximum rainfall intensities, flow volumes, maximum flow rates, event durations, the antecedent dry days and antecedent rainfall are presented.

The control sites are used to present litter data from 'typical' highway conditions. The sites are similar in many ways including: drainage systems with one inlet directly connected to one outfall; location on fill slopes; catchment areas less than one acre; and each are in urban freeway settings. However, there are substantial variations in the litter loads between the sites. Site ADT and litter loads by weight and volume are presented in Table 6-8. Comparison of ADTs, truck traffic and surrounding land use as well as litter load for these sites does not indicate a clear relationship. Surrounding land uses and types of vehicles (number of axles) were also compared to litter load on a cursory basis and no apparent trends were identified. Differences between the site litter loads could be influenced by other factors that were not evaluated during the LMPS including different traffic patterns, different prevailing wind directions, and highway shoulder conditions.

Observations from the litter data suggest that there were:

- Similar seasonal rainfall and runoff volumes observed at all sites (within approximately 20%).
- The largest amount of outfall litter at control areas was observed at Site 1-E, approximately 14 kg/ac, 104 L/ac, and 14,000 pieces/ac of litter for the study, captured during trigger events from two rain seasons (October 1998 to April 2000).
- The control outfalls at Sites 1-W and Site 6 had similar loads of litter and were about 25% less that site1E.
- Site 8 had between one-third and one-half the loads compared to site 1E.

All sites had higher outfall litter loads for the second year of monitoring.

Table 6–6
RECOVERY OF SPIKE ITEMS BY TYPE

Spike Type	Number of items placed, 1998-1999	Number of items placed, 1999-2000	Number of items recovered, 1998-1999	Number of items recovered, 1999-2000	Overall Percent Recovery
Cigarette Butts	1200	1440	684	782	56%
Fabric Scraps	480	576	340	472	77%
Gum Wrappers	960	1149	690	909	76%
Metal Cans	480	576	413	573	93%
Plastic Lids	240	287	205	287	93%
Poker Chips	240	288	185	288	90%
Popsicle Sticks	480	576	408	562	92%
Styrofoam	720	864	585	854	91%
Tongue Depressors	480	576	351	576	88%

Table 6-7
EVENT LITTER DATA - NORMALIZED BY AREA

Site 1E
Litter Pickup
Control

EVENT NUMBER	EVENT DATE	DRY WEIGHT*	VOLUME*	COUNT*	RAIN VOLUME**	MAX RAIN INTENSITY**	FLOW VOLUME**	MAX FLOW RATE**	EVENT DURATION**	ANT. DRY DAYS**	ANT. RAIN**
		(g/ac)	(ml/ac)	(#/ac)	(in)	(in/hr)	(in)	(cfs)	(hours)	(days)	(in)
1998e01	11/08/1998	1055	13936	1654	1.07	0.6	0.71	0.153	5:50	-	-
1998e02	11/28/1998	939	8305	968	0.29	0.3	0.16	0.239	3:26	20	0
1998e03	12/01/1998	6	108	25	0.17	0.15	0.06	0.01	4:42	3	0
1998e05	01/25/1999	139	2627	236	0.51	0.3	0.28	0.042	7:04	5	0.4
1998e06	02/09/1999	680	4507	854	0.35	1.8	0.19	0.29	5:15	5	0.3
1998e09	03/15/1999	911	6994	1145	0.58	2.4	0.34	0.202	3:47	34	0
1998e10	03/20/1999	2	33	25	0.18	0.15	0.06	0.007	3:58	5	0
1998e11	03/25/1999	465	5414	337	0.58	0.6	0.32	0.067	11:59	5	0
1998e12	04/06/1999	361	2352	635	0.41	0.6	0.18	0.018	5:25	12	0
1998e13	04/11/1999	107	1285	288	1.44	0.6	0.93	0.109	11:01	4	0.7
1999e03	12/31/1999	0	0	0	0.04	0.37	0	-	0:51	53	0.09
1999e05	01/25/2000	130	2237	269	0.57	0.6	0.18	0.016	18:44	78	0
1999e06	01/30/2000	0	0	0	0.23	0.15	0.06	0.01	6:31	5	0.07
1999e08	02/10/2000	1463	11352	1214	0.3	1.8	0.16	0.153	2:45	11	0
1999e09	02/12/2000	1102	8962	1368	0.52	1.2	0.28	-	2:20	2	0
1999e10	02/13/2000	0	0	0	0.35	0.1	0.16	0.008	16:42	1	0
1999e11	02/16/2000	110	1021	220	0.54	1.2	0.29	0.092	16:17	2	0
1999e12	02/20/2000	4217	23530	2966	2.33	3.4	1.55	-	34:31	4	0
1999e13	02/23/2000	867	4025	583	1.16	2.4	0.73	-	10:32	2	0
1999e14	02/27/2000	49	619	97	0.16	0.2	0.06	0.019	01:53	4	0
1999e15	03/04/2000	648	3373	582	1.79	2.4	1.2	0.271	30:17	1	0
1999e15A	03/03/2000	166	1241	334	0.35	1.2	0.14	0.037	3:38	5	0.01
1999e16	03/08/2000	552	2292	477	0.86	0.6	0.44	0.079	08:53	2	0
1998-99 Subtotal	**-**	**4664**	**45561**	**6167**	**5.58**	**-**	**3.23**	**-**	**-**	**-**	**-**
1999-00 Subtotal	**-**	**9305**	**58652**	**8111**	**9.2**	**-**	**5.25**	**-**	**-**	**-**	**-**
Total	**-**	**13970**	**104213**	**14278**	**14.78**	**-**	**8.48**	**-**	**-**	**-**	**-**

ADT for Freeway Section211300

*sum of three litter outfalls for the Control

**flow and rainfall measured at outfall 1-42

Table 6-7
EVENT LITTER DATA - NORMALIZED BY AREA

Site 1E
Litter Pickup
Treatment

EVENT NUMBER	EVENT DATE	DRY WEIGHT*	VOLUME*	COUNT*	RAIN VOLUME**	MAX RAIN INTENSITY**	FLOW VOLUME**	MAX FLOW RATE**	EVENT DURATION**	ANT. DRY DAYS**	ANT. RAIN**
		(g/ac)	(ml/ac)	(#/ac)	(in)	(in/hr)	(in)	(cfs)	(hours)	(days)	(in)
1998e01	11/08/1998	535	9084	851	1.1	0.6	0.61	0.125	5:16	-	-
1998e02	11/28/1998	534	5132	555	0.27	1.8	0.04	0.083	3:28	20	0
1998e03	12/01/1998	5	119	18	0.2	0.2	0.03	0.008	4:37	3	0
1998e05	01/25/1999	253	1974	347	0.52	0.3	0.34	0.055	6:55	5	0.4
1998e06	02/09/1999	662	3337	676	0.35	1.8	0.2	0.173	5:03	5	0.3
1998e09	03/15/1999	595	4472	743	0.61	2.4	0.31	0.115	3:48	34	0
1998e10	03/20/1999	1	16	15	0.17	0.15	0.02	0.005	3:37	5	0
1998e11	03/25/1999	156	1139	286	0.58	0.6	0.28	0.047	11:59	5	0
1998e12	04/06/1999	407	3112	418	0.37	0.12	0.15	0.02	5:14	12	0
1998e13	04/11/1999	171	960	277	1.52	0.6	1.05	0.132	10:52	4	0.7
1999e03	12/31/1999	0	0	0	0.04	0.2	0	0.004	0:58	53	0.14
1999e05	01/25/2000	2	124	22	0.58	0.3	0.12	0.011	18:27	78	0.01
1999e06	01/30/2000	0	0	0	0.22	0.15	0.02	0.006	6:15	5	0.09
1999e08	02/10/2000	1498	10444	1208	0.32	2.4	0.08	0.094	2:46	11	0
1999e09	02/12/2000	1077	4624	842	0.53	1.2	0.28	0.135	2:23	2	0
1999e10	02/13/2000	0	0	0	0.38	0.12	0.09	0.011	16:08	1	0
1999e11	02/16/2000	55	420	149	0.5	1.2	0.22	0.029	16:01	2	0
1999e12	02/20/2000	2111	9188	1301	2.43	3	1.42	0.327	34:42	4	0
1999e13	02/23/2000	683	2224	434	1.12	1.8	0.76	0.122	10:25	2	0
1999e14	02/27/2000	26	356	74	0.18	0.2	0.05	0.024	01:36	4	0
1999e15	03/04/2000	282	904	382	1.76	1.8	1.1	0.161	30:10	1	0
1999e15A	03/03/2000	196	1020	228	0.36	0.6	0.15	0.055	4:05	5	0
1999e16	03/08/2000	577	3032	761	0.94	1.2	0.58	0.122	08:43	2	0
1998-99 Subtotal	**-**	**3320**	**29346**	**4186**	**5.69**	**-**	**3.03**	**-**	**-**	**-**	**-**
1999-00 Subtotal	**-**	**6508**	**32336**	**5399**	**9.36**	**-**	**4.87**	**-**	**-**	**-**	**-**
Total	**-**	**9828**	**61682**	**9586**	**15.05**	**-**	**7.9**	**-**	**-**	**-**	**-**

ADT for Freeway Section211300

*sum of three litter outfalls for the Treatment
**flow and rainfall measured at outfall 1-46

Table 6-7
EVENT LITTER DATA - NORMALIZED BY AREA

Site 1W
Street Sweeping
Control

EVENT NUMBER	EVENT DATE	DRY WEIGHT*	VOLUME*	COUNT*	RAIN VOLUME**	MAX RAIN INTENSITY**	FLOW VOLUME**	MAX FLOW RATE**	EVENT DURATION**	ANT. DRY DAYS**	ANT. RAIN**
		(g/ac)	(ml/ac)	(#/ac)	(in)	(in/hr)	(in)	(cfs)	(hours)	(days)	(in)
1998e01	11/08/1998	670	11277	1214	0.95	0.6	0.52	0.124	5:40	-	-
1998e02	11/28/1998	711	5948	835	0.26	1.8	0.09	0.142	2:39	20	0
1998e03	12/01/1998	12	173	44	0.2	0.2	0.06	0.013	4:39	3	0
1998e05	01/25/1999	370	7702	769	0.5	0.2	0.24	0.04	7:02	5	1.2
1998e06	02/09/1999	402	2804	690	0.36	1.8	0.15	0.299	5:13	5	0.7
1998e09	03/15/1999	451	3999	715	0.59	1.8	0.3	0.261	3:46	34	0
1998e10	03/20/1999	11	88	43	0.17	0.15	0.05	0.009	3:51	5	0
1998e11	03/25/1999	90	873	181	0.55	1.2	0.26	0.05	7:06	5	0.1
1998e12	04/06/1999	334	2034	497	0.28	0.15	0.14	0.025	4:06	12	0
1998e13	04/11/1999	132	990	235	1.36	0.6	0.8	0.109	10:57	4	0.6
1999e03	12/31/1999	0	0	0	0.04	0.3	0	0.003	0:29	53	0.15
1999e05	01/25/2000	286	3319	412	0.52	0.3	0.18	0.026	18:35	78	0.01
1999e06	01/30/2000	0	0	0	0.18	0.1	0.05	0.015	5:56	5	0.09
1999e08	02/10/2000	2194	17379	2144	0.32	1.8	0.14	0.268	3:30	11	0
1999e09	02/12/2000	699	5085	1018	0.51	1.2	0.34	0.305	2:15	2	0
1999e10	02/13/2000	0	0	0	0.28	0.08	0.15	0.014	16:16	1	0
1999e11	02/16/2000	80	452	112	0.48	1.2	0.24	0.034	15:58	2	.01
1999e12	02/20/2000	2172	9500	1518	2.29	3	1.47	0.439	34:29	4	0
1999e13	02/23/2000	408	1254	285	1.05	1.8	0.69	0.189	10:20	2	0
1999e14	02/27/2000	42	577	105	0.18	0.2	0.07	0.032	01:57	4	0
1999e15	03/04/2000	211	1077	360	1.58	1.2	1.1	0.181	31:07	1	0
1999e15A	03/03/2000	120	915	284	0.34	0.6	0.16	0.064	4:04	5	0
1999e16	03/08/2000	292	1492	560	0.8	1.2	0.55	0.15	08:13	2	0
1998-99 Subtotal	**-**	**3184**	**35886**	**5223**	**5.22**	**-**	**2.61**	**-**	**-**	**-**	**-**
1999-00 Subtotal	**-**	**6504**	**41048**	**6797**	**8.57**	**-**	**5.14**	**-**	**-**	**-**	**-**
Total	**-**	**9688**	**76935**	**12020**	**13.79**	**-**	**7.75**	**-**	**-**	**-**	**-**

ADT for Freeway Section211300

*sum of three litter outfalls for the Control

**flow and rainfall measured at outfall 1-52

Table 6-7
EVENT LITTER DATA - NORMALIZED BY AREA

Site 1W
Street Sweeping
Treatment

EVENT NUMBER	EVENT DATE	DRY WEIGHT*	VOLUME*	COUNT*	RAIN VOLUME**	MAX RAIN INTENSITY**	FLOW VOLUME**	MAX FLOW RATE**	EVENT DURATION**	ANT. DRY DAYS**	ANT. RAIN**
		(g/ac)	(ml/ac)	(#/ac)	(in)	(in/hr)	(in)	(cfs)	(hours)	(days)	(in)
1998e01	11/08/1998	1338	12542	1207	1.04	1.2	0.84	0.193	4:57	-	-
1998e02	11/28/1998	495	6847	747	0.29	1.8	0.2	0.31	3:25	20	0
1998e03	12/01/1998	13	110	28	0.19	0.15	0.09	0.024	4:54	3	0
1998e05	01/25/1999	144	2165	311	0.51	0.2	0.43	0.068	7:14	5	1.2
1998e06	02/09/1999	566	2283	603	0.37	2.4	0.24	0.362	5:15	5	0.7
1998e09	03/15/1999	715	4120	955	0.61	2.4	0.45	0.327	3:50	34	0
1998e10	03/20/1999	5	64	45	0.18	0.2	0.09	0.017	4:05	5	0
1998e11	03/25/1999	152	1844	370	0.57	1.2	0.36	0.169	7:11	5	0.1
1998e12	04/06/1999	259	2452	509	0.31	0.15	0.2	0.022	4:30	12	0
1998e13	04/11/1999	63	490	200	1.43	0.6	1.1	0.15	11:43	4	0.6
1999e03	12/31/1999	0	0	0	0.05	0.6	0.02	0.018	0:50	53	0.2
1999e05	01/25/2000	91	1020	194	0.54	0.6	0.37	0.03	18:40	78	0.01
1999e06	01/30/2000	39	446	47	0.2	0.15	0.11	0.021	5:58	5	0.13
1999e08	02/10/2000	2881	14248	2260	0.32	2.4	0.21	0.253	2:45	11	0
1999e09	02/12/2000	851	3426	861	0.51	1.2	0.4	0.278	2:21	2	0
1999e10	02/13/2000	0	0	0	0.31	0.09	0.26	0.016	16:23	1	0
1999e11	02/16/2000	139	896	230	0.52	1.2	0.4	0.146	16:10	2	0
1999e12	02/20/2000	5369	15010	3723	2.26	4.2	1.9	1.2	34:19	4	0
1999e13	02/23/2000	315	1005	212	1.14	2.4	0.89	0.316	10:18	2	0
1999e14	02/27/2000	12	173	31	0.16	0.2	0.09	0.029	01:39	4	0
1999e15	03/04/2000	290	1139	270	1.72	1.8	1.64	0.439	30:13	1	0
1999e15A	03/03/2000	172	1193	309	0.33	0.6	0.26	0.139	4:05	5	0
1999e16	03/08/2000	77	550	177	0.81	0.6	0.69	0.161	10:16	2	0
1998-99 Subtotal	**-**	**3751**	**32918**	**4974**	**5.5**	**-**	**4**	**-**	**-**	**-**	**-**
1999-00 Subtotal	**-**	**10238**	**39104**	**8314**	**8.87**	**-**	**7.24**	**-**	**-**	**-**	**-**
Total	**-**	**13990**	**72022**	**13288**	**14.37**	**-**	**11.24**	**-**	**-**	**-**	**-**

ADT for Freeway Section211300

*sum of three litter outfalls for the Treatment

**flow and rainfall measured at outfall 1-58

Table 6-7
EVENT LITTER DATA - NORMALIZED BY AREA

Site 6
Modified Inlet
Control

EVENT NUMBER	EVENT DATE	DRY WEIGHT*	VOLUME*	COUNT*	RAIN VOLUME**	MAX RAIN INTENSITY**	FLOW VOLUME**	MAX FLOW RATE**	EVENT DURATION**	ANT. DRY DAYS**	ANT. RAIN**
		(g/ac)	(ml/ac)	(#/ac)	(in)	(in/hr)	(in)	(cfs)	(hours)	(days)	(in)
1998e01	11/08/1998	417	8763	783	0.69	0.6	0.45	0.133	4:60	-	-
1998e02	11/28/1998	680	7476	822	0.33	0.6	0.14	0.133	2:13	20	0
1998e03	12/01/1998	6	78	11	0.09	0.06	0	-	1:57	3	0
1998e05	01/25/1999	197	2893	336	0.36	0.2	0.18	0.06	6:24	5	0.7
1998e06	02/09/1999	375	2788	536	0.45	0.6	0.29	0.104	8:07	4	1.4
1998e09	03/15/1999	608	5078	904	0.5	0.6	0.34	0.172	4:04	34	0
1998e10	03/20/1999	3	26	9	0.08	0.1	0.01	-	3:48	5	0
1998e11	03/25/1999	4	58	5	0.14	0.15	0.03	0.009	5:04	5	0
1998e12	04/06/1999	227	1570	406	0.79	0.6	0.74	0.144	8:30	5	0.6
1998e13	04/11/1999	404	662	144	0.96	0.3	0.78	0.068	13:42	4	0.3
1999e03	12/31/1999	383	2881	472	0.16	0.6	0.02	0.051	6:45	53	0.06
1999e05	01/24/2000	387	3037	644	0.78	0.2	0.33	0.066	21:57	25	0.01
1999e06	01/30/2000	127	1222	288	0.24	0.3	0.07	0.051	5:19	5	0.12
1999e08	02/10/2000	1578	6837	1090	0.52	1.8	0.25	0.278	9:59	11	0
1999e09	02/12/2000	254	1686	359	0.4	0.6	0.22	0.115	1:56	2	0
1999e10	02/13/2000	30	148	53	0.32	0.3	0.08	0.031	16:39	1	0
1999e11	02/16/2000	323	1730	301	0.72	0.6	0.43	0.076	16:49	2	0
1999e12	02/20/2000	1403	6700	784	2.61	3	1.5	0.788	34:53	4	0
1999e13	02/23/2000	296	1685	376	1.23	1.8	0.87	0.333	09:22	2	0
1999e14	02/27/2000	76	756	101	0.19	0.15	0.11	0.047	02:25	4	0
1999e15	03/04/2000	75	615	167	1.56	0.6	0.78	0.089	33:11	1	0
1999e15A	03/03/2000	280	2189	458	0.54	1.2	0.3	0.146	2:46	5	0.01
1999e16	03/08/2000	302	2630	427	1.22	1.2	0.85	0.294	08:52	3	0.08
1998-99 Subtotal	**-**	**2922**	**29391**	**3957**	**4.39**	**-**	**2.96**	**-**	**-**	**-**	**-**
1999-00 Subtotal	**-**	**5515**	**32116**	**5519**	**10.49**	**-**	**5.81**	**-**	**-**	**-**	**-**
Total	**-**	**8437**	**61506**	**9476**	**14.88**	**-**	**8.77**	**-**	**-**	**-**	**-**

ADT for Freeway Section216600

*sum of three litter outfalls for the Control

**flow and rainfall measured at outfall 6-20E

Table 6-7
EVENT LITTER DATA - NORMALIZED BY AREA

Site 6
Modified Inlet
Treatment

EVENT NUMBER	EVENT DATE	DRY WEIGHT*	VOLUME*	COUNT*	RAIN VOLUME**	MAX RAIN INTENSITY**	FLOW VOLUME**	MAX FLOW RATE**	EVENT DURATION**	ANT. DRY DAYS**	ANT. RAIN**
		(g/ac)	(ml/ac)	(#/ac)	(in)	(in/hr)	(in)	(cfs)	(hours)	(days)	(in)
1998e01	11/08/1998	574	8389	676	0.67	0.6	0.39	0.109	4:10	-	-
1998e02	11/28/1998	787	10554	965	0.32	0.6	0.12	0.115	2:11	20	0
1998e03	12/01/1998	0	0	0	0.08	0.06	0	-	2:19	3	0
1998e05	01/25/1999	276	3770	466	0.36	0.2	0.16	0.045	6:32	5	0.7
1998e06	02/09/1999	140	1053	214	0.42	0.6	0.22	0.174	7:02	4	1.4
1998e09	03/15/1999	447	3269	632	0.48	0.6	0.26	0.332	4:06	34	0
1998e10	03/20/1999	9	61	22	0.06	0.1	0	-	3:49	5	0
1998e11	03/25/1999	0	0	0	0.14	0.08	0.02	0.007	5:17	5	0
1998e12	04/06/1999	143	661	172	0.76	0.6	0.33	0.155	8:33	5	0.6
1998e13	04/11/1999	78	296	127	0.94	0.3	0.58	0.073	13:14	4	0.3
1999e03	12/31/1999	259	2135	472	0.17	1.2	0.03	0.081	6:51	53	0.05
1999e05	01/24/2000	336	2845	520	0.79	0.2	0.38	0.066	21:31	25	0.01
1999e06	01/30/2000	159	1182	347	0.24	0.3	0.08	0.057	5:14	5	0.11
1999e08	02/10/2000	730	3311	525	0.51	2.4	0.26	0.299	9:53	11	0
1999e09	02/12/2000	197	1075	201	0.4	0.6	0.24	0.128	2:25	2	0
1999e10	02/13/2000	6	41	30	0.34	0.3	0.06	0.023	17:14	1	0
1999e11	02/16/2000	413	2068	287	0.74	0.6	0.44	0.083	16:18	2	0
1999e12	02/20/2000	1007	4615	573	2.57	3	1.65	1.042	34:47	4	0
1999e13	02/23/2000	233	824	200	1.21	1.8	1.03	0.392	10:01	2	0
1999e14	02/27/2000	38	584	89	0.19	0.2	0.11	0.049	02:00	4	0
1999e15	03/04/2000	45	291	80	1.55	0.6	0.88	0.103	33:07	1	0
1999e15A	03/03/2000	265	1601	353	0.53	1.8	0.33	0.174	2:46	5	0
1999e16	03/08/2000	195	1402	353	1.23	1.2	0.92	0.338	10:21	3	0.08
1998-99 Subtotal	**-**	**2454**	**28054**	**3275**	**4.23**	**-**	**2.08**	**-**	**-**	**-**	**-**
1999-00 Subtotal	**-**	**3882**	**21974**	**4030**	**10.47**	**-**	**6.41**	**-**	**-**	**-**	**-**
Total	**-**	**6336**	**50027**	**7305**	**14.7**	**-**	**8.49**	**-**	**-**	**-**	**-**

ADT for Freeway Section216600

*sum of three litter outfalls for the Treatment
**flow and rainfall measured at outfall 6-20F

Table 6-7
EVENT LITTER DATA - NORMALIZED BY AREA

Site 8
Bicycle Grate/LID
Control

EVENT NUMBER	EVENT DATE	DRY WEIGHT*	VOLUME*	COUNT*	RAIN VOLUME**	MAX RAIN INTENSITY**	FLOW VOLUME**	MAX FLOW RATE**	EVENT DURATION**	ANT. DRY DAYS**	ANT. RAIN**
		(g/ac)	(ml/ac)	(#/ac)	(in)	(in/hr)	(in)	(cfs)	(hours)	(days)	(in)
1998e01	11/08/1998	466	4540	485	0.45	0.12	0.15	0.077	4:22	-	-
1998e02	11/28/1998	461	3016	266	0.85	4.2	0.53	0.137	11:03	20	0
1998e03	12/01/1998	113	545	57	0.25	0.15	0.09	0.036	3:46	3	0
1998e05	01/25/1999	234	2287	202	0.41	0.6	0.18	0.048	5:43	5	0.5
1998e06	02/09/1999	54	534	148	0.29	0.6	0.1	-	7:04	4	1.3
1998e09	03/15/1999	321	1594	332	0.46	1.2	0.23	0.225	3:51	34	0
1998e10	03/20/1999	57	394	97	0.21	0.3	0.07	0.036	4:32	5	0
1998e11	03/25/1999	53	212	98	0.2	0.15	0.07	0.038	3:50	5	0
1998e12	04/06/1999	328	992	240	0.98	1.8	0.63	-	23:58	5	0.1
1998e13	04/11/1999	39	288	92	1.09	0.3	0.66	0.082	12:39	4	0
1999e03	12/31/1999	687	4003	697	0.24	0.6	0.05	0.086	4:19	53	0.03
1999e05	01/25/2000	487	3011	447	0.55	0.6	0.19	0.105	18:23	25	0.01
1999e06	01/30/2000	13	143	30	0.15	0.05	0.01	0.012	5:13	5	0.11
1999e08	02/10/2000	173	1409	240	0.27	1.2	0.1	0.177	3:48	11	0
1999e09	02/12/2000	311	1022	173	0.65	1.2	0.39	0.339	5:20	2	0
1999e10	02/13/2000	0	0	0	0.33	0.12	0.04	0.016	17:39	1	0
1999e11	02/16/2000	142	615	158	0.74	1.2	0.5	0.268	15:57	2	0
1999e12	02/20/2000	286	1560	291	2.35	2.4	1.8	0.628	31:47	4	0
1999e13	02/23/2000	353	1063	188	1.49	3	1.05	0.918	09:48	2	0
1999e14	02/27/2000	44	420	45	0.19	0.3	0.15	0.092	02:07	4	0
1999e15	03/04/2000	23	184	52	1.59	1.2	0.95	0.197	24:16	1	0
1999e15A	03/03/2000	125	481	153	0.45	1.8	0.25	0.233	2:31	5	0
1999e16	03/07/2000	77	357	107	0.86	1.2	0.54	0.014	11:09	3	0.01
1998-99 Subtotal	**-**	**2128**	**14402**	**2017**	**5.19**	**-**	**2.71**	**-**	**-**	**-**	**-**
1999-00 Subtotal	**-**	**2720**	**14269**	**2580**	**9.86**	**-**	**6.02**	**-**	**-**	**-**	**-**
Total	**-**	**4848**	**28671**	**4597**	**15.05**	**-**	**8.73**	**-**	**-**	**-**	**-**

ADT for Freeway Section227100

*sum of three litter outfalls for the Control

**flow and rainfall measured at outfall 8-23C

Table 6-7
EVENT LITTER DATA - NORMALIZED BY AREA

Site 8
Bicycle Grate/LID
Treatment

EVENT NUMBER	EVENT DATE	DRY WEIGHT*	VOLUME*	COUNT*	RAIN VOLUME**	MAX RAIN INTENSITY**	FLOW VOLUME**	MAX FLOW RATE**	EVENT DURATION**	ANT. DRY DAYS**	ANT. RAIN**
		(g/ac)	(ml/ac)	(#/ac)	(in)	(in/hr)	(in)	(cfs)	(hours)	(days)	(in)
1998e01	11/08/1998	462	4561	870	0.45	0.6	0.18	0.058	4:43	-	-
1998e02	11/28/1998	503	3436	375	0.85	3	0.76	0.988	11:06	20	0
1998e03	12/01/1998	109	516	68	0.26	0.15	0.08	0.048	4:05	3	0
1998e05	01/25/1999	137	1330	189	0.37	0.3	0.17	0.035	5:31	5	0.5
1998e06	02/09/1999	67	322	146	0.29	0.6	0.15	0.08	7:04	4	1.3
1998e09	03/15/1999	440	2524	570	0.46	0.6	0.22	0.157	3:50	34	0
1998e10	03/20/1999	49	319	107	0.19	0.2	0.05	0.012	4:53	5	0
1998e11	03/25/1999	51	296	64	0.2	0.12	0.06	0.012	5:33	5	0
1998e12	04/06/1999	238	883	183	0.98	1.8	0.59	0.212	23:58	5	0.1
1998e13	04/11/1999	48	258	110	1.09	0.6	0.61	0.056	12:34	4	0
1999e03	12/31/1999	191	990	268	0.29	0.6	0.13	-	4:23	53	0.03
1999e05	01/25/2000	199	1020	315	0.55	0.6	0.12	0.033	18:20	25	0
1999e06	01/30/2000	1	17	7	0.15	0.2	0.01	0.003	5:28	5	0.03
1999e08	02/10/2000	156	788	240	0.19	0.6	0.1	0.057	4:03	11	0
1999e09	02/12/2000	358	1732	235	0.62	1.2	0.31	0.097	5:08	2	0
1999e10	02/13/2000	0	0	0	0.33	0.15	0.08	0.01	17:39	1	0
1999e11	02/16/2000	185	689	146	0.78	1.2	0.49	0.086	15:56	2	0
1999e12	02/20/2000	1550	5662	357	2.35	1.2	1.7	0.135	32:22	4	0
1999e13	02/23/2000	736	2311	214	1.49	2.4	1.02	0.049	10:00	2	0
1999e14	02/27/2000	0	0	0	0.19	0.3	0.13	0.021	02:06	4	0
1999e15	03/04/2000	96	434	85	1.59	1.2	1.04	0.047	26:51	1	0
1999e15A	03/03/2000	118	689	207	0.5	1.2	0.21	0.043	2:32	5	0
1999e16	03/07/2000	115	603	135	0.86	1.2	0.41	0.039	11:22	3	0.01
1998-99 Subtotal	**-**	**2103**	**14447**	**2681**	**5.14**	**-**	**2.87**	**-**	**-**	**-**	**-**
1999-00 Subtotal	**-**	**3705**	**14934**	**2208**	**9.89**	**-**	**5.75**	**-**	**-**	**-**	**-**
Total	**-**	**5808**	**29381**	**4889**	**15.03**	**-**	**8.62**	**-**	**-**	**-**	**-**

ADT for Freeway Section227100

*sum of three litter outfalls for the Treatment

**flow and rainfall measured at outfall 8-B001

Table 6–8
COMPARISON OF SITE AADT TO CONTROL OUTFALL LITTER LOADS[1]

Site	Rte	Postmile	Litter Loads			Average Annual Gross Pollutants[2] (kg/ac)	AADT	Rank	% Non-Truck	%Truck	% 2 and 3 Axle Trucks	% 4 and 5 Axle Trucks	Surrounding Land Use
			Average Annual Air-Dried Weight (kg/ac)	Average Annual Volume (l/ac)	Rank								
Site 1E/1W (PM 12.30-12.87)													
1W	105	13.47	5.3	43	2	90	216000	3	90%	10%	6%	4%	Residential
1E	105	13.47	7.5	58	1	115	216000	3	90%	10%	6%	4%	Residential
Site 6 (PM 15.12-15.58)													
6	60	15.93	5.3	39	3	185	236000	2	89%	11%	5%	6%	Residential
Site 8 (PM 5.60-5.95)													
8	60	5.89	3.1	18	4	58	238000	1	90%	10%	5%	4%	Commercial

[1] Loads represent total outfall litter monitored for trigger storms and litter collected from non-trigger events.

[2] Average annual gross pollutant load represents the average annual total wet weight of litter and vegetation collected from trigger and non-trigger events.

7.1 BMP EFFECTIVENESS

This section evaluates the performance of the five BMPs used in the LMPS based on litter monitoring results. Performances are evaluated by calculating the reduction in litter reaching the drainage system outfalls where BMPs are implemented/enhanced (treatment outfalls), as compared to litter collected in the control outfalls.

This section also presents the annual data from the monitoring, explains the performance analysis methodology, and then presents results for area-normalized and flow-normalized data. To allow relative comparisons between the outfalls and sites, litter data from each outfall were normalized by unit area of the outfall catchment (i.e. presented in weight, volume, or items of litter per acre). In addition, the data were normalized by flow (i.e., presented in weight, volume, or items of litter per liter of storm water). Both area-normalized and flow-normalized data were used to assess BMP effectiveness. There are three times as many data points for the area-normalized data as only one treatment control pair was monitored for flow at each BMP site. The area-normalized and flow-normalized analyses are discussed separately in this section.

Discussion and implications of the results are presented in Section 8.

7.1.1 Collected Field Data Summary

Tables 7-1 and 7-2 present the seasonal total litter without normalization at each of the outfalls for litter air-dried weight, volume, and the number of items. The totals are a combination of litter collected during storm events and litter collection bags that were cleared either for false starts or non-monitored events (when there was not enough rainfall for a defined event). In addition, the outfall catchment areas, rainfall, and outfall flow volumes are presented. See Table 4-4 for an explanation of the rainfall and flow totals. The monitored litter for each outfall presented in Tables 7-1 and 7-2 are derived from different catchment areas and different flow volumes (as shown in the tables).

7.1.2 Cumulative Monitoring Results

Plots were prepared for the four study sites to illustrate the litter measured during the monitoring period in both the treatment and control outfalls. The plots show the cumulative quantity of litter monitored during individual events at each of the outfalls, normalized by area. These are presented for each parameter that was investigated (i.e. litter air-dried weight, litter volume, and litter count).

Figure 7-1 is an example of the cumulative plots; the remainder of the plots are presented in Appendix J. The plots illustrate the litter collected at the monitored outfalls, as well as litter collected from the inlet catch basin during, and at the conclusion of, the monitoring period. Close examination of the plots allows a visual QA step that quickly identifies where appreciable differences in litter discharges are monitored, either between outfalls or events.

Table 7-1
1998/1999 STORM SEASON
YEAR 1 LITTER MONITORING RESULTS(2)

Site	Outfall Pair	Outfall Type	Outfall	Catchment Area (ac)	Rainfall[1] (inches)	Flow Volumes[1] (cf)	Litter Air Dried Weight (kg)	Litter Volume (liters)	Litter Item Count
1E	P1	Control	1-B110	0.46			2.8	23.2	3492
		Treatment	1-47	0.43			2.1	17.3	2626
Litter	P2	Control	1-42	0.32	7.56	6485	2.0	20.5	2690
Pick-Up		Treatment	1-46	0.38	8.21	7370	1.0	9.5	1180
	P3	Control	1-B111	0.40			1.9	24.2	2946
		Treatment	1-44	0.44			1.9	16.2	2574
1W	P1	Control	1-52	0.43	7.75	8465	1.3	12.5	2105
		Treatment	1-58	0.37	8.38	11255	2.2	14.8	2080
Street	P2	Control	1-50	0.40			1.7	18.4	2645
Sweeping		Treatment	1-59	0.32			1.6	13.9	2172
	P3	Control	1-51	0.41			1.7	23.5	2884
		Treatment	1-60	0.32			1.2	13.5	2271
6	P1	Control	6-20G	0.51			2.6	22.1	4007
		Treatment	6-20H	0.64			3.3	30.9	4009
Modified	P2	Control	6-20E	0.42	7.43	6948	1.8	16.8	2695
Inlet		Treatment	6-20F	0.42	7.27	7732	2.2	18.7	2273
Grate	P3	Control	6-20C	0.42			2.5	23.1	2849
		Treatment	6-20B	0.42			1.5	15.3	2226
8	P1	Control	8-23C	0.62	6.98	12113	2.0	10.6	1398
		Treatment	8-B001	0.32	7.00	5695	0.8	5.3	1062
Bicycle	P2	Control	8-24D	0.62			2.3	13.9	2326
Grate		Treatment	8-24B	0.42			1.8	13.0	2197
	P3	Control	8-24E	0.58			2.0	14.5	1921
		Treatment	8-24F	0.91			2.7	18.5	3288

(1) See Table 4-4 for explanations of the flow and rainfall totals.

(2) Total outfall litter monitored for trigger storms and litter collected from non-trigger events.

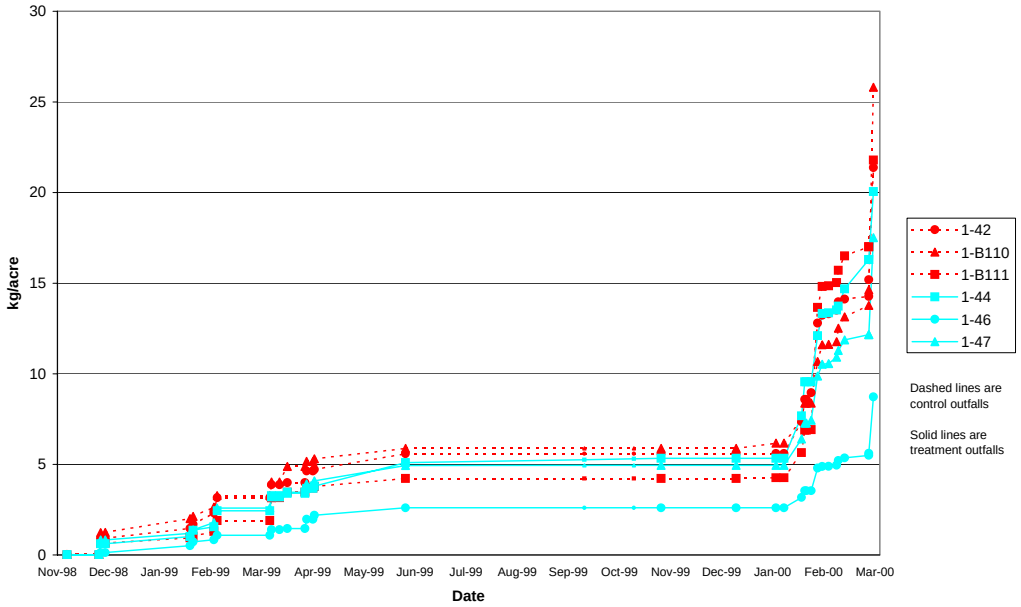
Table 7-2
1999/2000 STORM SEASON
YEAR 2 LITTER MONITORING RESULTS(2)

Site	Outfall Pair	Outfall Type	Outfall	Catchment Area (ac)	Rainfall[1] (inches)	Flow Volumes[1] (cf)	Litter Air Dried Weight (kg)	Litter Volume (liters)	Litter Item Count
1E	P1	Control	1-B110	0.46			3.3	20.0	3351
		Treatment	1-47	0.43			3.0	14.5	2967
Litter	P2	Control	1-42	0.32	9.76	7877	2.7	18.7	2663
Pick-Up		Treatment	1-46	0.38	10.08	8953	1.0	5.1	977
	P3	Control	1-B111	0.40			4.9	30.5	3565
		Treatment	1-44	0.44			4.2	22.6	3021
1W	P1	Control	1-52	0.43	9.29	10282	2.1	12.9	2154
		Treatment	1-58	0.37	9.62	12921	3.3	14.2	2487
Street	P2	Control	1-50	0.40			3.4	16.4	3156
Sweeping		Treatment	1-59	0.32			3.8	11.5	2718
	P3	Control	1-51	0.41			2.9	23.1	3277
		Treatment	1-60	0.32			3.7	15.6	3501
6	P1	Control	6-20G	0.51			3.2	17.6	3314
		Treatment	6-20H	0.64			2.8	16.1	3184
Modified	P2	Control	6-20E	0.42	11.06	10417	2.0	11.6	1850
Inlet		Treatment	6-20F	0.42	10.98	11593	1.5	7.8	1414
Grate	P3	Control	6-20C	0.42			2.2	14.1	2287
		Treatment	6-20B	0.42			1.5	9.1	1443
8	P1	Control	8-23C	0.62	10.22	17841	1.7	8.9	1445
		Treatment	8-B001	0.18	10.37	4722	0.7	3.9	422
LID	P2	Control	8-24D	0.62			0.8	3.5	764
		Treatment	8-24B	0.42			1.5	6.5	1152
	P3	Control	8-24E	0.58			2.4	13.6	2512
		Treatment	8-24F	0.91			3.5	13.8	1858

(1) See Table 4-4 for explanations of the flow and rainfall totals.

(2) Total outfall litter monitored for trigger storms and litter collected from non-trigger events.

Figure 7-1
EXAMPLE PLOT OF CUMULATIVE AIR-DRIED WEIGHT OF LITTER PER ACRE SITE 1E-LITTER PICK-UP



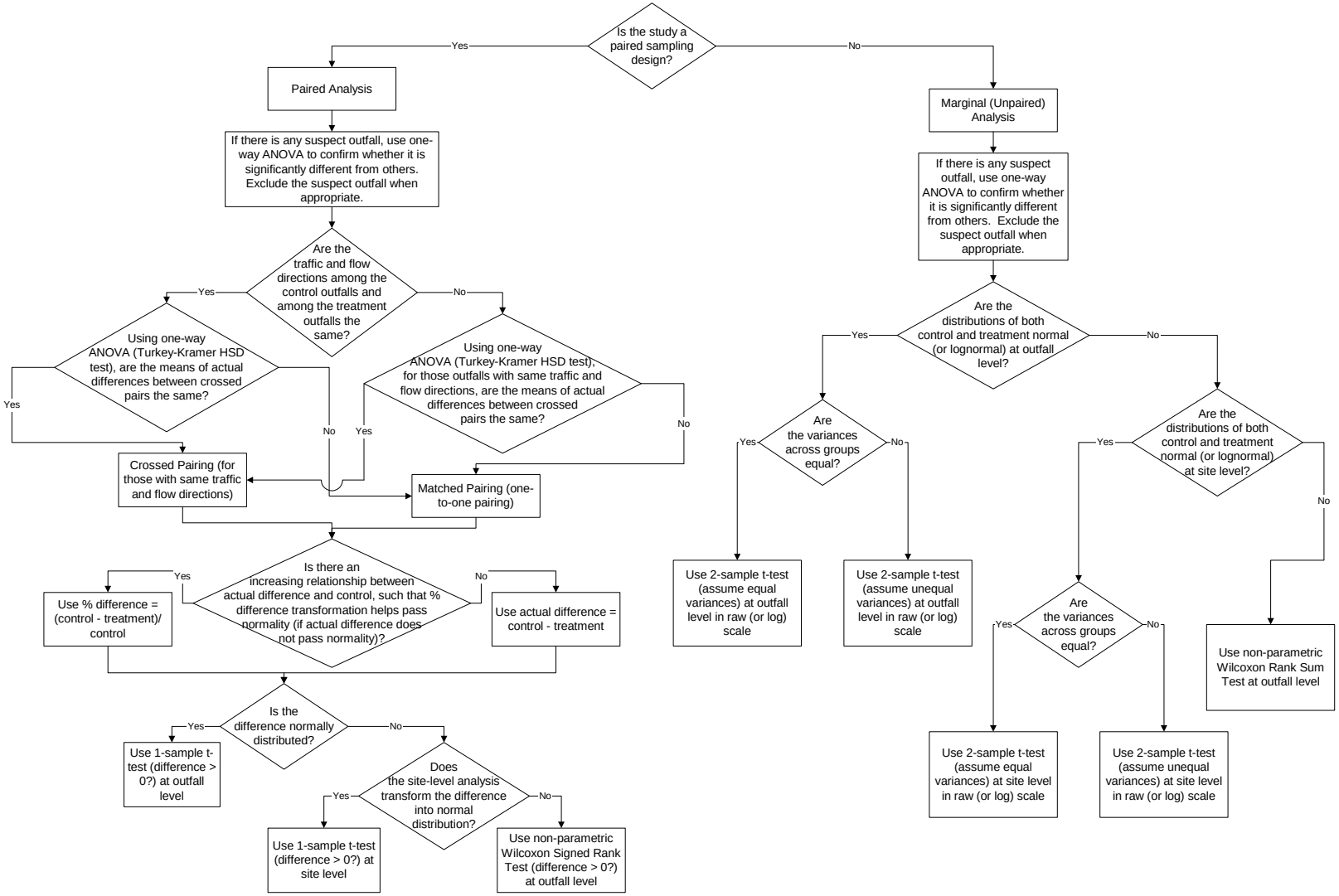
The plots also allow an initial visual qualitative investigation of the performance of the treatment outfalls compared to the control outfalls (dashed lines are control outfalls and solid lines are treatment outfalls). Section 7.1.3 outlines the statistical approach for estimating BMP performance.

One observation from the cumulative plots, presented in Appendix J, is the very different storm pattern between year 1 and year 2 of the study. In year 1, the cumulative litter collected gradually increased throughout the rainy season (November – April). In year 2, a large majority of the litter was collected during an 8-week period (late February – early March), corresponding to the storm pattern for the season. There does not appear to be a disproportionate amount of litter associated with the first rainstorm of either season. Relationships between litter discharge and hydrologic factors are discussed in Section 7.2.1.

7.1.3 Methods of Data Analysis

The BMP effectiveness at each site was evaluated by identifying whether the average event litter discharge was significantly reduced at treatment outfalls relative to control outfalls. A flow chart depicting the methodology for selecting the preferred statistical method is presented on Figure 7-2. The preferred method of statistical analysis for the LMPS is a paired analysis in which each treatment outfall is paired with one or more comparable control outfalls, in contrast to a marginal analysis. The differences in the event litter discharge between paired control and treatment outfalls were analyzed statistically to determine whether the average difference was greater than zero. In addition to analyzing litter discharged at the outfalls in monitored storm events, the total system litter during the study period were also analyzed. The total system litter was calculated as the sum of the cumulative litter discharged at an outfall and the litter retained in the corresponding inlet structure during the study period. Details of the statistical methods are provided in Appendix K.

Figure 7-2
FLOWCHART OF SELECTING THE PREFERRED STATISTICAL METHOD



The main steps of the data analysis were as follows:

1. Normalize data for each outfall by area and flow volume in the catchments. Perform exploratory data analysis (EDA) and check for data anomolies (See Appendix K, Attachment 1).
2. Check whether data differences among the control outfalls and among the treatment outfalls at each site are statistically significant. The appropriate method of statistical analysis is the one-way Analysis of Variance (ANOVA). During the project siting phase treatment and control outfalls that were as similar as possible were selected to maximize the likelihood that they would behave similarly and any differences among them would be purely random. However, unlike a controlled laboratory setting, a field study on an active freeway is a dynamic environment and unanticipated field conditions might affect a particular outfall, making it behave differently from others. If such conditions are known or suspected to have occurred at a site, the statistical analysis may be used to confirm whether an outfall has been significantly affected by these conditions.
3. Evaluate the statistical significance of the observed differences in the litter between comparable pairs of control and treatment outfalls. The appropriate method of statistical analysis is the paired test (a paired t-test if data are normally distributed and a signed rank test if not). Two approaches to pairing the outfalls were investigated – matched pairing and crossed pairing. In the first approach, each treatment outfall was matched with a specific control outfall based on similar field conditions. In the second approach, where treatment and control field conditions are similar for more than one pair, each similar treatment outfall was matched with each of the similar control outfalls. If the ANOVA of all pairs of control and treatment outfalls with the same traffic and water flow directions did not show systematic differences, each treatment outfall could be paired with each of the control outfalls in the same traffic and water flow directions (i.e., the three control outfalls were not different from each other, and separately, the three treatment outfalls were not different from each other). Cross-pairing increases the number of pairs and the resulting data used in analysis, and would be preferred when it is valid.
4. Perform the paired test both at the site level and outfall level, using both actual and percentage differences.

   At the outfall level, each data point at each outfall is considered to be an independent, random sample. At the site level, all control outfalls are grouped together and all treatment outfalls are grouped together. The total litter over all outfalls in each group is considered to be an independent, random sample. The site-level analysis filters some of the “noise” in the data associated with non-normally distributed outfall-level data and may result in normally distributed site-level data sets. If the site-level analysis consistently transforms data into normally distributed data sets, this analysis would be preferred to the outfall-level analysis.
5. If the actual differences show a large amount of variability and do not pass the normality test, transform the data by calculating the percentage difference (i.e., difference between control and treatment divided by the control amount, expressed as a percentage). If the differences show an increasing relationship with the control amount, the percentage difference transformation would be appropriate to consider. This is because, under these circumstances, the transformation may reduce the coefficient of variation of the data and is more likely to

produce normally distributed data. If the actual differences are not normally distributed, but the percentage differences are, use the percentage differences.

6. Evaluate the results of the different methods to determine the statistical significance of the observed differences, taking into account the validity of each method for the given data. If the p-value is less than 0.05, it can be concluded that the results are significant.

7.1.4 Statistical Results – Normalized By Area

Detailed results of the evaluation of BMP effectiveness, normalized by area, are presented in Appendix K. Recommendations regarding the results are presented in Section 8.1. Results (p-values) are summarized in Table 7-3 and discussed below.

Conclusions of the statistical tests are as follows:

1. Increasing the frequency of litter pick-up (Site 1E) from monthly to weekly appears to be effective at a five percent significance level for all parameters (count, volume, and weight). This conclusion is quite robust because it remains unchanged under most of the other methods of paired analysis (see Appendix K). The ANOVA results did not show any significant differences among the three treatment outfalls.
2. Increasing the frequency of street sweeping (Site 1W) from monthly to weekly does not appear to be effective at a five percent significance level for count or weight, but appears to be effective for volume. This conclusion is very robust for count and weight because it remains unchanged under all methods of paired analysis (see Appendix K). The conclusion regarding volume is not robust because it changes if other methods of paired analysis are used. Additionally, the average volume reduction is only about 9% and does not appear to be practically significant.
3. Modified inlet (Site 6) appears to be effective at a five percent significance level for all parameters (count, volume, and weight) This conclusion is fairly robust because it remains unchanged under most methods of paired analysis.
4. Bicycle grate (Site 8) does not appear to be effective at a five percent significance level for any of the measures. This conclusion is very robust because it remains unchanged under all methods of paired analysis.
5. LID (Site 8) appears to be effective at a five percent significance level for reducing count, but not volume or weight. This conclusion is fairly robust because it remains unchanged under most methods of paired analysis.
6. The marginal analysis consistently fails to conclude that the observed differences are significant for any BMP and any measure. For a paired sampling design (which was used in the LMPS), this generally will be the case. This is because a paired analysis typically reduces the data variability caused by factors other than the application of a BMP. In a paired sampling design, other factors can be assumed to affect both control and treatment outfalls in a similar way. The marginal analysis fails to reduce the variability caused by other factors and generally results in a higher variance. The higher variance means that the power of detecting a specified difference would be less.

Table7-3
RESULTS OF EVALUATION OF BMP EFFECTIVENESS (DATA NORMALIZED BY CATCHMENT AREA) (1)

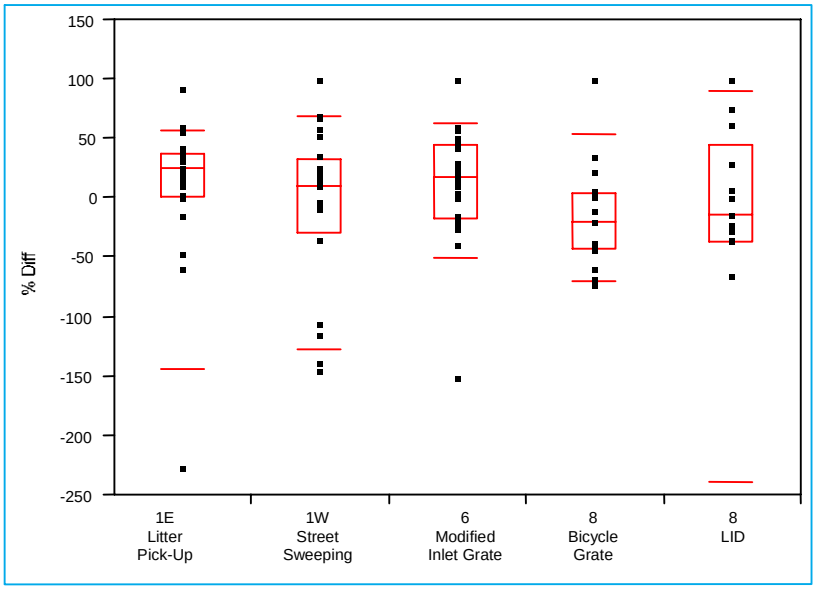
Site	BMP	Measure	Paired Analysis					
			Matched Pairs		Crossed Pairs		Site Level	
			Actual Diff.	% Diff.	Actual Diff.	% Diff.	Actual Diff.	% Diff.
1E	Litter Pickup	Count	***0.000***	***0.001***	***0.000****	***0.000***	***0.003***	***0.040***
		Volume	***0.000***	***0.000***	***0.000****	***0.000***	***0.000***	***0.000***
		Weight	***0.012***	***0.016***	***0.000****	***0.002***	***0.046***	0.059
1W	Street Sweeping	Count	0.351	0.367	0.426*	0.530	0.463	0.370
		Volume	0.109	0.254	***0.032****	0.151	0.256	0.277
		Weight	0.643	0.817	0.656*	0.890	0.774	0.721
6	Modified Inlet	Count	***0.001***	***0.023***	***0.000****	***0.002***	***0.028***	***0.030***
		Volume	***0.022***	***0.047***	***0.000****	***0.002***	***0.045***	***0.013***
		Weight	***0.017***	0.161	***0.000****	***0.020***	0.064	0.051
8	Bicycle Grate	Count	0.918	0.890	0.991*	0.985	0.912	0.905
		Volume	0.273	0.315	0.546	0.351	0.626*	0.335
		Weight	0.297	0.173	0.321	0.429	0.133*	0.635
8	LID	Count	0.512	0.846	0.566	0.924	0.682	0.607
		Volume	0.746	0.943	0.816	0.965	0.604	0.830
		Weight	0.815	0.966	0.901	0.991	0.773	0.793
1E (w/o outfall 1-46)	Litter Pickup	Count	0.179	0.319	***0.013***	0.056	0.125	0.329
		Volume	***0.018***	***0.027***	***0.000***	***0.001***	***0.011***	***0.009***
		Weight	0.578	0.546	0.481	0.685	0.526	0.555
8 (w/o outfall 8-24D)	LID	Count	***0.041***	0.119	***0.008****	***0.046***	***0.040***	0.137
		Volume	0.343	0.511	0.241	0.397	0.338*	0.607
		Weight	0.314	0.489	0.279*	0.379	0.446	0.527

* Preferred Method (See Appendix K Table 3)
(1) Large bold font indicates that the average litter amount in the control is greater than the treatment based on statistical testing (α=0.05).
(2) Preferred method is without Control 8-24D below.
(3) Preferred method is 1E above.

Detailed results of BMP effectiveness normalized by area are presented in Appendix K. The following discussion describes the results for an example litter measurement parameter. The example illustrates the percentage difference by count using outfall-level data. Positive values of percentage difference mean that the average litter discharged at treatment outfalls is lower than at control outfalls, thus suggesting that the BMP may be effective in reducing litter.

The box plot (Figure 7-3) illustrates the range of litter reduction efficiencies that could be expected for the different BMPs. The plot shows that litter pickup (Site 1E) demonstrates a reduction in the litter measured in count (items/acre) for 75% or more of the events, with the 25th-percentile above 0% difference. Modified inlet (Site 6) may appear to reduce litter measured in count, with the 25th-percentile just below 0% difference.

Figure 7-3
DISTRIBUTION OF EVENT PERCENTAGE DIFFERENCE BY BMPS FOR COUNT (DATA NORMALIZED BY CATCHMENT AREA)



7.1.5 Statistical Results – Normalized By Flow

Detailed results of the evaluation of BMP effectiveness normalized by flow are also presented in Appendix K. Results (p-values) are summarized in Table 7-4 and discussed below. Recommendations regarding these results are presented in Section 8.1.

One of the three pairs of control/treatment outfalls at each site has flow volume data, and only monitored storm events have flow volume data, therefore, the number of data points are substantially smaller than the normalized by catchment area analysis. Thus, the results and conclusions are less powerful for data normalized by flow volume. The statistical test results confirm that litter pick-up (Site 1E) and modified inlet (Site 6) appear to be effective in litter reduction in all three measures (as seen in normalized by catchment area analysis). Also, bicycle

Table 7-4
RESULTS OF EVALUATION OF BMP EFFECTIVENESS
(DATA NORMALIZED BY FLOW VOLUME) (1)

Site	BMP	Measure	Paired Analysis Matched Pairs Actual Diff.	% Diff.
1E	Litter Pickup	Count	***0.000***	***0.000****
		Volume	***0.000****	***0.001***
		Weight	***0.000****	***0.002***
1W	Street Sweeping	Count	***0.045****	***0.000***
		Volume	***0.027****	***0.001***
		Weight	***0.082****	***0.024***
6	Modified Inlet	Count	***0.030****	0.060
		Volume	***0.016****	***0.030***
		Weight	***0.002****	***0.022***
8	Bicycle Grate	Count	0.402*	0.500
		Volume	0.104*	0.213
		Weight	0.090*	0.057
8	LID	Count	0.840	0.895*
		Volume	0.449*	0.748
		Weight	0.449*	0.593

* Preferred Method (See Appendix K Table 5)

(1) Large, bold font indicates that the average litter amount in the control is greater than the treatment based on statistical testing (α=0.05).

grate (Site 8 in 1998/1999) and LID (Site 8 in 1999/2000) do not show significant litter reduction. For the actual difference analysis, street sweeping (Site 1W) appears to be effective for count and volume, but not for weight.

The results of flow-normalized analysis are consistent with those of area-normalized analysis for all parameters except for two for the preferred statistical method. The exceptions are count at Site 1W and count at Site 8 (LID). For count at Site 1W, the reduction is significant for the flow-normalized analysis, but not for the area-normalized analysis. For count at Site 8 (LID), the reduction is not significant for the flow-normalized analysis, but is significant for the area-normalized analysis. As noted above, the number of data points is substantially larger for the area-normalized analysis and hence the results of that analysis are considered more reliable.

7.1.6 Results of Total System Litter Analysis

Litter data were collected for two components of the storm drain system – the litter retained in the inlet during a given study period and the litter discharged to an outfall in each monitored storm event during the study period. Each inlet was cleaned at the start and end of the study

period. These data provided an estimate of the litter retained in the system during the study period. The total system annual litter for each outfall was calculated as the sum of two components: (1) the litter retained in the system in the study period (measured using the inlet cleanout data); and (2) the cumulative litter collected at an outfall in monitoring events during the study period. The differences in the total system litter were analyzed statistically using the methods described in Section 7.1.3. The details of the analysis are presented in Appendix K.

The main conclusions of the analysis of the total system litter were identical to those of the analysis of the outfall-discharged litter with the only exception of count at Site 8 (LID). Thus, litter pickup (Site 1E) and modified inlet (Site 6) appear to be effective in reducing both the total system litter and the litter discharged to an outfall in storm events. Street sweeping (Site 1W) appears to reduce both total system litter volume and outfall-discharged litter volume, but not for litter count and weight. Bicycle grate (Site 8, 1998/1999) and LID (Site 8, 1999/2000) do not appear to be effective in reducing either the total system litter or the litter discharged to an outfall in a storm event. At Site 8 (LID), the count reduction is not significant at the level of the total system litter, but is significant at the level of outfall-discharged litter. The data at Site 8 (LID) show that the average litter count is lower for the treatment in the outfall-discharged litter, but higher in the litter retained in inlets. The net effect is that the count reduction is not significant for the total system. It should be noted that the LID construction was completed in October 1999. As a result, it was not in place during the late spring through early fall dry season.

7.1.7 Statistical Analysis of Water Quality Data

The chemical water quality data were evaluated to characterize the effectiveness of the litter BMPs in removing pollutants from storm water. The approach used for evaluating chemical water quality is similar to the approach used for litter data. A paired analysis was done to determine whether or not there was a significant difference between the station or event mean concentrations (EMCs) of the control and treatment outfall for each of the sites. By design, only one pair of treatment and control outfalls for each BMP was monitored for chemical water quality data. This allows a "matched pair" analysis for chemical water quality data for each BMP. If either the treatment or control outfall was non-detect one-half of the reported detection limit was assigned to the sample that was below the detection limit.

The steps involved in the data analysis are described as follows:

1. Calculate the difference between each pair of control and treatment outfalls for each BMP, for each storm event.
2. Test the distribution of difference for normality using Lilliefors Test at 5% significance level.
3. Hypothesis testing:

   Null hypothesis, H_0: $\mu_{difference} = 0$

   Alternative hypothesis, H_A: $\mu_{difference} \neq 0$

1) If the distribution of *difference* is normal, the one-sample two-sided t-Test at an overall 5% significance level is used to test the hypotheses. A minimum sample size of 7 is

recommended for this test to obtain meaningful results (USEPA, 1989). Because a large number (more than 25) of chemical parameters would be analyzed, the overall significance level was adjusted using the Bonferroni method to reduce the false positive error. In order to maintain an adequate power of detecting specified differences, USEPA has recommended that the significance level for an individual test be no less than 1% (USEPA, 1989). Based on this guideline, the hypothesis testing was performed using a significance level of 1% for all individual tests. The two-sided test is appropriate because the interest is in finding whether a BMP increases or decreases concentrations. If the two-sided p-value of the t-Test is less than 0.01, the null hypothesis is rejected and it is concluded that the average *difference* is different from 0, i.e., there is a statistically significant change in the chemical constituent concentration at the treatment outfalls.

2) If the distribution of *difference* is not normal, the two-sided Wilcoxon Signed-Rank Test (a non-parametric test) is used instead of the t-Test at an overall 5% significance level. A minimum sample size of 9 is recommended for this test (USEPA, 1989). Again, a significance level of 1% was used for individual tests based on USEPA guidelines. If the two-sided p-value of the Wilcoxon Signed-Rank Test is less than 0.01, the null hypothesis is rejected and it is concluded that the average *difference* is different from 0.

The Lilliefors test showed that normal distribution could be assumed for 55% of the data sets, but not for the remaining data sets. Because the transformation to percentage differences did not improve the normality of the non-normal data sets and because actual differences are less sensitive to small values at the control outfalls than percent differences, the actual paired difference was chosen for BMP effectiveness analyses.

The paired t-test or Wilcoxon Signed-Rank test was done on the difference between treatment and controls and this evaluation indicated that for the vast majority (93%) of the parameters, the mean or median difference was not significantly different from zero. However, there were 9 individual tests for which the mean or median difference between treatment and control EMCs was different from zero. The results that show statistical significance are presented in Table 7-5. At Site 8 (LID), none of the constituents showed a statistically significant difference. At Sites 1E, 6, and 8 (Bicycle), only one constituent showed a statistically significant difference. The difference at Site 8 (Bicycle) is only marginally significant, because the sample size is seven, which barely meets the minimum sample size criterion, and the p-value is only slightly below the threshold of 0.01. At Site 1W, 6 constituents showed a statistically significant difference. Five of these differences are negative, suggesting that the concentrations are higher on the treatment side.

Examination of box plots done on the difference data also showed that the confidence interval about the median of these distributions did not include zero, another indication that the concentrations are different. Figure 7-4 presents the box plots of the distributions for parameters that the statistical tests indicated were different between the BMP treatment and control sites.

The analyses performed on the water quality data failed to show that any of the BMPs consistently reduced or increased chemical constituent concentrations in storm water runoff for the parameters monitored. Site-1W (street sweeping) did have several pollutants for which the difference between treatment and control sites was statistically significant; all of which (except

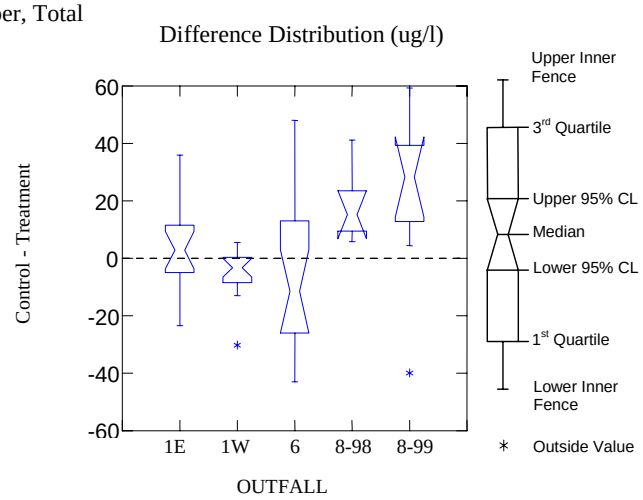
for NO3-N:Total) were negative. This would indicate that increasing street sweeping from monthly to weekly could actually be increasing the average chemical constituent concentration in runoff at this site.

Table 7-5
SIGNIFICANT RESULTS ON MEAN OR MEDIAN DIFFERENCE BETWEEN TREATMENT AND CONTROL OUTFALLS

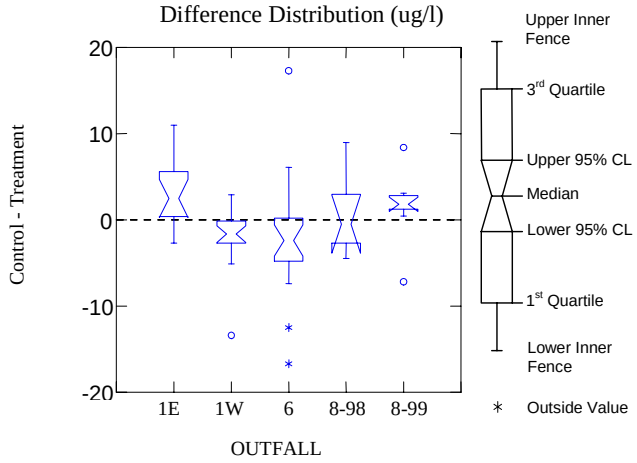
Site	Parameter	Number of Samples	P-Value (Two-sided)	Mean or Median Difference (Control – Treatment)	Standard Deviation of Mean Difference	Units
Litter Pickup						
Site-1E	Copper, Dissolved	16	0.008	2.85	3.76	ug/l
Street Sweeping						
Site-1W	Hardness	17	0.006	-15.41	23.95	mg/l
Site-1W	TPH (Diesel)	13	0.002	-7.49	9.98	mg/l
Site-1W	Copper, Total	18	0.004	-5.12	7.98	ug/l
Site-1W	Copper, Dissolved	18	0.010	-2.05	3.45	ug/l
Site-1W	Nickel, Dissolved	18	0.007	-1.61	2.21	ug/l
Site-1W	NO_3-N	17	0	0.58	0.45	mg/l
Perforated Plate						
Site-6	Hardness	17	0.005	14.59	27.43	mg/l
Bicycle Grate						
Site-8-98	Copper, Total	7	0.009	18.30	12.74	ug/l

Figure 7-4
BOX PLOTS OF CONSTITUENTS THAT SHOWED A STATISTICAL DIFFERENCE BETWEEN TREATMENT AND CONTROL OUTFALLS

Copper, Total



Copper, Dissolved



Nickel, Dissolved

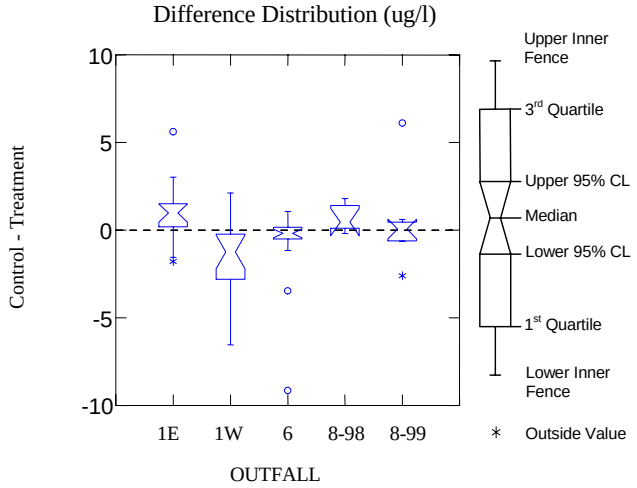
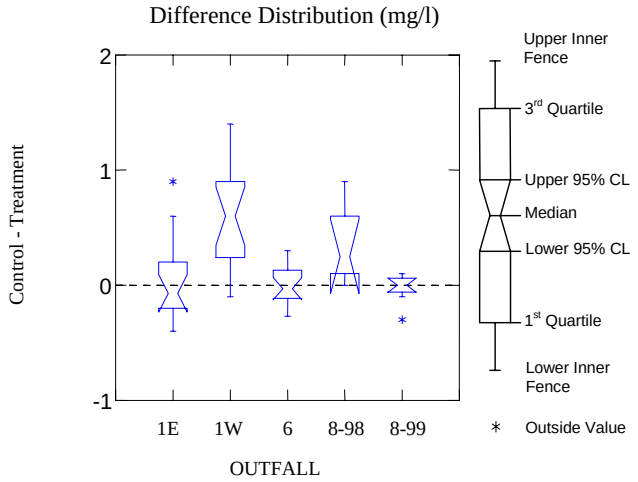
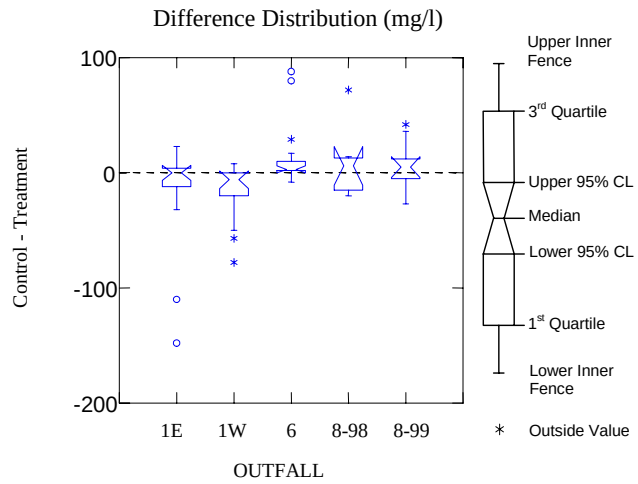


Figure 7-4 (continued)
BOX PLOTS OF CONSTITUENTS THAT SHOWED A STATISTICAL DIFFERENCE BETWEEN TREATMENT AND CONTROL OUTFALLS

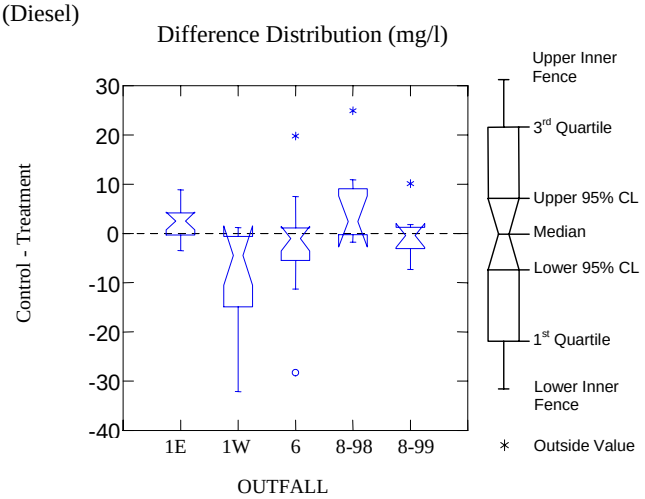
NO3-N



Hardness



TPH (Diesel)



7.2 OTHER ANALYSES

Though the objective of the LMPS is to evaluate the effectiveness of BMPs in reducing litter on Caltrans highways, the data collected allow for a general analysis of trends that might exist between litter and various other elements, such as site hydrology, chemical constituents, and inlet volumes. Analysis of trends between litter and each of these elements is presented in subsections below.

7.2.1 Evaluation of Relationships Between Litter and Site Hydrology

Data collected during the LMPS can be used to examine the relationship between storm water litter discharge and hydrologic factors. Data presented previously in this report may suggest a relationship between total seasonal litter and total seasonal rainfall and flow.

Table 6-7 shows total annual litter from outfall monitoring and total seasonal rainfall. Rainfall totals for year 2 of monitoring were higher than totals for year 1 at all sites. Seasonal outfall litter discharges were also higher at all control sites during year 2 of monitoring. The increased amount of litter during year 2 is also apparent in the cumulative litter plot shown in Figure 7-1. The cumulative litter plot also shows that litter is transported to the outfalls and collected during wet weather periods.

If a correlation between litter and hydrologic factors exists for the LMPS it would be consistent with the findings of Allison et al. (1998). Allison et al. conducted grab sampling of gross pollutants (combined vegetative material and litter) at one to twenty minute intervals during storms in large (2.5 to 20 Ha) urban catchments during a one year period (1994-1995). In contrast, the LMPS conducted litter monitoring over a two year period in small freeway catchments (<0.4 Ha), collecting all litter discharged during a storm after the event. Allison et. al. found that the highest amount of gross pollutants occurred mostly during peak discharges. Allison et. al. also found that during rain periods of similar magnitude that occurred frequently (i.e. two distinct rain periods on the same day), gross pollutant discharges were similar. Allison et. al. stated that these observations suggest a relationship between rainfall, runoff volume, and gross pollutant loads. These observations were based on one year of data and are not supported by statistical analysis.

In order to examine the relationship between hydrologic factors and litter discharge more closely for LMPS data, correlations were examined between event litter discharges and various hydrologic parameters. Litter data were compared to peak flow, total flow, and rainfall intensity, and antecedent dry period for monitored events at each outfall. Control outfalls with flumes (chemical water quality sites) were used in the comparison with peak and total flow, while all outfalls were used in the comparison with antecedent period. The antecedent dry period used was the number of days between rain events of 0.1 inches or greater. The data are presented on Figures 7-5 to 7-9. These figures illustrate that no clear relationship between event litter discharges and any of the individual factors can be identified. Several regressions were performed on the data sets, including linear, logarithmic, and 2nd and 3rd order polynomial. None of these regressions demonstrate that a strong correlation between a single event parameter and litter load exist. An r-squared value of 0.85 is typically considered the minimum value that indicates a good correlation. In

addition, similar plots were prepared, though not presented here, to look at any site-specific correlations and none were found. Intuitively, it should be expected that a multi-factor relationship exists. For example, if two intense storms occur days apart, the first storm would flush the majority of the litter, leaving little for the second storm, even if the second storm was more intense.

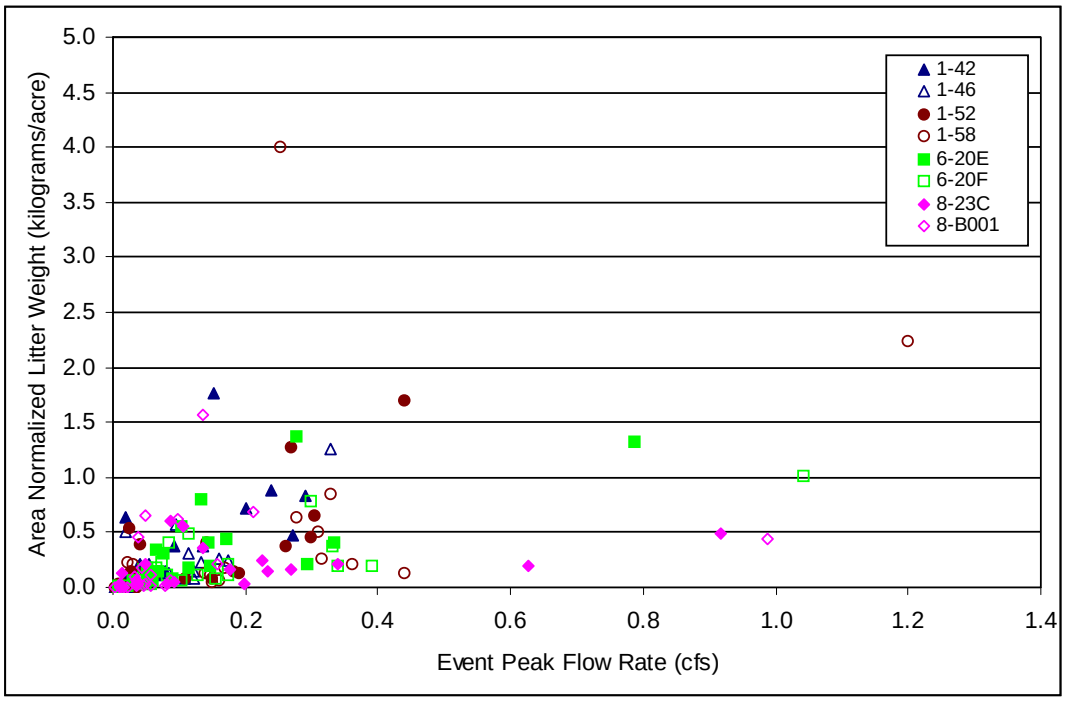
Several different analyses were conducted in an attempt to identify a multi-factor relationship that might exist. Figure 7-9 is an example of one analysis conducted that attempts to identify the relationship between litter and flow, also taking the antecedent dry period into account. Other various multi-factor analyses were conducted, such as using alternative groupings of antecedent days and evaluating multi-variable relationships between event total flow, event litter, and antecedent days. These additional analyses also failed to identify a strong correlation.

The event-by-event analysis described above was initially selected as the best method to assess correlations between hydrologic data and litter discharge because it provides an opportunity to use a large number of data points. Because the event-by-event analysis did not reveal any correlations, additional correlations were performed looking at seasonal totals for litter, flow, and rainfall. The correlation between total seasonal litter (air-dried weight) and flow with data from all sites plotted together was poor (R^2 = 0.4). The data population was low for Site 6 (n=4) and Site 8 (n=4) because there are only two stations with rainfall and flow data at each site and two years of data. Therefore, regression was not considered meaningful at these sites. A site-specific regression for Site 1 data was performed (n=8). The highest r-squared value was0.65 for the correlation between total seasonal litter (air-dried weight/both trigger and non-trigger events) and total seasonal rainfall (See Figure 7-10), where the seasonal litter load was the area normalized combined loads of treatment or control outfalls.

7.2.2 Evaluation of Relationship Between Litter and Chemical Constituent Quantities

Event litter and chemical constituent data for each outfall were plotted to determine if a correlation exists between litter and chemical constituents. Constituent loads were calculated by multiplying the constituent concentration by the total flow per event at the water quality sites. Probability plots were then created with both the litter and chemical constituent data. These plots indicate that both the litter and constituent chemical data are

Figure 7-5
CORRELATION BETWEEN EVENT PEAK FLOW AND LITTER LOAD



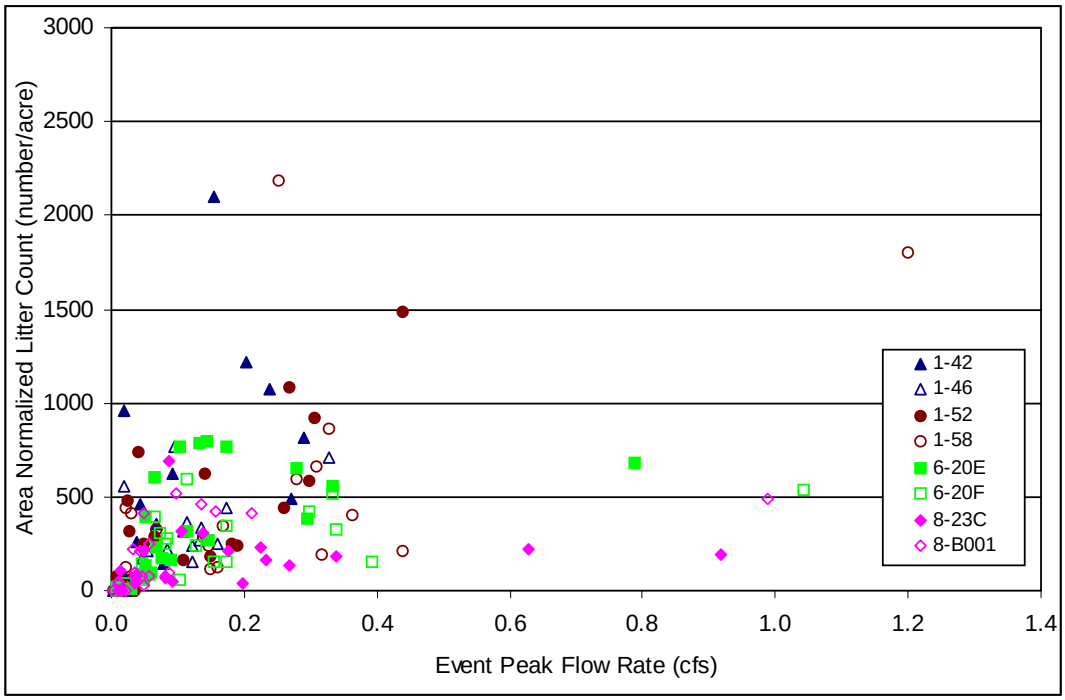
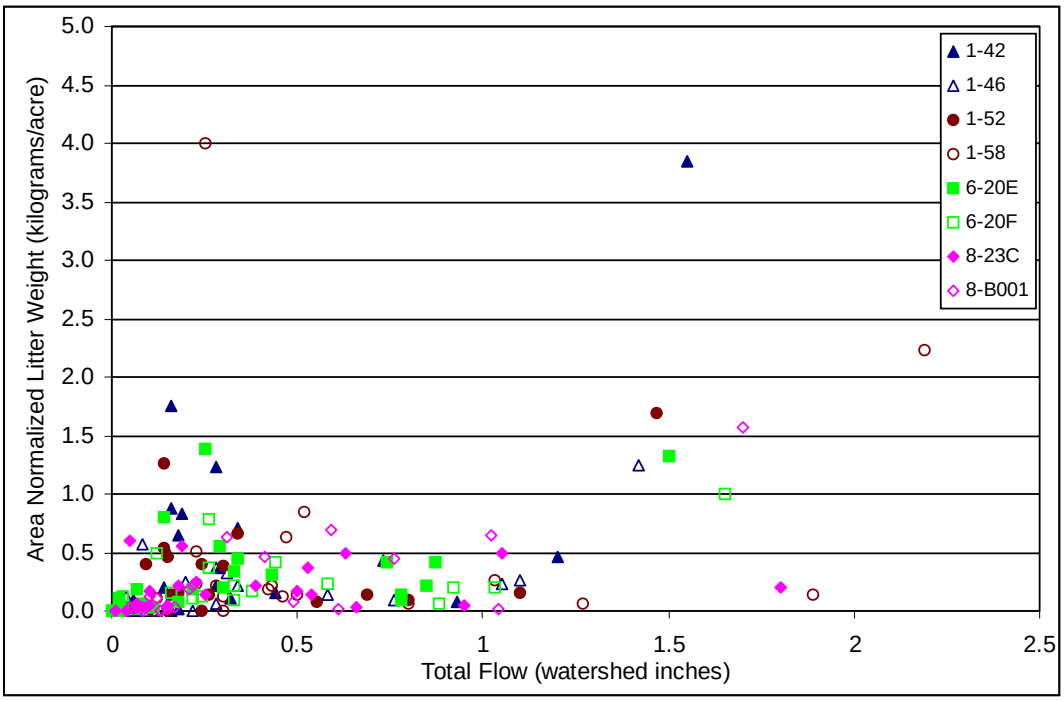


Figure 7-6
CORRELATION BETWEEN EVENT TOTAL FLOW AND LITTER LOAD



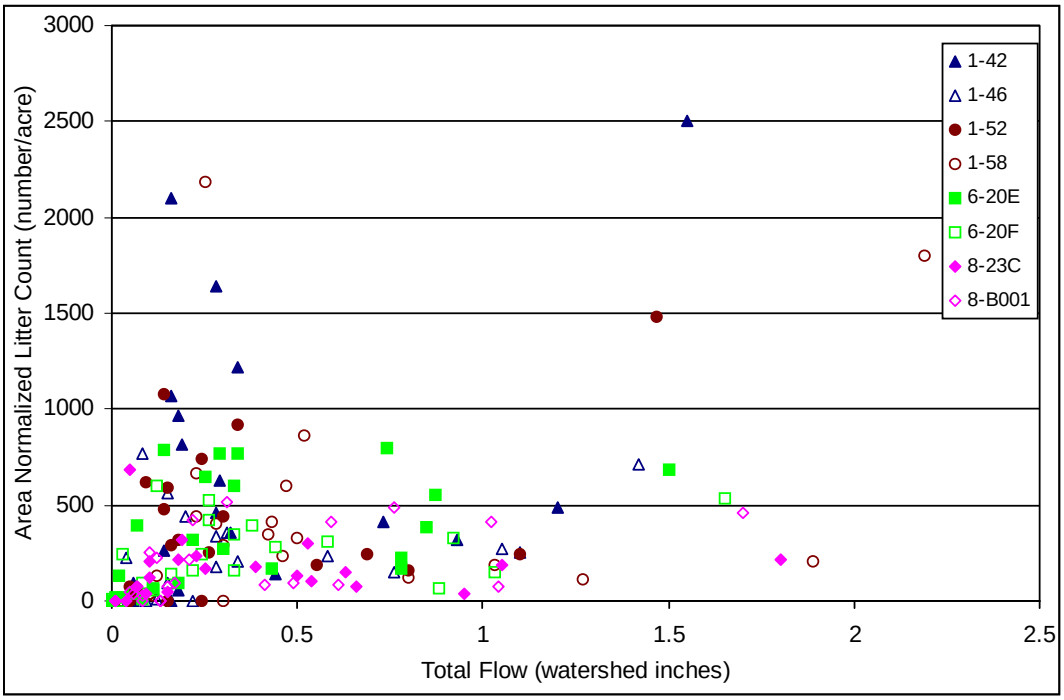
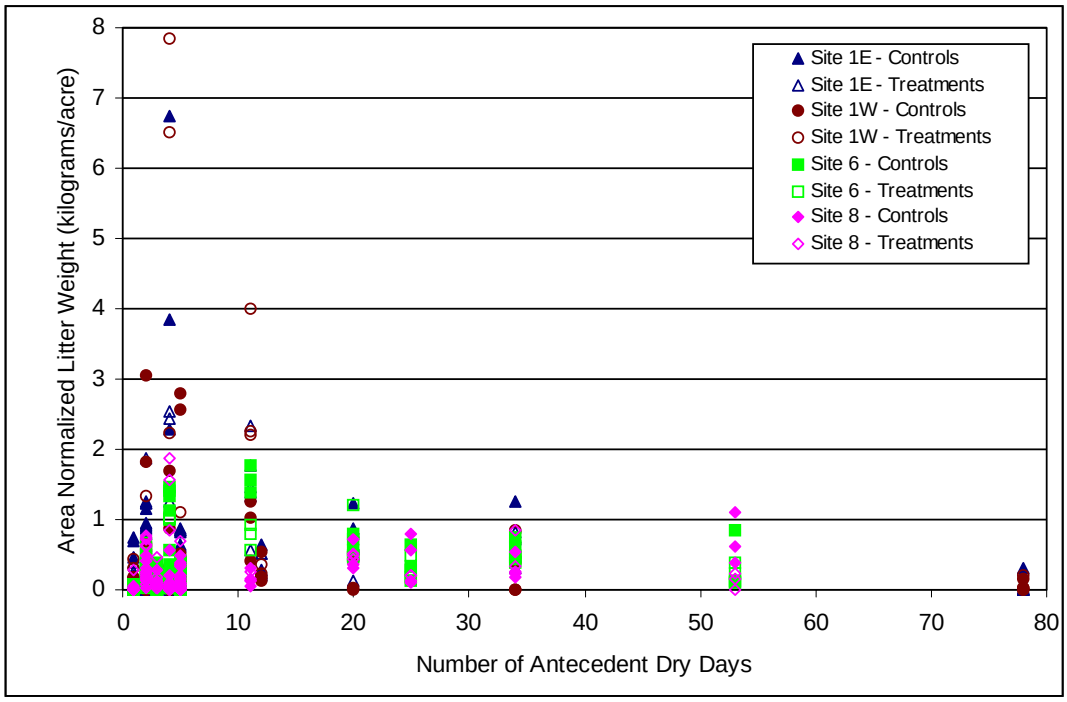


Figure 7-7
CORRELATION BETWEEN ANTECEDENT DAYS AND LITTER LOAD



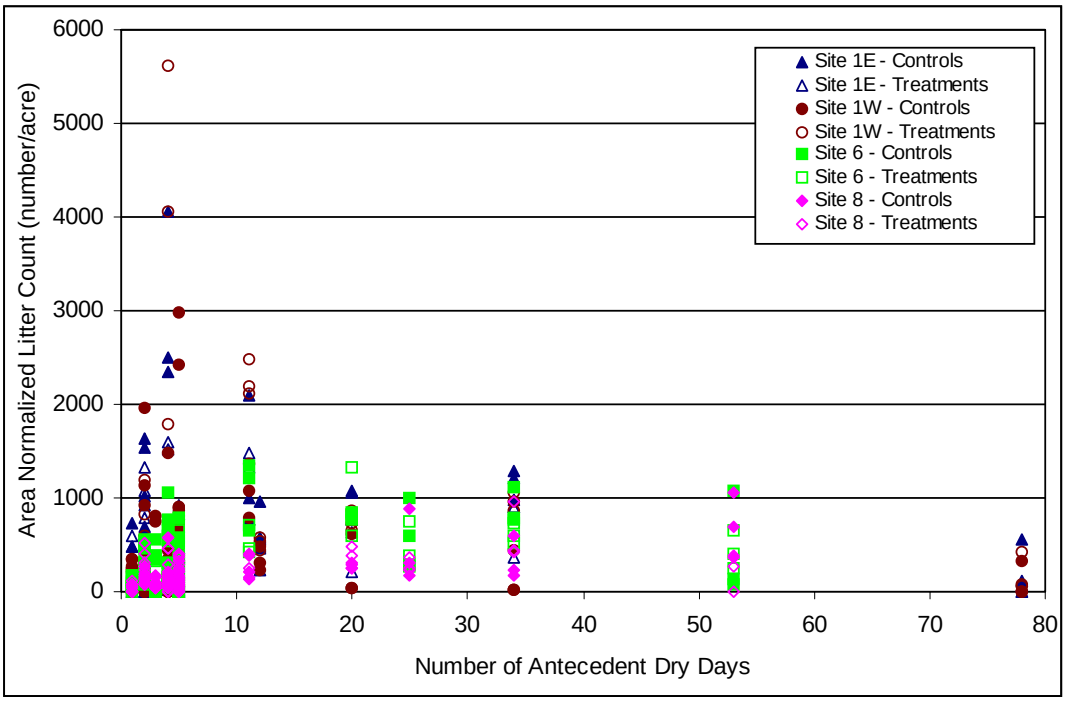
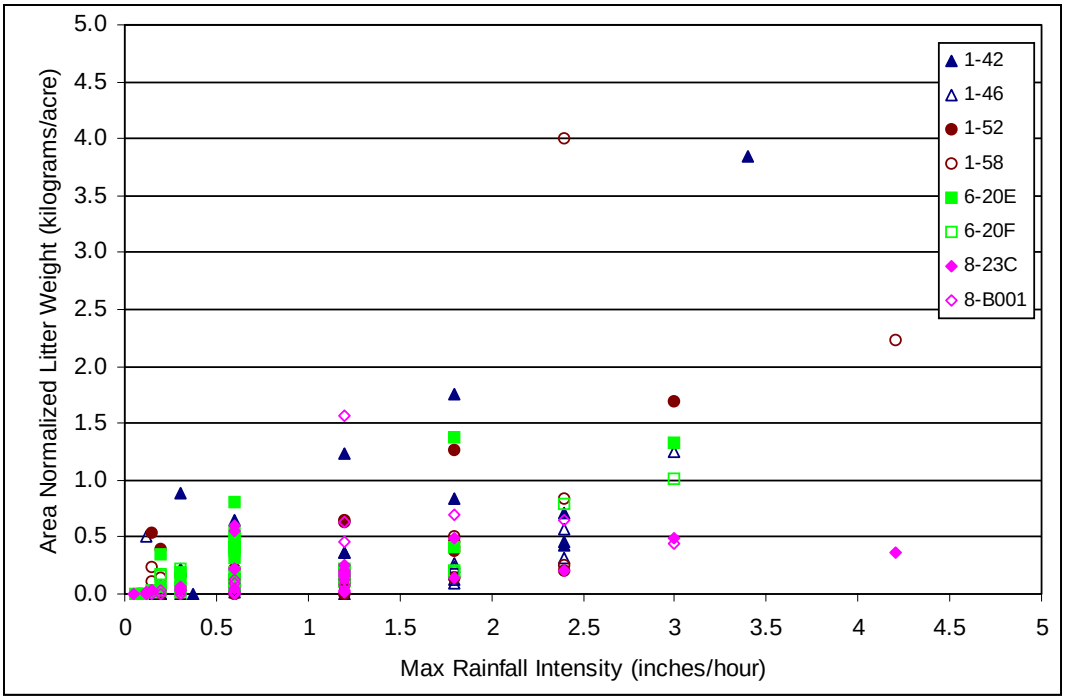


Figure 7-8
CORRELATION BETWEEN EVENT MAXIMUM RAINFALL INTENSITY AND LITTER LOAD



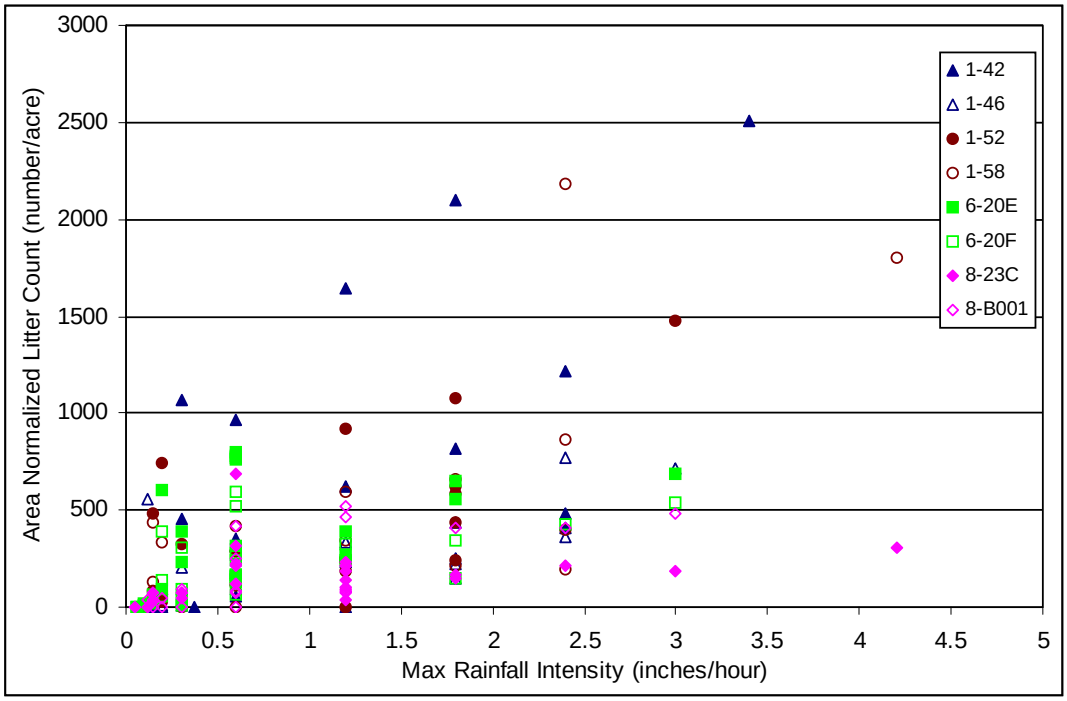


Figure 7-9
CORRELATION BETWEEN EVENT PEAK FLOW, ANTECEDENT DAYS, AND LITTER LOAD

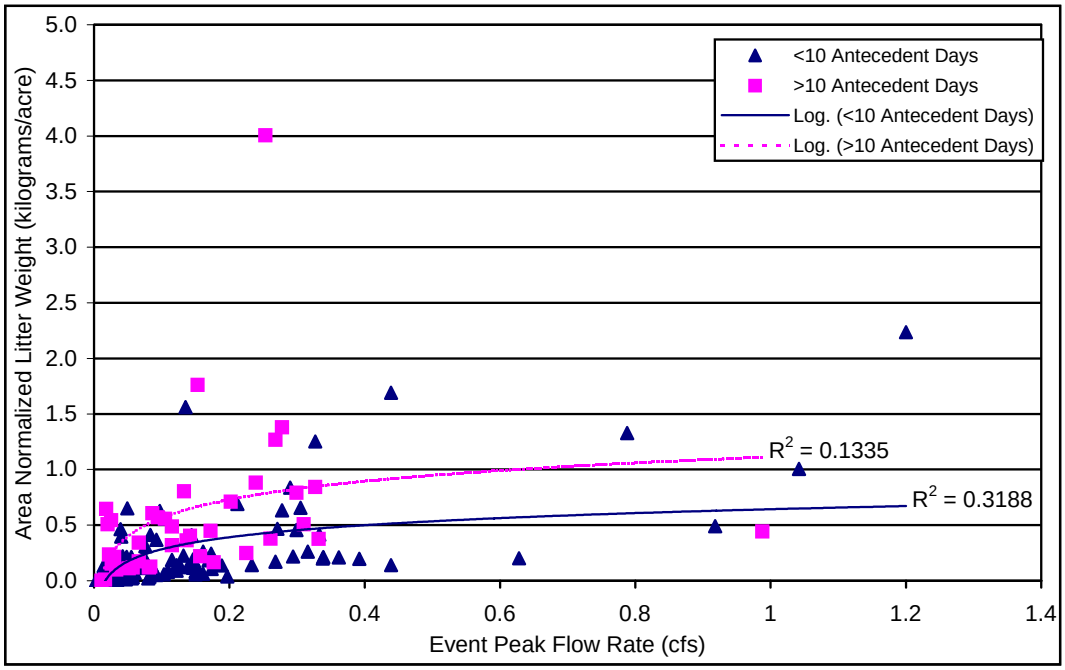
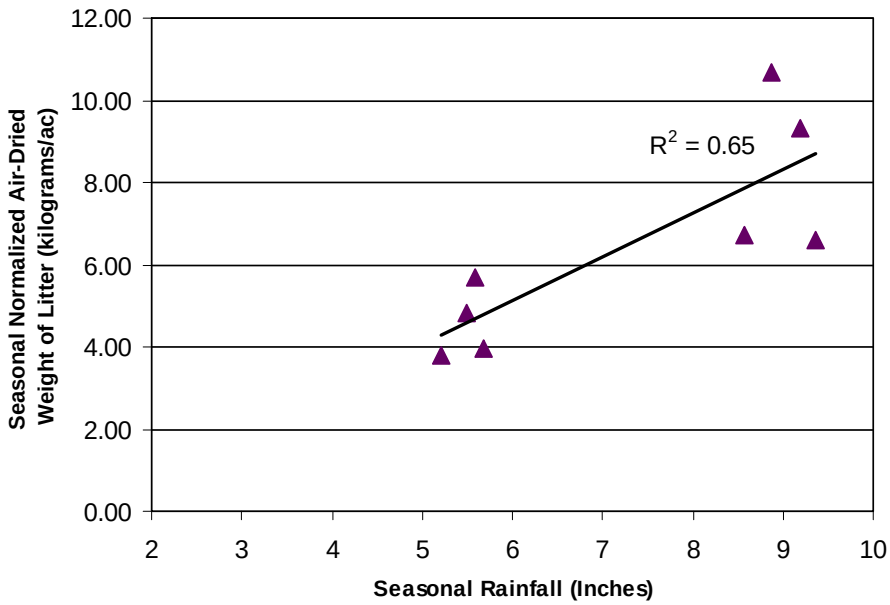


Figure 7-10
SEASONAL RAINFALL (IN) VS. TOTAL AIR-DRIED WEIGHT - COMBINED SITE OUTFALLS - TRIGGER AND NON-TRIGGER EVENTS



relatively log-normally distributed and would be best represented in log-log space. Scatter plots were then generated for each constituent and outfall to evaluate the relationship between the log-transformed data sets. These plots are presented in Appendix L. Regression analyses were conducted for each plot. A linear model of the log-transformed data was selected from a variety of standard functional relationships (e.g., linear, exponential, polynomial, and power functions). In the absence of either a theoretical or empirical basis for utilizing any of the more complex models examined, the linear fit (in log-log space) was chosen as the best approximation for inclusion in this report. The highest r-squared value is 0.66 for the relationship between litter and oil and grease. An r-squared value of 0.85 is typically considered the minimum value that indicates a good correlation. The results indicate that there is no correlation between litter and chemical water quality for any of the constituents monitored.

7.2.3 Assessment of Wet vs. Dry Inlet Deposition for the LID BMP

As discussed in Section 4.3.1, inlet deposition patterns were monitored at the Site 8 (LID) inlets to estimate the relative amount of material that makes its way into inlets during dry weather as opposed to wet weather. This information can be used in evaluating the benefit of pursuing dry weather deposition BMPs such as the LID. From June 1999 through March 2000, inlet deposition measurements were taken at the 24 LMPS study inlets. In addition, the quantity of material that was transported through the drain system during specific storm events was measured by collecting material (vegetative material and litter) at outfalls associated with each inlet. Although the LMPS was not designed with the above objective in mind, measurements collected may be used to estimate

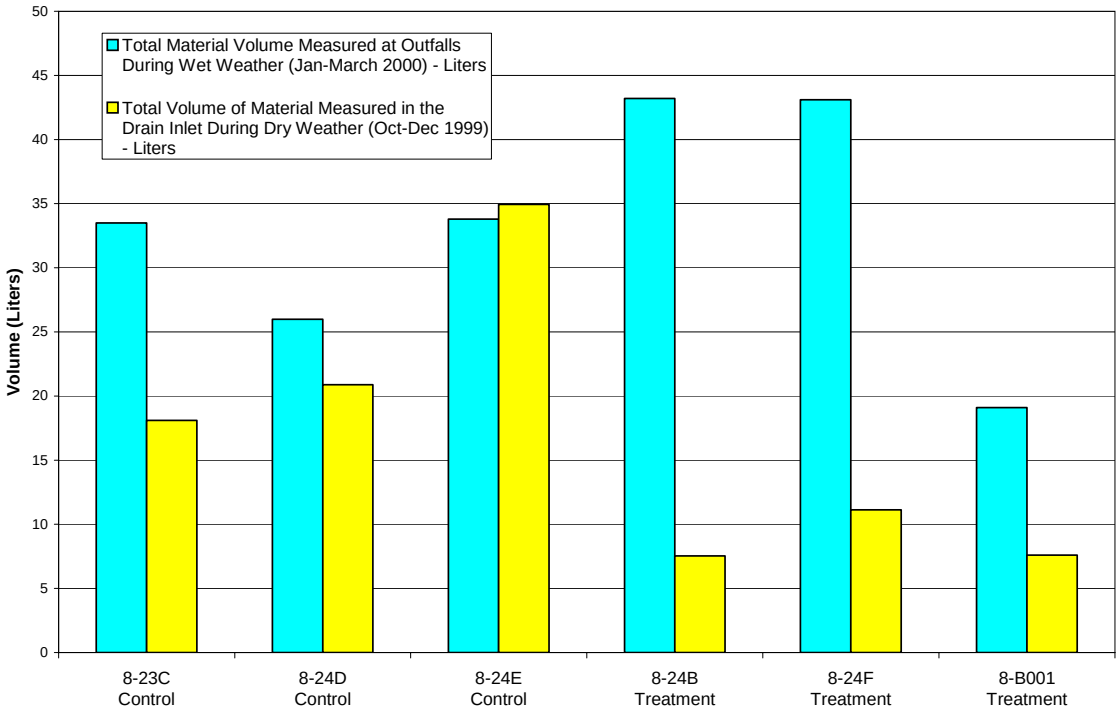
dry vs. wet weather deposition of material at the Site 8 inlets to evaluate the benefit of the LID to reduce dry weather deposition.

Figure 7-11 shows the comparative volumes of the following material measured in the drainage system during year 2 of monitoring:

- The total volume of material captured at the outfall due to storm event monitoring (January - March 2000)
- The total volume of material measured to accumulate in the inlets during dry weather (October - December 1999).

Figure 7-11 shows that for the LID treatment inlets (8-24B, 8-24F, and 8-B0001), the amount of material measured at the outfall substantially exceeds the amount of material that accumulated in the inlets during dry weather. Because the LID reduces dry weather deposition as shown in Figure 7-11, there was little material in the LID treatment inlets (10 liters or less per inlet) prior to the storm season and therefore little inlet material available for transport via flow to the outfalls. However, there were similar quantities of material monitored in the outfalls from both treatment and control inlets, suggesting that the large size openings of the LID allow larger items to enter the drainage system during storms. The LIDs were installed in October 1999, which allowed three months of dry weather accumulation in both treatment and control inlets. If dry weather inlet volumes were larger at the start of the rain season, a larger amount of material may have been transported to the outfalls from the control inlets, thereby off-setting the amount of material transported through the LIDs during storms.

Figure 7-11
OUTFALL WET WEATHER MATERIAL VOLUMES (NOT NORMALIZED) AND DRY WEATHER INLET MATERIAL VOLUMES - Site 8 (LID)



The LMPS is one of numerous research projects currently conducted by Caltrans with the common goal of improving the quality of runoff from Caltrans highway drainage facilities. The focus of the LMPS was field-testing and evaluation of litter management practices to assess their effectiveness in reducing litter that is discharged from Caltrans storm water conveyance systems. The conclusions and recommendations are presented in separate subsections. Each subsection is organized into two parts, one related specifically to the study objective of evaluating BMP effectiveness and the second for other data observations collected during the course of the LMPS. The LMPS focuses on litter (manufactured material) that can discharge through the Caltrans freeway storm drain system that are larger than ¼ inch, and that could impact beneficial uses of receiving waters. All the BMPs tested were at the freeway surface and not at the end-of-pipe (point of discharge).

8.1 CONCLUSIONS

8.1.1 BMP Effectiveness

The LMPS was designed to evaluate the effectiveness of non-structural and structural BMPs in reducing litter in the Caltrans storm water system by comparing litter amounts at outfalls from paired treatment and control catchments. The non-structural BMPs evaluated were increased street-sweeping frequency and increased litter pick-up frequency. The structural BMPs evaluated were replacing the standard parallel bar inlet grate with a bicycle grate, replacing the standard parallel bar inlet grate with a perforated plate modified grate, and replacing the standard top-entry inlet with a curb inlet including the LID BMP described in Section 3.4.3.

Catchments monitored for the LMPS range in size from 0.18 acres to 0.91 acres. In order to compare litter results from individual catchments for BMP evaluation and between sites, data were normalized by unit area and by unit flow per storm event. Statistical analysis for BMP effectiveness was performed using both area-normalized and flow-normalized data. Area-normalized data are considered to be more robust because there were three times as many data points as only one treatment-control pair was monitored for flow at each BMP site. Where BMPs were demonstrated to result in a statistically significant reduction, an estimate of the average annual reduction observed is presented.

8.1.1.1 Street Sweeping

As detailed in Section 7.1, statistical tests have shown that increasing the frequency of street sweeping from monthly to weekly does not statistically reduce ($\alpha = 0.05$) the count or weight of litter observed at the outfalls or in the total system load. This is the case for weight regardless of whether the litter data are normalized by catchment area or flow, and which method of paired analysis is used. For count, the reduction is not significant for the area-normalized analysis, but is statistically significant for the flow-normalized analysis. Because the number of data points is substantially larger for the area-normalized analysis, the results of that analysis are considered more powerful. The volume reduction for this BMP is statistically significant under one method of paired analysis (crossed pairs using *Act Diff*) but not under other methods. The statistical analysis of the total system litter (sum of the litter manually collected from the inlets during cleaning at the end of the study and litter monitored at the outfalls) corroborates these

conclusions. These results suggest that weekly sweeping is not more effective than monthly sweeping in reducing litter in runoff from freeways with standard inlet grates.

8.1.1.2 Litter Pick-Up

Statistical tests have shown that increasing the frequency of litter pickup from monthly to weekly reduces the quantity of litter observed at the outfalls, with $\alpha = 0.05$. This is the case for all measuring parameters (weight, volume, and count) regardless of whether the litter data are normalized by watershed area or flow. Additionally, the statistical analysis of the total system litter (sum of the litter manually collected from the inlets and litter monitored at the outfalls) corroborates these conclusions.

Based on the total event litter collected at treatment and control outfalls for each year of the LMPS (Table 6-7), the average annual reductions demonstrated by study data normalized by area are as follows:

	Weight	Volume	Count
Average Annual Reduction Between Treatment and Control Areas	2.1kg/acre (30%)	21.3 liters/acre (41%)	2346 items/acre (33%)

8.1.1.3 Modified Inlet Grate

Statistical tests have shown that the modified inlet grate reduces the quantity of litter observed at the outfalls, with $\alpha = 0.05$. This is the case for all measuring parameters (weight, volume, and count) regardless of whether the litter data are normalized by watershed area or flow and which method of paired analysis is used. Additionally, the statistical analysis of the total system litter (sum of the litter manually collected from the inlets and litter monitored at the outfalls) corroborates these conclusions

Based on the total event litter collected at treatment and control outfalls for each year of the LMPS (Table 6-7), the average annual reductions demonstrated by study data normalized by area are as follows:

	Weight	Volume	Count
Average Annual Reduction Between Treatment and Control Areas	1.1 kg/acre (26%)	5.7 liters/acre (19%)	1,086 items/acre (23%)

8.1.1.4 Bicycle Grate

The standard Caltrans bicycle grate is shown in Photo 3–4 and is identical to the existing parallel bar grates at Site 8, with the addition of cross bars, resulting in reduced grate opening size. This retrofit was evaluated during the first study year. Based on analysis of year one data and field observations, the project team including Caltrans, NRDC, and TAG members agreed to discontinue

testing of the bicycle grate alternative. All parties agreed that the bicycle grate appeared to have little potential to reduce the quantity of litter entering drain inlets. More details are provided in Section 7.1.

8.1.1.5 Curb Inlet with LID

Results of inlet deposition monitoring indicate that the LID BMP is effective in reducing dry weather deposition (see Figure 4-5). Additionally, an important finding from the field evaluation of the LID BMP, is that the LID gates operated well in storm conditions. The gates remained closed during low flows, allowing runoff to enter the inlets through slots designed in the flap. Under heavier flows, the gates opened allowing water to pass freely into the inlets.

The statistical analysis however, did not confirm that the BMP is effective in reducing volume or weight regardless of whether the litter data are normalized by watershed area or flow and which method of paired analysis is used. For count, the reduction is significant for the outfall-discharged, area-normalized load, but is not significant for either the outfall-discharged, flow-normalized load or the total system load. The data suggest that the litter count is lower at the treatment outfalls, but higher in the treatment inlet with the net effect showing no significant reduction in the litter count.

It should be noted that the LID is designed to minimize the amount of litter that can move from the highway surface and shoulder area into the drain inlet and drainage system during dry-weather conditions. In order to assess inlet deposition patterns associated with the LID BMP, inlet deposition monitoring was initiated before the second year of LMPS monitoring. Though results of statistical tests show no reduction in outfall litter from the LID, this result may have been influenced by the 1999-2000 storm pattern and dry-weather deposition period. The storm pattern during the period that the LID was evaluated had a large majority of the storms occur in a six- to eight-week period in February and early March 2000, with only short dry-weather periods between each storm. The LIDs were in-place for three months of dry weather preceding the monitored storm season.

8.1.1.6 BMP Effectiveness for Chemical Water Quality Constituents

Statistical analysis was also conducted to assess the effectiveness of the litter BMPs evaluated during the LMPS for any improvement in chemical water quality between treatment and control areas. The BMPs did not show a reduction in chemical water quality concentration that could clearly be attributed to the BMP under evaluation, see Table 7-5. One interesting observation in the data shown on Table 7-5 is the higher concentrations of hardness, total copper, dissolved copper, dissolved nickel, and TPH(Diesel) in the treatment outfall as compared to the control outfall at Site 1W. This indicates that an increase in street sweeping frequency from monthly to weekly may have the tendency to increase some chemical water quality constituents

8.1.2 Conclusions Related to Other Observations

Although the major focus of the LMPS was to evaluate BMP effectiveness, the data collected during this pilot study provides extensive information that can be used to enhance the state of

knowledge related to litter on Caltrans highways. The following general observations may be useful related to future projects designed to understand and/or control litter on Caltrans highways.

8.1.2.1 Litter Characteristics Collected from Outfalls

The LMPS included a monitoring program of collecting litter discharged from highway storm drain outfalls. Lab analysis showed that such litter consists of paper, plastic, wood, cigarette butts, styrofoam, metal, and glass. The distribution by category is presented in Figures 6-2 to 6-7. Litter pieces collected from the drainage system were small in size resulting from the sieving effect of the Caltrans standard parallel bar grate. The Caltrans standard parallel bar inlet grate has 1-meter bars, with 35 mm (1½-inch) spacing and is effective in keeping large pieces of litter out of the drain inlets.

8.1.2.2 Composition of Gross Pollutants Collected

The material collected in the outfall monitoring nets consisted of gross pollutants comprising litter and vegetative material. The majority of all material collected was found to be vegetation. Site averages for percent vegetative material monitored in the outfalls range from 75 to 87 percent by wet weight for the four sites (see Figure 6-1). Site 6 had the highest average with 87 percent vegetative material in outfall material collected. The higher percentage at Site 6 likely results from trees that overhang a soundwall at the site. The high percent vegetative material in storm water gross pollutants is consistent with other studies conducted in Australia that found 60-90 percent vegetative material. The high percentage of vegetative material should be considered in the design of treatment BMPs because it is infeasible to separate vegetation from litter during treatment. These results also suggest that any device designed to capture litter will capture a majority of vegetation.

8.1.2.3 Control Area Outfall Litter Loads

Annual litter loads for each of the study sites can be derived from data collected at the LMPS control outfalls. Data presented below are the average combined total loads for the three control outfalls at each site normalized by the total area of control catchments. It should be noted that normalization by this method assumes a straight-line relationship between catchment size and litter load. The loads below include litter monitored at control outfalls from trigger events as well as litter collected from non-trigger storms. It is not the intent of this data presentation to predict average litter loads in other areas but instead give a general indication of loads and the variation between the LMPS sites. Based on these results, it is apparent that substantial variation exists in typical outfall litter loads between the LMPS sites. This did not affect the study objective of determining BMP effectiveness. However, additional monitoring would be required in other areas to provide an estimate of Caltrans litter load in the Los Angeles area. The average annual LMPS litter loads observed are as follows:

Average Annual LMPS Litter Load Per Site	Air-Dried Weight (kg/acre)	Volume (l/acre)	Count (#/acre)
Site 1E	7.5	58.1	7,926
Site 1W	5.3	43.0	6,541
Site 6	5.3	39.0	6,297
Site 8	3.1	17.9	2,848

Observations related to the site litter data include:

- Similar seasonal rainfall and runoff volumes were observed at all sites (within approximately 20%).
- The greatest amount of litter was observed at Site 1-E,
- Sites 1-W and Site 6 had similar loads of litter and were about 25% less than the quantities at Site 1E.
- Site 8 had between one-third and one-half the loads compared to Site 1E.

The sites are similar in many ways including: drainage systems with one inlet directly connected to one outfall; location on fill slopes; catchment areas less than one acre; and each are in urban freeway settings. However, there are substantial variations in the litter loads between the sites. Differences between the site litter loads could be influenced by many factors that were not evaluated during the LMPS including different traffic congestion patterns, different prevailing wind directions, and highway shoulder conditions. A comparison of litter load for these sites to ADTs, truck traffic or adjacent land use of did not indicate a clear relationship.

8.1.2.4 Litter Characterization Activities

Litter was characterized in many different ways during the LMPS. The litter data collected at the 24 outfalls during this two-year study are believed to provide a generally representative sample of the litter characteristic from Caltrans Los Angeles highways. Conclusions from characterization activities are presented below.

- ***Litter Usage Analysis*** – Data from the LMPS indicate that smoking- and food-related litter account for 20-30% of the litter by weight and volume. However, the relatively small size of individual litter pieces likely contributed to item usage not being identifiable, and may contribute to the large percentage (79% by weight and 71% by volume) of usage in the "other" category. These results are consistent between year 1 and year 2 data. Due to the high percentage of material that cannot be identified, determining the sources of freeway storm water litter is not possible by conducting inlet or outfall monitoring.
- ***Floatable Litter Analysis*** - During the development of the Study Plan it was believed that identifying the floatable fraction of the litter might provide some insight related to selecting and designing BMPs more effectively and to assess the portion of litter that would be most

likely to be transported to receiving waters. The LMPS data indicate that approximately 80% of the litter collected by count, weight, and volume is floatable (Table 6-2). It should be noted that the method that was developed for the LMPS floatable analysis is a laboratory procedure that assessed general floatability of litter items without attempting to replicate flow, turbulence, and other physical conditions present in a Caltrans storm water conveyance system.

- ***Oven Drying Analysis*** – The LMPS performed oven drying on litter sub-samples during the second year of monitoring to assess litter moisture content by category and event. Moisture contents by category, after a minimum of 24 hours of air-drying, ranged from a season average of 0% for glass items to a high of 36% for cigarette butts (Table 6-1). The total moisture content of all categories by event generally ranged from 2% to 23%.

8.1.2.5 Street Sweeper Litter Characterization

The litter portion of sweeper debris was characterized in the litter lab from March to October 1999 to compare sweeper litter to outfall litter with respect to visual appearance and composition. Analysis shows that the types of litter materials present in sweeper litter are similar to outfall litter, with higher proportions of glass, moldable plastics, and metals, and a lower proportion of paper and film plastic in sweeper litter (Figures 4-6 to 4-8). This may be explained by the sweepers' ability to remove larger items such as bottles, plastic containers and large metal scraps that can not fit through drain inlet grates. The proportion of the number of cigarette butts in sweeper debris (38%) is comparable to the percentage of cigarette butts in outfall litter by count (34%).

8.1.2.6 Litter Pick-Up Characterization

The litter portion of litter pick-up debris was characterized in the litter lab during September and October 1999 to compare litter collected during litter pick-up activities to outfall litter with respect to visual appearance and composition. Analysis shows that the types of materials present in litter collected from the freeway ROW are similar to outfall litter with higher proportions of chipboard/cardboard, glass, and wood, and a much lower proportion of cigarette butts in ROW litter (Figures 4-6 to 4-8). This may be explained by the removal of larger items during litter pick-up that can not fit through drain inlet grates. In accordance with standard District 7 AAH litter collection practices, the AAH contractor does not remove individual cigarette butts, and no butts were found in the ROW litter analyzed.

8.1.2.7 Site Hydrology and Litter Collected at Outfall

The data were evaluated to identify trends that might exist between litter and various elements related to site hydrology. Litter data were compared to rainfall intensity, peak flow, total flow, and antecedent dry period for monitored events at each outfall. No clear relationship between litter and any of the individual factors were identified for the analysis of event by event or total seasonal data.

8.1.2.8 Litter Load vs. Chemical Constituents

Litter and chemical constituent quantities for each outfall were plotted to look for possible correlations (Appendix L). The highest r-squared value is 0.66 for the relationship between litter and oil and grease. The results indicate that there is no correlation between litter and chemical quantities for any of the constituents monitored.

8.1.2.9 Inlet Litter Deposition

The volume of debris in each inlet was measured at two-week intervals during year 2 of the LMPS using the protocol presented in Appendix F. Inlet deposition monitoring was conducted to evaluate the effectiveness of the LID BMP to reduce dry weather deposition. Plots of inlet material volumes (Figures 4-2 to 4-5) show that dry weather deposition contributes to material present in LMPS drainage systems.

Inlet litter deposition rates were calculated using the percentage of litter observed in each inlet during each inlet deposition measurement event. Average litter deposition rates for the LMPS occurred at up to 0.04 liters/day during dry weather periods (May 1999 to December 1999). Wet weather deposition rates averaged -0.22 liters per day to 0.07 liters per day. These rates indicate that inlet volumes are reduced during wet weather. It should be noted that the percentage of litter applied to the measured inlet material volumes from each measurement event are based on visual observations that are inherently subjective and represent an estimate of the litter on the surface of the inlet material only.

8.2 RECOMMENDATIONS

8.2.1 Recommendations for Further Study

While the original study objectives have been achieved, some recommendations regarding other potential studies were able to be drawn from this research.

8.2.1.1 Street Sweeping

Increasing the frequency of street sweeping did not result in a significant reduction in freeway storm water litter based on data normalized by area. As presented in the Study Plan, varying the frequency of the street sweeping was considered as the operational change most likely to reduce litter in Caltrans storm drain systems. Therefore, no additional studies are recommended to evaluate the use of sweepers as a BMP to reduce litter in freeway storm water.

8.2.1.2 Litter Pick-Up

No further evaluation of litter pick-up as a storm water litter BMP is recommended.

8.2.1.3 Modified Inlet Grate

No further evaluation of the modified inlet grate as a storm water litter BMP is recommended.

8.2.1.4 Bicycle Grate

No further evaluation of the bicycle grate as a storm water litter BMP is recommended.

8.2.1.5 Litter Inlet Deflector Improvements

As a prototype, it is expected that the LID design will evolve with continuing improvements. The following observations should be considered as the design of the LID BMP evolves:

- Litter and debris accumulate around the vertical support riser in front of the gate. A re-design to remove the vertical riser would eliminate this problem.
- Litter and debris lodge the gate open and get stuck during storm events, leaving the gate ajar during dry weather. A re-design to allow the litter to easily fall away from the gate, after it enters the curb inlet, could minimize this problem and further reduce dry-weather deposition.
- Grooving the pavement in front of the curb inlet to direct flow into the inlet will likely increase maintenance costs as it reduces the depth of the topcoat. Evaluating the use of a standard Caltrans gutter depression instead of grooving the pavement is recommended.
- Design a feature to reduce wet weather transport of litter to the drainage system upgradient of the LID BMP.

APPENDIX A

This appendix consists of findings from dry weather field investigations conducted in June 1999 and wet weather field investigation conducted during year 2 of monitoring.

INTRODUCTION

The current District 7 Litter Management Pilot Study includes 3 distinct sites on I-105 and State Route 60. Site 1 spans the I-105 freeway from Gertrude to Atlantic on both the eastbound (1E) and westbound (1W) sides. Site 6 covers the eastbound side of State Route 60 from Turnbull Canyon Road to the Kwis Street pedestrian overcrossing. Site 8 is located between Garfield and Fulton, also along State Route 60.

The watershed areas for each of the inlets at the study sites were initially calculated using engineering as-built drawings. After year 1 runoff volumes were obtained, a dry weather field survey was conducted on June 2-3, 1999 to perform a more detailed assessment of field characteristics that could influence runoff at each study site. The dry weather field survey provided a more complete picture of catchment characteristics than could be determined from the as-built drawings alone. The results of this field survey are detailed in this appendix, along with some explanation regarding the influences those characteristics could have on actual runoff into the study site inlets. Wet weather observations were conducted during year 2 of monitoring and are described in the second part of these findings. Final estimated watershed areas are presented in Table 2-2 of this report and are based on as-built areas, field investigation findings, and final hydrologic analysis.

PART 1 - DRY WEATHER INVESTIGATION FINDINGS

Site 6

General Site Conditions

Most of the pavement characteristics within Site 6 are consistent throughout the site. The concrete slabs of the roadway itself are well worn with seams, occasional lips, and slope irregularities. These conditions are expected and appear typical of well-traveled freeway surfaces and could contribute to limited infiltration throughout the site.

Outfall specific findings

20H (0.64 acres)

The contributing watershed area for 20H is larger than originally calculated. Tapering super-elevation in the upstream section of the watershed area extended the length to 385 feet, creating a new watershed area of 0.64 acres, as compared to the previous estimate of 0.51 acres.

20G (0.51 acres), **20F** (0.42 acres), **20E** (0.42 acres), **20C** (0.42 acres), **20B** (0.42 acres)

Site 8

General Site Conditions

The concrete slabs making up the travelway at this site are seamed, particularly at the edge of the travelway (See Picture 1.)

Picture 1

The slopes here are very low (0.3%-0.5%), which could contribute to less than expected runoff into the adjacent inlets during storms.

Outfall specific findings

23C (0.62 acres)

B001 (0.32 acres)

Over half of B001's expected watershed area is on or before the bridge crossing Garfield Ave. The bridge itself arches upwards, and an asphalt lip and slight ridge exist on the upstream bridge seam, both of which could combine to divert water that would otherwise travel down the slope to B001 to instead flow 'upstream' to another drainage. This characteristic is estimated to reduce the watershed for B001 from 0.51 acres to 0.32 acres.

24B (0.42 acres)

Like B001, 24B's watershed area spans the Garfield Bridge and, also similar to B001, a lip at the upstream bridge seam reduces the watershed area to from 0.57 acres to 0.42 acres.

24D (0.62 acres)

Signs of pumping were observed approximately 260 feet upstream of 24D.

24E (0.62 acres)

The watershed area for 24E includes a bridge crossing over Wilcox. There is a lip at the bridge seams, which may divert flow back to 24F, the inlet just upstream. Wet weather observations are necessary to confirm.

24F (0.87 acres)

A new asphalt top-coat from the recent installation of fiber-optics creates a lip and the possibility for flow-by inlet. Ponding was also evident in a long, flat spot in front of the construction area inlet. 24F may receive flow from the 24E catchment (see above). Wet weather observations are necessary to confirm.

SITE 1

General Site Conditions

The 105 freeway is a relatively recent construction and the roadway is in good condition throughout. An earthen mound rises next to the shoulder along each watershed area in the site, the runoff from which was not included in the original watershed area calculations.

Outfall Specific Findings

58 (0.29 roadway + 0.03 lightly vegetated earthen mound = 0.32)

59 (0.29 roadway + 0.03 lightly vegetated earthen mound = 0.32)

60 (0.29 roadway + 0.03 lightly vegetated earthen mound = 0.32)

52 (0.40 roadway + 0.03 heavily vegetated earthen mound = 0.43)

The inside shoulder in this area has an approximate 10-foot-wide median turn-out. The area has therefore been increased to 0.40 acres of roadway and 0.03 acres of heavily vegetated earthen mound.

50 (0.36 roadway + 0.04 heavily vegetated earthen mound = 0.40)

51 (0.37 roadway + 0.04 heavily vegetated earthen mound = 0.41)

The furthest lane from the median contains a slight taper from a merging lane, causing a slight increase in watershed area from that previously estimated.

42 (0.29 roadway + 0.03 lightly vegetated earthen mound = 0.32)

Based on as-built engineering drawings, the study plan presented watershed areas along the eastbound side calculated with an additional lane of travel; the areas have now been recalculated.

B111 (0.36 roadway + 0.04 moderately vegetated earthen mound = 0.40)

The watershed area for B111 was recalculated.

B110 (Indeterminable from dry weather investigation + lightly vegetated earthen mound)

An existing turnout upstream of B110 spanning B109 (See Picture 2) is not shown on the construction as-builts. This turnout adds area to B110's watershed and may allow flow-by at B109, which may contribute to B110's watershed. Wet weather observations are necessary to confirm the watershed area.

Picture 2

44 (0.41 roadway + 0.03 medium vegetated earthen mound = 0.44)

The inside shoulder in this area is slightly larger than previously estimated, and the area has been recalculated to include the wider shoulder and correct number of lanes.

46 (Indeterminable from dry weather investigation + lightly vegetated earthen mound)

A turnout spans the 46 inlet and it no longer lays flush with the outside of the shoulder but instead is located in the middle of the shoulder (See Picture 3).

The distances between the inlets to either side of 46 differ from as-built dimensions used to calculate areas in the study plan. The inside shoulder is also wider than estimated through this area.

Picture 3

47 (0.40 roadway + 0.03 lightly vegetated earthen mound = 0.43)

The inside shoulder is slightly wider than the as-built engineering drawings showed, which adds to the watershed area for 47.

Wet weather field observations were conducted during year 2 of monitoring to observe runoff patterns at the outfall catchments. These observations were used to verify the earlier dry-weather survey that identified possible characteristics of each study site that could influence freeway runoff. The following presents a summary of the observed wet weather conditions.

PART 2 – WET WEATHER OBSERVATIONS

Site 8

Outfall B001

Wet weather observation shows ponding on the bridge shoulder; however, no water was observed leaving the west edge of the bridge deck. Minor flow was noted moving off the deck to the east towards inlet B001.

Ponding to the east of the bridge deck during storm events occurs due to a newly built fiber-optics line and submerged cabinet (See Picture 4). Observations during a post-storm trip to the site noted that while ponding remained on the bridge and in various portions of the shoulder, ponding on and around the fiber-optics trench and cabinet had dissipated.

Picture 4 – Fiber-optics trench and cabinet upstream of B001

Minor flow was observed entering the LID at B001 from the east due to moderate ponding caused by the roadway's shallow slope. During a relatively heavy event, a moderate flow was observed entering the LID from the west. The gates deflected open to accommodate the water, which required one-half of the four-foot gate.

Outfall 24B

Flow from the bridge over Garfield Avenue is higher to 24B than bridge flow in Outfall B001's watershed directly across the freeway. The entire bridge may be contributing to the watershed area for Outfall 24B, with the seam at the west edge of the bridge deck acting as the upgradient catchment limit. Flow into the LID at 24B was more substantial than at B001 during the same storm events.

During moderate flows water passed over the flow diverters and angled towards the front of the LID gate faces, which opened allow the water to enter the inlet. The flow decreased in depth and intensity as it passed down the length of the LID gates (See Picture 5). No flow-by at any of the LID inlets was observed.

Floatable debris flowed along the shoulder until it reached the LID inlets. Buoyant debris, such as sticks, plastics, and vegetation, was pressed up against the gate faces, often clogging the voids created by the open LID gate and slowing the water flow into the gate. However, observed flow did not exceed the capacity of the LID gates. Post-storm event observations noted that debris remained wedged in some of the gates and continued to prop them open.

Outfall 23C

The hydraulic conditions within the watershed area of Outfall 23C functioned well during all wet weather observations. Slight ponding was evident due to the shallow slope of the freeway, but water flowed steadily after a short period of rain.

Picture 5 – Moderate flow into 24B

Outfall 24D

A turnout was constructed in the area of Outfall 24D prior to year 2 of monitoring, which shifted the outfall to the middle, rather than the new edge, of pavement (See Picture 6). The flow-line has been preserved, however, and water flows directly towards the inlet, down the middle of the turnout. The flow was wide and slow during several storm events with moderate to heavy rain, although 20-30% of the water flowed past the inlet.

Picture 6 – Flow-by at Inlet 24D

Outfall 24E

Wet weather observations at Outfall 24E indicate that the outfall's upgradient catchment limit is the east edge of the Wilcox Avenue overpass bridge deck. Rain east of the bridge deck flowed towards Outfall 24F.

Outfall 24F

As noted above, Outfall 24F's downgradient catchment limit was shown to be greater than the as-built engineering drawings illustrated.

Outfall 24F's watershed area is larger than the other outfalls in the study at Site 8 and therefore had a larger flow into the large 16-foot LID inlet. During all observations the flow diverters worked well in directing water towards the LID gates and into the inlet. Bots dots have been placed in rows beyond the flow diverters to channel water to the inlet, but they are located nearly 4 feet from the curb and are therefore only partially utilized during observed flow levels.

More debris was evident at this outfall than either of the other two LID inlets. Plastics and branches floated in front of some of the LID gates and were wedged into the open gates, partially blocking and slowing flow (See Picture 7). The vertical support bars placed along the front of the LID also collect and hold debris; however long or flexible litter was observed wrapping around the bars, potentially contributing to litter blockage.

Picture 7 – Flow into Inlet 24F

SITE 1

Outfalls 42, 44, 47, 50, 51, 52, 58, 59, 60, B110, B111

The hydraulic conditions within these watershed areas functioned well.

Outfall 46

An existing turn-out is present at this inlet (See Picture 8). The flow-line was preserved, but during moderate rainfall 10-20% flow-by was observed.

Picture 8 – Outfall 46 during moderate rainfall

Site 6

Site 6 was found to perform very well hydraulically. Although ponding was evident in areas along the shoulder, all flow continued downstream rather than flowing back to an upgradient inlet and all water was diverted back to the shoulder before by-passing any catch basins.

Grab Sampling Field Data Log

(Fill out one for each station visit)

GENERAL:

Site & Outfall ID _____ Your Name _____

Date _____ Field Crew _____

GRAB SAMPLES : *Put on latex gloves*

24-hr Time of Collection _____

One outfall will have additional bottles for field duplicates and equipment blanks _____

If this station has equipment blanks, you MUST prepare the equipment blanks BEFORE the scoop contacts storm water (or anything else). If you have any questions about preparing an equipment blank or a duplicate PLEASE refer to the Standard Operating Procedures or call the SEC.

	Filled and labeled (Check)
2 - 500 mL amber glass (HCL preservative) for oil & grease, TPH-diesel:	_____
2 - 40 mL VOA vials are filled to the top (no head space) for TPH-gasoline:	_____
1 - plastic bottle (approx. 100 mL) with preservative tablet for coliform:	_____
1 - glass bottle (approx. 100 mL) for pH and conductivity:	_____
Field duplicates	_____
Field equipment blanks	_____

Temperature _____ ^{o}F ***(Be sure to keep temperature meter dry)***

Conductivity _____umho/cm ***(Be sure to keep pH/conductivity meter dry)***

pH_____ pH units ***(Be sure to keep pH/conductivity meter dry)***

PRE-STORM EVENT LITTER COLLECTION FIELD DATA FORM

Names of Field Crew Members: _____ Signed: _____

_____ Today's Date: _____

OBSERVATIONS AND ACTIVITIES	8-B001	8-23C	8-24B	8-24D	8-24E	8-24F
Time:						
Damage, vandalism, stolen equipment, etc. Check box and provide specific comments below.						
Photograph area around, inlet grate to document any accumulated litter or debris.						
Pour contents of litter spike into the storm drain inlet.						
For good housekeeping of sites, clear enclosure areas of trash. Place in trash bag to dispose later.						
Replace existing ("old") litter bag with new bag. Ensure the litter bag is securely fastened by strap. Water quality sampling sites MUST receive litter bag with black velcro flap for grab sampling. Velcro flap should be positioned facing up.						
Put "old" litter bag in plastic trash bag, and label with date and location.						
Second field crew member review label and initial that it is accurate.						
Return labeled trash bag containing the litter bag to the litter lab.						

Comments: _____

_____

_____

PRE-STORM EVENT LITTER COLLECTION FIELD DATA FORM

Names of Field Crew Members: _____ Signed: _____

_____ Today's Date: _____

OBSERVATIONS AND ACTIVITIES	6-20E	6-20F	6-20B	6-20C	6-20G	6-20H
Time:						
Damage, vandalism, stolen equipment, etc. Check box and provide specific comments below.						
Photograph area around, inlet grate to document any accumulated litter or debris.						
Pour contents of litter spike into the storm drain inlet.						
For good housekeeping of sites, clear enclosure areas of trash. Place in trash bag to dispose later.						
Replace existing ("old") litter bag with new bag. Ensure the litter bag is securely fastened by strap. Water quality sampling sites MUST receive litter bag with black velcro flap for grab sampling. Velcro flap should be positioned facing up.						
Put "old" litter bag in plastic trash bag, and label with date and location.						
Second field crew member review label and initial that it is accurate.						
Return labeled trash bag containing the litter bag to the litter lab.						

Comments: _____

_____

_____

PRE-STORM EVENT LITTER COLLECTION FIELD DATA FORM

Names of Field Crew Members: _____ Signed: _____

_____ Today's Date: _____

OBSERVATIONS AND ACTIVITIES	1-42	1-B110	1-B111	1-46	1-44	1-47
Time:						
Damage, vandalism, stolen equipment, etc. Check box and provide specific comments below.						
Photograph area around, inlet grate to document any accumulated litter or debris.						
Pour contents of litter spike into the storm drain inlet.						
For good housekeeping of sites, clear enclosure areas of trash. Place in trash bag to dispose later.						
Replace existing ("old") litter bag with new bag. Ensure the litter bag is securely fastened by strap. Water quality sampling sites MUST receive litter bag with black velcro flap for grab sampling. Velcro flap should be positioned facing up.						
Put "old" litter bag in plastic trash bag, and label with date and location.						
Second field crew member review label and initial that it is accurate.						
Return labeled trash bag containing the litter bag to the litter lab.						

Comments: _____

_____

_____

PRE-STORM EVENT LITTER COLLECTION FIELD DATA FORM

Names of Field Crew Members: _____ Signed: _____

_____ Today's Date: _____

OBSERVATIONS AND ACTIVITIES	1-52	1-50	1-51	1-58	1-59	1-60
Time:						
Damage, vandalism, stolen equipment, etc. Check box and provide specific comments below.						
Photograph area around, inlet grate to document any accumulated litter or debris.						
Pour contents of litter spike into the storm drain inlet.						
For good housekeeping of sites, clear enclosure areas of trash. Place in trash bag to dispose later.						
Replace existing ("old") litter bag with new bag. Ensure the litter bag is securely fastened by strap. Water quality sampling sites MUST receive litter bag with black velcro flap for grab sampling. Velcro flap should be positioned facing up.						
Put "old" litter bag in plastic trash bag, and label with date and location.						
Second field crew member review label and initial that it is accurate.						
Return labeled trash bag containing the litter bag to the litter lab.						

Comments: _____

_____

_____

POST-STORM EVENT LITTER COLLECTION FIELD DATA FORM

Names of Field Crew Members: _____ Signed: _____

_____ Today's Date: _____

OBSERVATIONS AND ACTIVITIES	8-B001	8-23C	8-24B	8-24D	8-24E	8-24F
Time:						
Damage, vandalism, stolen equipment, etc. Check box and provide specific comments below.						
Remove existing ("old") litter bag and place inside plastic trash bag. Label trash bag with date and location.						
Second field crew member review label and initial that it is accurate.						
Look up into storm drain pipe and note what type of material is still present.						
Place new litter bag on outfall and ensure it is securely fastened by strap. Water quality sampling sites MUST receive litter bag with black velcro flap for grab sampling. Velcro flap should be positioned facing up.						
Return "old" litter bag to litter lab						

Comments: _____

_____

_____

POST-STORM EVENT LITTER COLLECTION FIELD DATA FORM

Names of Field Crew Members: _____ Signed: _____

_____ Today's Date: _____

OBSERVATIONS AND ACTIVITIES	6-20E	6-20F	6-20B	6-20C	6-20G	6-20H
Time:						
Damage, vandalism, stolen equipment, etc. Check box and provide specific comments below.						
Remove existing ("old") litter bag and place inside plastic trash bag. Label trash bag with date and location.						
Second field crew member review label and initial that it is accurate.						
Look up into storm drain pipe and note what type of material is still present.						
Place new litter bag on outfall and ensure it is securely fastened by strap. Water quality sampling sites MUST receive litter bag with black velcro flap for grab sampling. Velcro flap should be positioned facing up.						
Return "old" litter bag to litter lab						

Comments: _____

_____

_____

POST-STORM EVENT LITTER COLLECTION FIELD DATA FORM

Names of Field Crew Members: _____ Signed: _____

_____ Today's Date: _____

OBSERVATIONS AND ACTIVITIES	1-42	1-B110	1-B111	1-46	1-44	1-47
Time:						
Damage, vandalism, stolen equipment, etc. Check box and provide specific comments below.						
Remove existing ("old") litter bag and place inside plastic trash bag. Label trash bag with date and location.						
Second field crew member review label and initial that it is accurate.						
Look up into storm drain pipe and note what type of material is still present.						
Place new litter bag on outfall and ensure it is securely fastened by strap. Water quality sampling sites MUST receive litter bag with black velcro flap for grab sampling. Velcro flap should be positioned facing up.						
Return "old" litter bag to litter lab						

Comments: _____

_____

_____

POST-STORM EVENT LITTER COLLECTION FIELD DATA FORM

Names of Field Crew Members: _____ Signed: _____

_____ Today's Date: _____

OBSERVATIONS AND ACTIVITIES	1-52	1-50	1-51	1-58	1-59	1-60
Time:						
Damage, vandalism, stolen equipment, etc. Check box and provide specific comments below.						
Remove existing ("old") litter bag and place inside plastic trash bag. Label trash bag with date and location.						
Second field crew member review label and initial that it is accurate.						
Look up into storm drain pipe and note what type of material is still present.						
Place new litter bag on outfall and ensure it is securely fastened by strap. Water quality sampling sites MUST receive litter bag with black velcro flap for grab sampling. Velcro flap should be positioned facing up.						
Return "old" litter bag to litter lab						

Comments: _____

_____

_____

AUTOMATED SAMPLER STATION CHECKLIST

One crew member performs actions, other crew member checks that all actions were completed correctly

Site and Outfall #: _____

MUST Check One: ☐ Pre-Storm Set Up ☐ Post-Storm Shut Down

Field Crew Names: _____

Date and Time: _____

SET-UP CHECKS:

_____ Check desiccant indicator (color); blue is acceptable, pink is not
_____ Check flow monitor connections; bubbler line is connected, no kinks or loose fittings
_____ Check pump tubing condition/connections; no cracks, properly positioned
_____ Check intake tubing conditions/connections; no kinks or loose fittings; tubing slopes downward
_____ Clear away any accumulated sediment around the intake tubing in mouth of outfall pipe
_____ Insert sample bottles (check for retainer ring and proper bottle position)
_____ Put ice in sampler; ensure ice does not impede movement of distributor arm
_____ Remove all jar lids. Put lids in a clean Ziploc bag and place in enclosure
_____ Replace existing battery with freshly charged battery.
_____ Start sampler program→NEW program; DO NOT RESUME program. Verify "Program Running".
_____ Program flow meter: sampler pacing and cell phone to hourly for 20 minutes
_____ Start flow meter→NEW program; DO NOT RESUME program. Verify "RUNNING."

SHUT-DOWN CHECKS:

_____ Turn the sampler "**OFF**."
_____ Put lids on sample bottles
_____ Properly label all sample bottles
_____ Complete the following table.

Bottle #	Sample Volume? (1/3, 1/2, 2/3, 3/4, full, etc.)
1	
2	
3	
4	
5	
6	
7	
8	

_____ Put ice in Ziploc bags and place in cooler with bottles. **Use bubblewrap to protect bottles.**
_____ Replace existing battery with freshly charged battery.
_____ Program flow meter for cell phone to be turned on daily at time specified for sampling station.
_____ RESUME program. Verify that the flow meter is "RUNNING."

Noted Problems:_____

Actions Taken to Correct Problems:_____

URS Greiner Woodward Clyde

Completed By: _____
Date: _____

Check list for Weekly BMP Inspection

Part 1

Monday

- [ ] Contact Anthony Guyon (310.397.5347) regarding any scheduled maintenance activities to be conducted in the study area for the week. Check off items from the LMPS weekly maintenance report.
- [ ] Notify Masoud Nassimi (310.609.0363) regarding the days and times that litter pick-up & street sweeping will be done for the week.
- [ ] Call Adopt a Highway - Joe Dillman (800)358-0231 xt.207; Paul Morin pgr (949)737-0643

Wednesday

- [ ] Receive and log faxed copy of Adopt a Highways report for litter pick-up. Check problem report section for anything unusual.

Thursday

- [ ] Meet with Chase at 10:00 (at California Street Maintenance yard) Go through Check list.

Equipment:

Shovel (flat)	5 gallon bucket
Wheel barrow	Gloves
Volume measuring frame	Trash bags
Sifter	

Friday

- [ ] Receive and log faxed copy of California Street Maintenance report for street sweeping. Insure that there is a weight ticket.

Fax to Kim Walter in the San Diego Office:
1) Caltrans maintenance weekly
2) Adopt a Highway weekly report
3) California Street Maintenance weekly report
4) WWC weekly BMP inspector report

URS Greiner Woodward-Clyde

Completed By: _____
Date: _____

Check list for Weekly BMP Inspection

Part 2

Completed During Street Sweeping

SWEEPER

- ☐ Insure that Crew chief (Chase) is aware of area to be swept
- ☐ Drop off truck with equipment at the Transfer station - exit Garfield Ave. from the 105 E., turn right, right at Peterson St.
- ☐ Check that caution signal on rear truck is operational
- ☐ Hydraulics operational
- ☐ Water level @ 1/2 min.
- ☐ Rotating beacon operational
- ☐ Water spray system operational
- ☐ Sweeper broom operational (right and left gutter & rear)
- ☐ Sweeper Speed _____ (MPH)

AREA SWEPT

Scenario 1

- ☐ **Treatment Implementation Westbound Harris to Gertrude (once a week)**
  Hopper Percentage full_____%
- ☐ Create date card and take picture of large debris

VOLUME

Width of Frame _____
Length of Frame _____
Irregularities in debris:_____

Volume of debris sifted (goal: 15 gallons) _____ gallons
Volume of sediment after sifting _____ gallons

Problem Report:

Scenario 2 ☐ **Control Implementation Westbound & Eastbound Atlantic to Gertrude (once a month)**

Westbound ☐ Medium & Shoulder Dump & get weight ticket

☐ Hopper Percentage full_____%

VOLUME
Width of Frame _____
Length of Frame _____
Irregularities in debris: _____
_____
_____
Volume of debris sifted (goal: 15 gallons) _____ gallons
Volume of sediment after sifting _____ gallons

Eastbound ☐ Medium & Shoulder Dump & get weight ticket

☐ Hopper Percentage full_____%

☐ Create date card and take picture of large debris

VOLUME
Width of Frame _____
Length of Frame _____
Irregularities in debris: _____
_____
_____
Volume of debris sifted (goal: 15 gallons) _____ gallons
Volume of sediment after sifting _____ gallons

Problem Report: _____
_____
_____
_____

Part 3

Litter Pick-up Inspection

☐ From the 105 W. exit Long Beach Bl. go south, left (east) at Josephine.
Inspect Harris to Atlantic for scenario 1 or Gertrude to Atlantic for scenario 2

Scenario 1 ☐ Treatment Implementation **Eastbound** Harris to Atlantic (once a week)

Problem Report: _____
_____
_____
_____

Scenario 2 ☐ Control Implementation **Eastbound** Gertrude to Atlantic (once a month)

Problem Report: _____
_____
_____
_____

CALTRANS DISTRICT 7 LITTER MANAGEMENT PILOT STUDY (LMPS)
MAINTENANCE REPORT

Completed by:			
Date:		Period:	
Site:			
Caltrans Maintenance Region/Area:			
Caltrans Road Crew Point of Contact::			
Title:		Phone:	
Caltrans Landscape Crew Point of Contact::			
Title:		Phone:	

MAINTENANCE ACTIVITIESCONDUCTED IN THE STUDY AREA

	Activity – Indicate activities which were conducted during this period with a check mark	Description (Date(s)/Location)
	Street Sweeping	
	Lane Closures Scheduled in the Study Area by Special Crews or Others (Site 1 only)	
	Large Debris Removed From Lanes/ Shoulder/Row	
	Flooding - Maintenance Response Activities	
	Accidents - Debris Generated/Cleaned	
	Pavement Repair - Lanes or Shoulders	
	Painting/Stripping	
	Other Activities Which May Impact Water Quality	
	Landscape Maintenance - Tree Trimming; Other Shrub Trimming or Mowing	
	Litter Pick-Up - AAH Bags Collected by CT (Applicable to Sites 6 & 8 only).	
	Litter Pick-Up – Conducted by Caltrans	

Year 1 (1998-1999)

False Starts Event Nos. 1998-04,1998-07,1998-08

On three occasions during year 1 of monitoring, December 3, 1998, February 19, 1999, and March 5, 1999, field crews were mobilized for pre-event setup based on quantitative precipitation forecasts. However, as each storm onset time approached, actual storm conditions did not meet predicted precipitation forecasts to warrant mobilization of field crews for grab sampling.

Predicted Event: December 4, 1998 (1998-04)

Based on the QPFs issued for December 4, field crews mobilized on the afternoon of December 3. The initial QPF on December 3, 1998, 0947 PST, indicated a storm would deliver 0.95 to 0.99 inches at the monitoring sites. By December 4, 1999 - 0500 PST, a new QPF indicated a lesser rainfall total ranging from 0.40 to 0.46 inches, with a rainfall probability of 70 percent. By December 4, 1000 PST, a new QPF lowered the precipitation total to between 0.20 and 0.23 inches, with a probability of 60 percent. Based on this QPF, the SEC suspended the monitoring event. Post-storm event rain gauge recordings for the monitored sites indicated rainfall totals at sites ranging from 0.05 to 0.13 inches.

Predicted Event: February 21, 1999 (1998-07)

On February 19, 1999, 0549 PST, a QPF was issued by Fox Weather indicating an impending storm with rainfall totals ranging from 0.70 to 0.88 inches for the monitoring sites. The probability of 0.20 inches of precipitation was estimated at 90 percent for onset beginning February 21 at approximately 0600 PST. Based upon this QPF, the SEC mobilized a pre-setup crew at Noon on February 19, 1999. A subsequent QPF issued at 1418 PST, lowered expected total rainfall to between 0.48 and 0.57 inches, with a probability of 80 percent. This updated QPF, despite indicating lowered expectations, continued to represent a storm event sufficient for monitoring. By February 20, 1999, 1500 PST, the QPF still indicated a total rainfall of between 0.39 and 0.55 inches, with 80 to 90 percent probability. The SEC also relied upon National Weather Service (NWS) reports from Oxnard, California. These NWS reports indicated a significantly less total rainfall and probability. Based on the accuracy of past forecasts, the SEC decided to not mobilize field teams for storm water grab sampling. This decision proved to be accurate as post-event rain gauge checks revealed no precipitation at monitored sites for February 21, 1999.

Predicted Event: March 6, 1999 (1998-08)

On March 5, 1999 - 0424 PST, a QPF was issued for a storm event with rain onset for March 6 at 0900 PST. Forecasts indicated a total rainfall of 0.15 to 0.20 inches, with probability of 50 percent. However, Fox Weather indicated through verbal discussions with the SEC that the issued QPF was a conservative forecast. Fox Weather indicated that the system moving into southern California would likely gain more moisture locally. Based upon the QPF and these additional factors, the SEC mobilized a pre-storm setup team on the afternoon of March 5. By March 6, 0354 PST, a newly issued QPF predicted total rainfall of 0.11 to 0.15 inches.

Probability for rainfall remained at 40 percent for 0.20 inches rainfall. On March 7, 1999, 0530 PST, Fox Weather issued a QPF with decreased predicted rainfall totals of 0.10 to 0.14 inches, with a 20 percent probability for 0.20 inches rainfall. Based on the latest QPF, the SEC decided to not mobilize a grab sampling crew. Rain gauges at monitored outfalls recorded no precipitation, except for Site 6-20E and 6-20F, with total recorded rainfall of 0.02 and 0.03 inches.

Year 2 (1999-2000)

False Starts Event Nos. 1999-01, 1999-02, 1999-04, 1999-07

On four occasions during year 2 of monitoring, November 14-17, 1999, December 10, 1999, January 15-18, 2000, and February 5, 2000, field crews were mobilized for pre-event setup based on quantitative precipitation forecasts. However, as each storm onset time approached, actual storm conditions did not meet predicted precipitation forecasts to warrant mobilization of field crews for grab sampling. Each event is described below.

Predicted Event: November 14-17, 1999 (1999-01)

Based on QPFs issued for an event predicted to occur on November 15, 1999, field crews mobilized on November 14, 1999 to perform pre-storm set-up activities. However, the storm predictions weakened throughout the late afternoon and evening of November 14, 1999 and sampling activities for November 15, 1999 were cancelled. The contract meteorologist, Fox Weather, indicated that another storm was predicted (85 percent probability of 0.7 inch rainfall) to occur on November 16, 1999 with onset around 9pm. Crews were dispatched to re-ice samplers during the morning of November 16, 2000. By 9pm on November 16, 2000, Fox Weather indicated that the second front had weakened as well and that the storm was not anticipated to meet trigger criteria. Rain gauges indicated no recorded precipitation during this period.

Predicted Event: December 10, 1999 (1999-02)

Based on QPF's issued for an event predicted to occur on December 10, 1999, field crews mobilized on December 9, 1999 to perform pre-storm set-up activities. A 70 percent average probability of 0.25+ inch rainfall was predicted at the four LMPS sites. By 3pm on December 9, 1999, Fox Weather substantially lowered the precipitation forecast to 0.1 inch rainfall and by 9 pm, Fox Weather indicated that the storm had dried up and would not likely generate conditions for storm water sampling. Rain gauges indicated no recorded precipitation during this period.

Predicted Event: January 15-18, 2000 (1999-04)

Based on QPFs issued for an event predicted to occur on January 16, 2000, field crews mobilized on January 15, 2000 to perform pre-storm set-up activities. A 80 percent probability of 0.2 inch rainfall at all sites was predicted to begin at approximately 8 am on January 16, 2000. However, at 6 am on January 16, 2000 Fox weather indicated that the front had weakened and the storm would not be suitable for grab sampling, but that sampling would be possible for the night of

January 16-17, 2000. By 1 pm on January 16, 2000, the predicted nighttime rain had also weakened. Grab sampling was cancelled. The contract meteorologist, Fox Weather, indicated that another storm was to occur for the night of January 17-18, 2000 so field crews re-iced samplers and performed set-up checks on January 17, 2000 for the newly predicted event. At 9pm on January 17, 2000, Fox Weather indicated that rain would not occur before 3am on January 18, 2000. At 6 am on January 18, 2000, Fox Weather's QPF predicted rainfall totals of 0.00 to 0.03 inches at the four LMPS sites. Sampling activities were called off. Rain gauges indicated no recorded precipitation during this period.

Predicted Event: February 5, 2000 (1999-07)

Based on QPFs issued for, and discussion with Fox Weather regarding, an event predicted to occur on February 5, 2000, field crews mobilized on February 4, 2000 to perform pre-storm set-up activities. An 80 percent probability of 0.20 inch rainfall was predicted at the four LMPS sites. By 11pm on February 4, 2000, Fox Weather issued an updated SSMI moisture analysis, indicating that there was a "substantial decrease in intensity of the front." A QPF issued at 5:31 am on February 5, 2000 indicated that the storm had dried up and would not generate conditions for storm water sampling. Rain gauges indicated no recorded precipitation during this period.

D.1 METHODS USED FOR VALIDATING HYDROLOGIC RAW DATA

Event hydrographs were generated for each event using minute by minute rainfall and flow data recorded by each outfall's data logger. The plots are provided in Appendix E. Additional parameters were calculated after initial analysis of the hydrologic and hydraulic conditions present during early events. These parameters were used to determine the validity of the values originally estimated for each catchment, (e.g., estimated runoff coefficient, sample pacing). A macro was used to perform calculations on event specific data in a consistent and rigorous manner.

D.1.1 VARIABLES AND HYDROLOGIC DATA

Variables Initially Assumed

Assumed outfall variables included drainage area, runoff coefficient, and depression storage. As-built areas from Caltrans drawings were assumed to represent the areas draining to each outfall. For the first event, an assumed runoff coefficient of 0.90 and depression storage of 0.00 were used at all outfalls. Following the first event, values calculated for runoff coefficient and depression storage from the first event at each outfall were used as a basis for assumptions for the outfall for the 1998-1999 wet weather season. As the study progressed, these assumed values were corrected and refined based on available data.

For Event 1998-01 the intra-event cumulative rainfall records were used to determine an initial estimate for the runoff coefficient and check assumptions about watershed characteristics for sample pacing purposes. The rainfall record over the duration of the event is shown in Figure 1. This graph was the first examination in a series of integrated QA/QC checks (summarized in Section 4.2.1) of the rainfall and runoff field data. In addition to ensuring that the equipment was functioning properly, the cumulative rainfall curves for the four water quality outfalls at Site 1 were used as replicates to increase the level of confidence in the rainfall recorded.

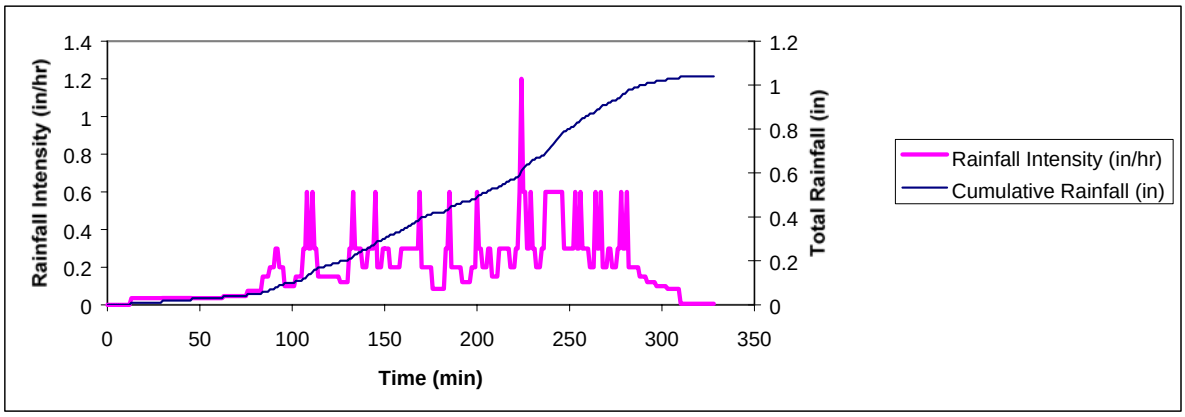


Figure 1
Recorded Cumulative Rainfall and
Rainfall Intensity for Event 1998-01 at Outfall 1-58

Having a high degree of confidence in the rainfall record at the Site based on the replicate rainfall records, the flow data was examined along with the rainfall record to approximate the time of concentration, and response of the watershed to rainfall. Figure 2 shows the runoff flow rate as a function of rainfall intensity.

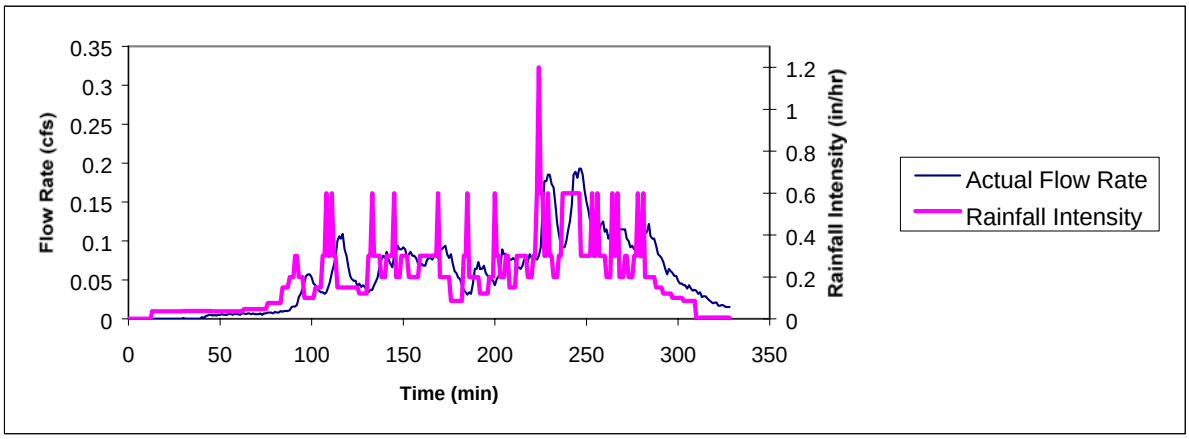


Figure 2
Recorded Rainfall and Flow Rate for Event 1998-01 at Outfall 1-58

Based on the initial assumptions [a runoff coefficient of approximately 0.9 for an imperivous surface and an approximate time of concentration (TOC) of 4 minutes], and the actual rainfall intensity, predicted flow rate was calculated for the first event. This calculated flow rate is shown along with the actual recorded flow rate in Figure 3, and the recorded cumulative flow volume and the predicted flow volume are shown in Figure 4.

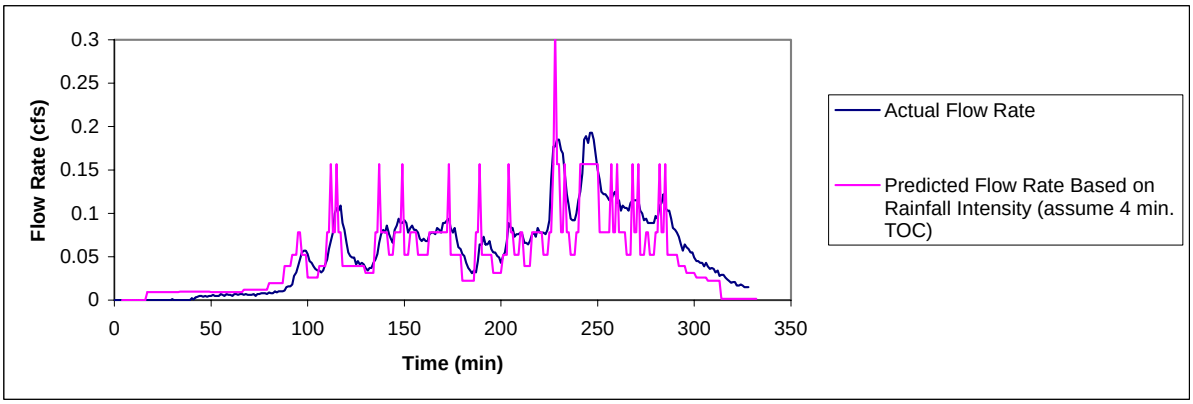


Figure 3
Flow Rate Recorded and Predicted Flow for Event 1998-01 at Outfall 1-58

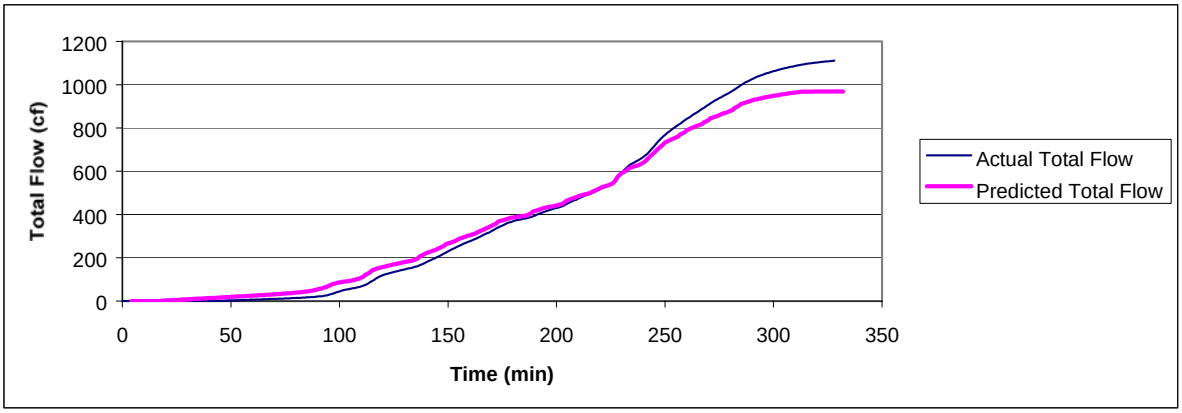


Figure 4

Comparison of Actual Cumulative Flow and Predicted Cumulative Flow Based on a Runoff Coefficient of 0.90 for Event 1998-01 at Outfall 1-58

Regressing the two variables for the Event 1998-01 generated the slope of the rainfall/runoff curve for the intra-event cumulative rainfall and runoff values. The data and regression lines are shown in Figure 5. A portion of the early rainfall/runoff record was excluded from the regression due to the violation of the assumption that the time of concentration is approximately four minutes.

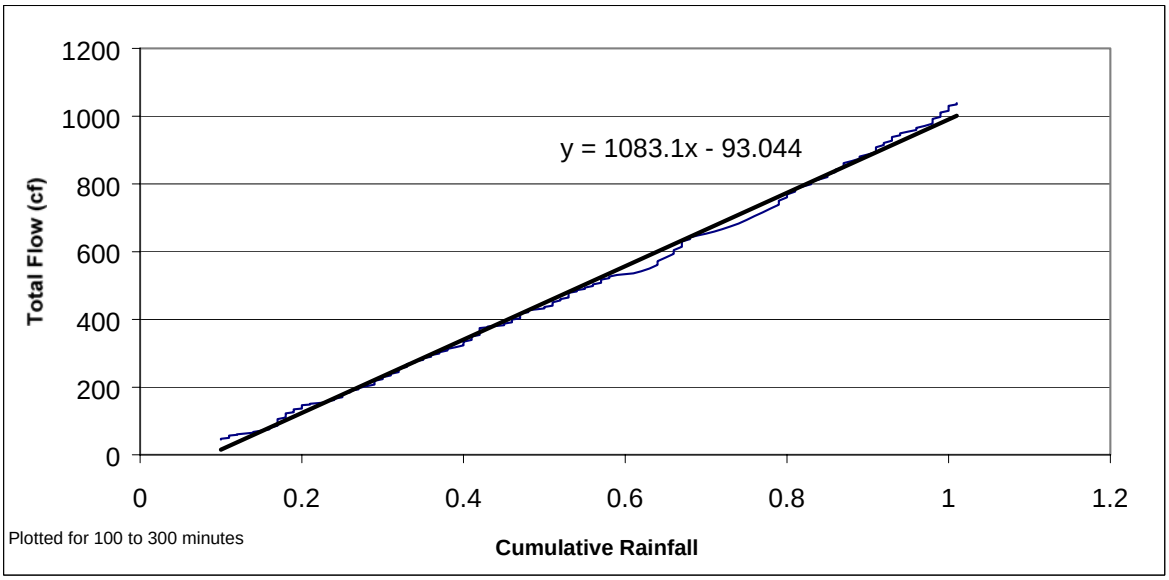


Figure 5

Regression of Intra-Event Runoff as a Function of Rainfall for Event 1998-01 at Outfall 1-58

The slope of the regression given by the rainfall/runoff curve was converted to units of watershed inches of flow per inch of rainfall [1083.1 ft^3 flow/in / (0.29 ac) / (3630 ft^3/ac-in) / (1 in) = 1.03 watershed in / in rainfall or a runoff coefficient of 1.029. Depression storage was estimated from the x-intercept of the regression line. An assumed value for depression storage

for each outfall was generated based on the Event 1998-01 calculated depression storage for the outfall. Analyses identical to that shown in Figures 1-5 were conducted for each outfall in the study. The resulting estimates for the runoff coefficient are shown in Table 1.

Table 1
Initial Estimates for Runoff Coefficient (C) and Depression Storage Based on Event 1998-01

Site	Outfall	As-Built Area (acres)	Assumed C Events 1998-02 to 1998-13	Assumed Depression Storage (in) Events 1998-02 to 1998-13
1E	42	0.34	0.664	0.150
	46	0.46	0.488	0.252
1W	52	0.38	0.633	0.165
	58	0.29	1.029	0.086
6	20e	0.42	0.730	0.113
	20f	0.42	0.655	0.112
8	23c	0.62	0.281	0.119
	b001	0.57	0.281	0.119

The monitoring results for Event 1998-02 were checked against the information gleaned from the intra-event analysis of Event 1998-01. Event 1998-02 was a short duration storm (~3 hours) with high one minute peak intensity at Site 8 (as much as 4.2 in/hr at outfall b001 and 23c), and low volume at Sites 1 and 6. Although Event 1998-02 did not provide a large quantity of useful intra-event information, the total rainfall and runoff amounts were not inconsistent with those found for Event 1998-01.

Refinement of Watershed Characteristics

As further detailed event rainfall and runoff information became available throughout the study, the characteristics of the watershed draining to each outfall were better understood, which in turn made estimates of runoff increasingly accurate. The refined information describing the runoff characteristics of the watershed was useful for both pre-event equipment setup (sampler pacing) and data analysis.

Hydrologic Data

Hydrologic data recorded for each outfall consisted of unedited minute by minute rainfall and flow data downloaded directly from the outfalls' data logger.

D.1.2 CALCULATIONS

Definition of the Event

The LWA data reporting protocol provides a definition of a precipitation event that contains three criteria indicating the start of a storm and three criteria indicating the end of a storm when

minute by minute precipitation data is used. The criteria for the start of the precipitation event include 1) the event begins in a minute in which precipitation is recorded, 2) within the 6 hours following and including the first minute of the storm, 0.1 inches of precipitation or greater are recorded, and 3) within the first hour following and including the first minute, greater than 0.01 inches of precipitation are recorded. The criteria defining the end of a precipitation event include 1) the event ends in a minute in which precipitation is recorded, 2) within the hour preceding and including the last minute, greater than 0.01 inches of precipitation are recorded, and 3) during the six hours following and not including the last minute, less than 0.01 inches of precipitation is recorded in each hour.

In order to identify the start and stop times of each event, a series of if/then statements were created to evaluate each minute of rainfall data that was downloaded from the Sigma Samplers. Two if/then statements checked the start criteria, and two if/then statements checked the end criteria. A fifth if/then statement checked each column of start/stop criteria for the first occurrence of all start criteria being met in one minute and the occurrence of all stop criteria being met in one minute, and then placed the flag "STARTTIME" or "STOPTIME" in the appropriate row.

It was assumed that event flow began in the same minute that marked the start of the precipitation event. Event flow was truncated 60 minutes after the end of the precipitation event to remove flow values that were potentially based on standing water in the flumes from calculations of event flow. This time was shown to be well in excess of the time of concentration for each of the watersheds in the study even at very low rainfall intensities.

Event Precipitation and Flow Calculations

All calculations were performed using the minute by minute data between the marked start and end times for precipitation and flow.

Rainfall intensity was calculated in each minute in which rainfall was recorded by using the value of how much time had passed since the previous minute with recorded rainfall to determine an average intensity over the time period. Rainfall intensities in the hydrographs are presented as one minute intensities. Although this format does not give intensity on the order of the time of concentration, it was used due to the increased ability for the hydrographs to quickly identify rainfall errors and accurately represent the rainfall record. In addition, the use of 15-min rainfall averages would minimize the ability to gauge the response of the watershed to rapid changes in rainfall intensity. Time of concentration can be quite low for the smaller watersheds during large events.

Flow rate was calculated for each minute by the data logger based on the level in the flume. Only flow between the marked start and end times was used for identification of the peak flow rate and summing of total flow during the event.

Event Observed Runoff Coefficient and Depression Storage Calculations

The observed runoff coefficient was calculated using the total flow recorded between the start and end flow times, the as-built area draining to the outfall, and the total rainfall recorded between the start and end of the precipitation event.

The observed depression storage was calculated by determining the total rainfall that had fallen since the start rainfall time and the when the flow was less than or equal to 1 cf.

D.2 RAINFALL QA/QC

The study strategy of using reference watersheds and the required use of multiple water quality monitoring stations at each site allows for comparisons of the rainfall record at adjacent outfalls. Site 1E, Site 1W, Sites 6 and Site 8 each have two sets of water quality monitoring equipment and thus have two rainfall gauges. Section 3, the Addendum and Figures 3-3 through 3-5 in the Final Detailed Study Plan and Design (URSGWC, 1998) provide specific information about the relative location of each of the rainfall gauges. For the events monitored, the rainfall record, intra-storm rainfall accumulations, and calculated intensities can be compared between each set of co-located rainfall gauges. Table 4–2 shows the recorded rainfall totals for each water quality event. The column labeled "Rainfall Abnormality" shows rainfall records that were deemed to be outside of the expected rainfall total for the event. A total of 18 "abnormalities" were identified from examination of the replicates and supporting information about the rainfall total for each location.

Three primary reasons for disagreement between gauges at the same site are plausible:

1. Introduction of foreign materials into or on top of the rain gauge, (e.g., bird droppings or vegetative mater)
2. Rain shadow resulting from vegetation
3. Unexplained equipment problems

In a number of cases, the introduction of foreign materials into the rain gauge was documented by field crews. This is the case for the low rainfall totals during event 1998e01 at outfall 23c, event 1998e02 at outfall 46, event 1998e5 outfall 42 (see Table 4–2). The other cases (e.g., event 1998e02 and event 1998e13 at outfall 23c) could not be directly identified as being caused by plugging or the presence of foreign material on the rain gauge funnel screen. During analysis of year 2 data it became apparent that the rain gauge at outfall 8-23c recorded a low rainfall total for a number of events. Initial indications for the abnormal gauge measurements at 8-23c during year 1 were assumed to be the result of vegetative matter in the rain gauge during the event, however, during year 2 a rigorous field check of the gauges indicated that this was not the case. Each gauge was checked to ensure the gauge was level and clean prior to each event. This is most likely due to rain shadow resulting from nearby vegetation. The average rainfall totals recorded at the site were used to correct rainfall abnormalities.

D.3 RUNOFF QA/QC AND ANALYSIS OF RAINFALL/RUNOFF CURVES

After the raw data was separated into discrete storm events, the relationship between runoff and rainfall volume was examined for all of the events at each outfall. Rainfall totals are based on Caltrans definition of an event as provided by Larry Walker and Associates. Flow totals are for a period beginning at the start time of the event and ending one hour after the event ends. Four steps were followed in evaluating the quality of the rainfall/runoff pairs and the observed relationship between rainfall and runoff: The initial analysis of runoff was based on as-built

areas. Revised regressions are based on additional field work conducted as shown following this section.

1. The rainfall/runoff data was examined for outliers using a linear regression model and the studentized residual as an indicator of points that are possible outliers. The goal of this analysis is to identify points that are "contaminated" by external factors not related to the phenomena of interest (i.e., the rainfall/runoff curve for each watershed). Outliers are identified where the studentized residual is large (absolute value greater than 2 or 3). The results of this analysis are shown in Figures 6–13.
2. The studentized residual is used to determine if a given point is an outlier with respect to the dependent variable. The following description of the studentized residual for outlier detection is presented in *Data Quality Control/Quality Assurance* by Edwards.

"Outliers in regression can be detected by means of studentized residuals. Several varieties have been defined, but the so-called externally studentized residual is recommended:

$$r_i = \frac{e_i}{\sqrt{MSE_{(-i)}\left(1-h_i\right)}}$$

where e_i is the ith ordinary residual (actual Y_i - predicted Y_i) and $MSE_{(-i)}$ is the error mean square for the regression excluding the ith pair. (h_i is the y-value for the ith data point)

If the formal assumptions of the regression analysis hold, studentized residuals can be used to test for contamination, since each r_i follows a Student's t-distribution with (n-3) degrees of freedom under the hypothesis of no contamination.

These outlier tests are only valid if the assumptions of the regression hold, however. These assumptions, verbally stated, are:

- The values of the regressor X are known constants (measured with negligible error).
- At any fixed X, the long-run mean of many Y-values, say m(X), is a linear function of X.
- The regression "errors" (the deviations of repeated Y-values at a given X from their long-run mean m(X)) are Normally distributed, with constant variance, and are independent."

A studentized residual in excess of 2 is often considered an outlier. Leverage is determined by using Cook's distance (D).

Cook's distance measures the influence of each sample observation on the coefficient estimates. Observations that are far from the average of all the independent variable values or that have large residuals tend to have a large Cook's distance value. Cook's D actually follows closely an F distribution, so aberrant values depend on the sample size. As a rule of thumb, under normal regression assumptions, the (Cook's distance) can be compared to an F distribution with p and N-p degrees of freedom. We don't want to find a large Cook's D value for an observation because it would mean that the coefficient estimates would change substantially if we deleted that observation. (SPSS, 1998)

Typically a point with Cook's D in excess of 0.5 is considered to have high leverage. In none of the cases presented in the following discussion, was high leverage cause for exclusion from the final regression analysis. In fact, it is these high rainfall/runoff values that are most interesting and informational.

When examining the statistical analysis done in this section it should be noted that the approach does not identify data contamination of pairs of rainfall/runoff data that lie close to the regression model.

The analysis of year 1 rainfall and runoff data is presented below. Year 2 data was analyzed identically. Identified rainfall and flow abnormalities in year 2 were corrected in an analogous manner to the year 1 data.

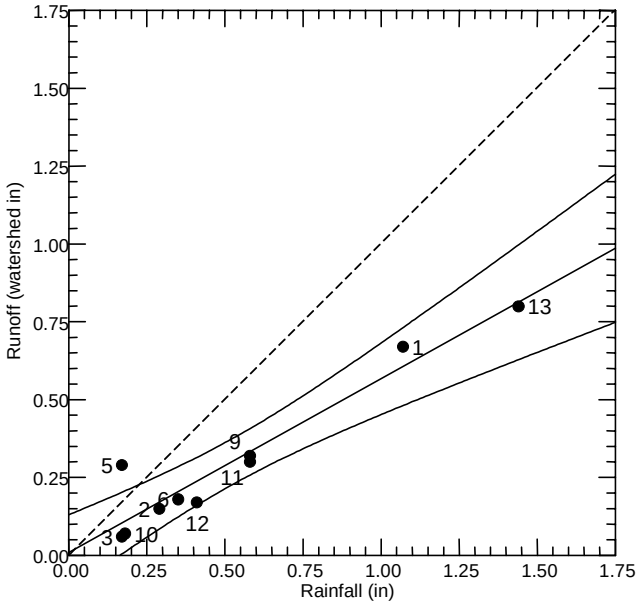


Figure 6

Initial year 1 regression of rainfall versus runoff for Outfall 42. Slope of regression line is 0.56, Event 5 is considered an outlier with a Studentized Residual of 6.607. Event one has large leverage (0.621), (95% confidence interval shown along with 1:1 reference line).

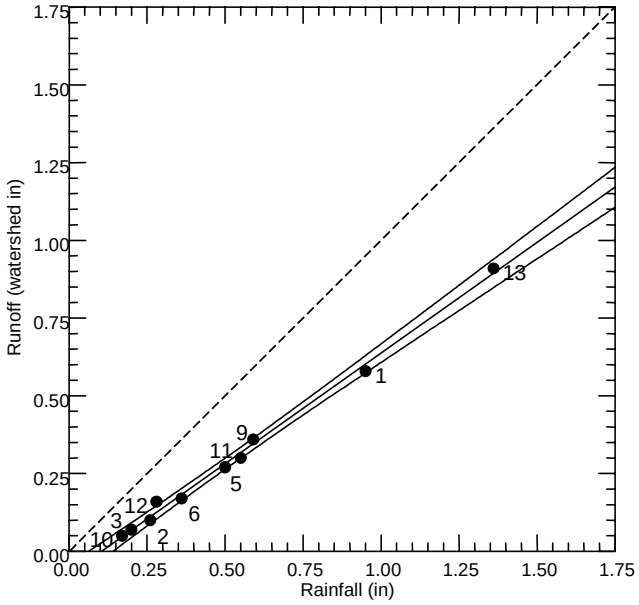


Figure 7

Initial year 1 regression of rainfall versus runoff for Outfall 46. Slope of regression line is 0.59, Event 13 is considered an outlier with a Studentized Residual of 2.391. Event 13 has large leverage (0.631), (95% confidence interval shown along with 1:1 reference line).

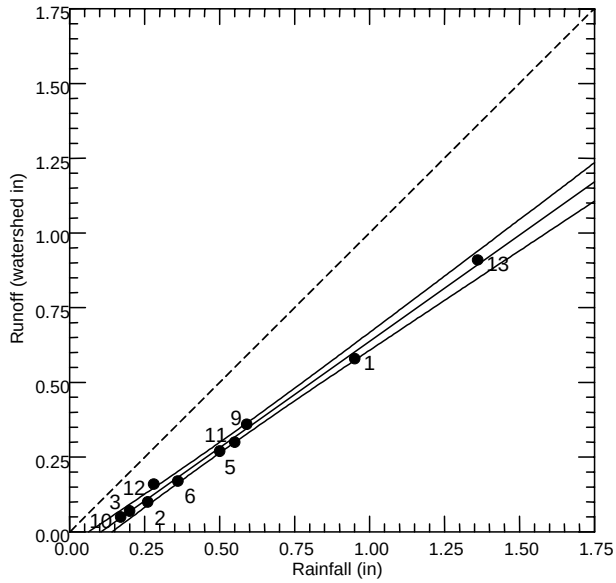


Figure 8

Initial year 1 regression of rainfall versus runoff for Outfall 52. Slope of regression line is 0.719, Event 12 is considered an outlier with a Studentized Residual of 2.663. Event 13 has large leverage (0.652), (95% confidence interval shown along with 1:1 reference line).

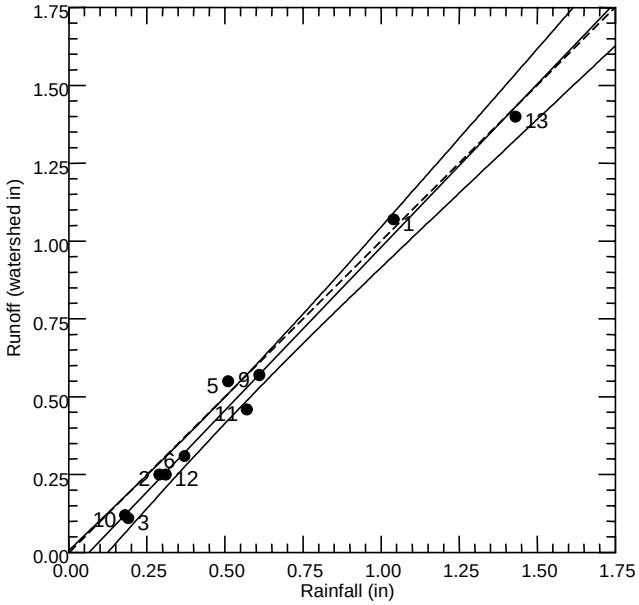


Figure 9

Initial year 1 regression of rainfall versus runoff for Outfall 58. Slope of regression line is 1.048, Event 5 is considered an outlier with a Studentized Residual of 2.559. Event 13 has large leverage (0.636), (95% confidence interval shown along with 1:1 reference line).

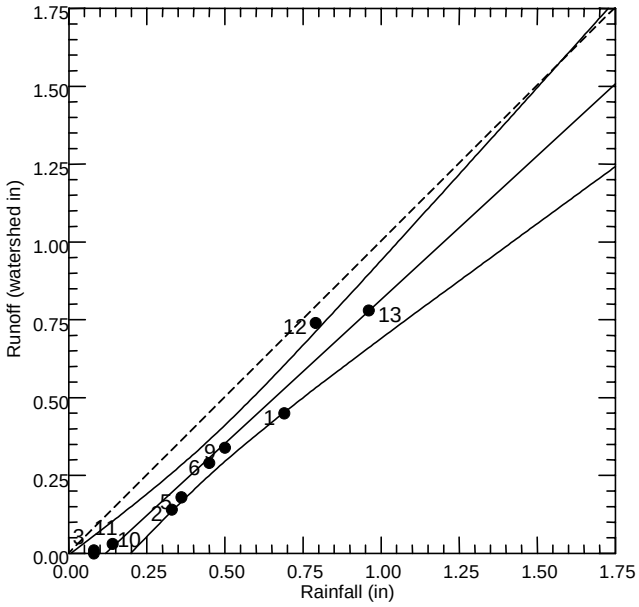


Figure 10

Initial year 1 regression of rainfall versus runoff for Outfall 20e. Slope of regression line is 0.924, Event 12 is considered an outlier with a Studentized Residual of 3.560, (95% confidence interval shown along with 1:1 reference line).

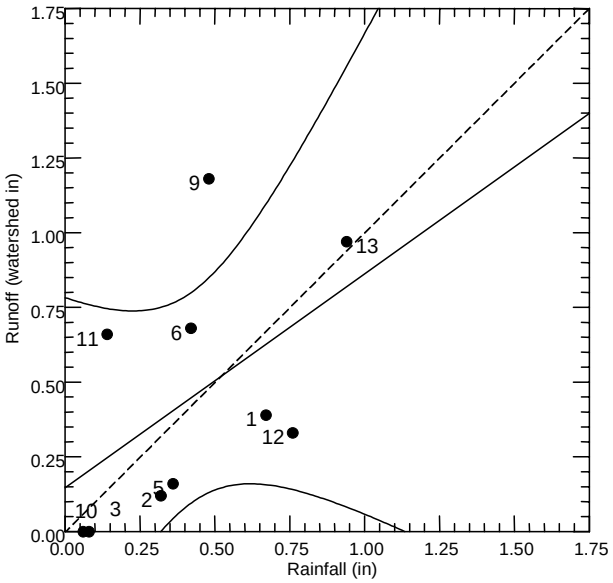


Figure 11

Initial year 1 regression of rainfall versus runoff for Outfall 20f. Slope of regression line is 0.716, Event 9 is considered an outlier with a Studentized Residual of 2.533, (95% confidence interval shown along with 1:1 reference line)

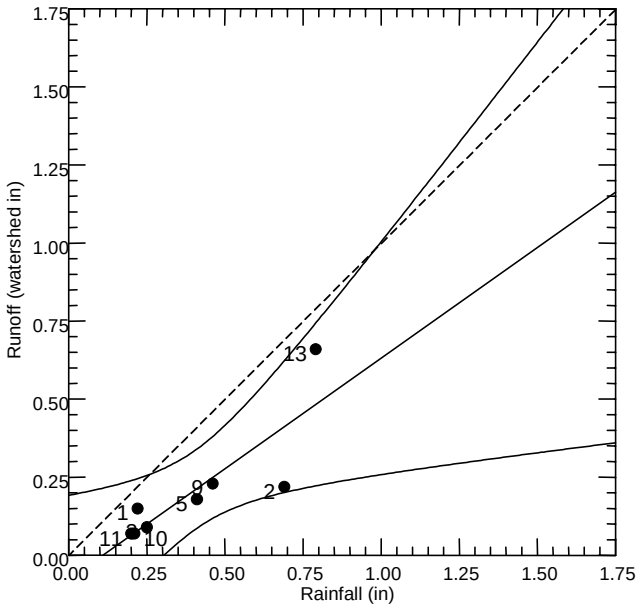


Figure 12

Initial year 1 regression of rainfall versus runoff for Outfall 23c. Slope of regression line is 0.709, Events 2 and 13 are considered outliers with Studentized Residuals of –3.864 and 6.373 respectively, (95% confidence interval shown along with 1:1 reference line).

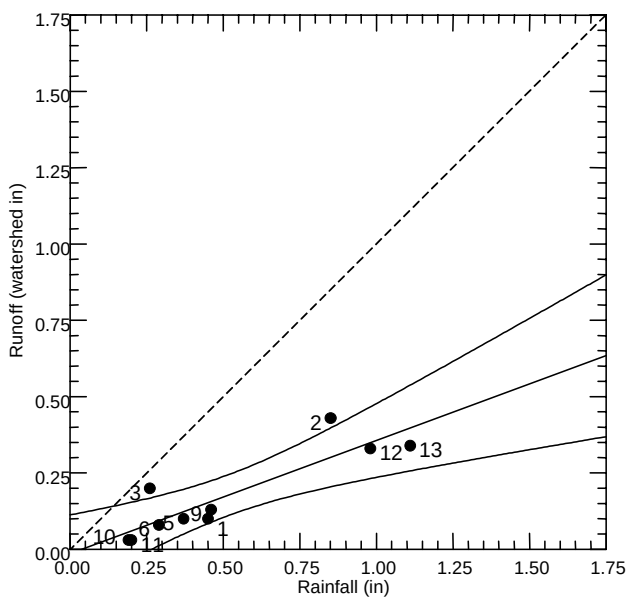


Figure 13

Initial year 1 regression of rainfall versus runoff for Outfall b001. Slope of regression line is 0.307, Event 2 is considered an outlier with a Studentized Residual of 2.805, (95% confidence interval shown along with 1:1 reference line).

ELIMINATION OF KNOWN EQUIPMENT PROBLEMS

The quantitative identification of contaminated data is supported by additional analysis of intra-event flow information. In two situations, spikes in the flow record occurred due to equipment problems as indicated in the flow record:

- Event 10 at outfall 42
- Event 11 at outfall 20f

These spikes were identified through examination of hydrographs and cumulative flow curves for all events and outfalls. In neither case was there a corresponding increase in rainfall intensity that would account for the rapid increase and subsequent decrease in flow rate. For event 11 at outfall 20f the reading for flow rate far exceeded the capacity of the measuring device. The spikes were removed from the flow record. After this was done, the cumulative flow volumes for the storms were adjusted appropriately and the rainfall/runoff curves for these outfalls were redone. These modified rainfall/runoff curves, including year 1 events, are presented in Figures 14 and 15.

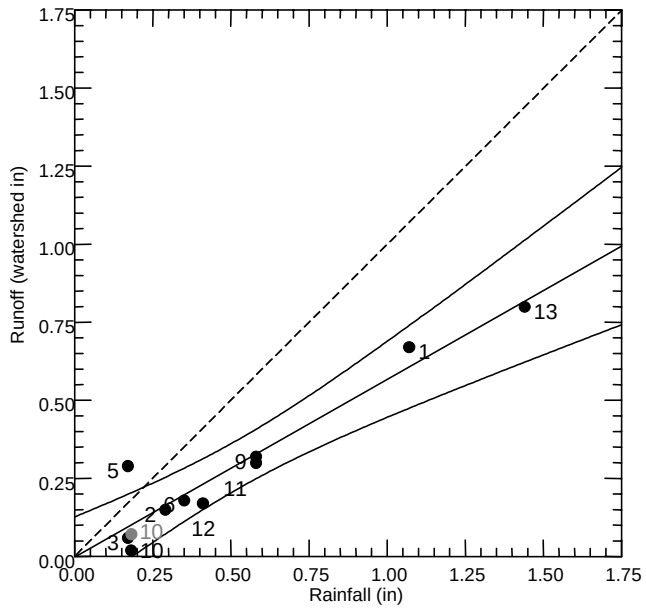


Figure 14

Regression of rainfall versus runoff for Outfall 42. Slope of regression line is 0.569. Removal of spike in flow record for event 10.

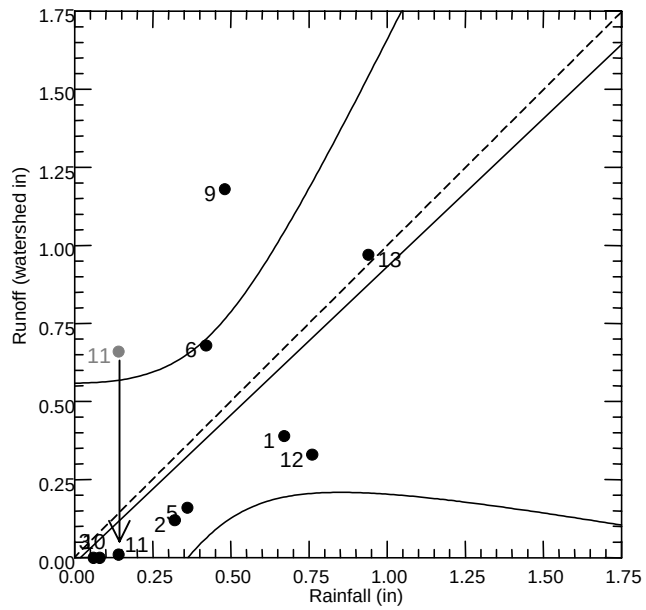


Figure 15

Regression of rainfall versus runoff for Outfall 20f. Slope of regression line is 0.949. Removal of spike in flow record for event 11.

REMOVAL OF RAINFALL ANOMALIES.

Four cases in the year 1 rainfall record were verified as having abnormal rainfall totals. Adjacent rainfall gauges at each site were used as surrogate values for each of these instances. The modifications made are shown graphically in Figures 16 through 18 and described in Table 4–3.

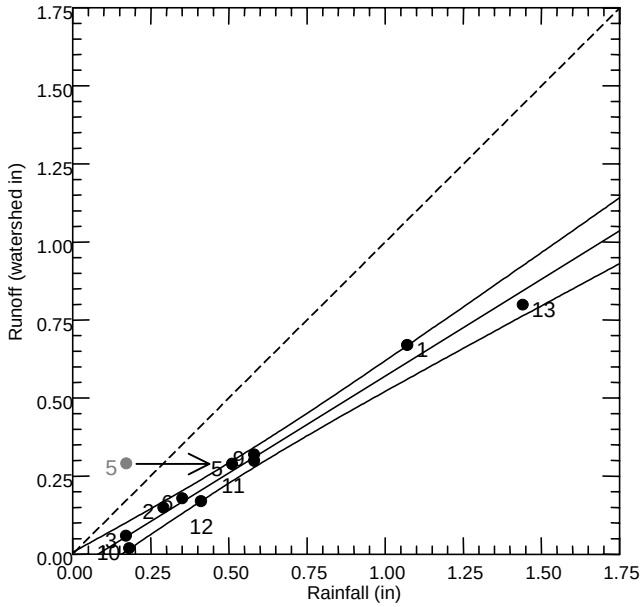


Figure 16

Modification made to rainfall record for event 5 at outfall 42 and resulting regression. Replacement value taken from average of values recorded at outfalls 42,52, and 58. (95% confidence interval shown).

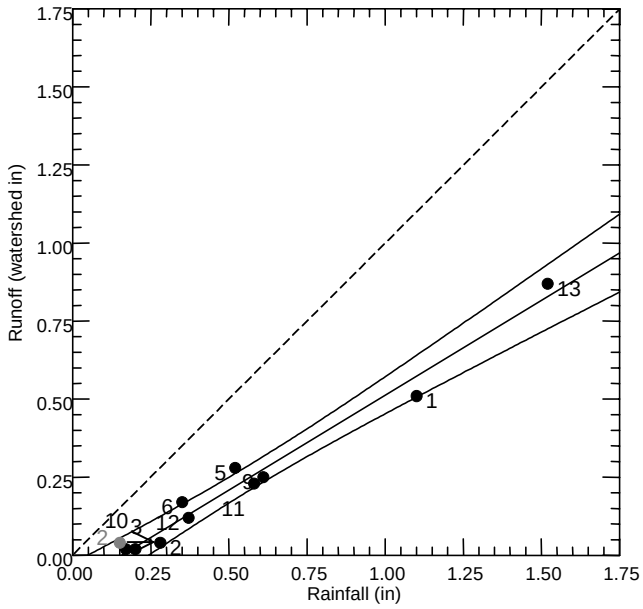


Figure 17

Modification made to rainfall record for event 2 at outfall 46 and resulting regression. Replacement value taken from average of values recorded at outfalls 42,52, and 58. (95% confidence interval shown).

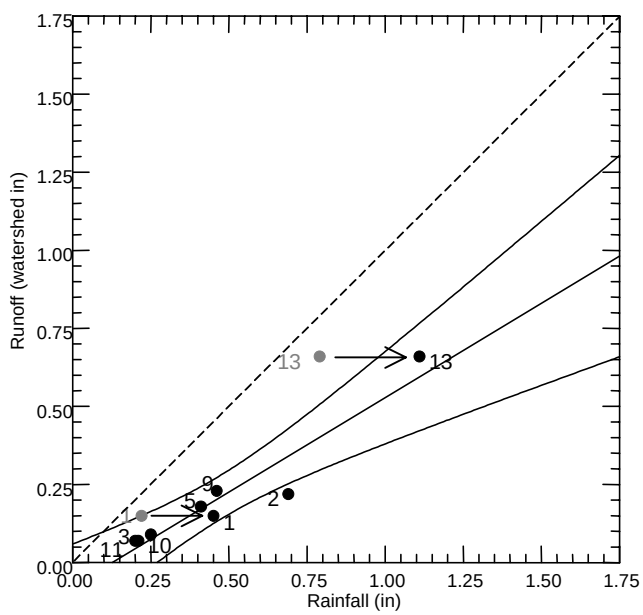


Figure 18

Modification made to rainfall record for events 13 and 1 at outfall 23c and resulting regression. Replacement values taken from outfall b001. (95% confidence interval shown).

Similar analysis and adjustments were made to all abnormal rainfall totals in year 2.

YEAR 1 REGRESSIONS. ELIMINATION OF ADDITIONAL DATA POINTS THAT ARE SIGNIFICANTLY OUTSIDE THE EXPECTED RANGE

Graphs for outfalls affected are presented addition to those that remain unchanged. A detailed description of the rationale behind the exclusion of data points is given in Table 4–3.

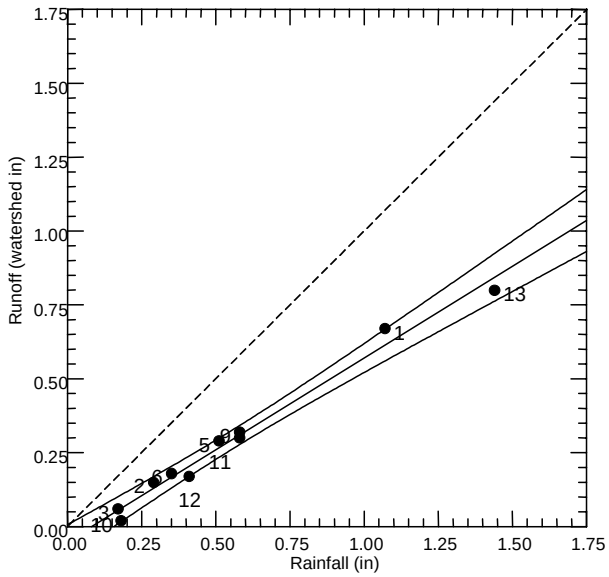


Figure 19

Final regression of rainfall/runoff data for outfall 42. Slope of regression line is 0.621. (95% confidence interval shown)

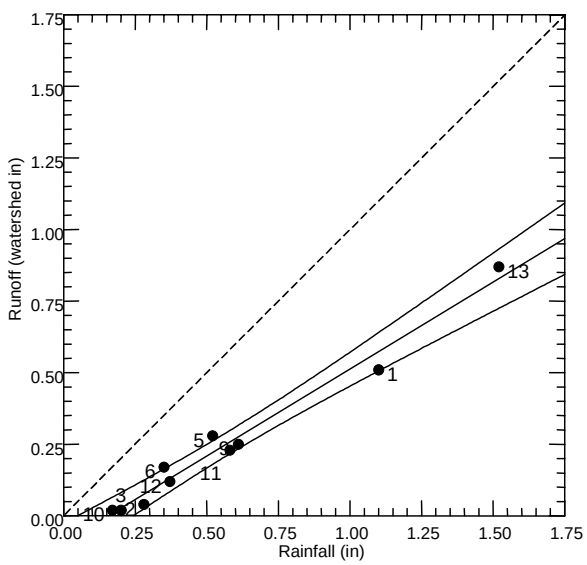


Figure 20

Final regression of rainfall/runoff data for outfall 46. Slope of regression line is 0.612. (95% confidence interval shown).

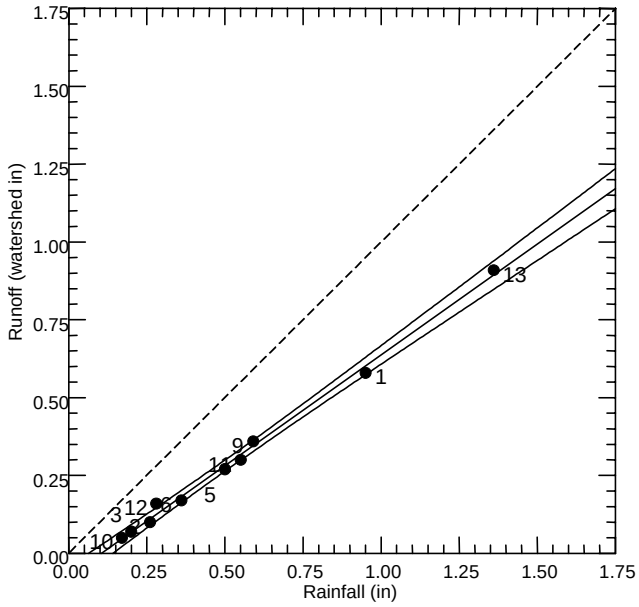


Figure 21

Final regression of rainfall/runoff data for outfall 52. Slope of regression line is 0.711. (95% confidence interval shown).

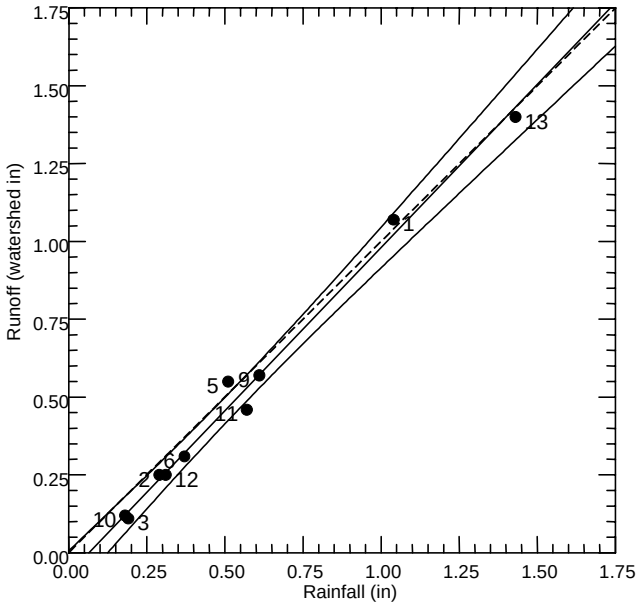


Figure 22

Final regression of rainfall/runoff data for outfall 58. Slope of regression line is 1.048. (95% confidence interval shown).

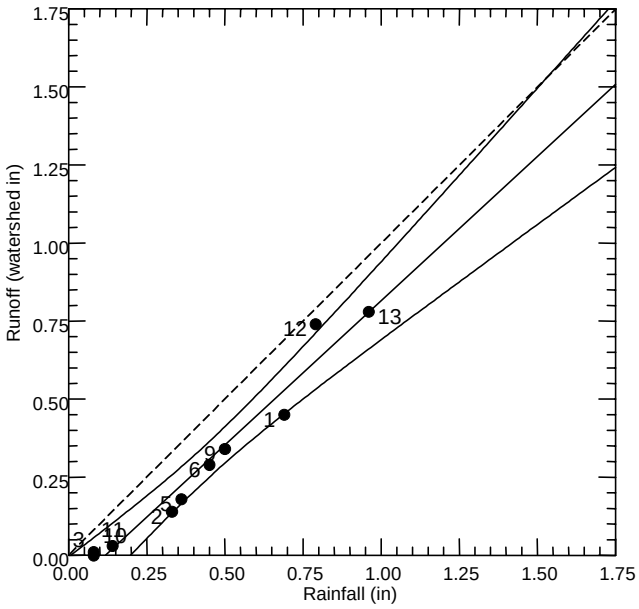


Figure 23

Final regression of rainfall/runoff data for outfall 20e. Slope of regression line is 0.924. (95% confidence interval shown).

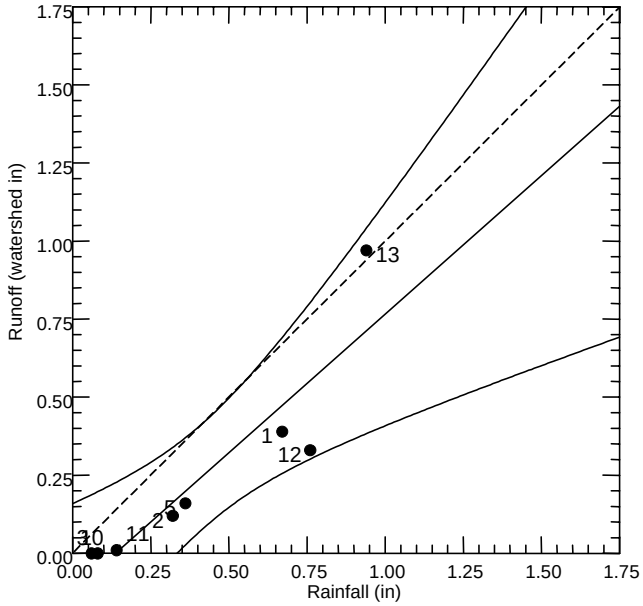


Figure 24

Final regression of rainfall/runoff data for outfall 20f. Slope of regression line is 0.887. (95% confidence interval shown).

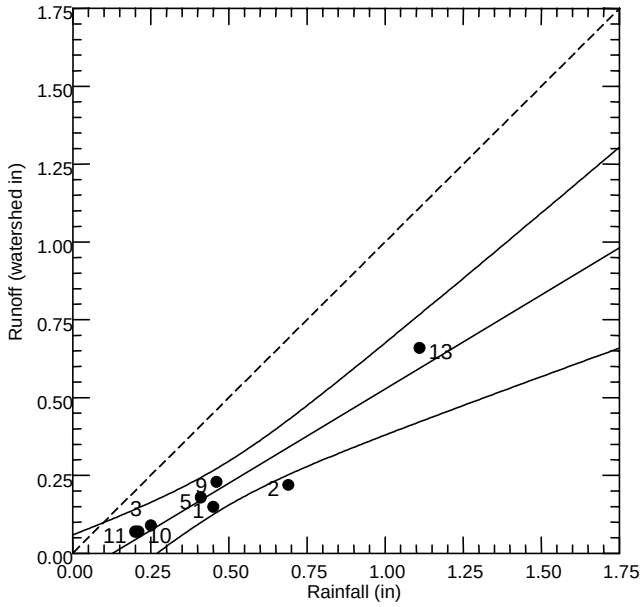


Figure 25

Final regression of rainfall/runoff data for outfall 23c. Slope of regression line is 0.605. (95% confidence interval shown)

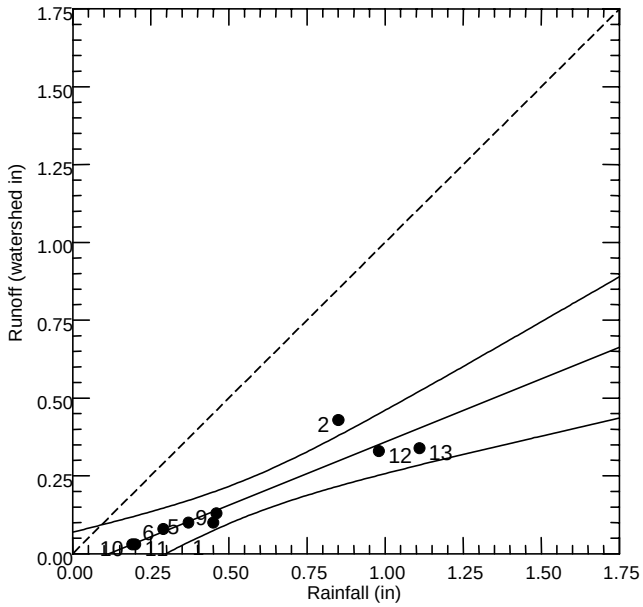


Figure 26

Final regression of rainfall/runoff data for outfall b001. Slope of regression line is 0.405. (95% confidence interval shown)

D.4 RE-EVALUATION OF YEAR 1 RAINFALL/RUNOFF RELATIONSHIP AFTER UPDATE OF WATERSHED AREAS RESULTING FROM FIELD VERIFICATION

Additional fieldwork, prior to the year 2 monitoring season, confirmed that both the watershed areas, and thus, the estimated runoff coefficient for many of the water quality outfalls could be improved. Figures 27 through 34 show the results of the revised watershed areas on runoff versus rainfall curves for year 1 data.

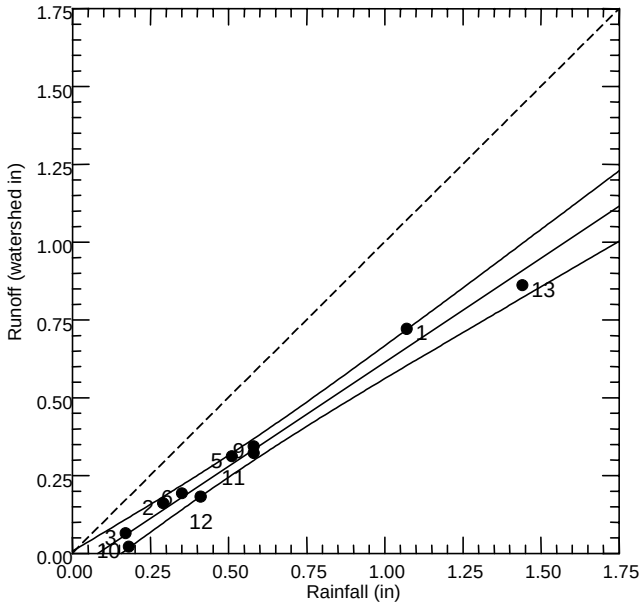


Figure 27

Regression of rainfall/runoff data for outfall 42 after year 1. Slope of regression line is 0.669. (95% confidence interval shown).

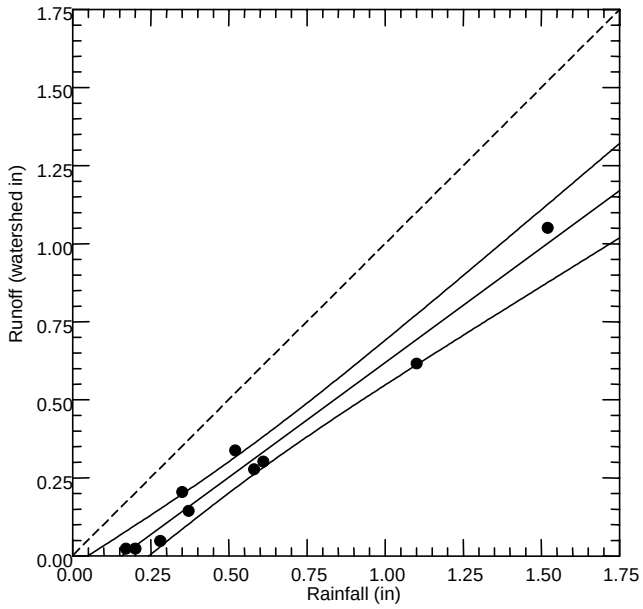


Figure 28

Regression of rainfall/runoff data for outfall 46 after year 1. Slope of regression line is 0.734. (95% confidence interval shown).

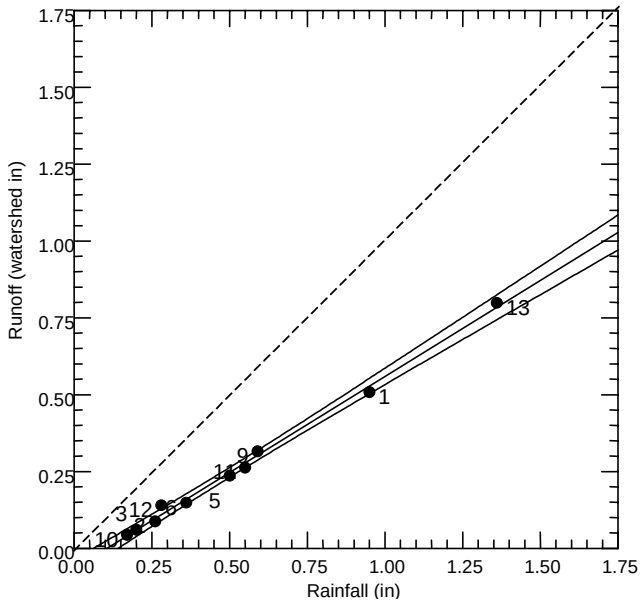


Figure 29

Regression of rainfall/runoff data for outfall 52 after year 1. Slope of regression line is 0.625. (95% confidence interval shown).

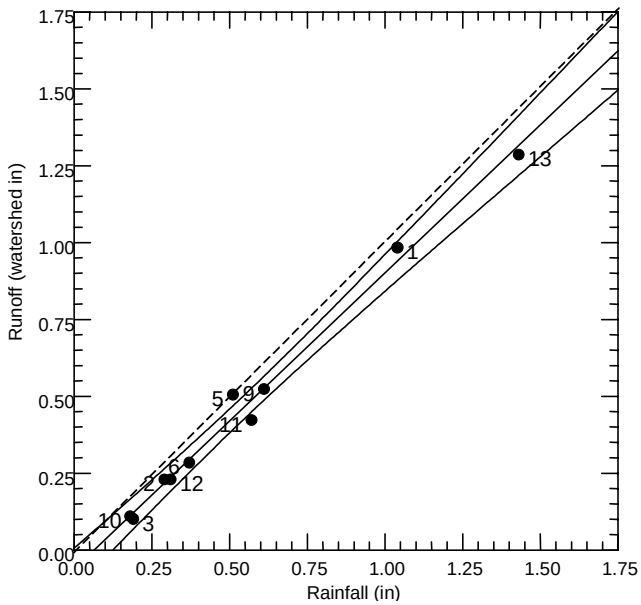


Figure 30

Regression of rainfall/runoff data for outfall 58 after year 1. Slope of regression line is 0.963. (95% confidence interval shown).

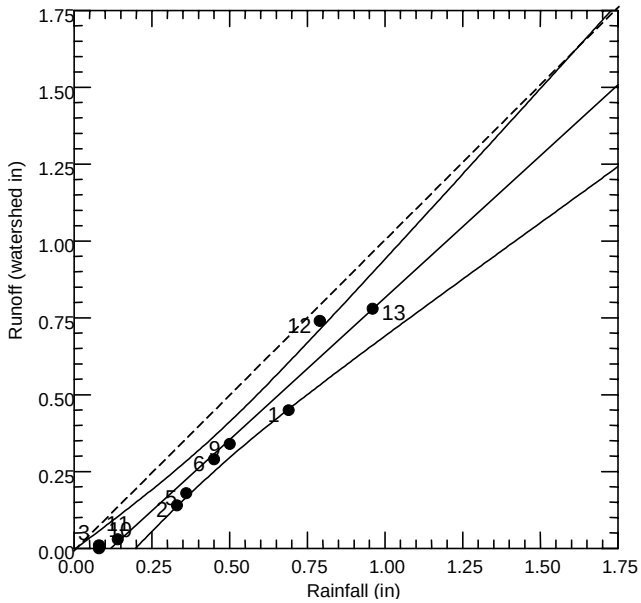


Figure 31

Regression of rainfall/runoff data for outfall 20e after year 1. Slope of regression line is 0.924. (95% confidence interval shown)

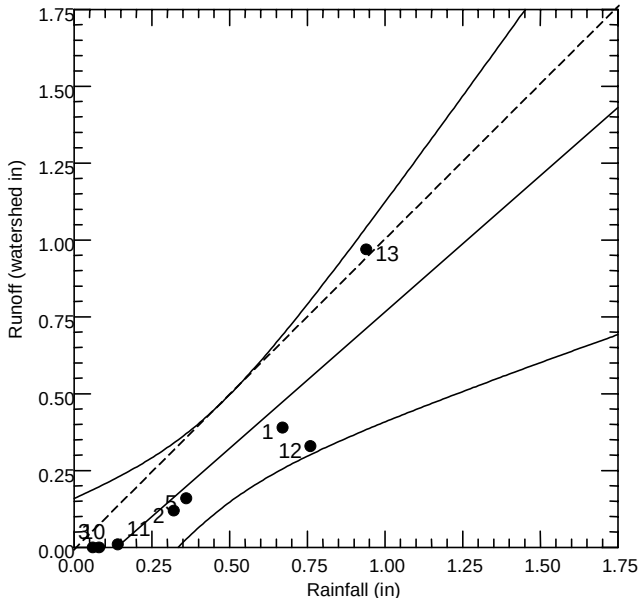


Figure 32

Regression of rainfall/runoff data for outfall 20f after year 1. Slope of regression line is 0.887. (95% confidence interval shown)

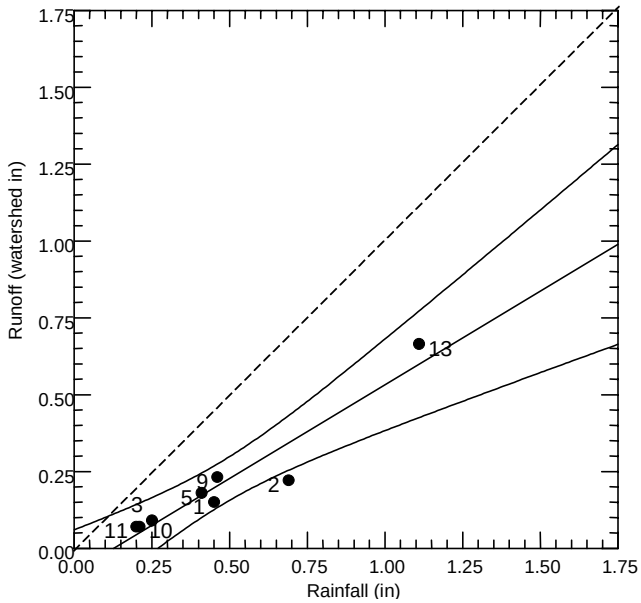


Figure 33

Regression of rainfall/runoff data for outfall 23c after year 1. Slope of regression line is 0.609. (95% confidence interval shown)

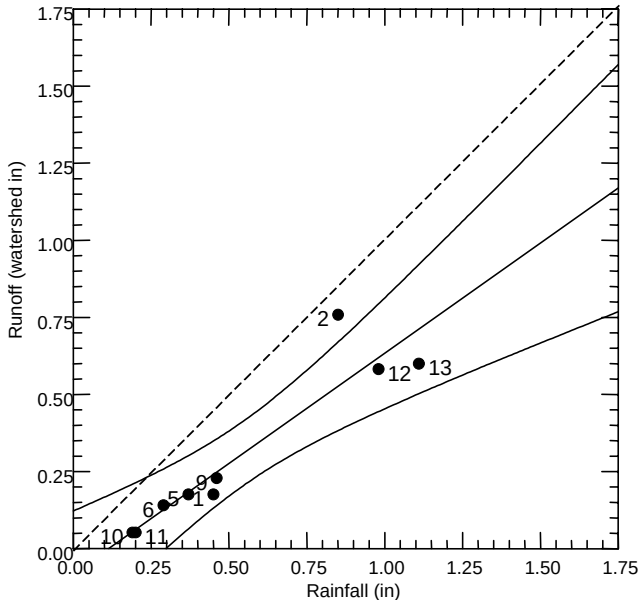


Figure 34

Regression of rainfall/runoff data for outfall b001 after year 1. Slope of regression line is 0.715. (95% confidence interval shown)

D.5 FINAL POST QA/QC RAINFALL/RUNOFF CURVES FOR COMBINED YEAR 1 AND YEAR 2 DATA

Year 2 monitoring data was analyzed and added to the continuous record as events occurred. The updated information from these events allowed for the comparison between values obtained from year 1 of the study shown in the previous section. This additional data helped to support and refine watershed characteristics identified during year 1. With the exception of the runoff observations made at outfall 8-B001, year 2 data was generally consistent with observations made during year 1.

As discussed in Section 4.2.3, the runoff observed at 8-B001 during the second year of the study was appreciably less than the runoff for similar magnitude events observed during the first year of the study. Figure 35 shows the marked difference between year 1 and year 2 rainfall versus runoff values at 8-B001. The runoff is presented here in cubic feet in order to demonstrate the difference.

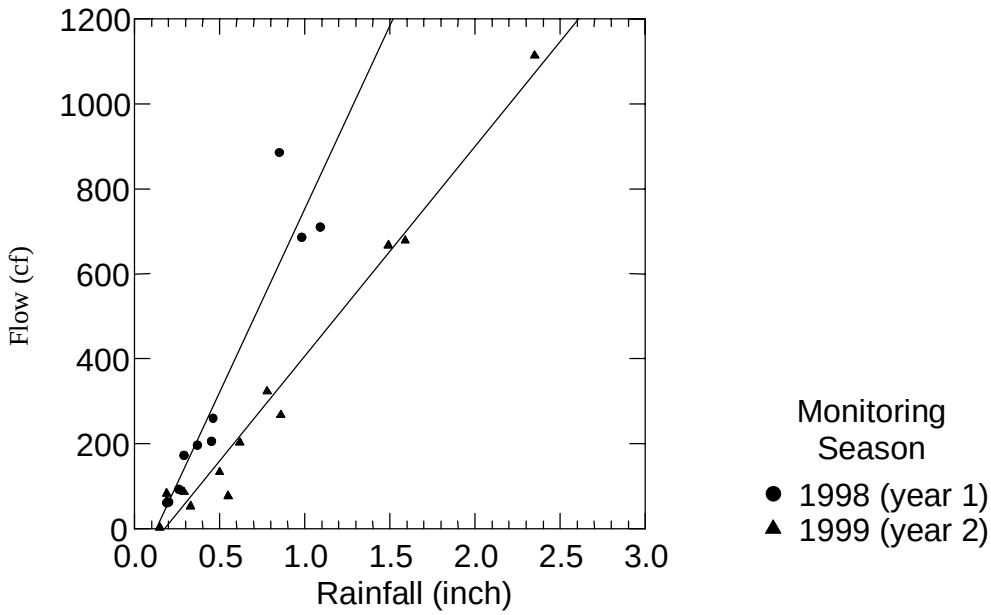


Figure 35

Runoff for outfall 8-B001 as a function of rainfall depth for year 1 and year 2 monitoring periods.

As a result of field wet weather observations and measured flow at 8-B001, the watershed area was adjusted from 0.32 ac, for year 1, to 0.18 ac, for year 2. This adjustment allowed for maintenance of the runoff coefficient of 0.74 in each of two monitoring years. The changes to the watershed area are due to a portion of the freeway being effectively hydraulically disconnected from the inlet for 8-B001. This change most likely resulted from changes to shoulder pavement conditions in the B001 catchment due to the installation of a fiber-optics trench between year 1 and year 2 monitoring. This shift in runoff quantity was not observed consistently at the other seven water quality outfalls.

Year 2 data provided a number of events that had depths that were larger than the maximum depth observed during year 1. These additional relatively large events helped to further clarify watershed runoff characteristics.

Data were reviewed using a formal outlier analysis to identify abnormal rainfall and runoff values. All data from both years were subjected to the QA/QC procedures described in Section 4.2.1. Regressions of runoff as a function of rainfall were regularly updated during year 2 monitoring and used on a continuing basis to assess the year 2 results in a manner similar to the summary of year 1 data described in Section D.3 above.

At the conclusion of the year 2 monitoring period, final regressions of the relationship between rainfall and runoff were compiled. These curves are presented in Figures 36 – 43. These plots provide a graphical means for assessing watershed characteristics and data precision for the values used in various analyses throughout the study. All values that were estimated, as identified in Section 4 in Tables 4-2 and 4-3, are in the figures. Table 4-1 provides a tabular summary of runoff coefficients (slopes of the regression lines presented here). Large storms are identified in these plots by study year and event number.

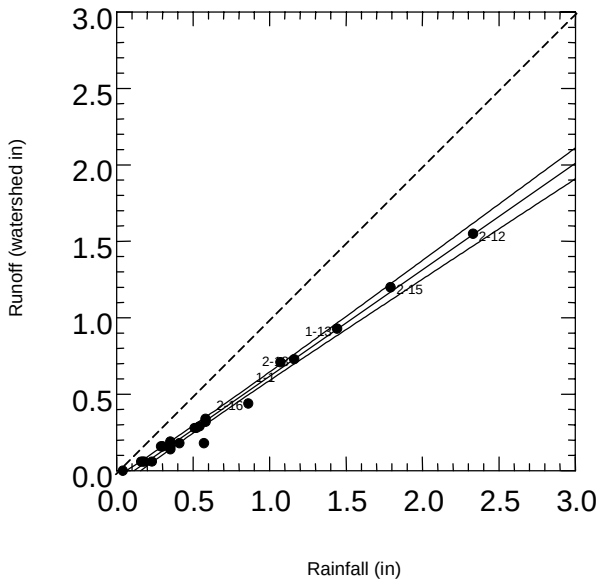


Figure 36

Regression of rainfall/runoff data for outfall 42, combined year 1 and year 2. Slope of regression line is 0.70. (95% confidence interval and 1:1 dotted reference line shown).

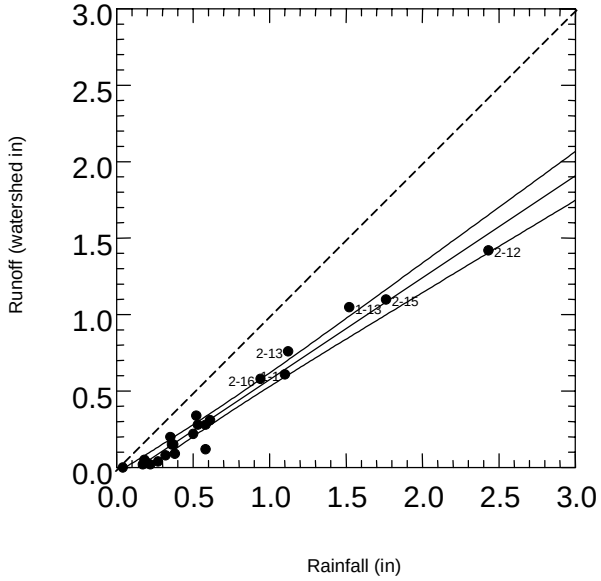


Figure 37

Regression of rainfall/runoff data for outfall 46, combined year 1 and year 2. Slope of regression line is 0.67. (95% confidence interval and 1:1 dotted reference line shown).

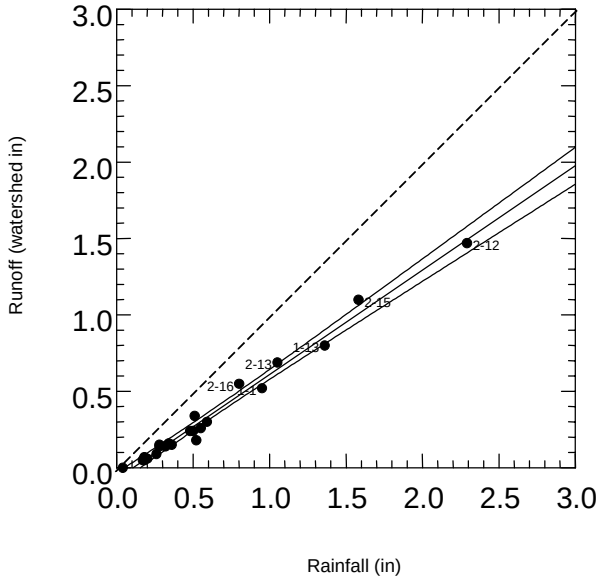


Figure 38

Regression of rainfall/runoff data for outfall 52, combined year 1 and year 2. Slope of regression line is 0.68. (95% confidence interval and 1:1 dotted reference line shown).

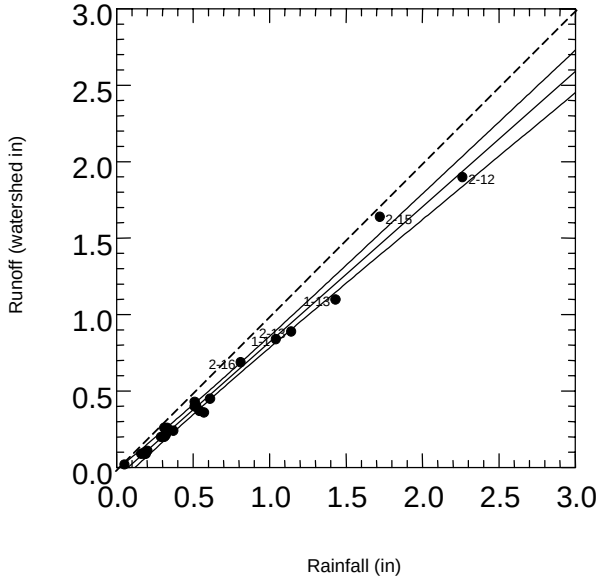


Figure 39

Regression of rainfall/runoff data for outfall 58, combined year 1 and year 2. Slope of regression line is 0.89. (95% confidence interval and 1:1 dotted reference line shown).

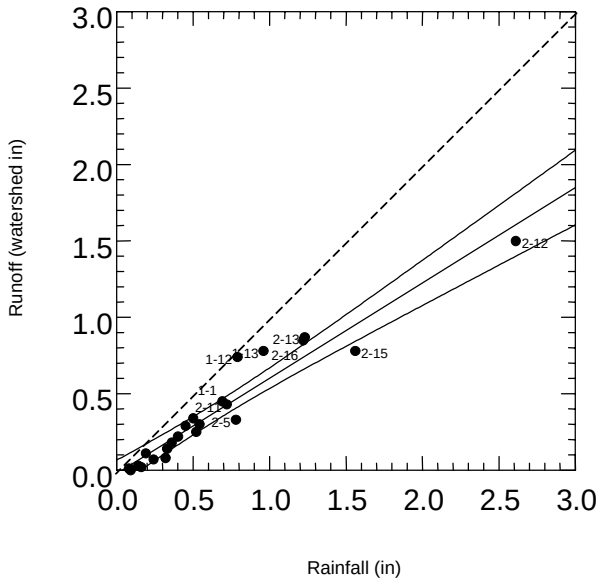


Figure 40

Regression of rainfall/runoff data for outfall 20E, combined year 1 and year 2. Slope of regression line is 0.62. (95% confidence interval and 1:1 dotted reference line shown).

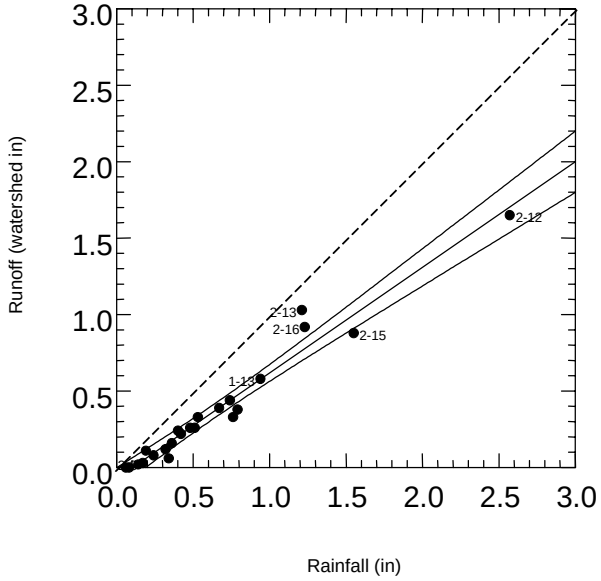


Figure 41

Regression of rainfall/runoff data for outfall 20-f, combined year 1 and year 2. Slope of regression line is 0.69. (95% confidence interval and 1:1 dotted reference line shown).

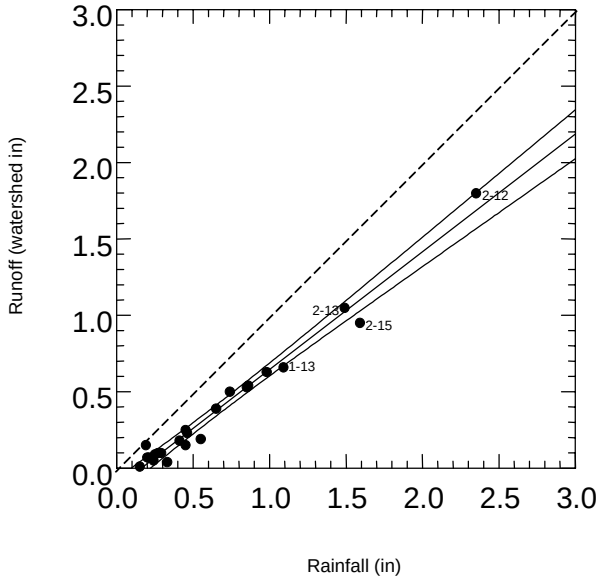


Figure 42

Regression of rainfall/runoff data for outfall 8-23c, combined year 1 and year 2. Slope of regression line is 0.77. (95% confidence interval and 1:1 dotted reference line shown).

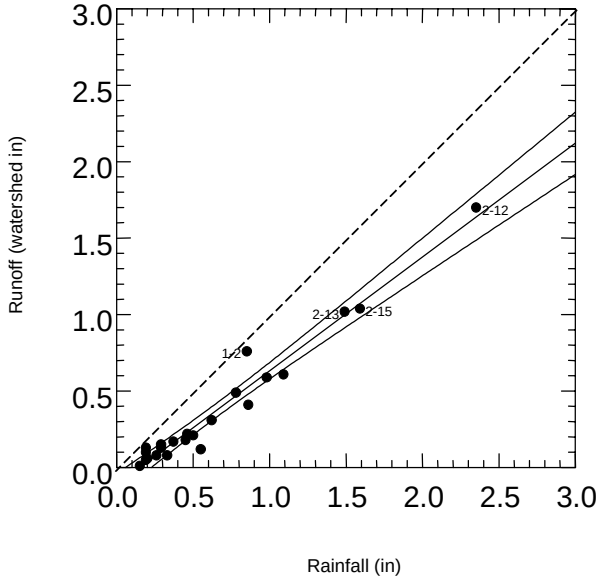
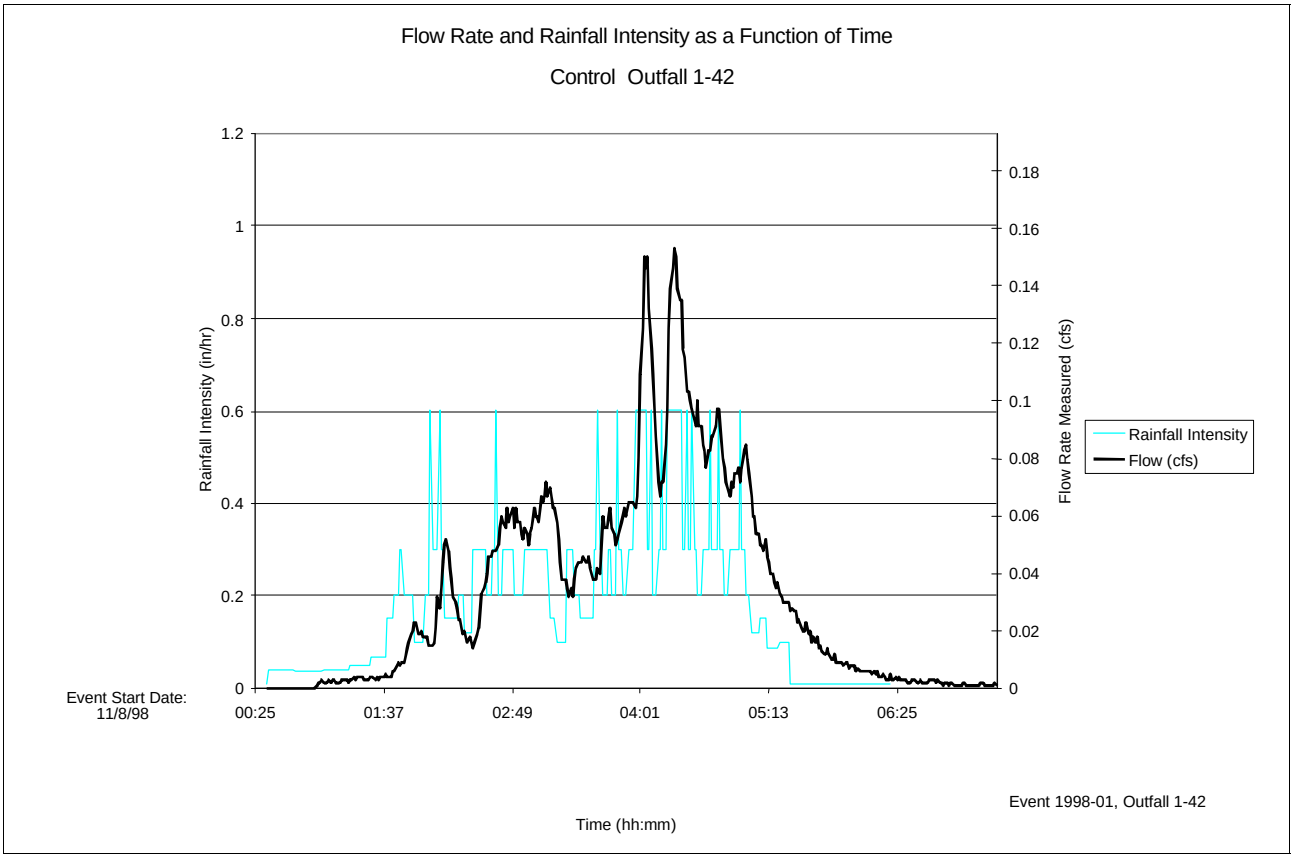
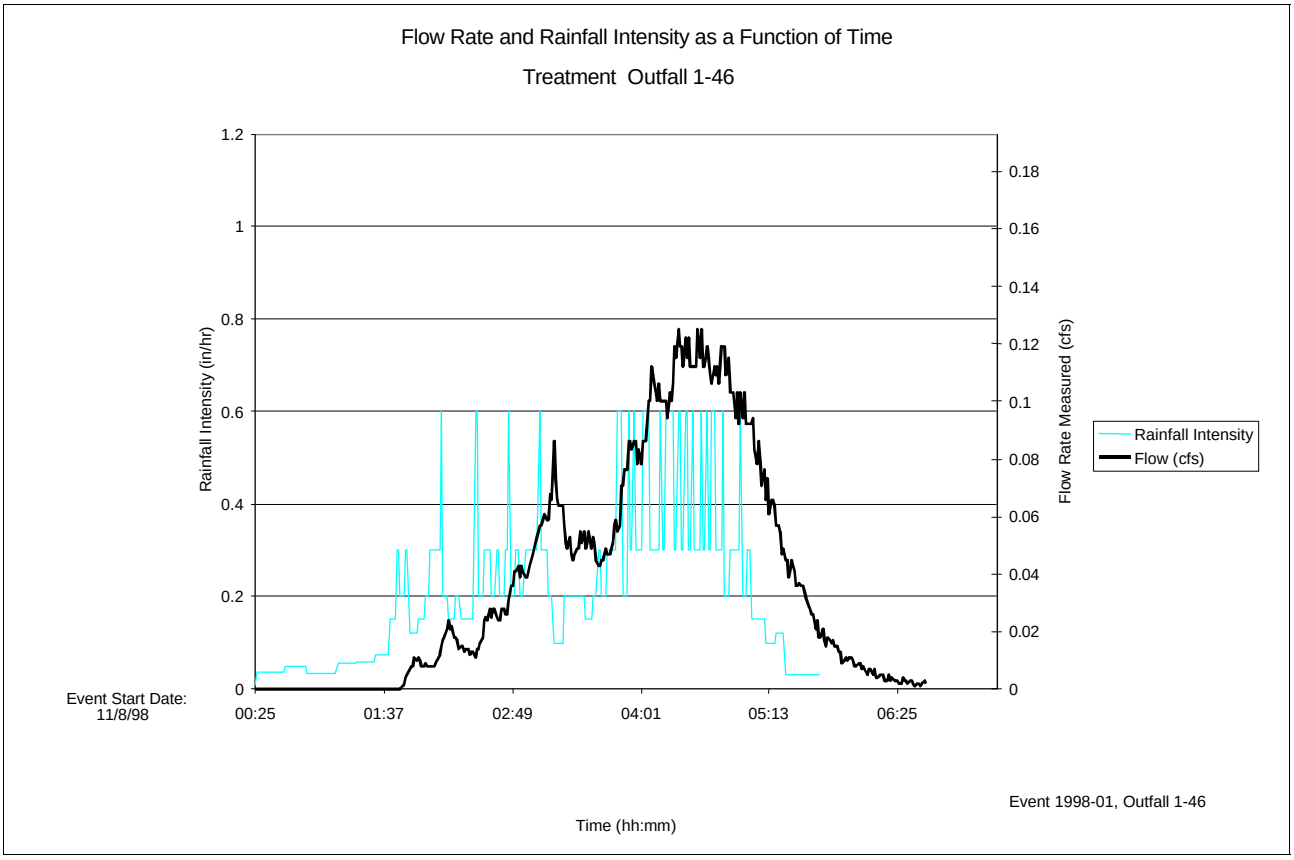


Figure 43

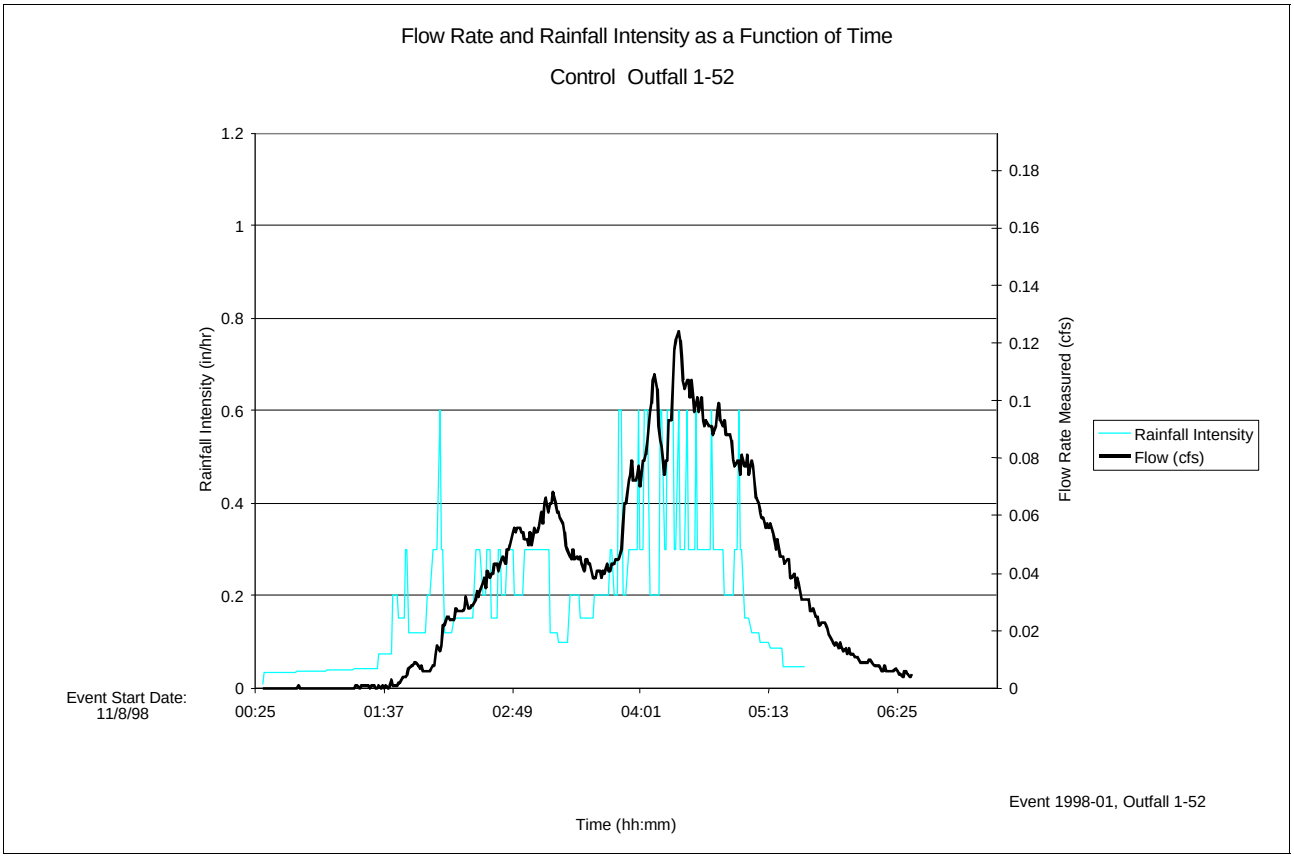
Regression of rainfall/runoff data for outfall 8-B001, combined year 1 and year 2. Slope of regression line is 0.74. (95% confidence interval and 1:1 dotted reference line shown).

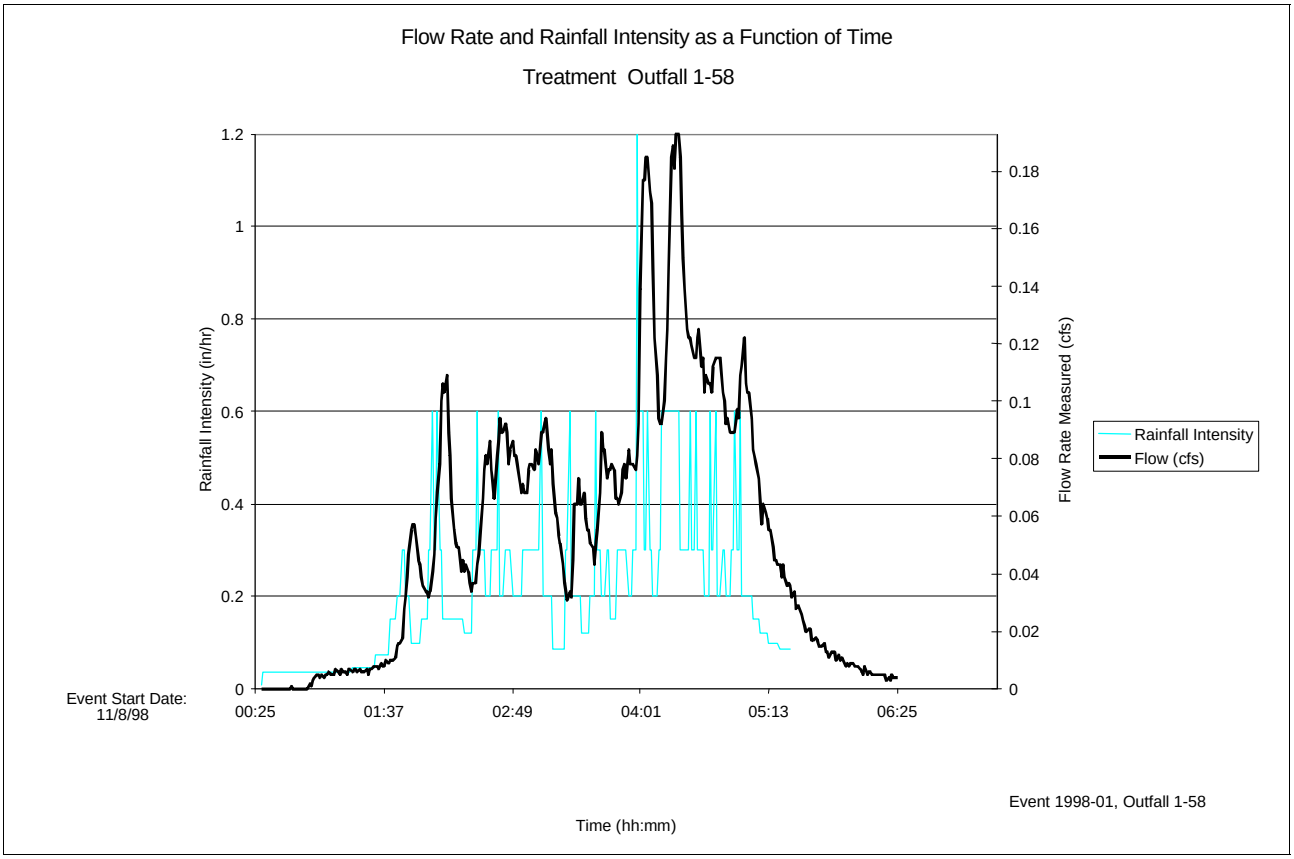
Site 1E - Litter Pickup Event No. 1998e01 - 11/8/98



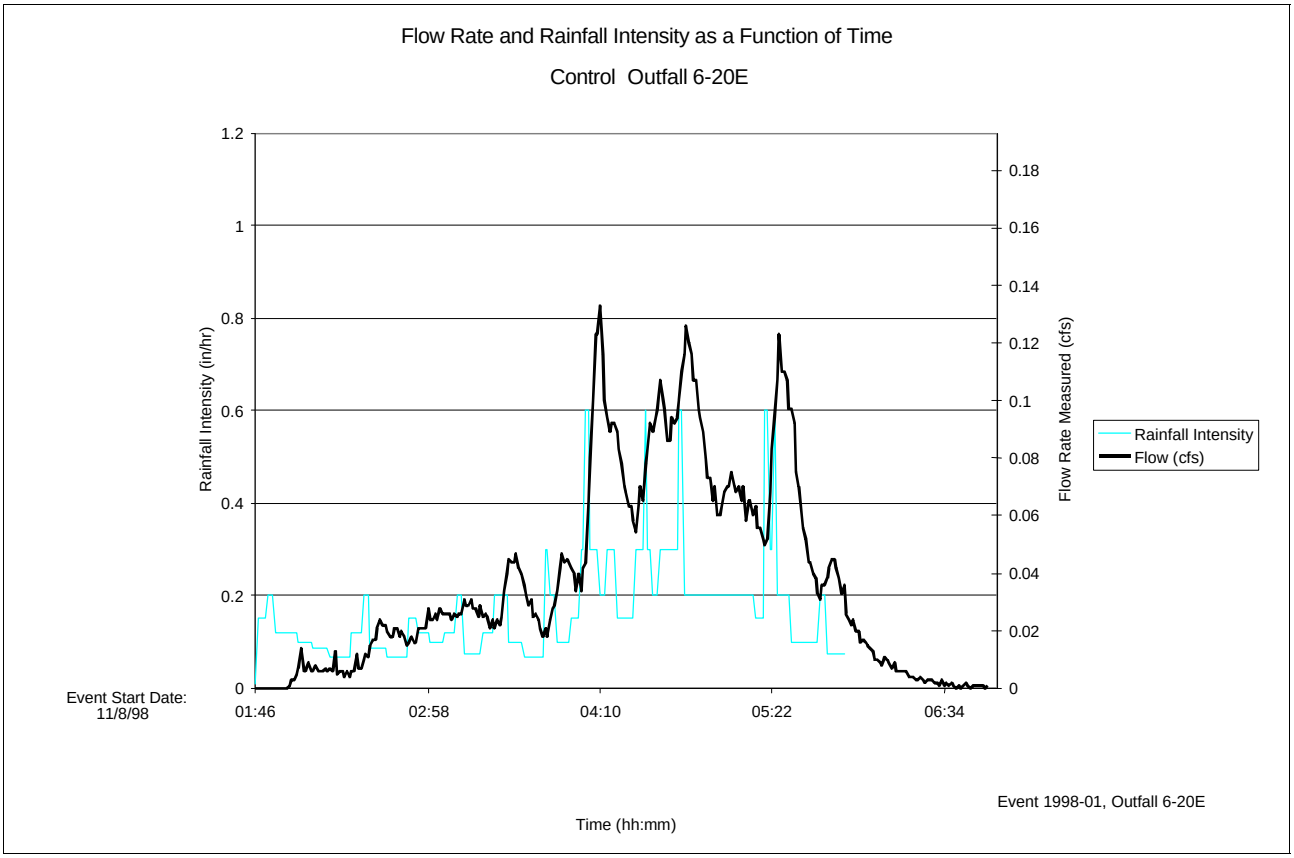


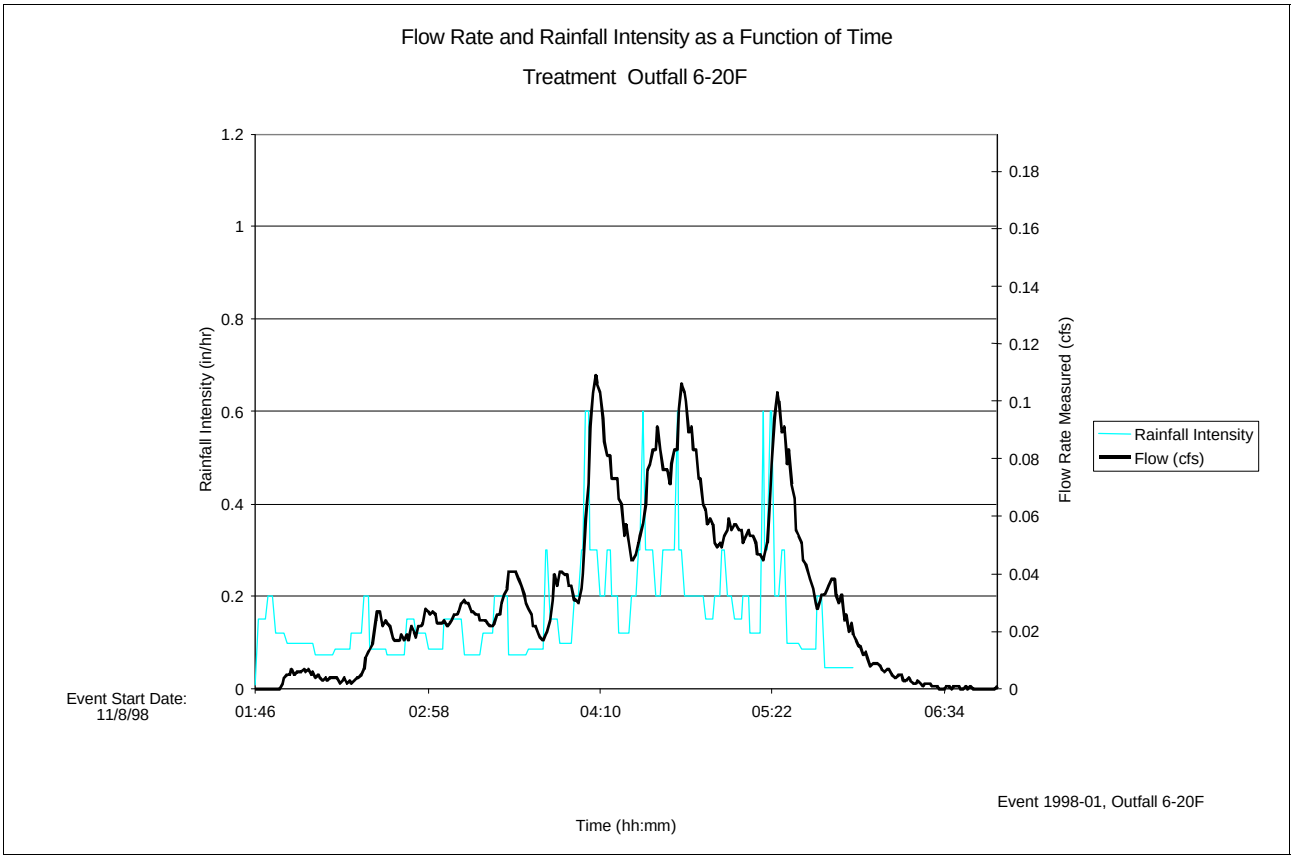
Site 1W - Street Sweeping Event No. 1998e01 - 11/8/98



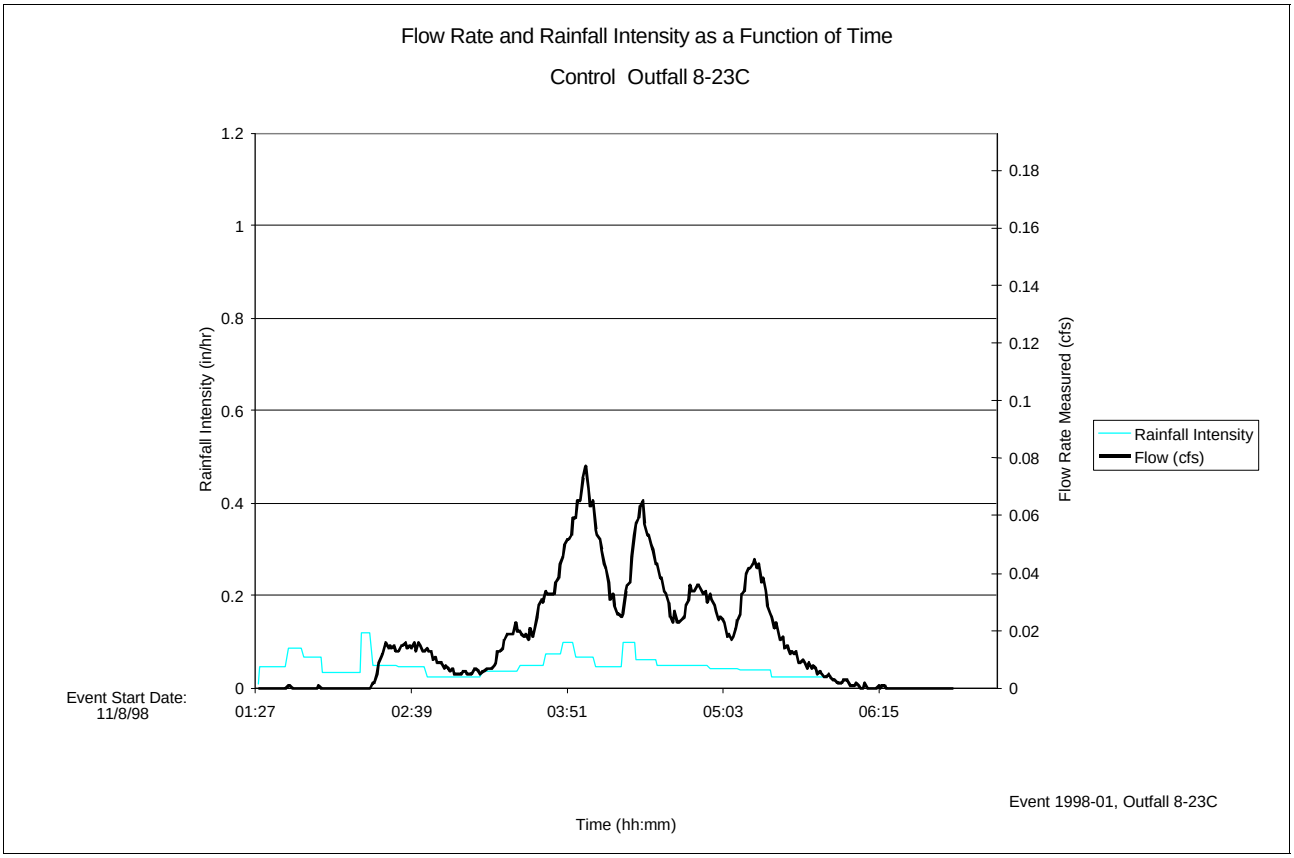


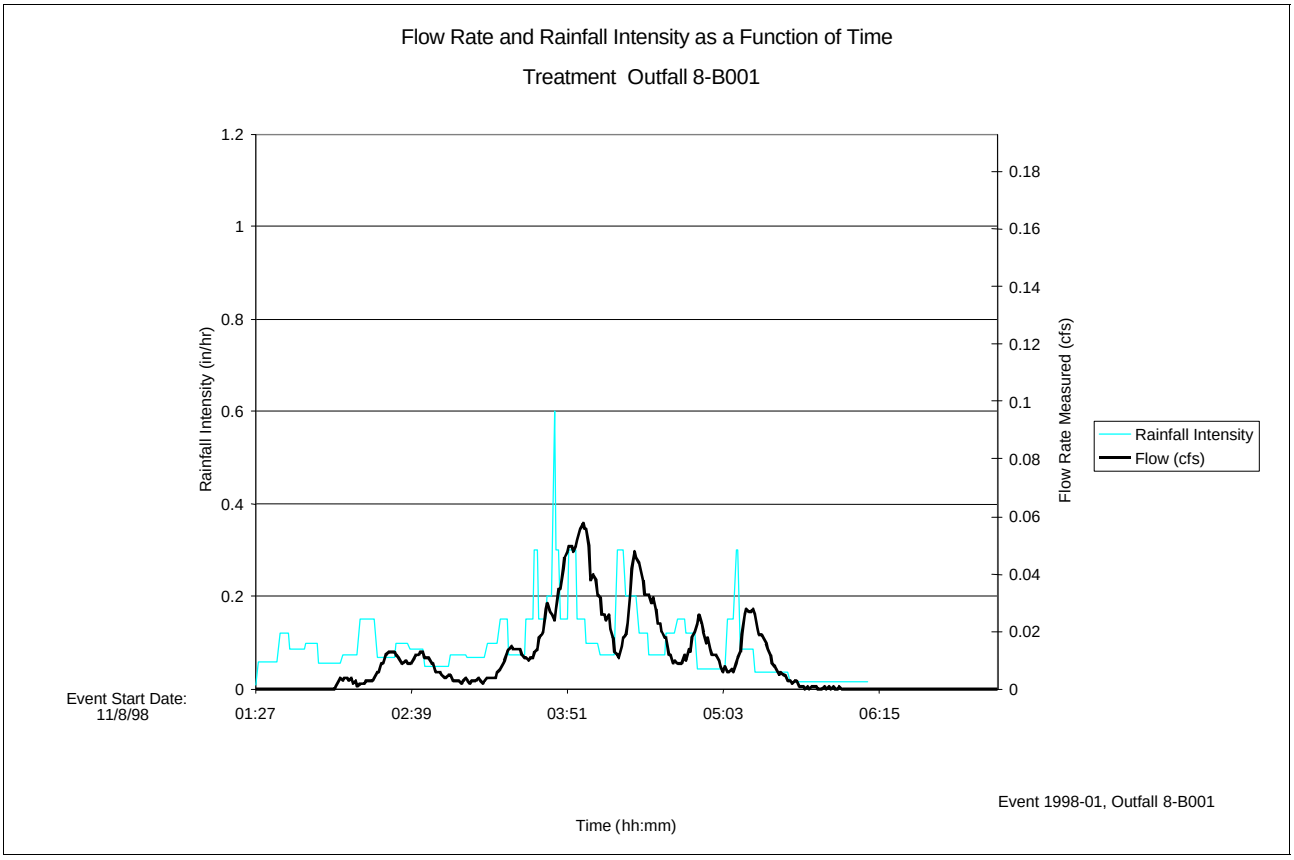
Site 6 - Modified Inlet Event No. 1998e01 - 11/8/98



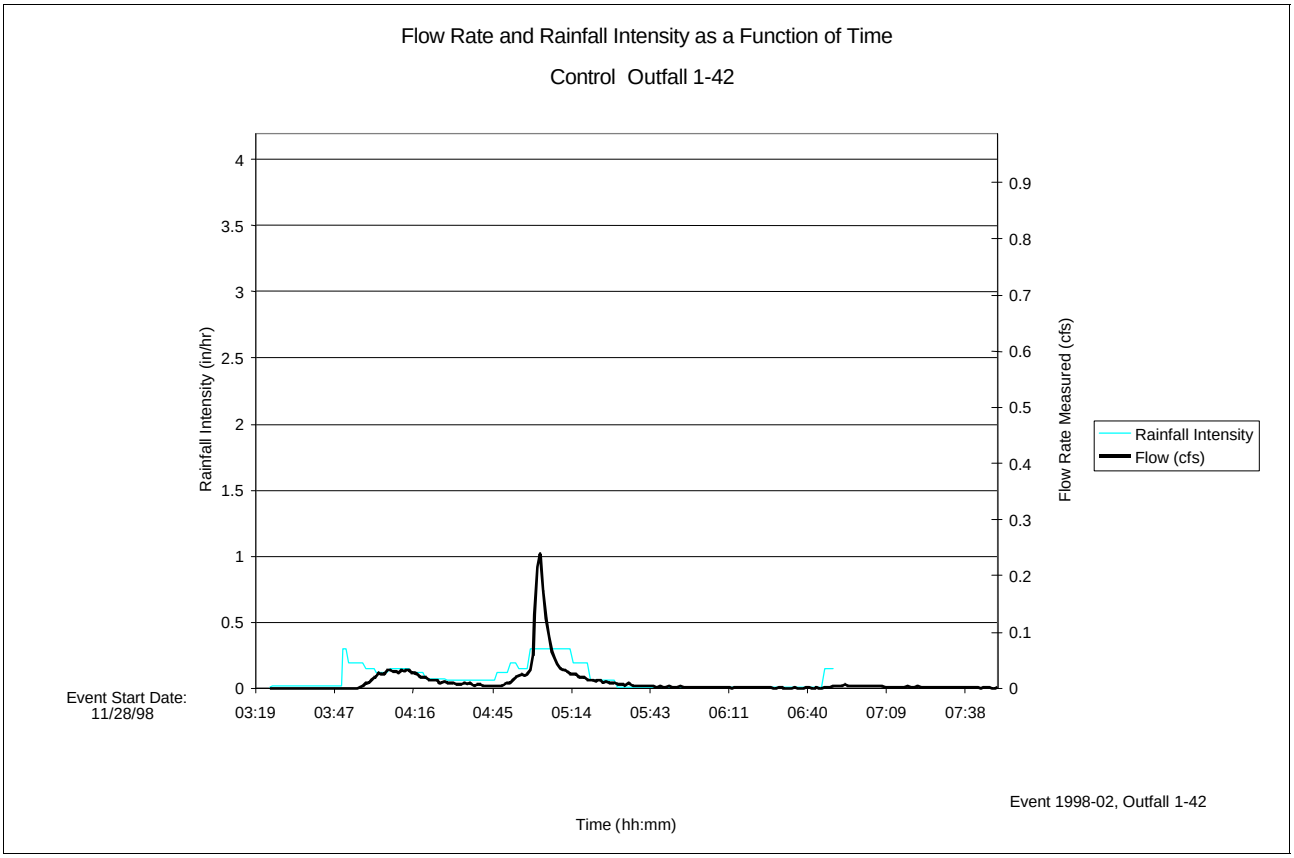


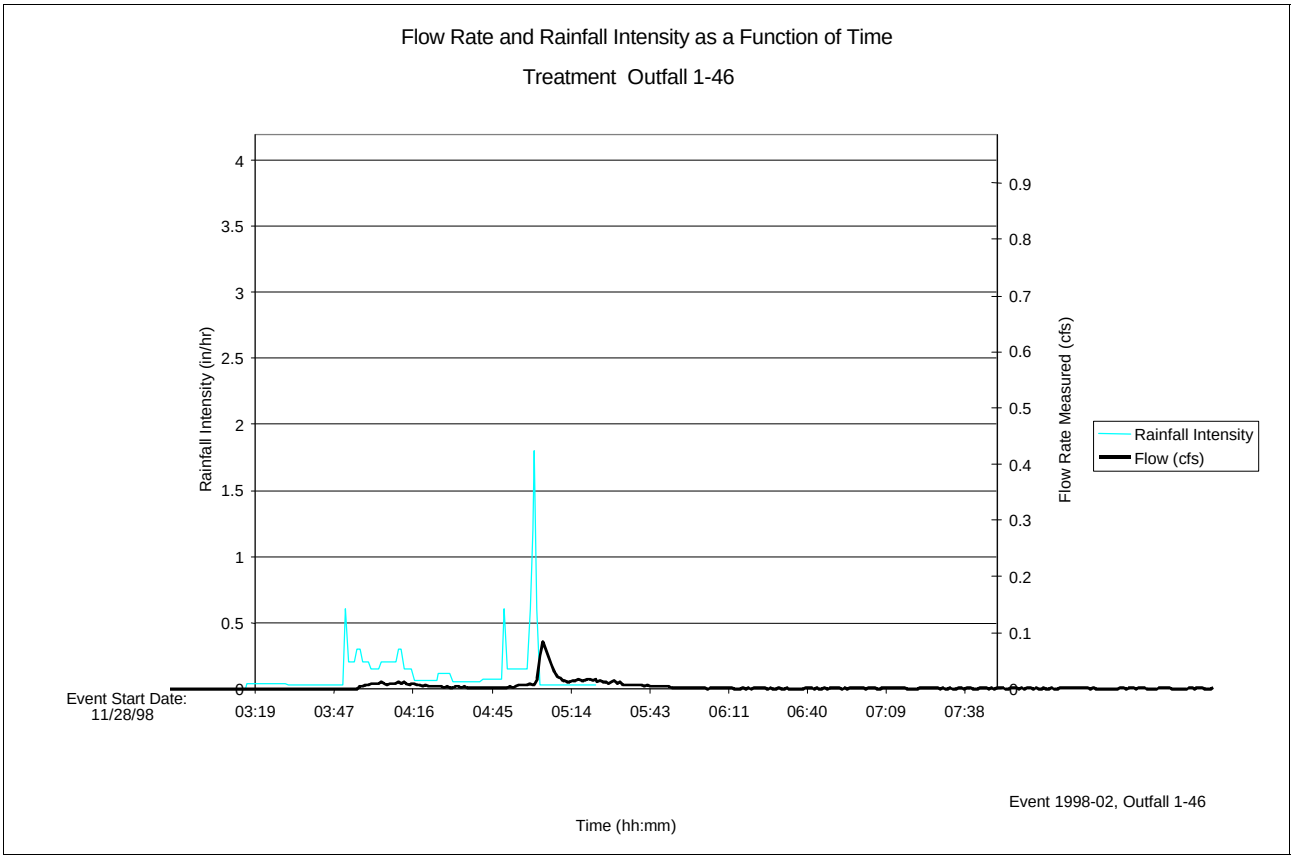
Site 8 - Bicycle Grate/LID Event No. 1998e01 - 11/8/98



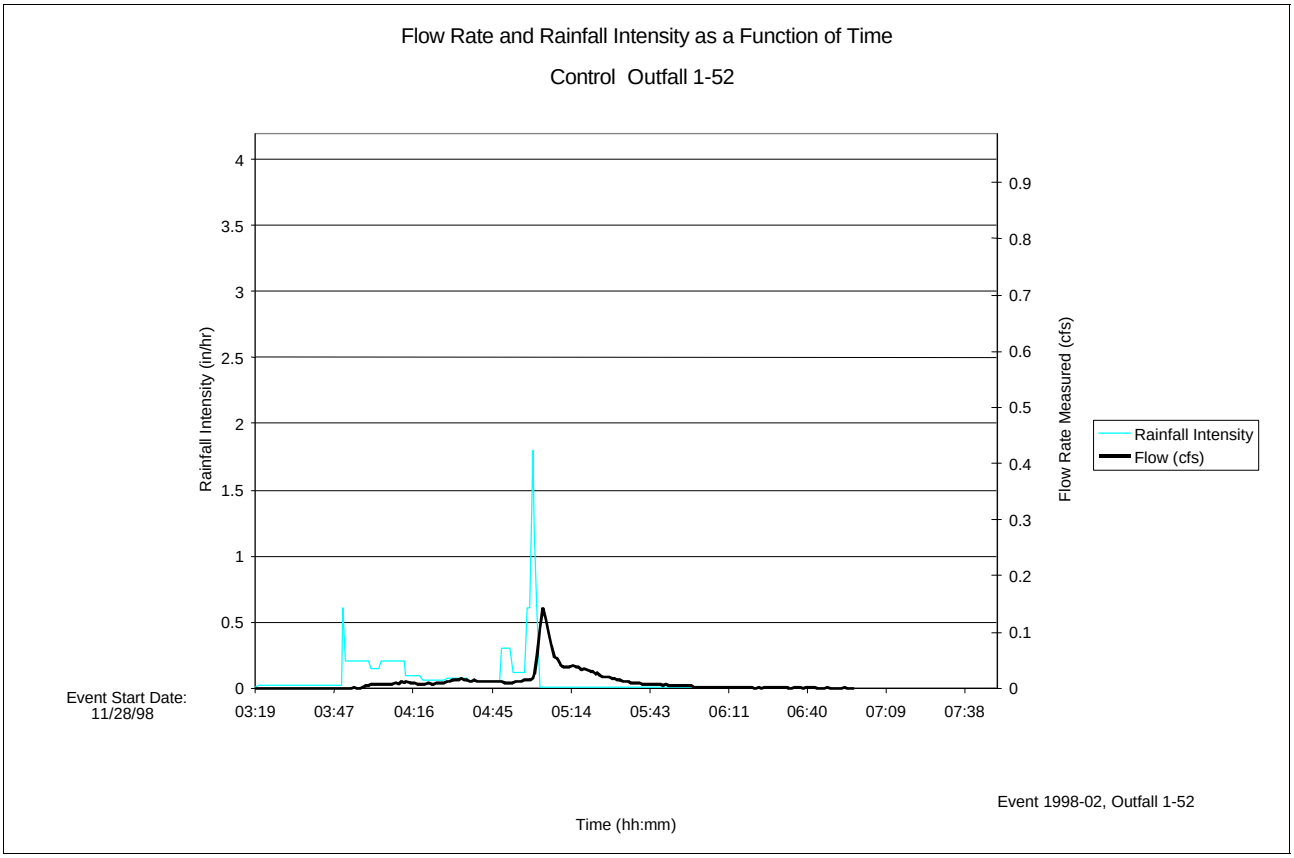


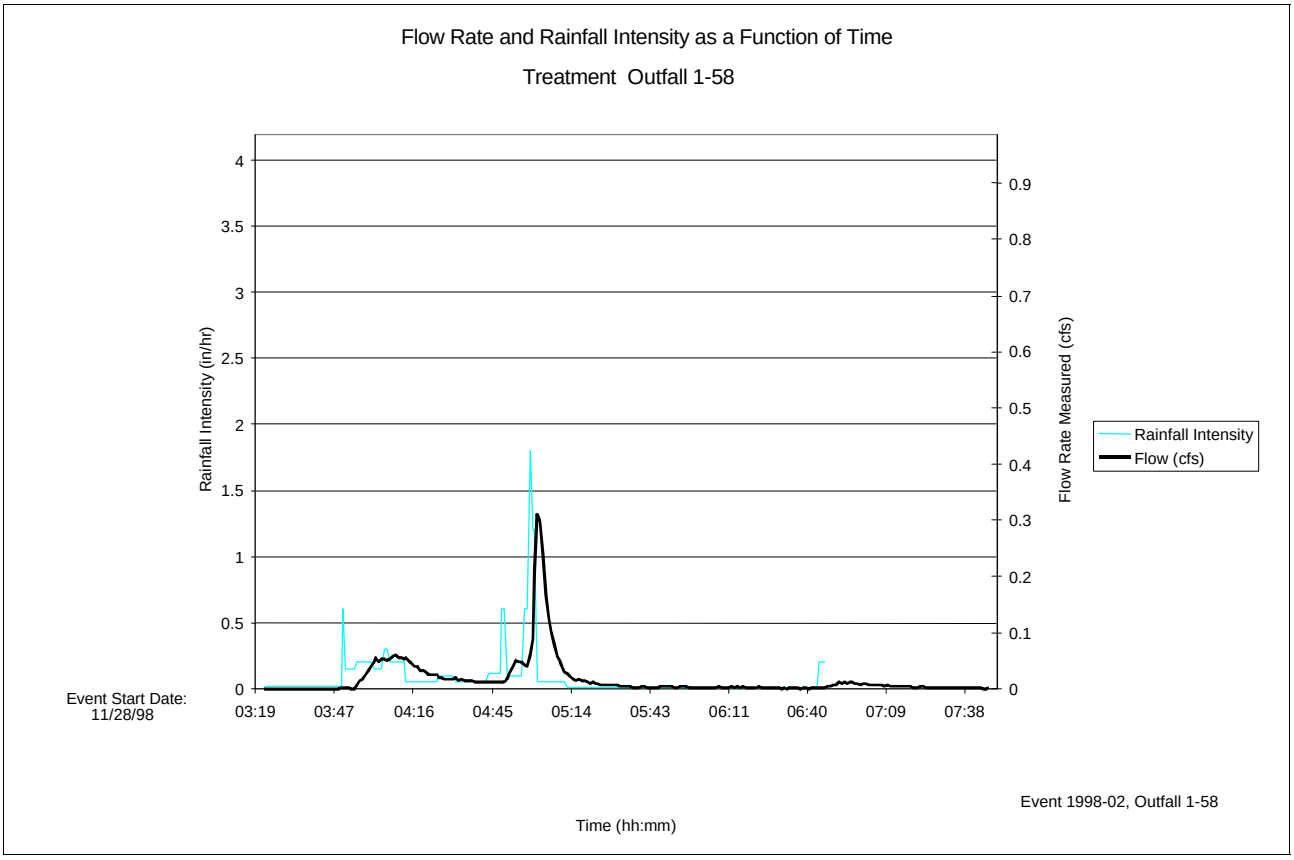
Site 1E - Litter Pickup Event No. 1998e02 - 11/28/98



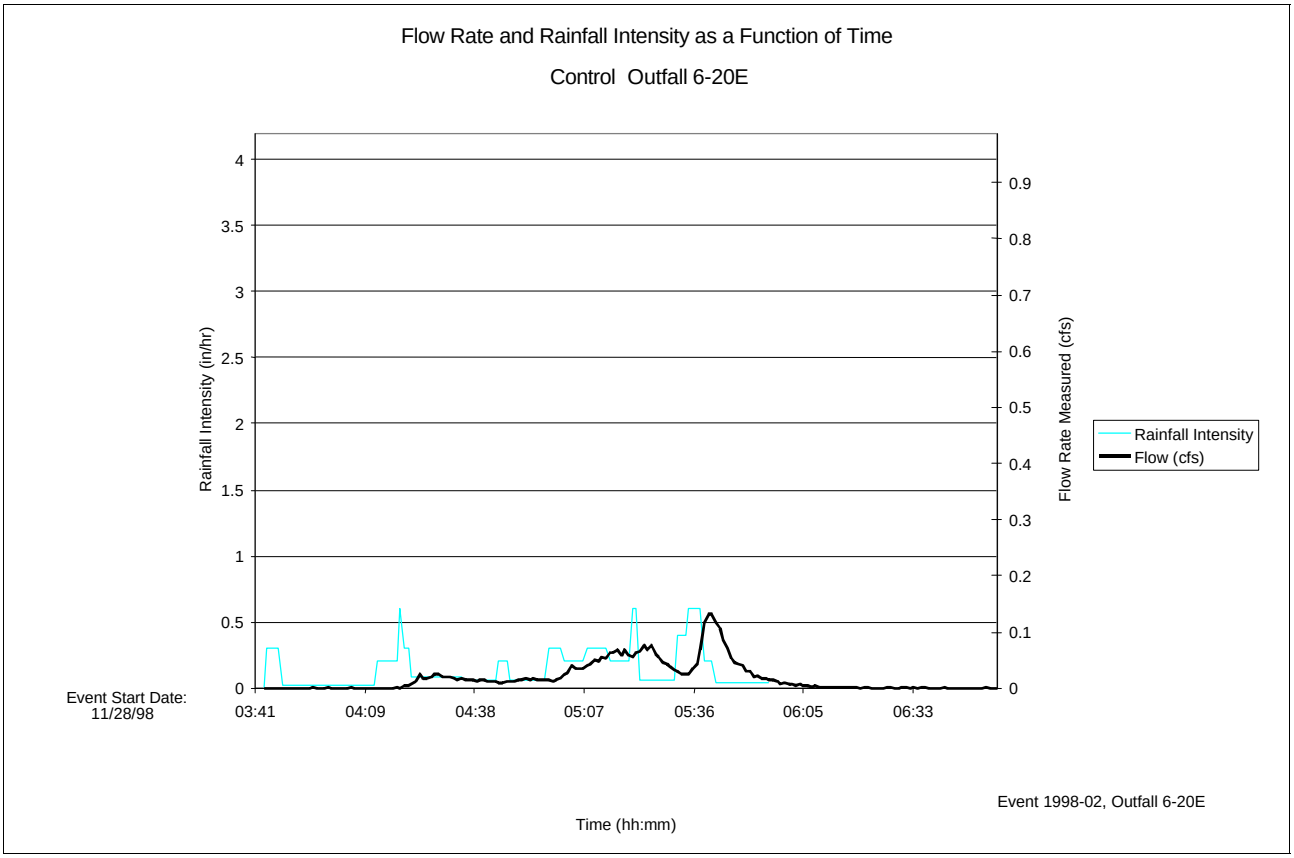


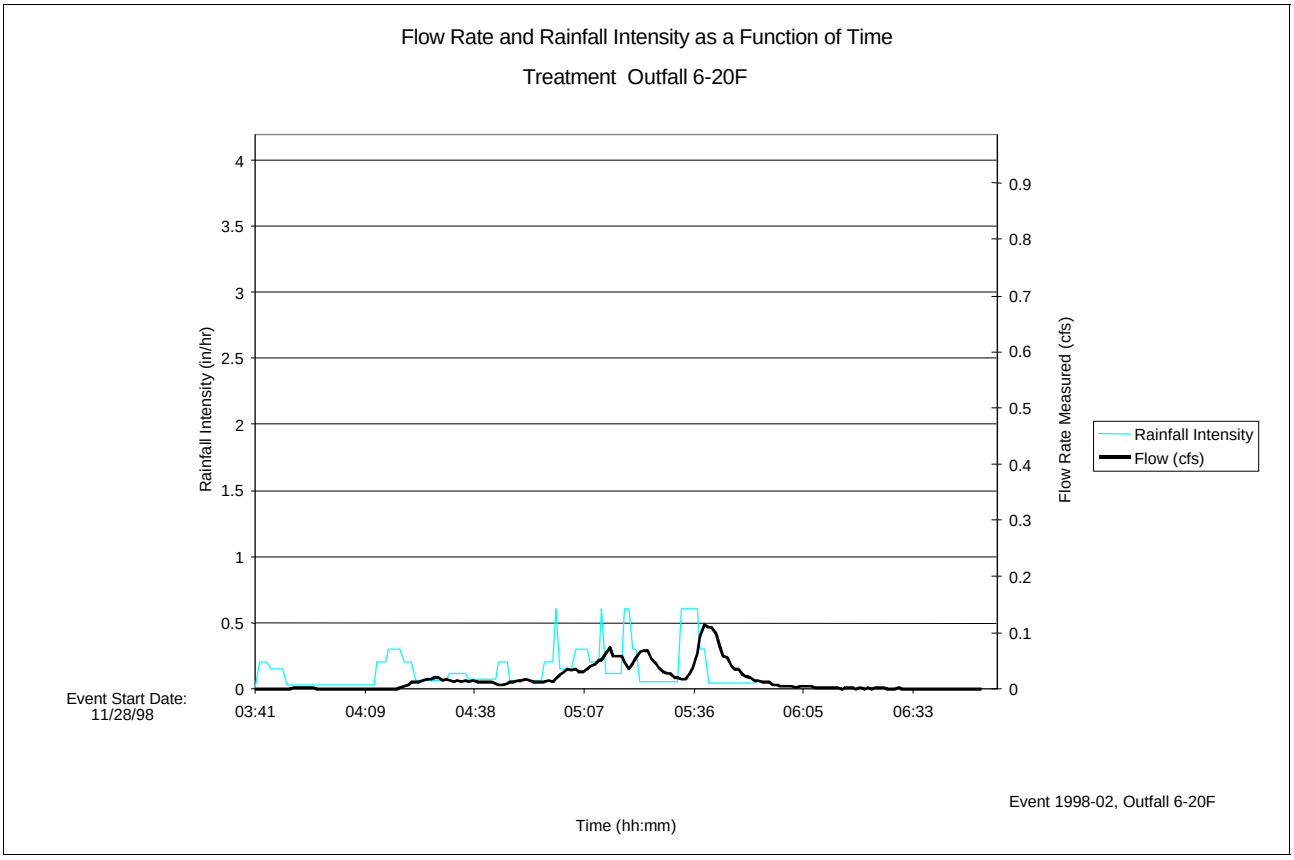
Site 1W - Street Sweeping Event No. 1998e02 - 11/28/98



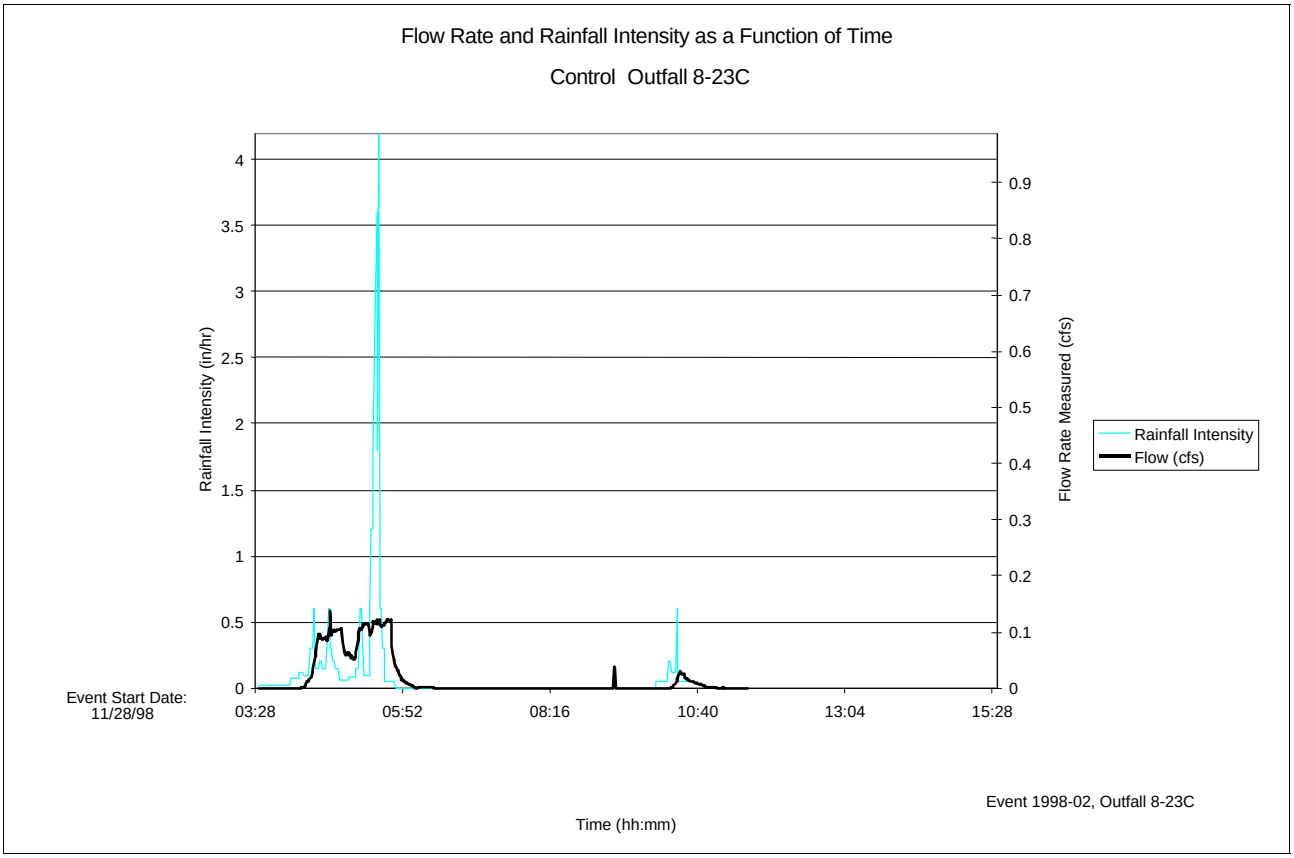


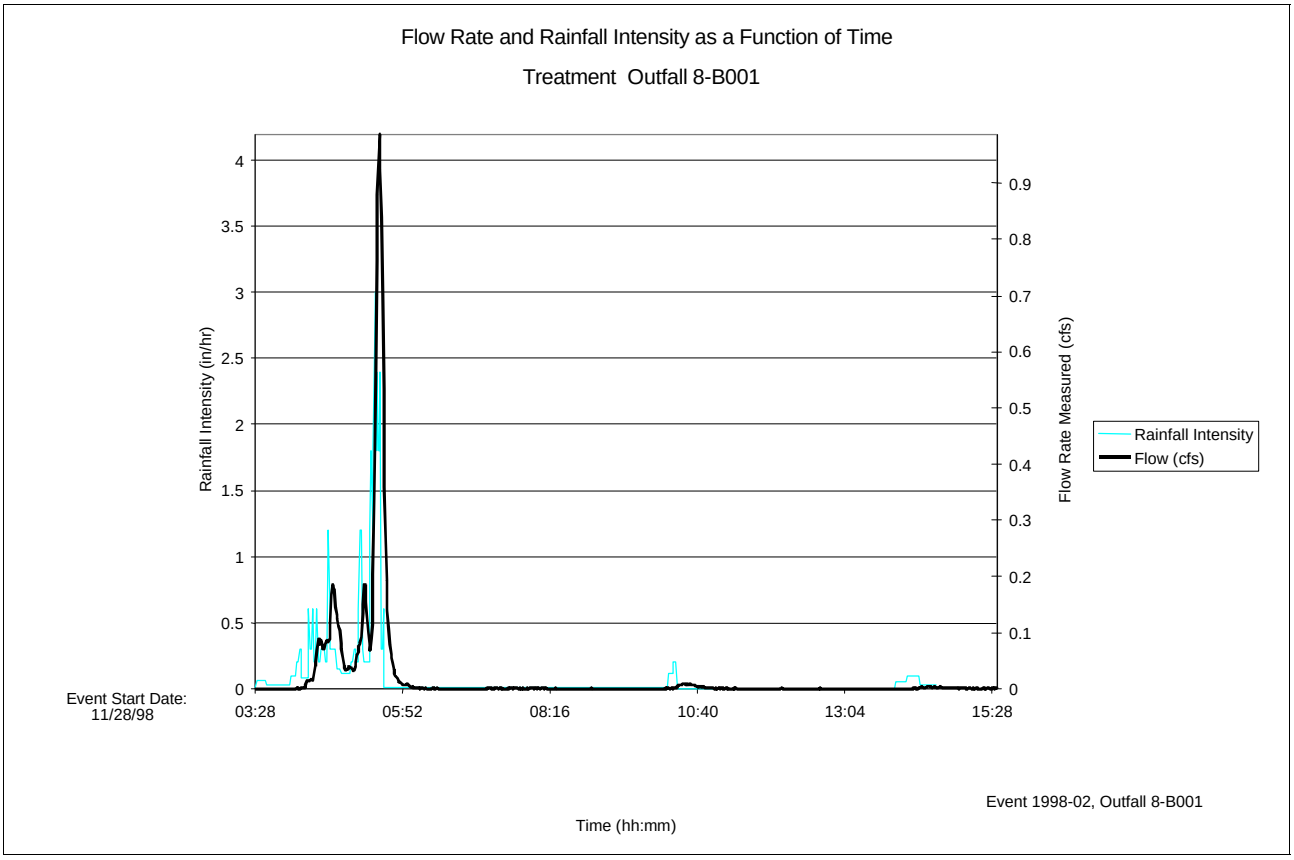
Site 6 - Modified Inlet Event No. 1998e02 - 11/28/98



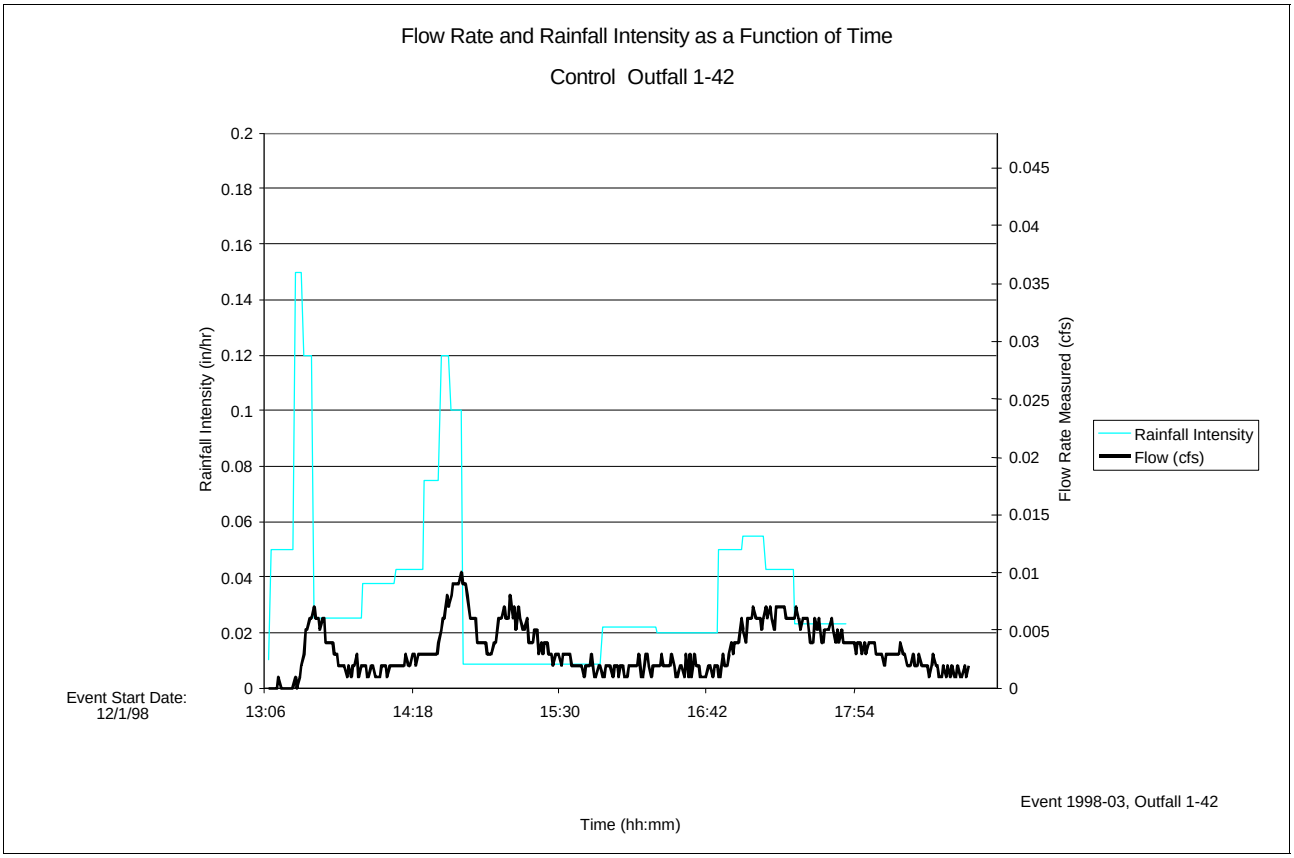


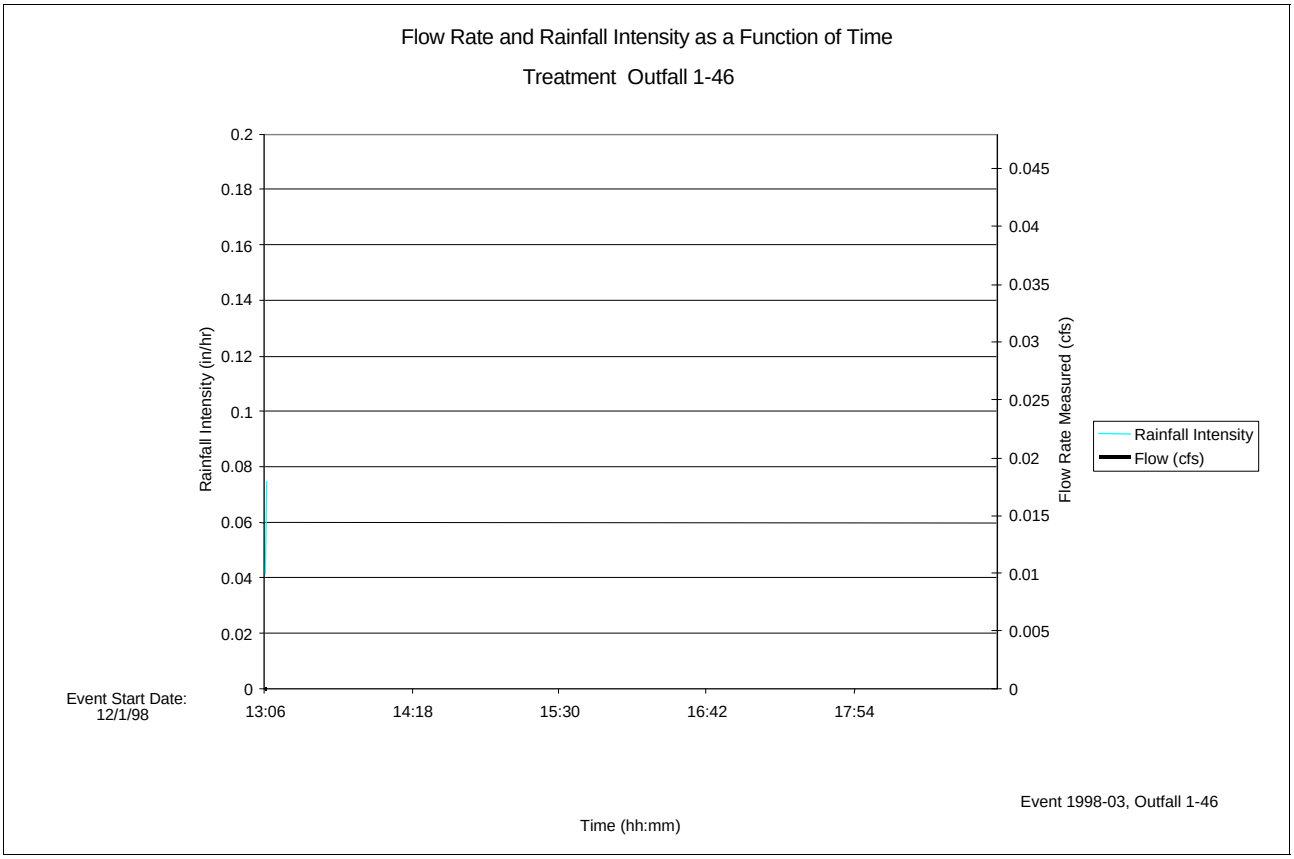
Site 8 - Bicycle Grate/LID Event No. 1998e02 - 11/28/98



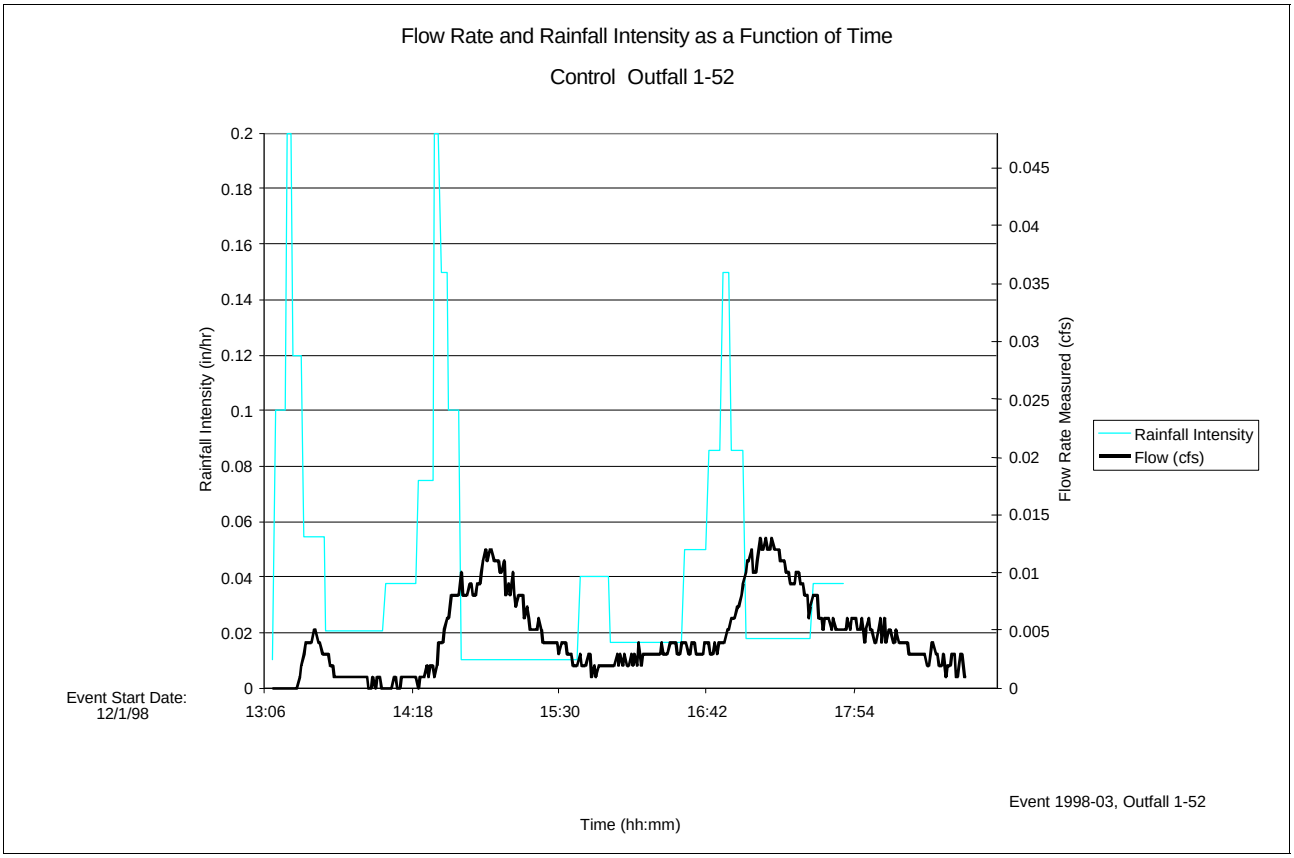


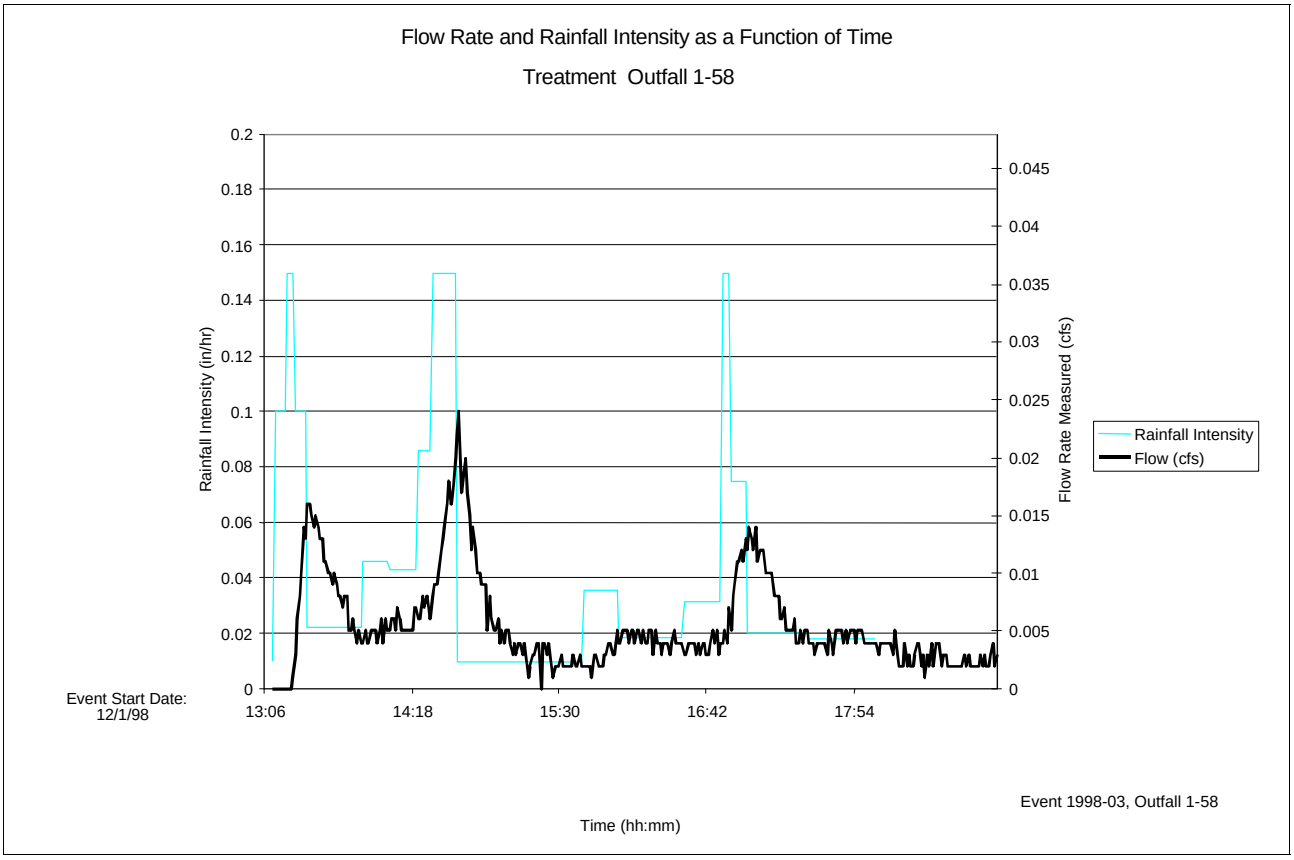
Site 1E - Litter Pickup Event No. 1998e03 - 12/1/98



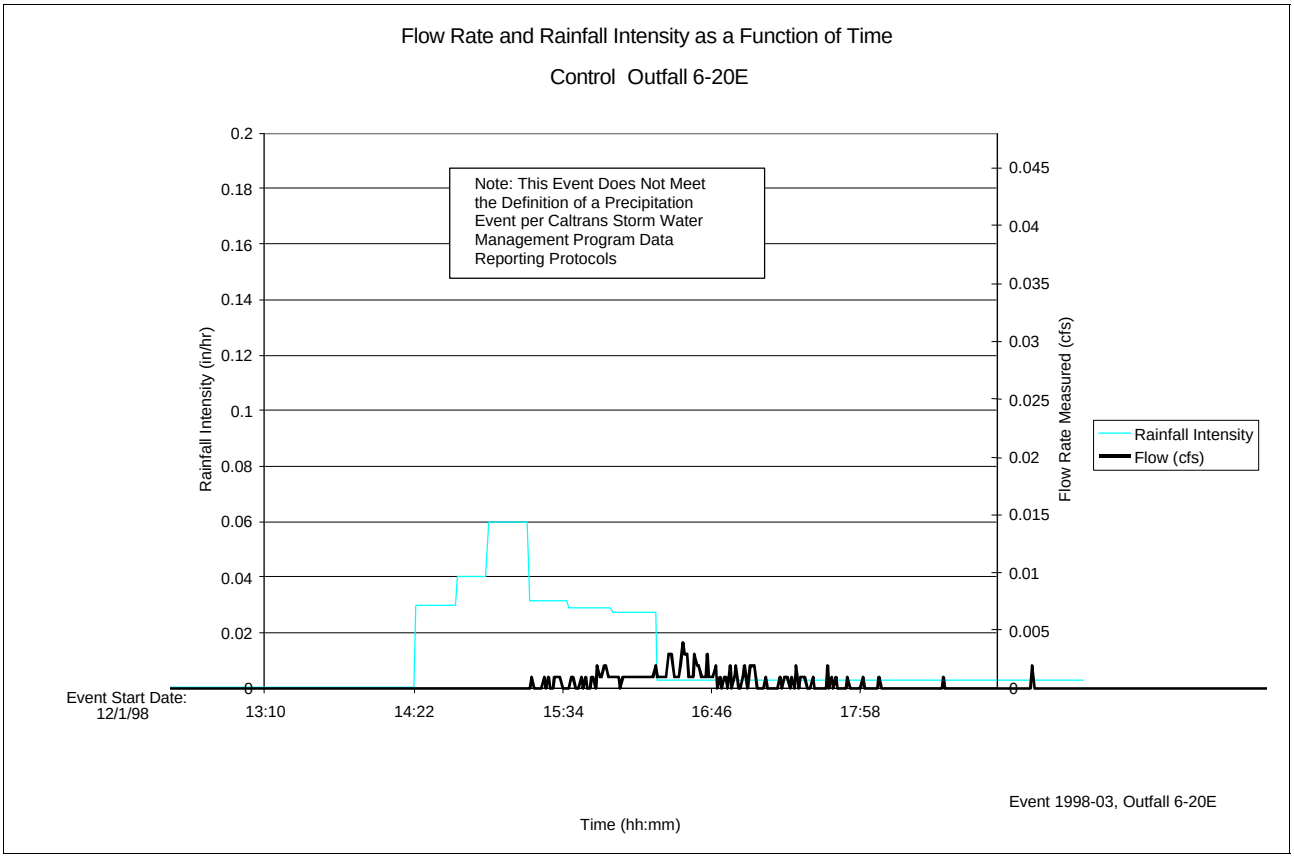


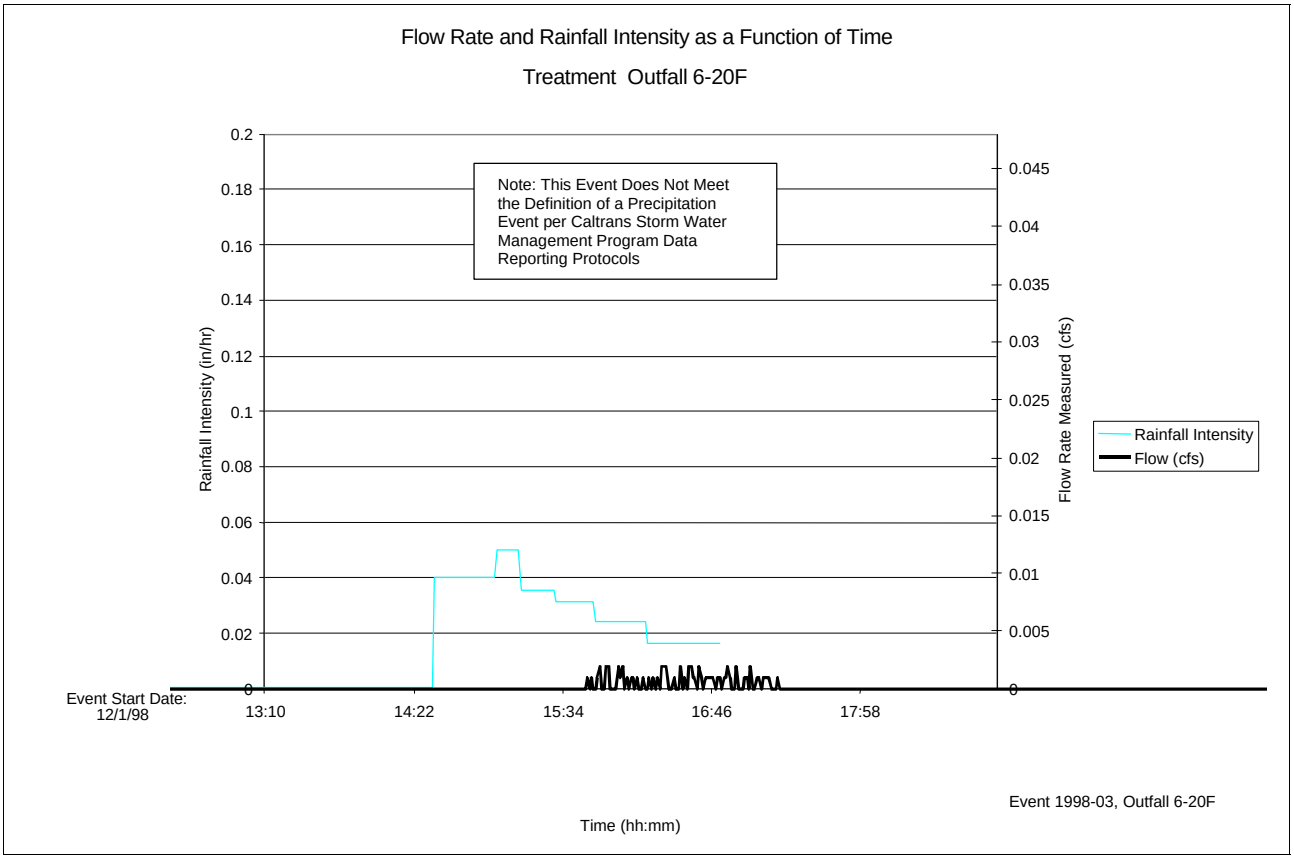
Site 1W - Street Sweeping Event No. 1998e03 - 12/1/98



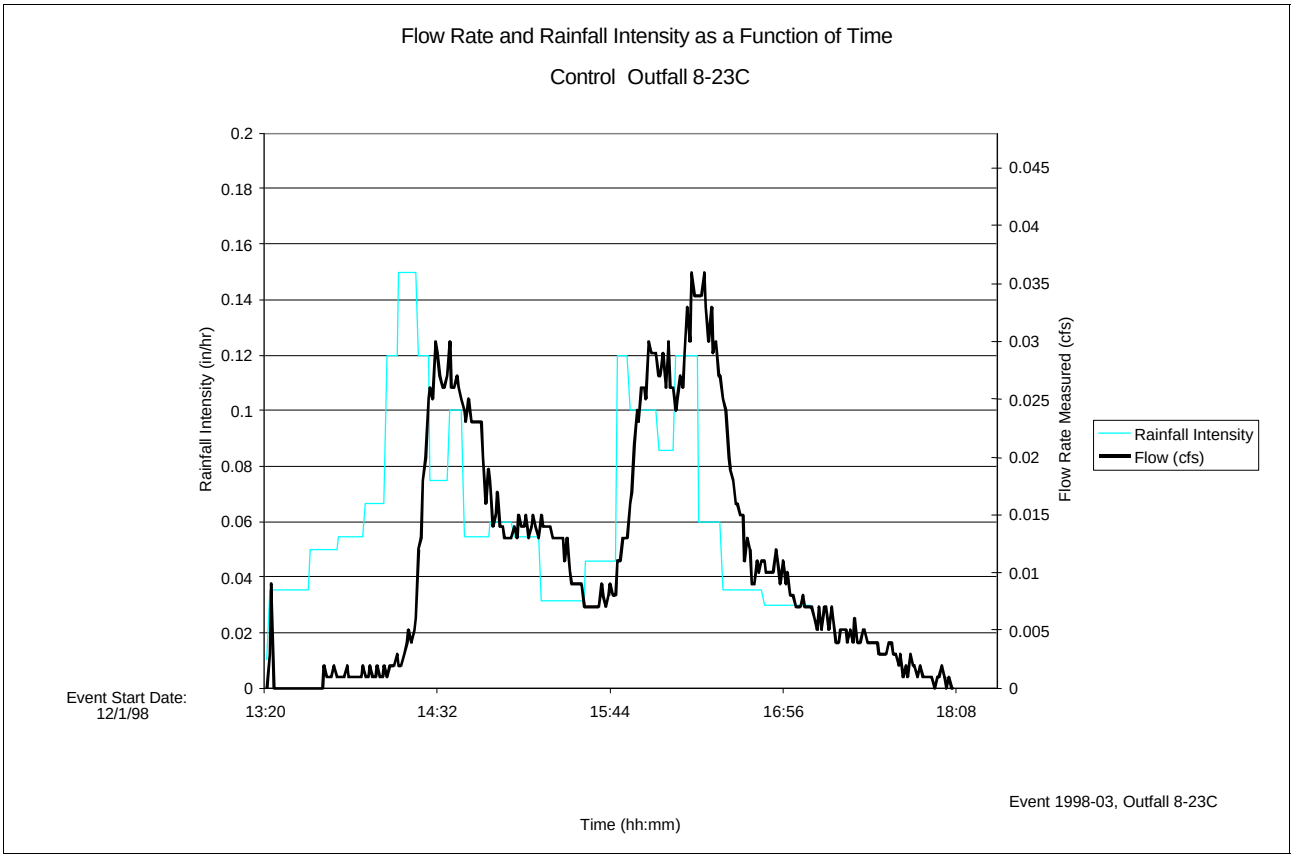


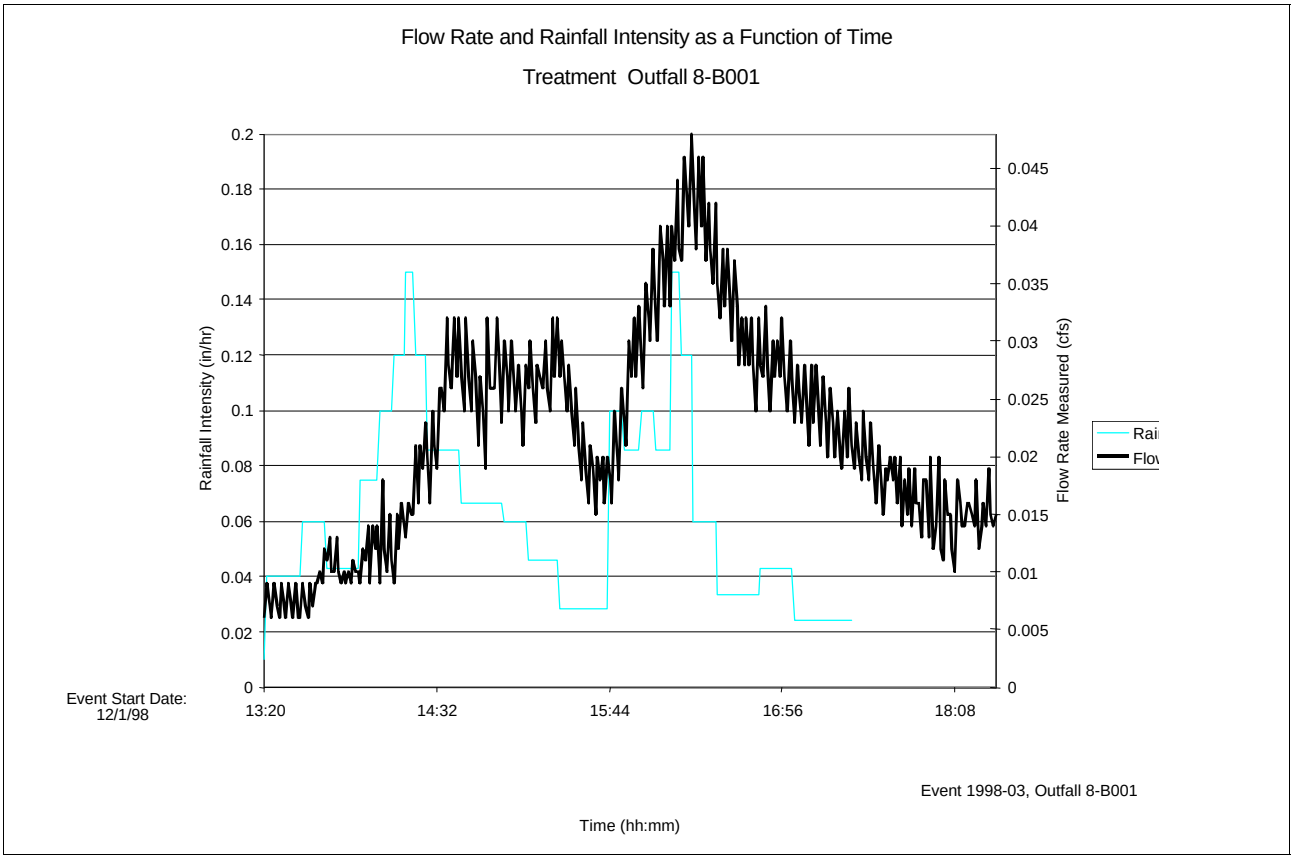
Site 6 - Modified Inlet Event No. 1998e03 - 12/1/98



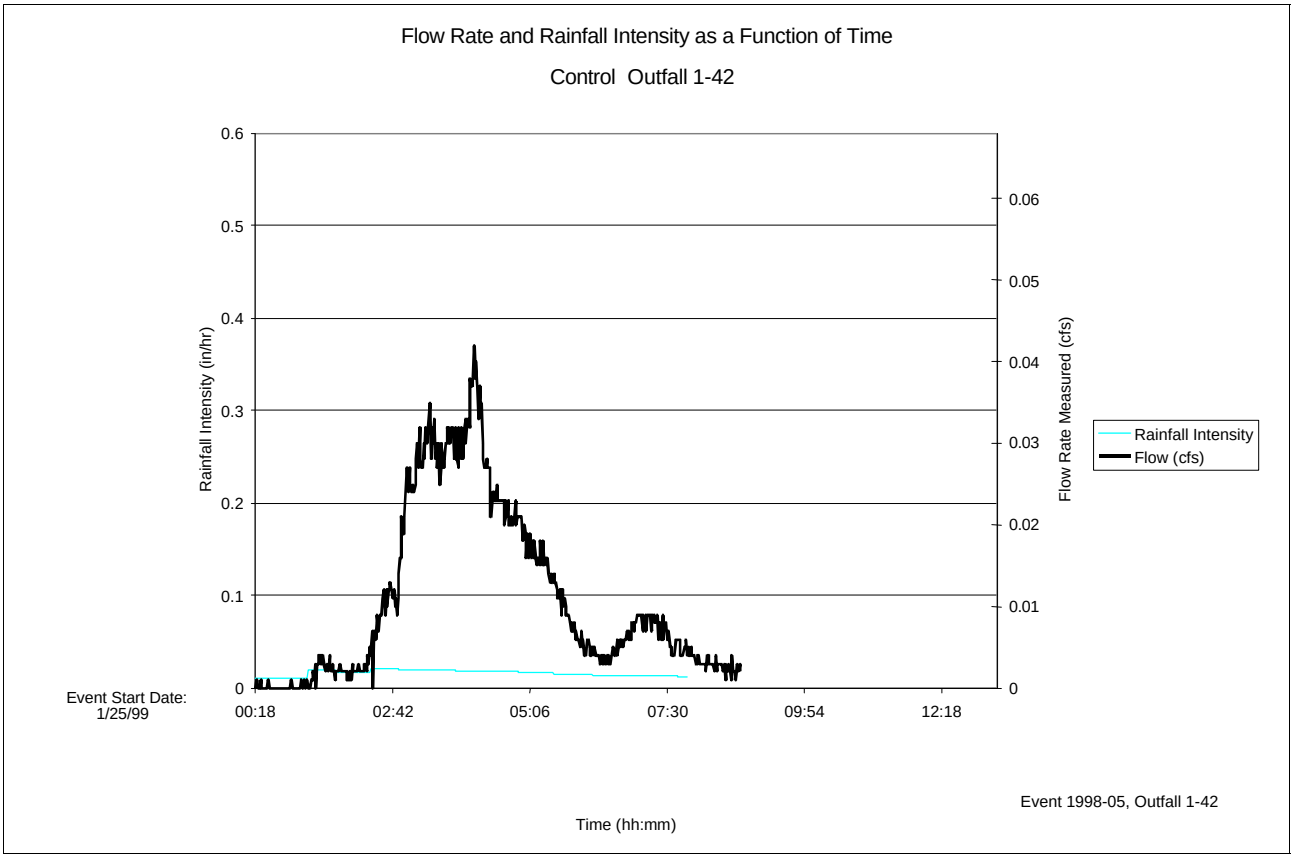


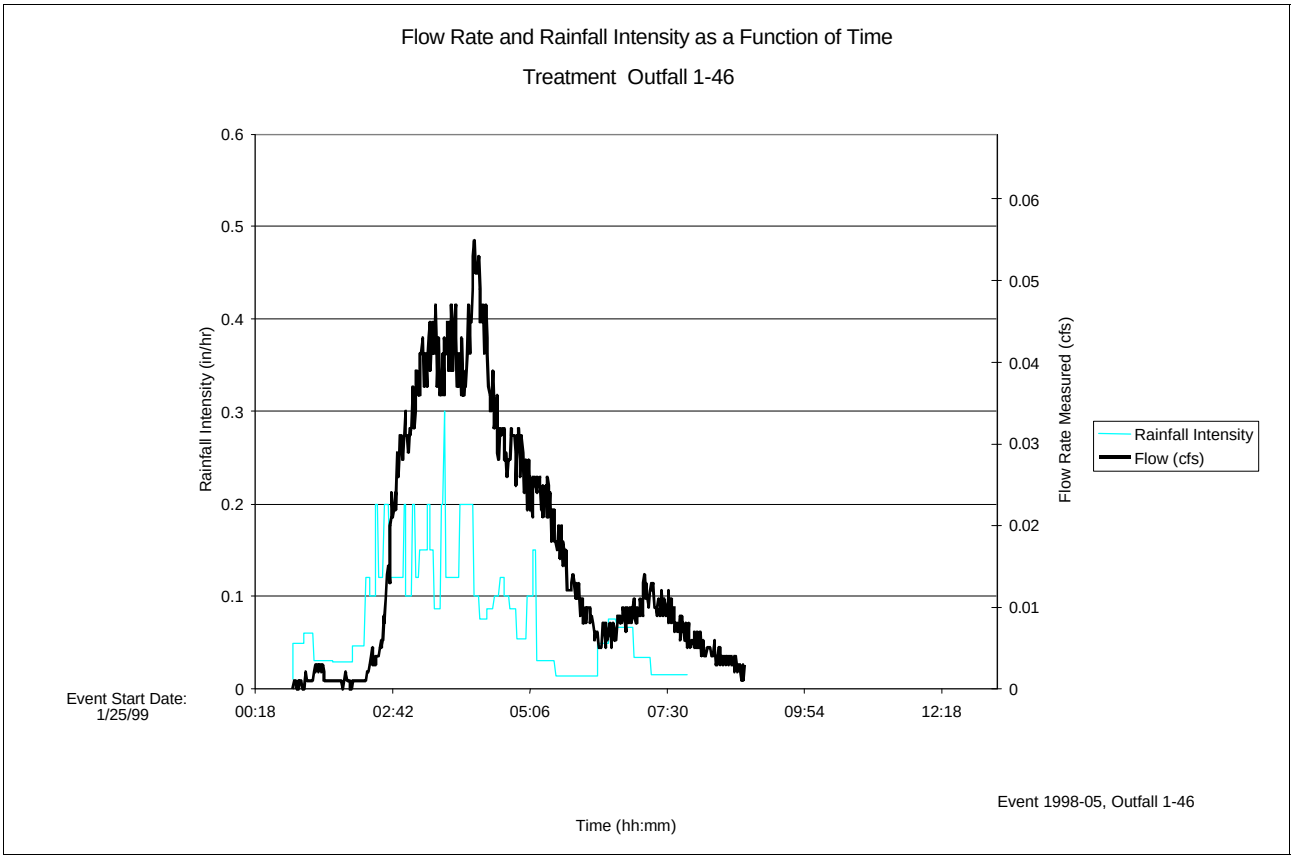
Site 8 - Bicycle Grate/LID Event No. 1998e03 - 12/1/98



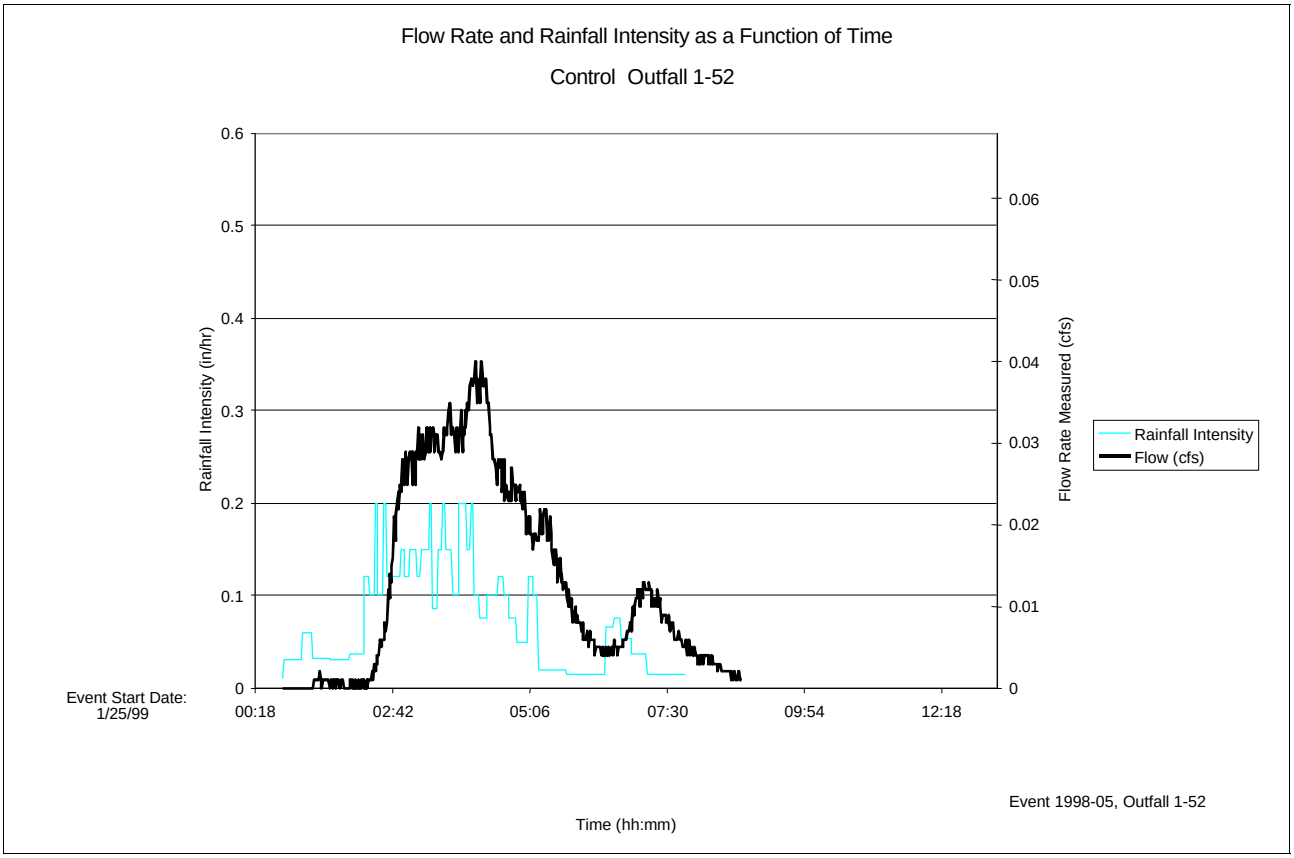


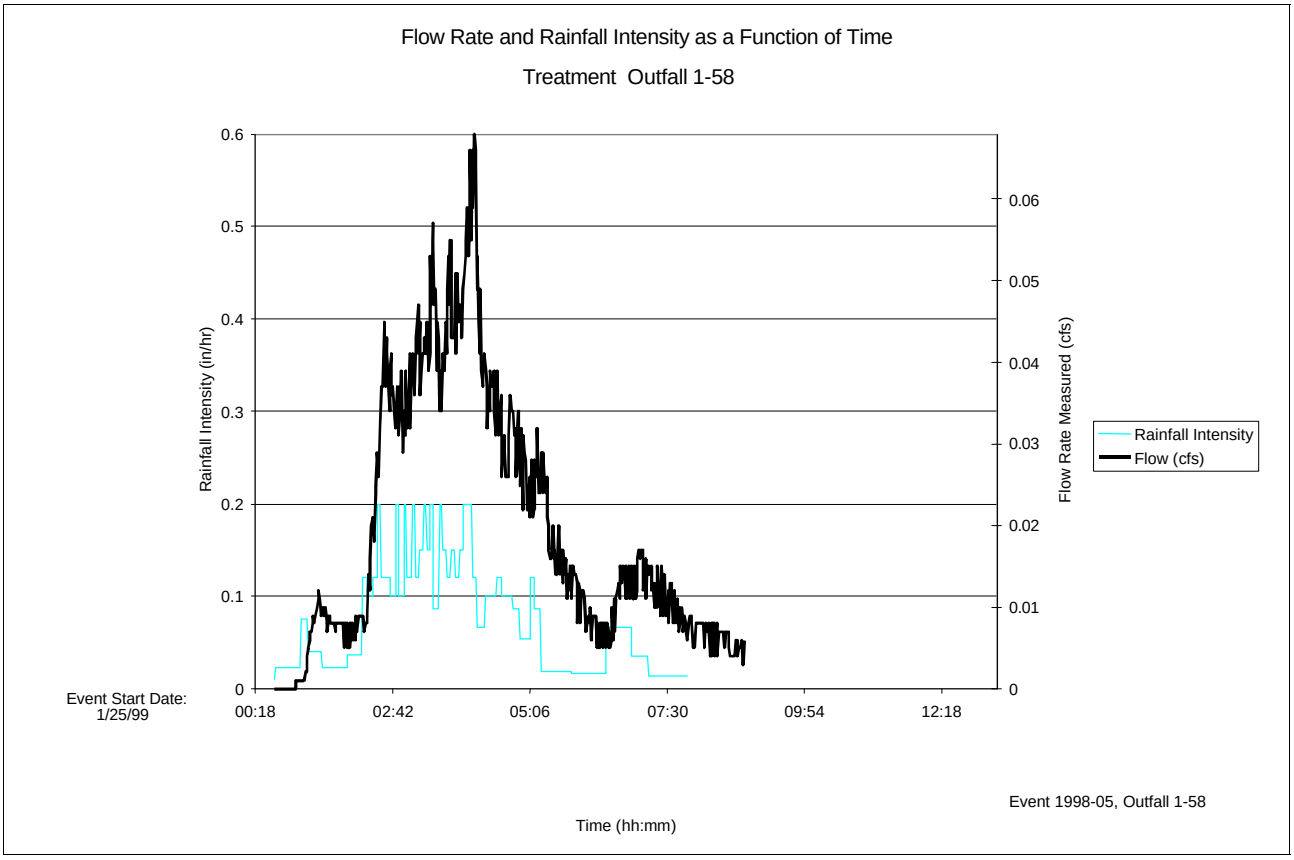
Site 1E - Litter Pickup Event No. 1998e05 - 1/25/99



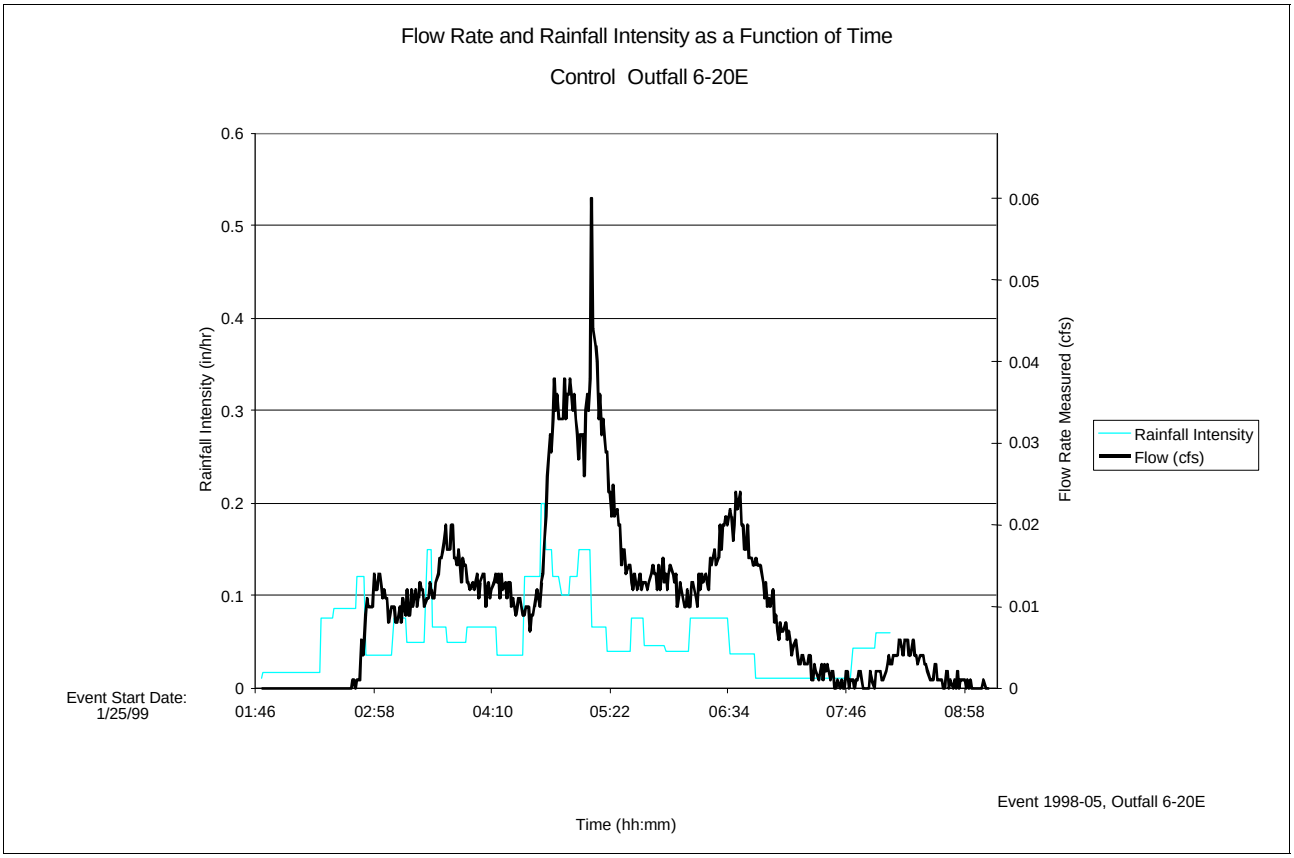


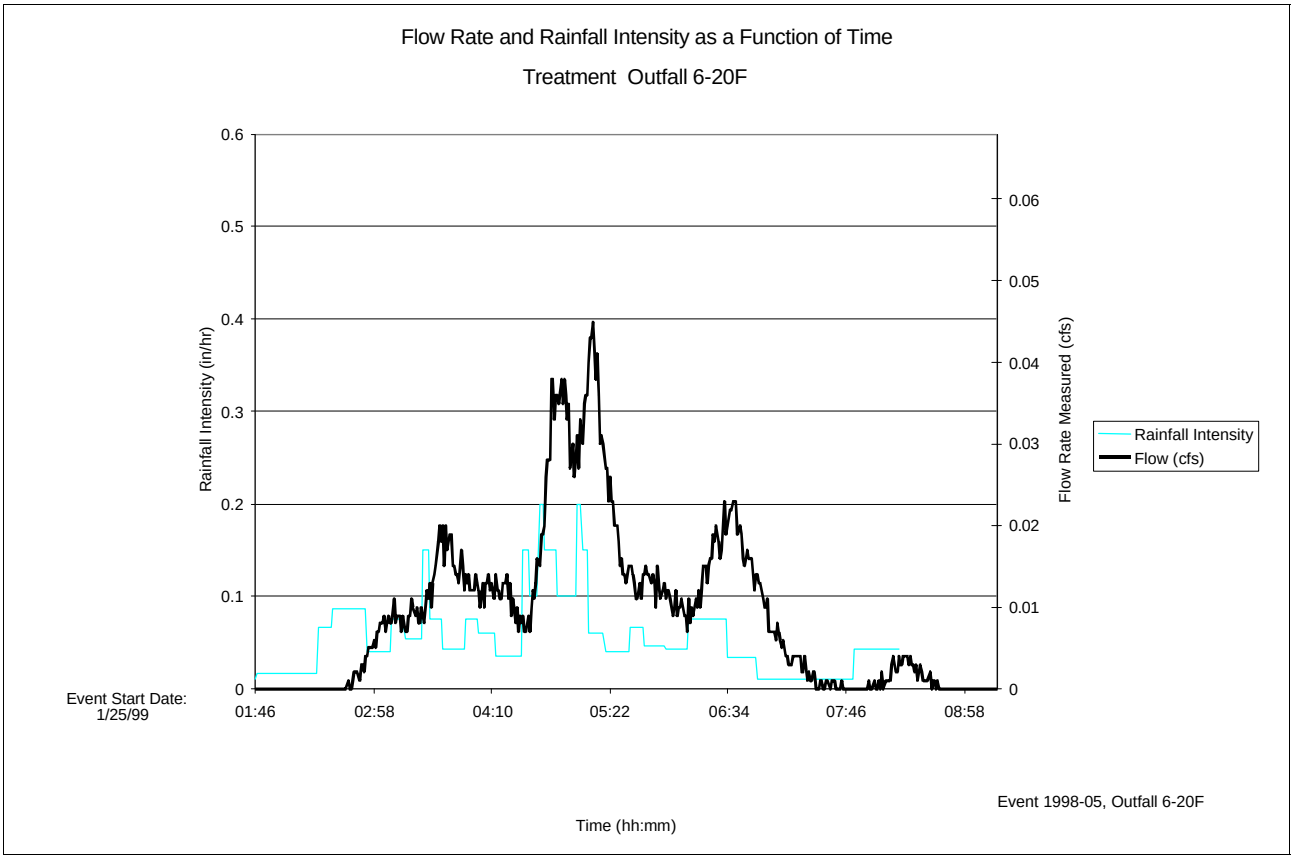
Site 1W - Street Sweeping Event No. 1998e05 - 1/25/99



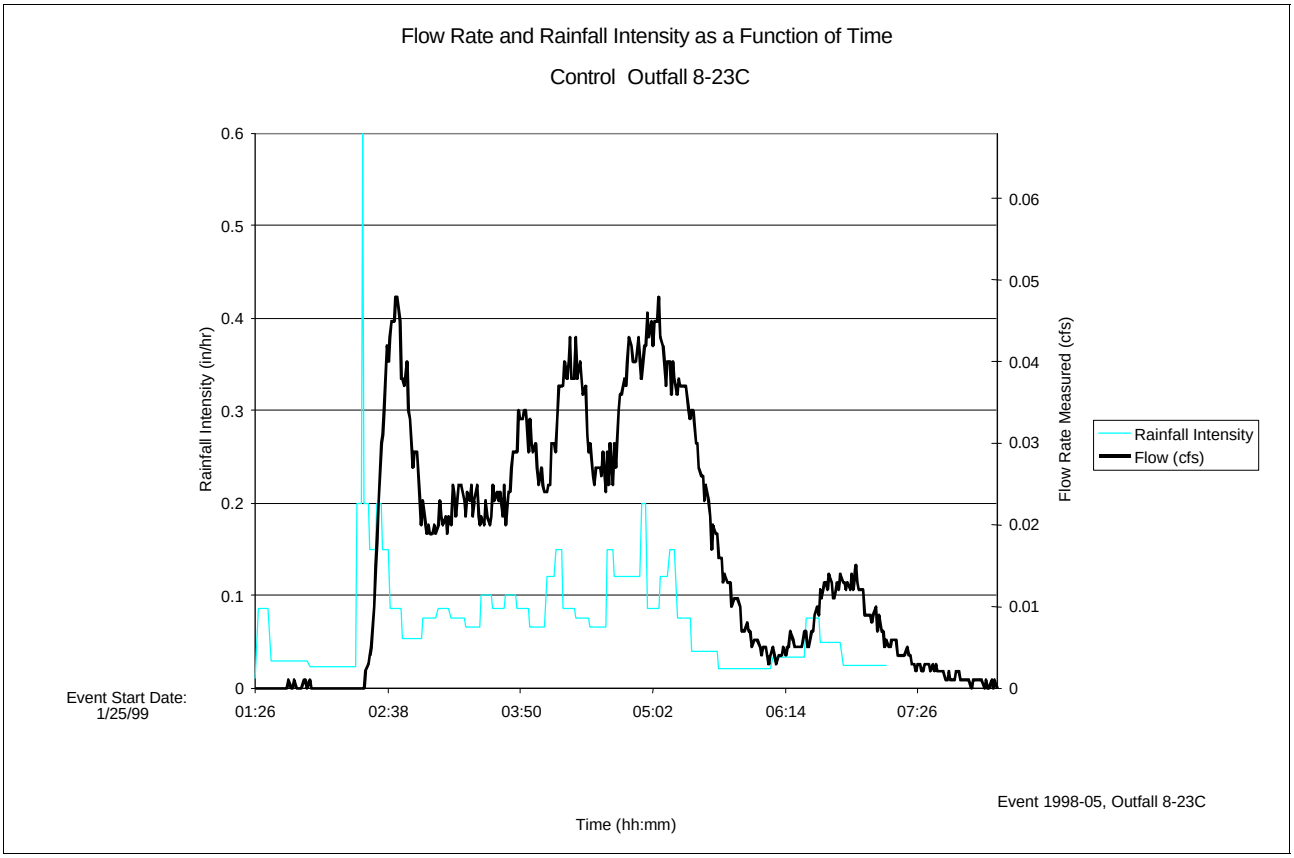


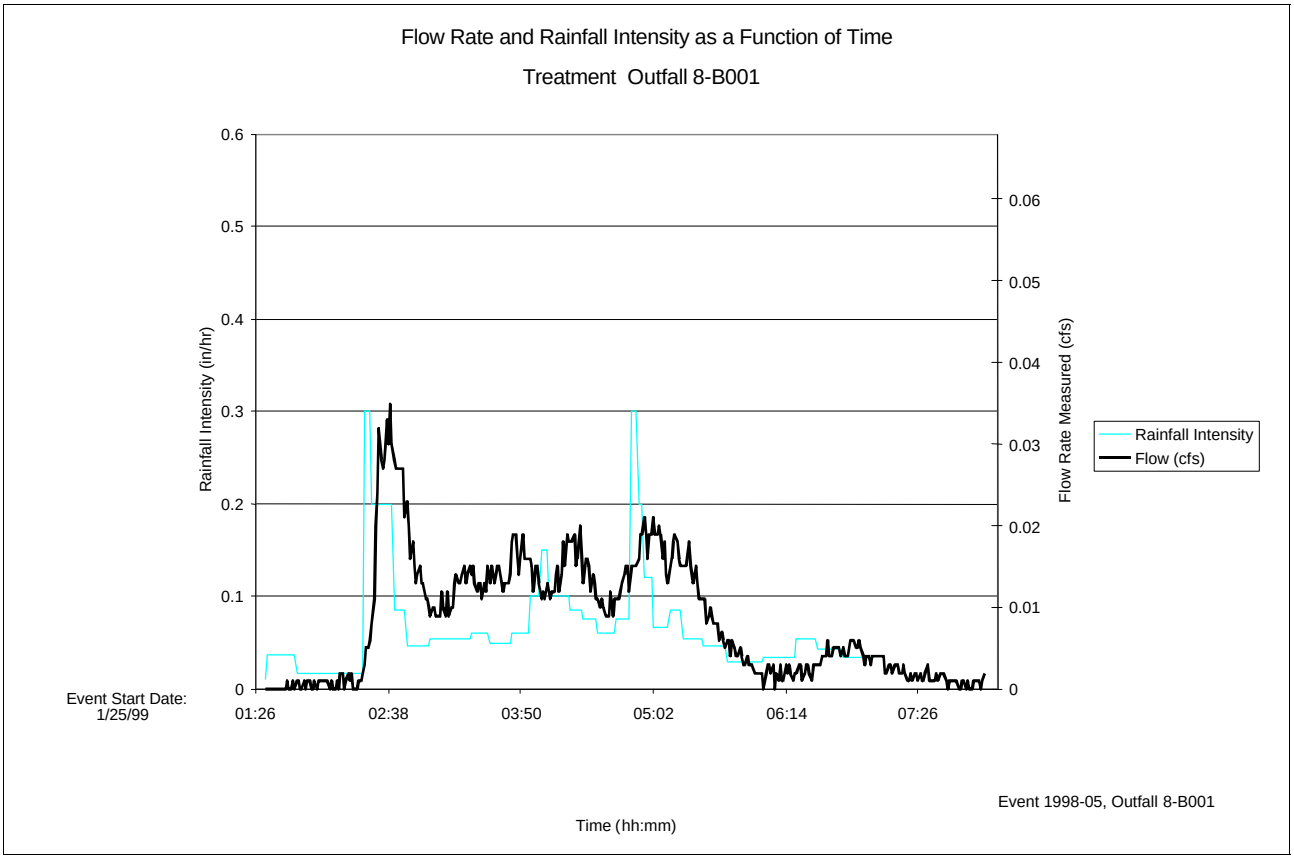
Site 6 - Modified Inlet Event No. 1998e05 - 1/25/99



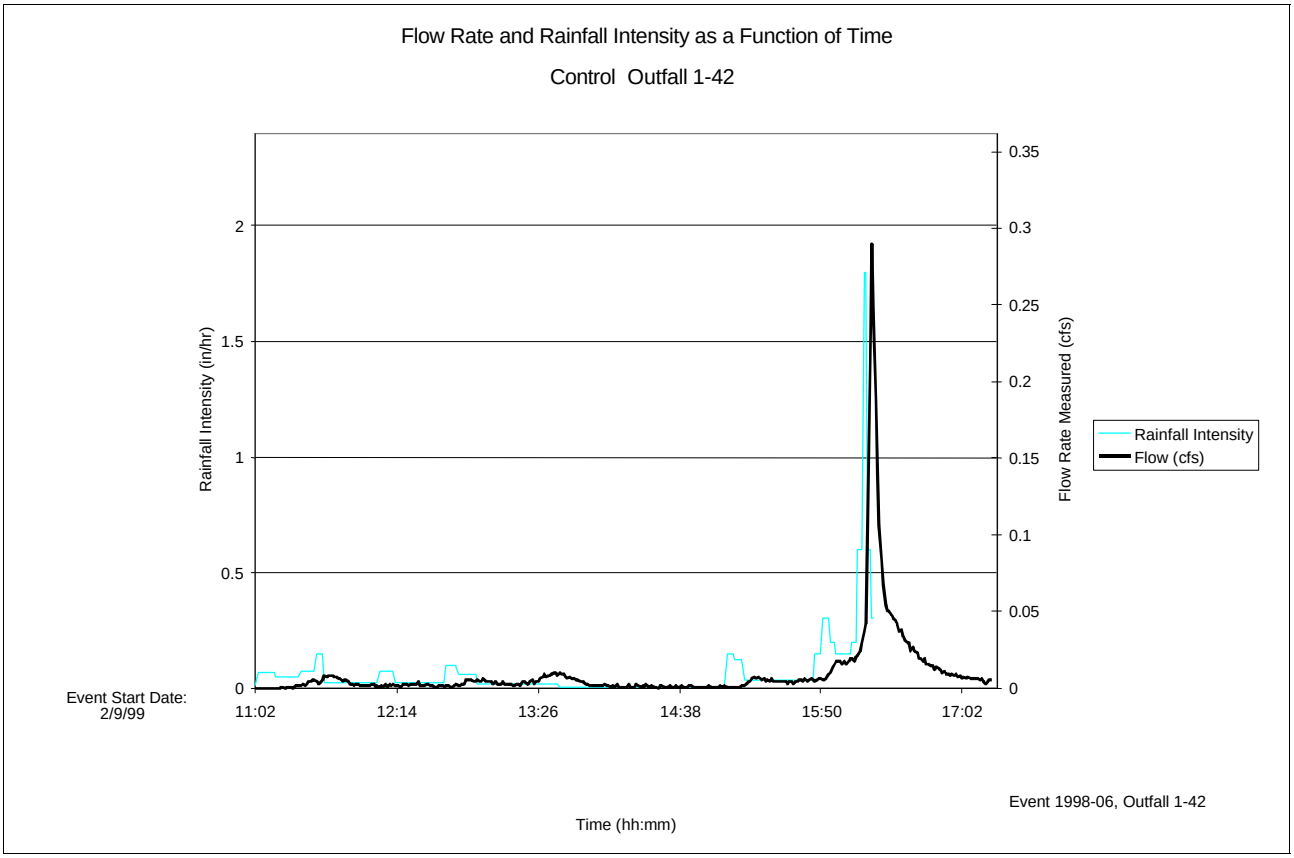


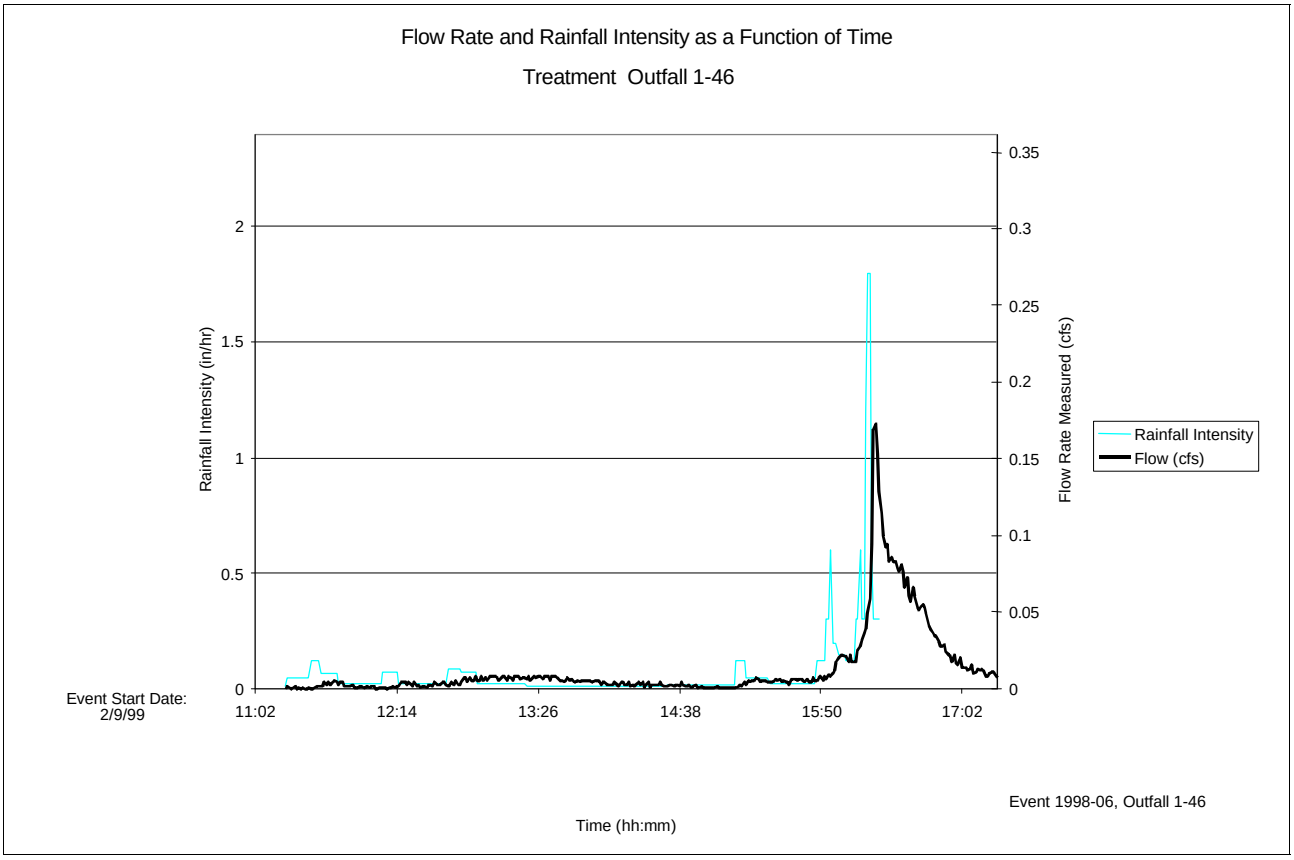
Site 8 - Bicycle Grate/LID Event No. 1998e05 - 1/25/99



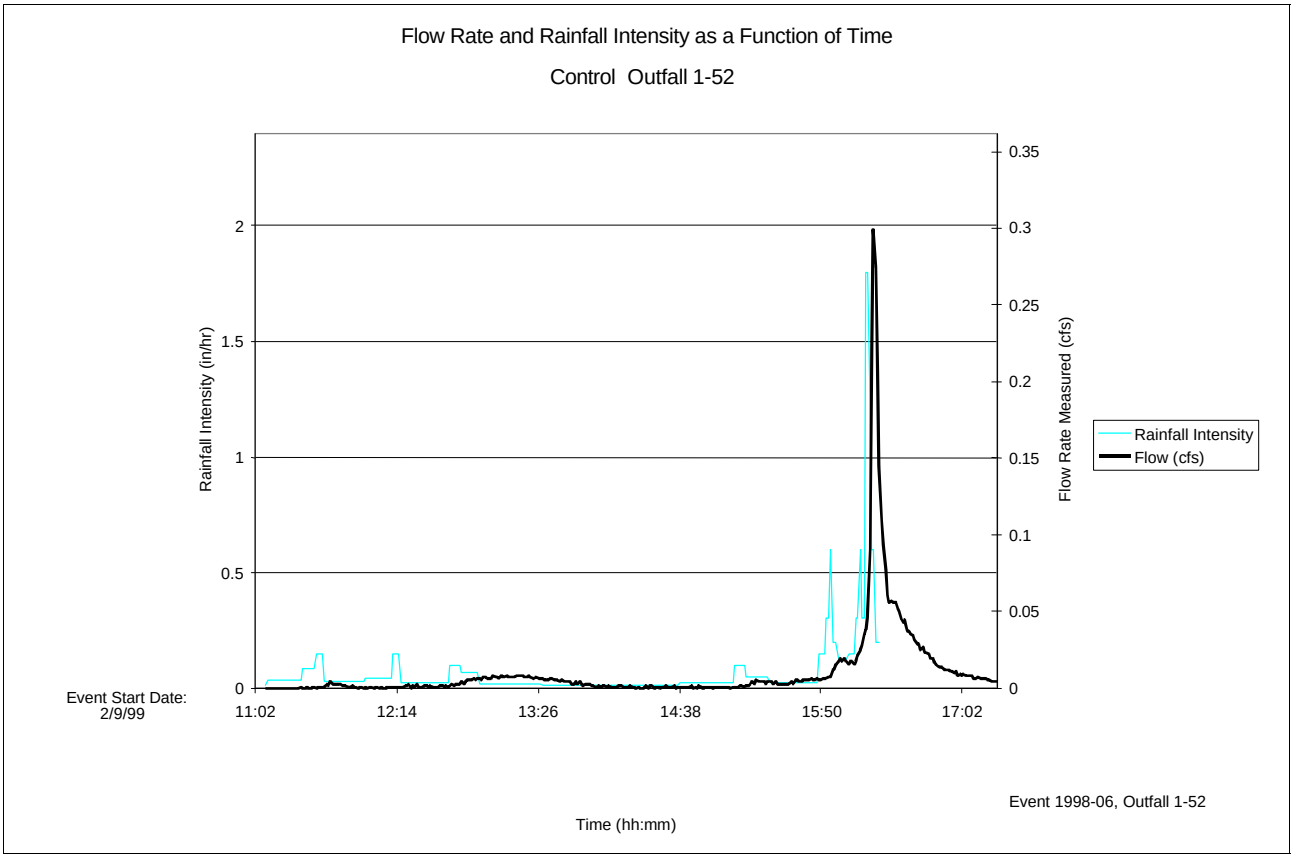


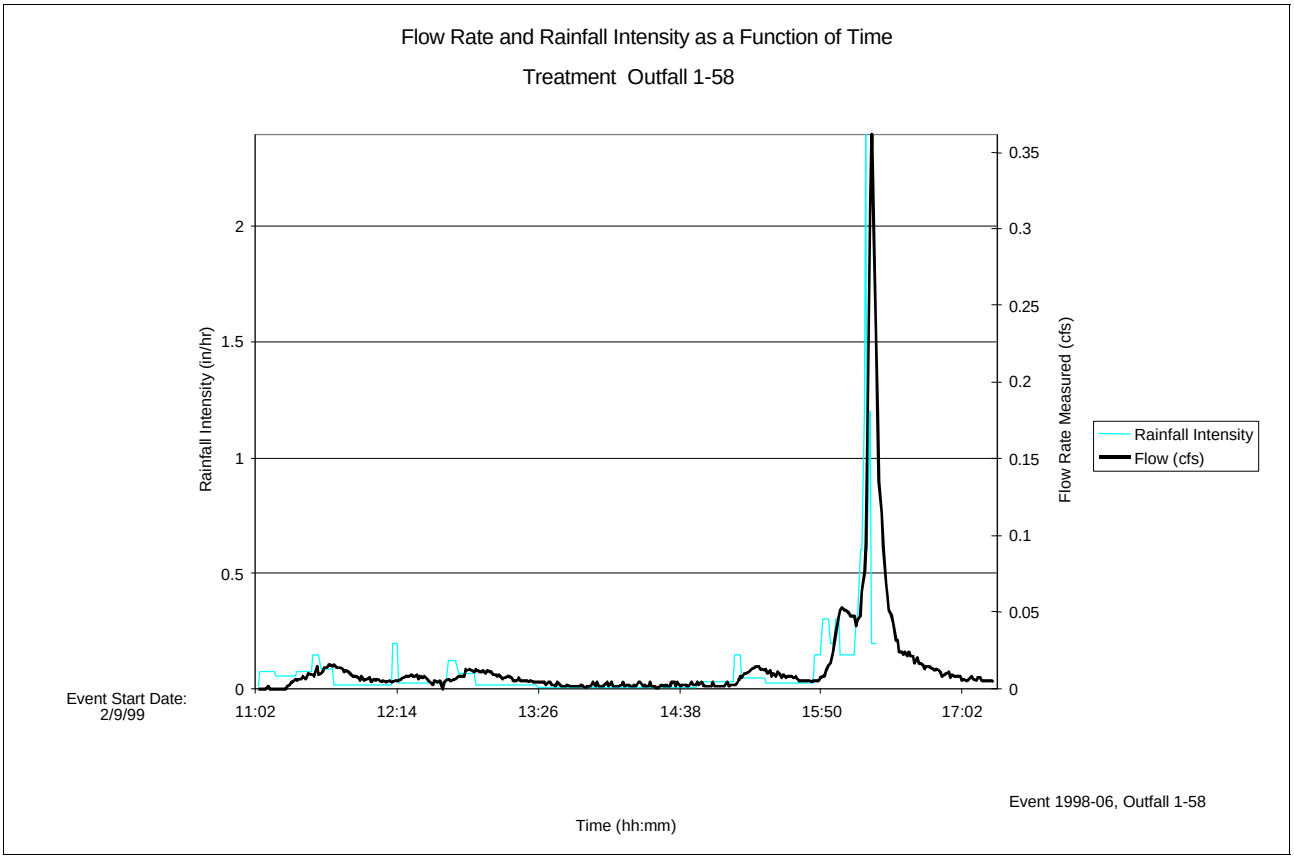
Site 1E - Litter Pickup Event No. 1998e06 - 2/9/99



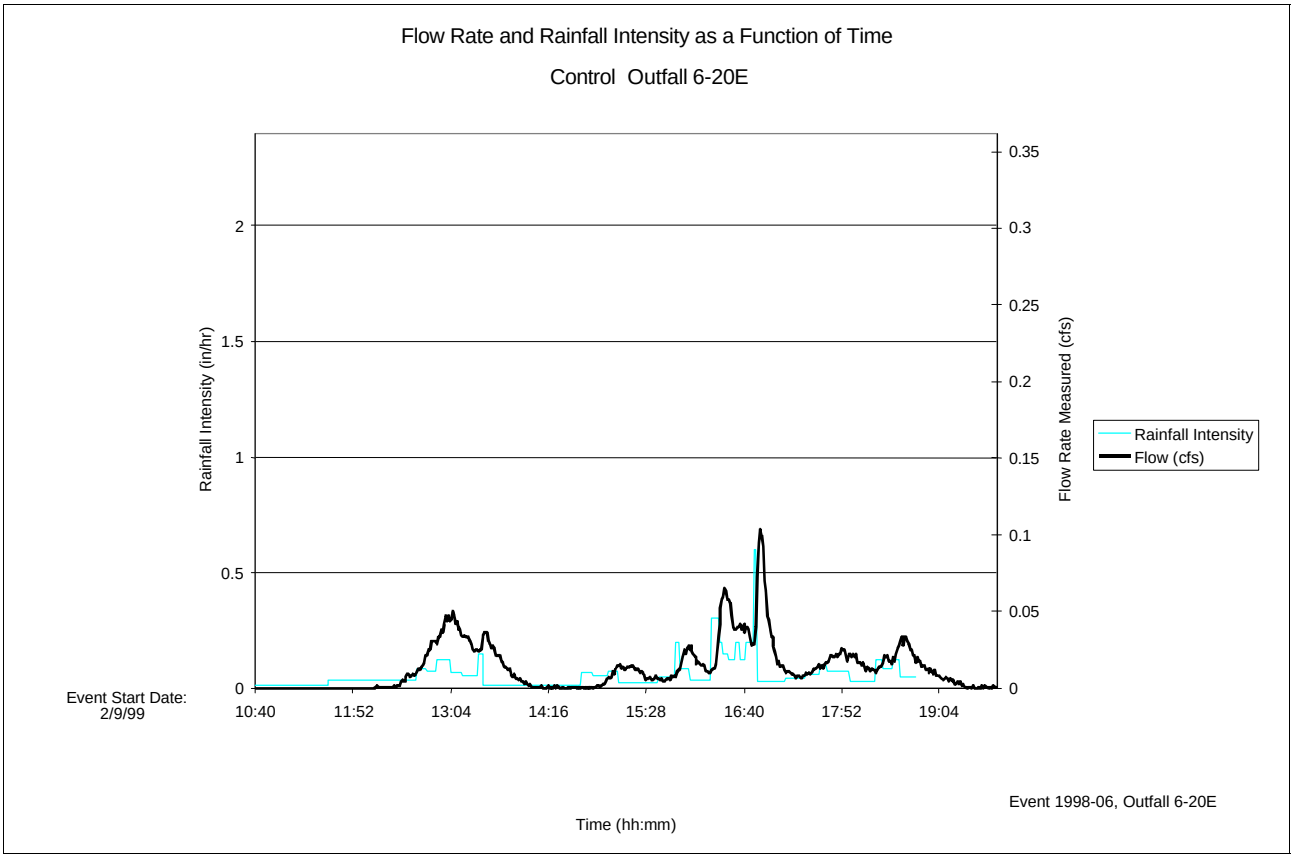


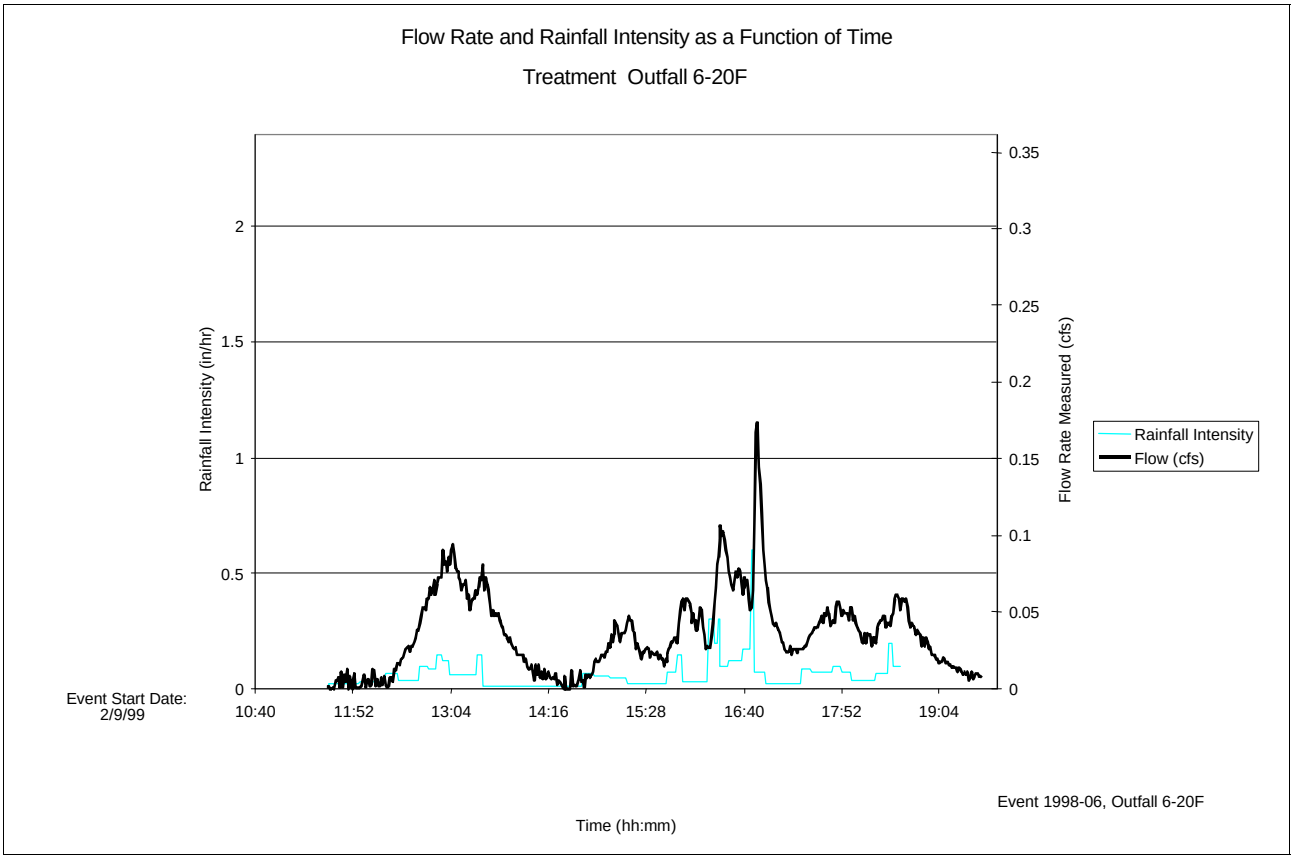
Site 1W - Street Sweeping Event No. 1998e06 - 2/9/99





Site 6 - Modified Inlet Event No. 1998e06 - 2/9/99





Site 8 - Bicycle Grate/LID Event No. 1998e06 - 2/9/99

Flow Rate and Rainfall Intensity as a Function of Time

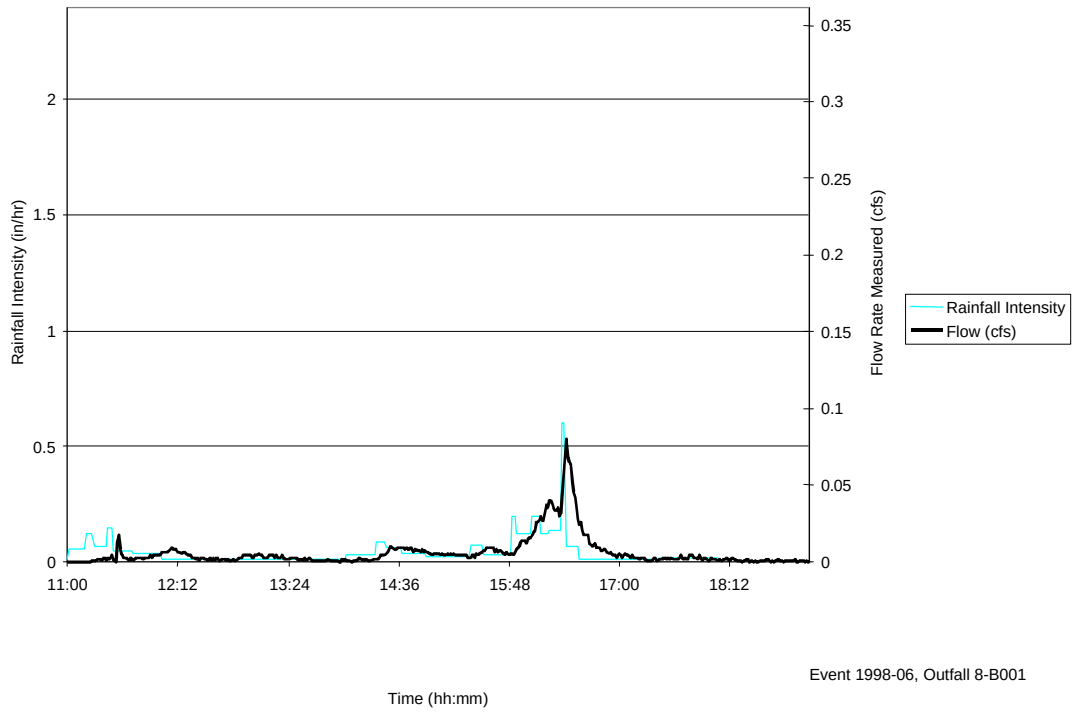
Control Outfall 8-23C

No Hydrologic Data Available for this Event For this Outfall

Event Start Date:
2/9/99

Flow Rate and Rainfall Intensity as a Function of Time

Treatment Outfall 8-B001

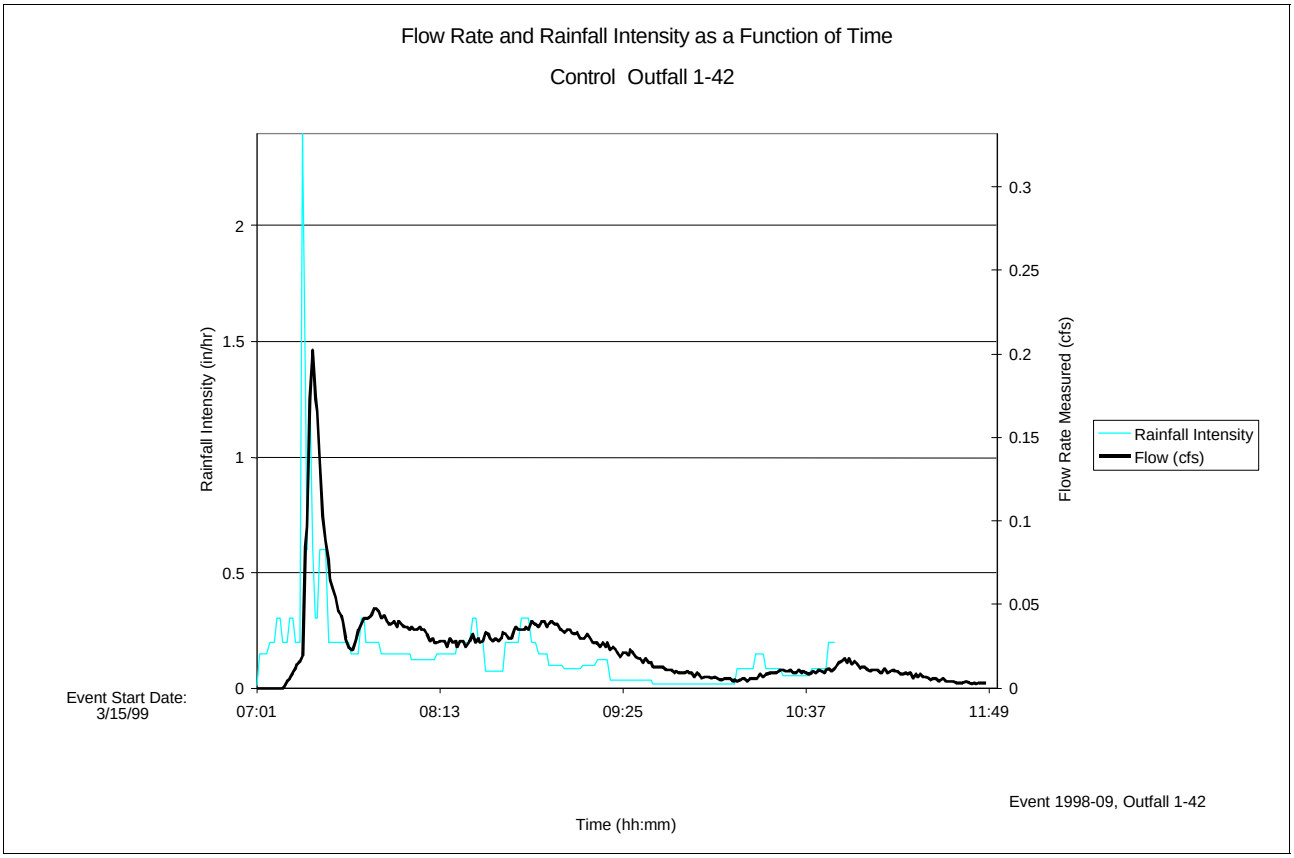


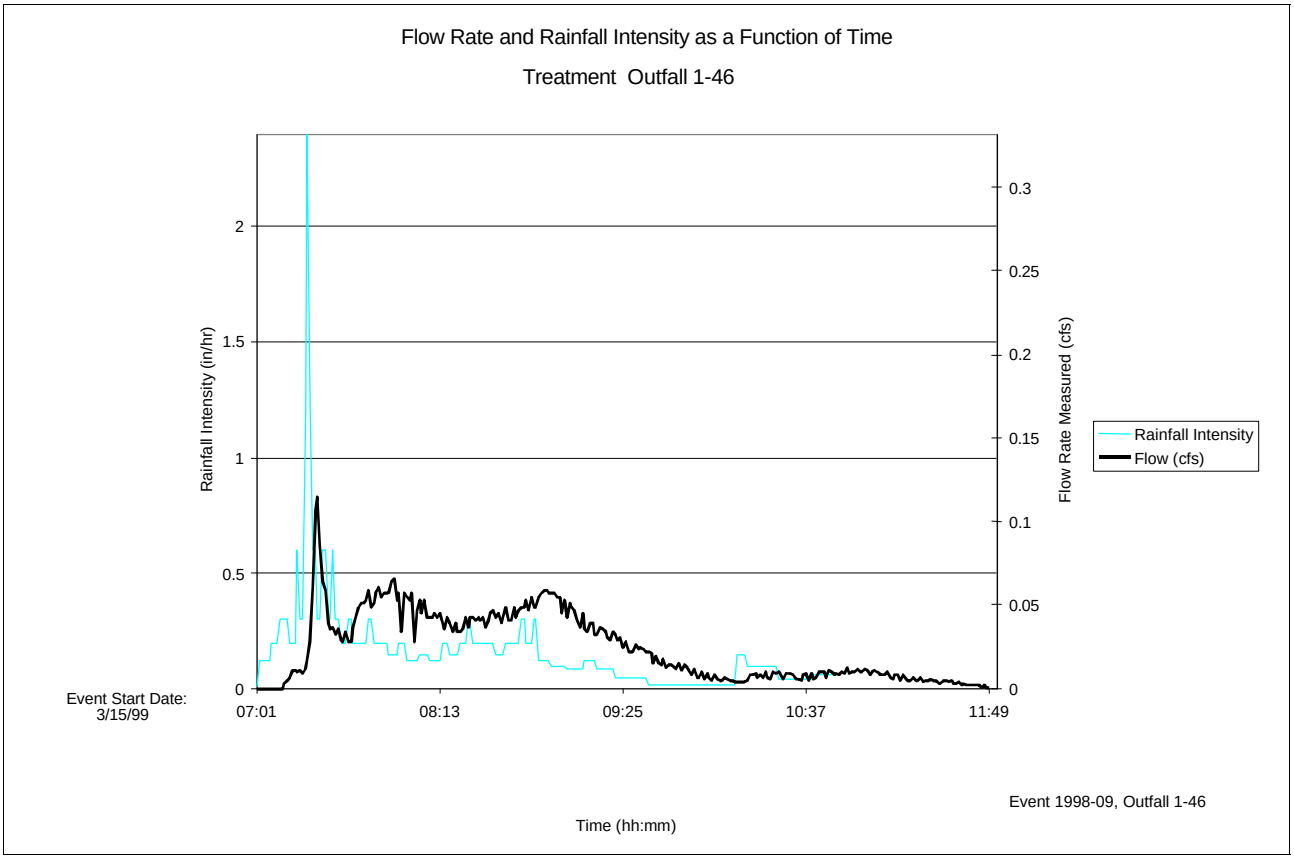
Event Start Date:
2/9/99

Event 1998-06, Outfall 8-B001

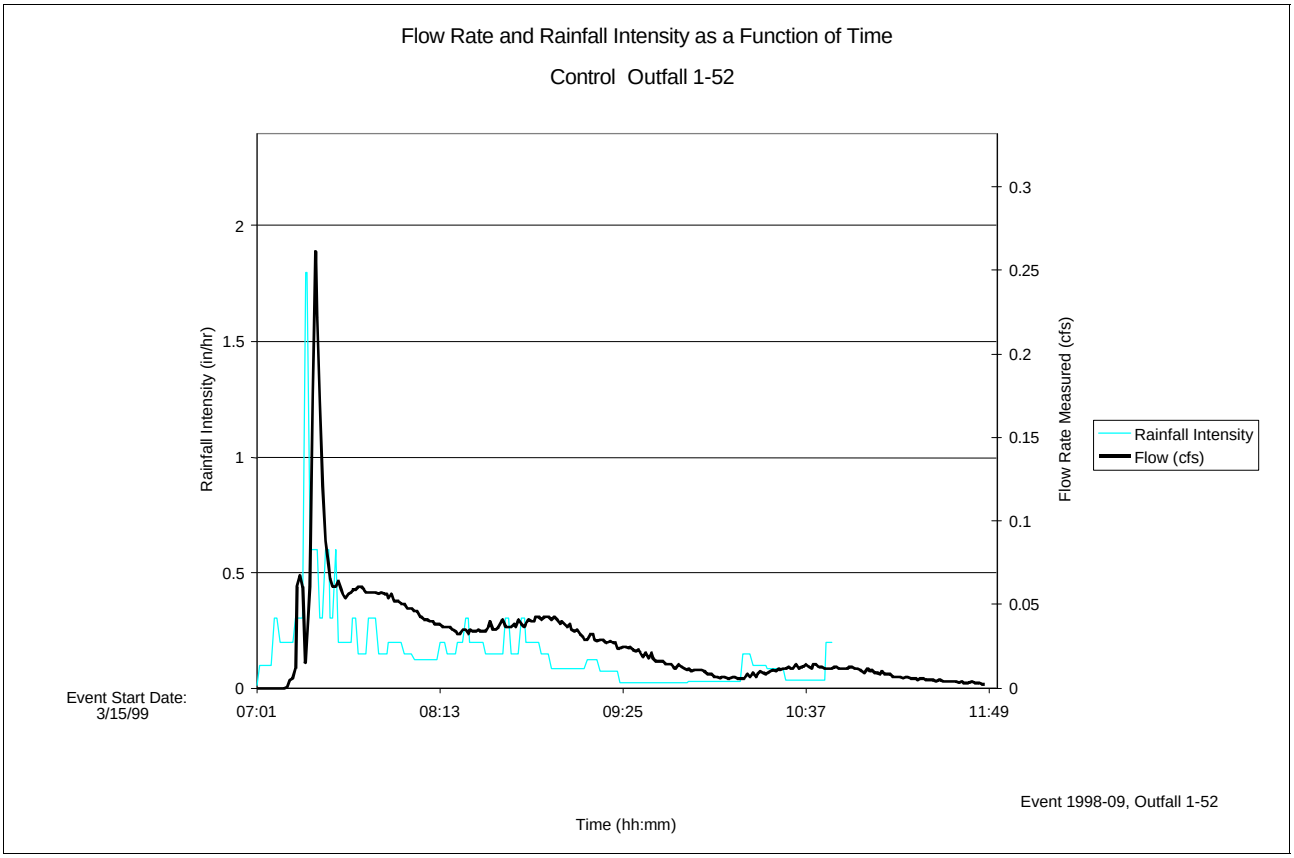
Site 1E - Litter Pickup

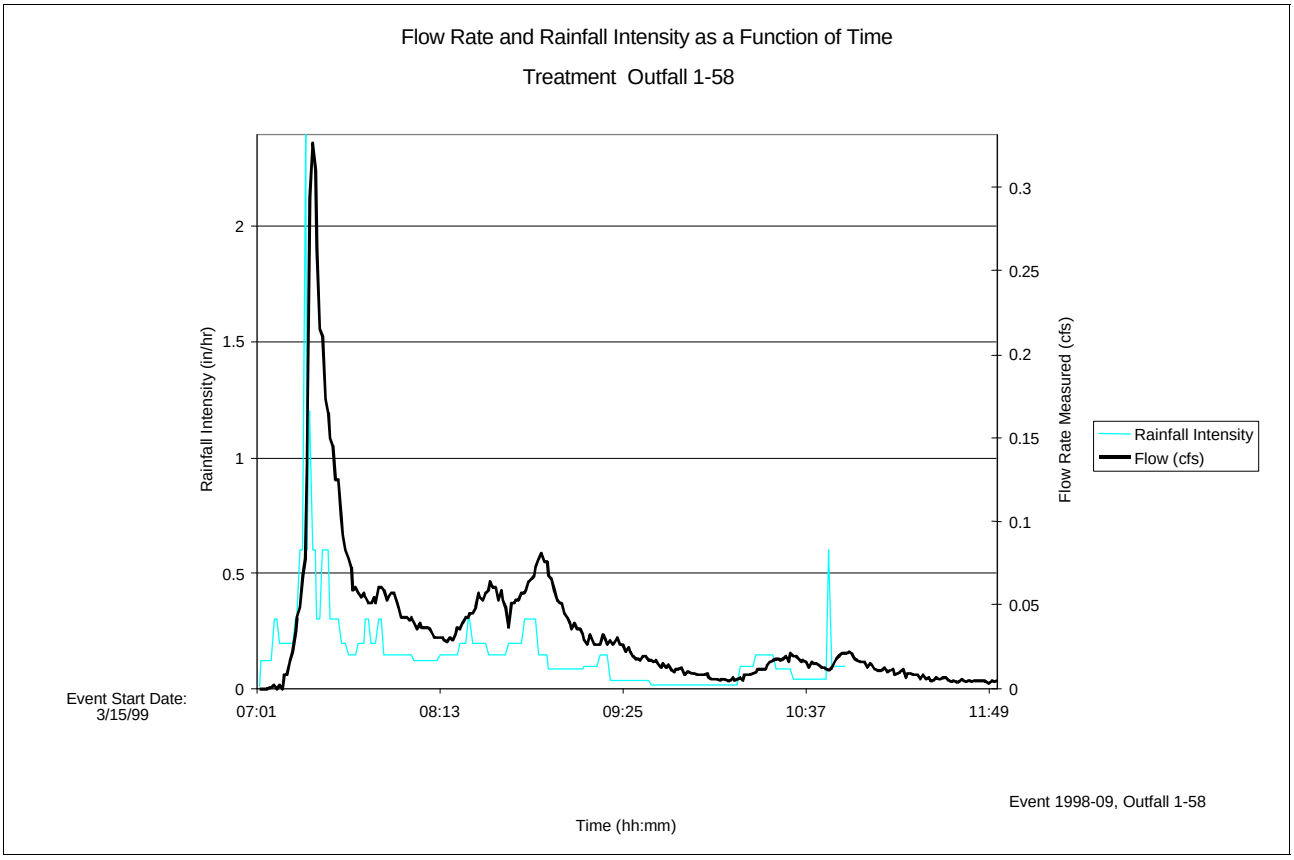
Event No. 1998e09 - 3/15/99



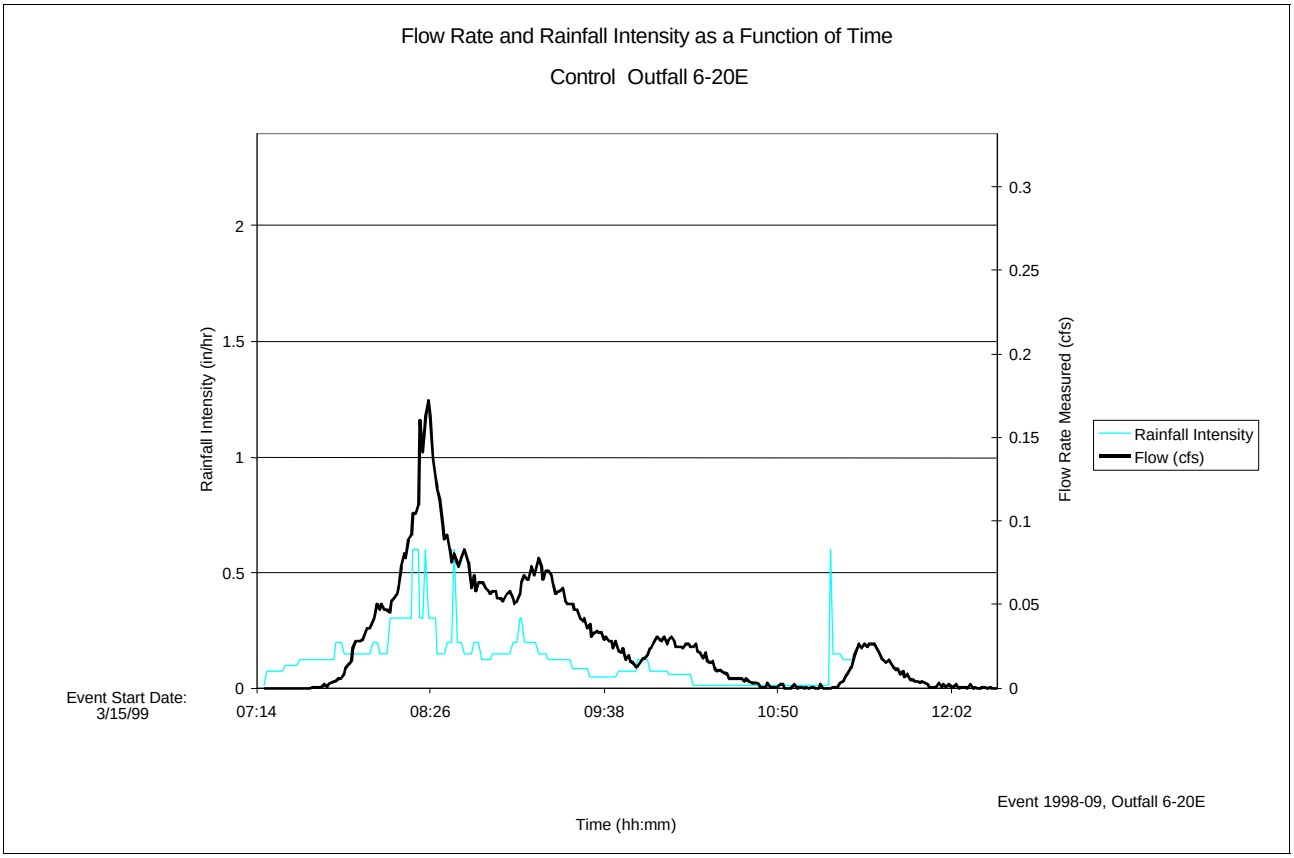


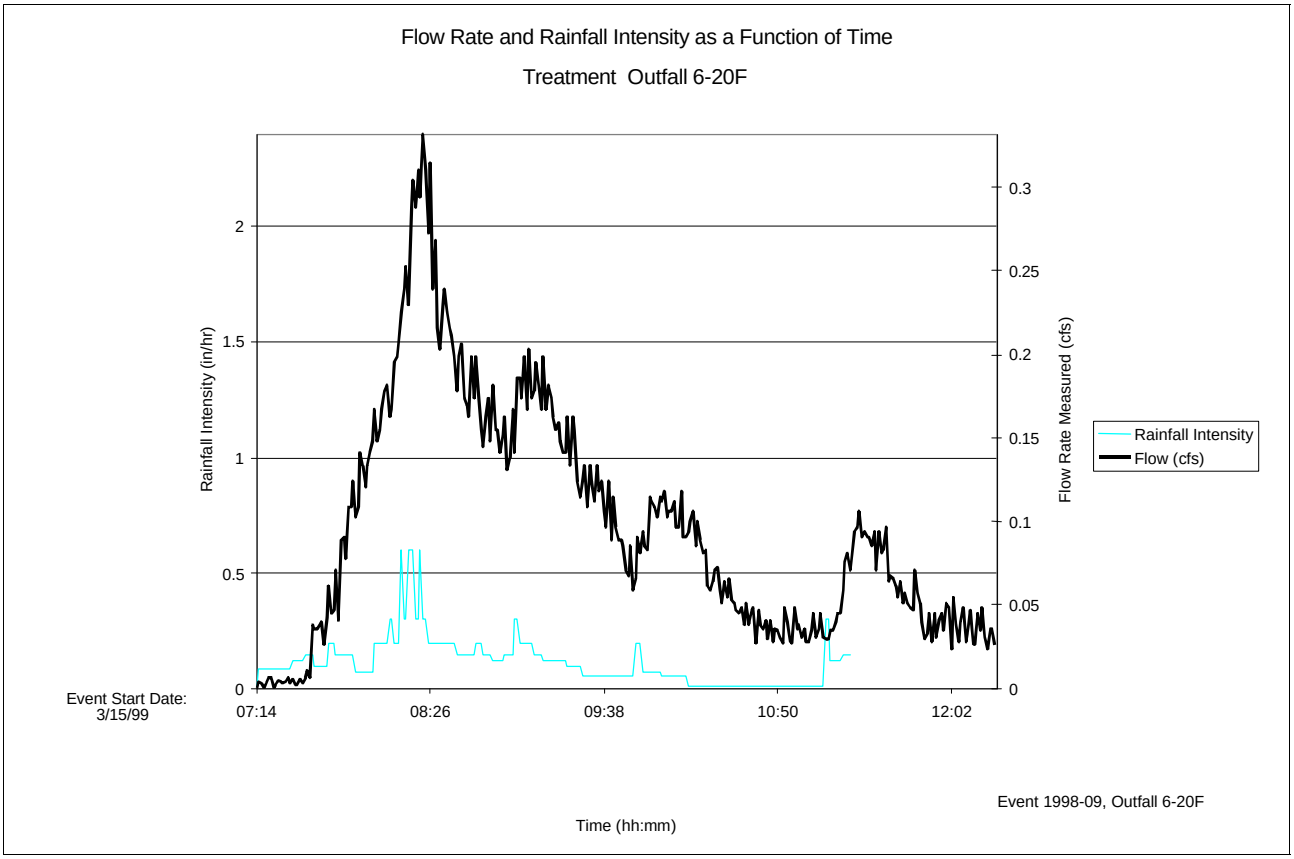
Site 1W - Street Sweeping Event No. 1998e09 - 3/15/99



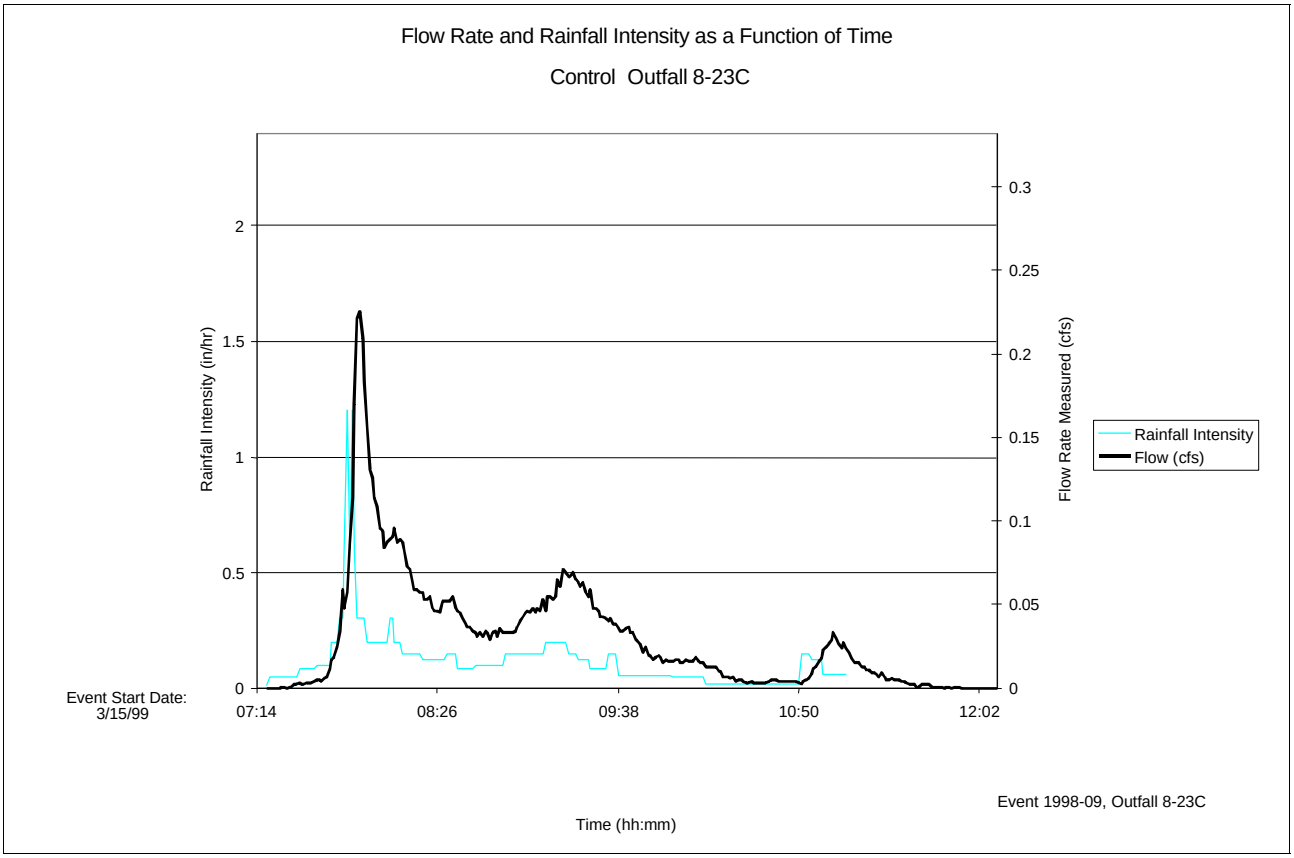


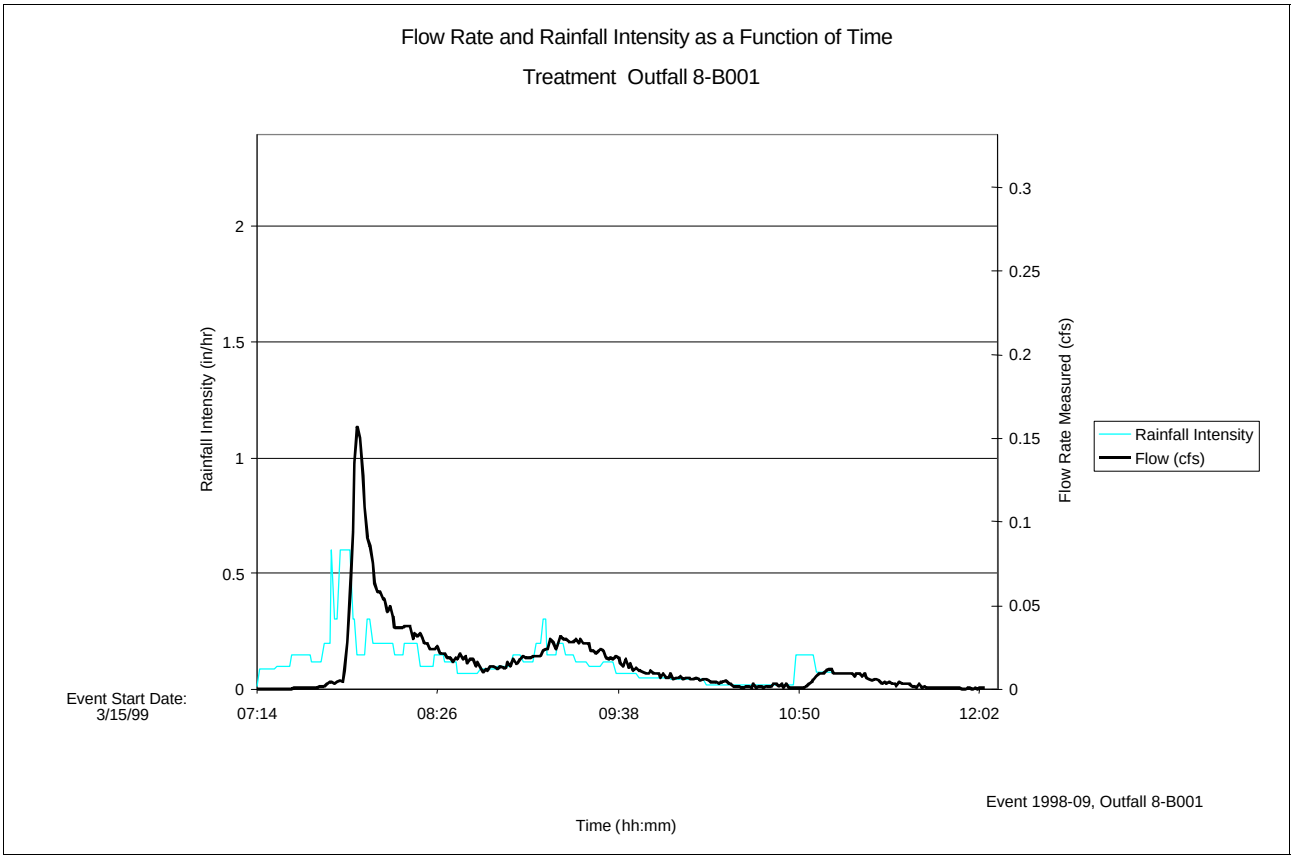
Site 6 - Modified Inlet Event No. 1998e09 - 3/15/99



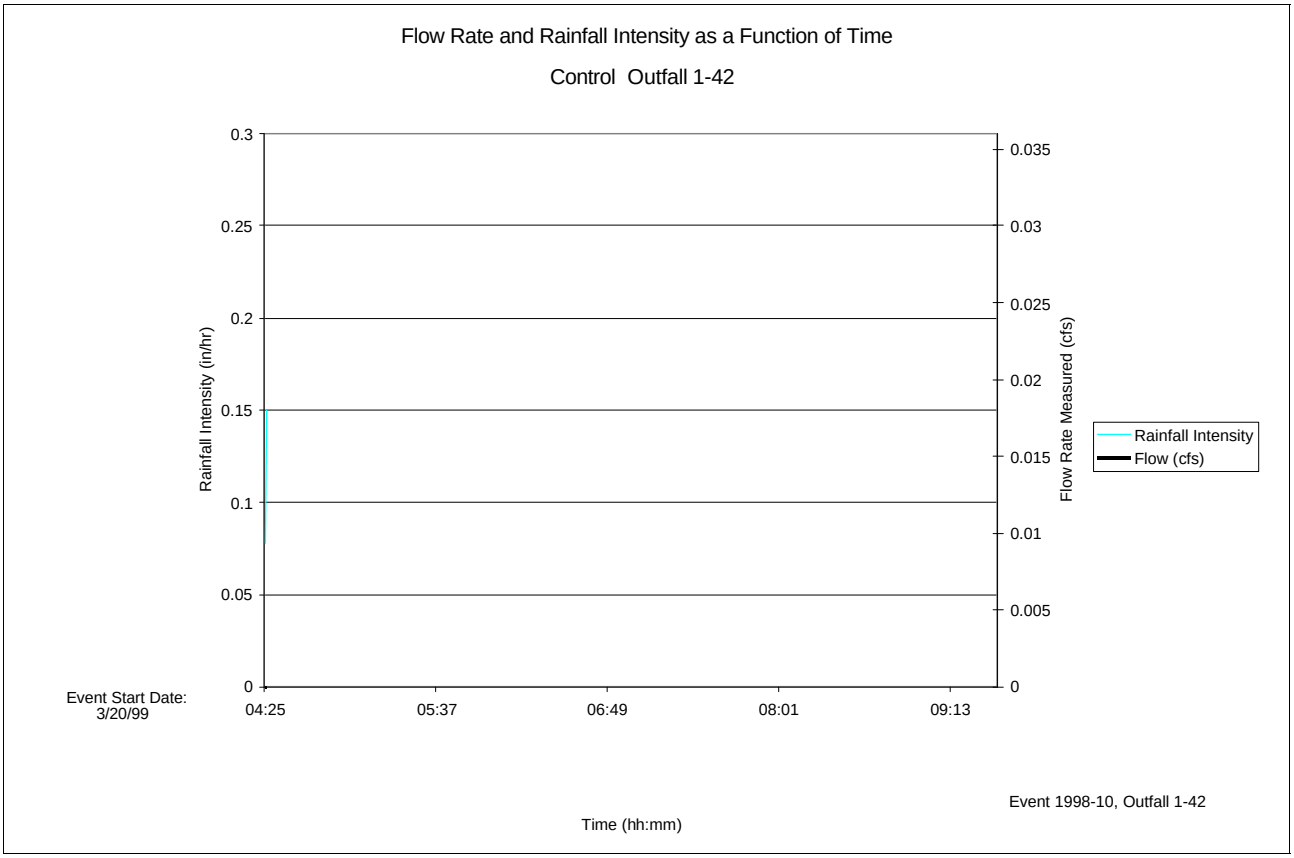


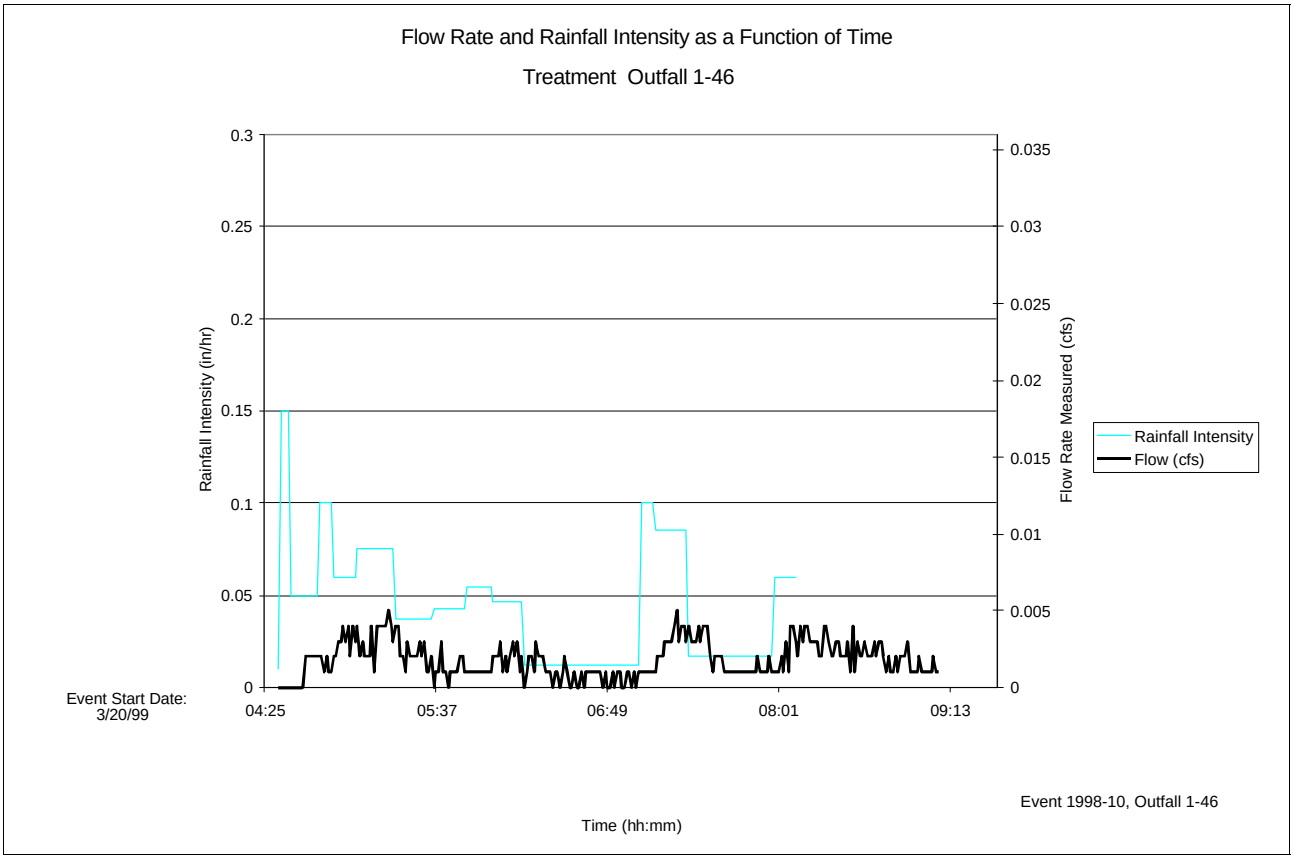
Site 8 - Bicycle Grate/LID Event No. 1998e09 - 3/15/99



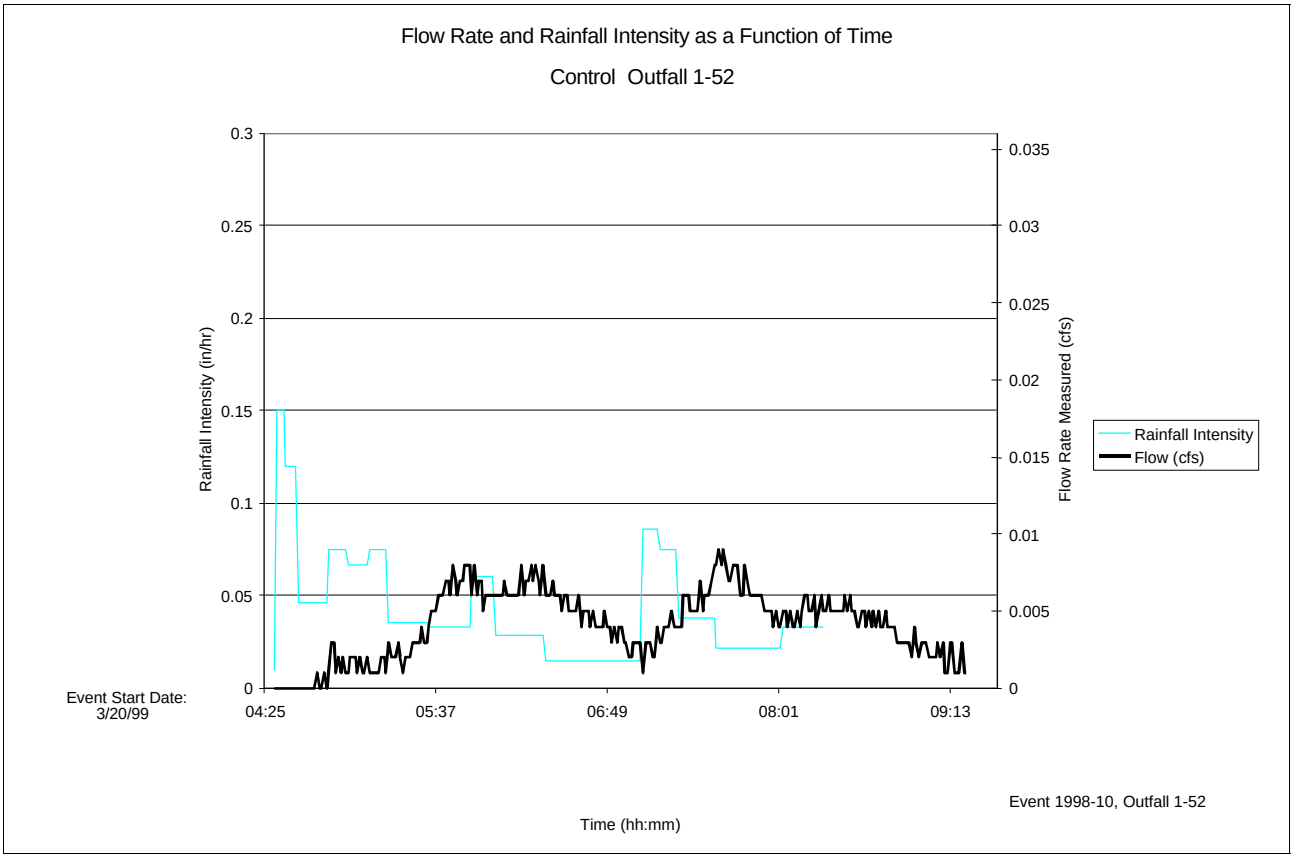


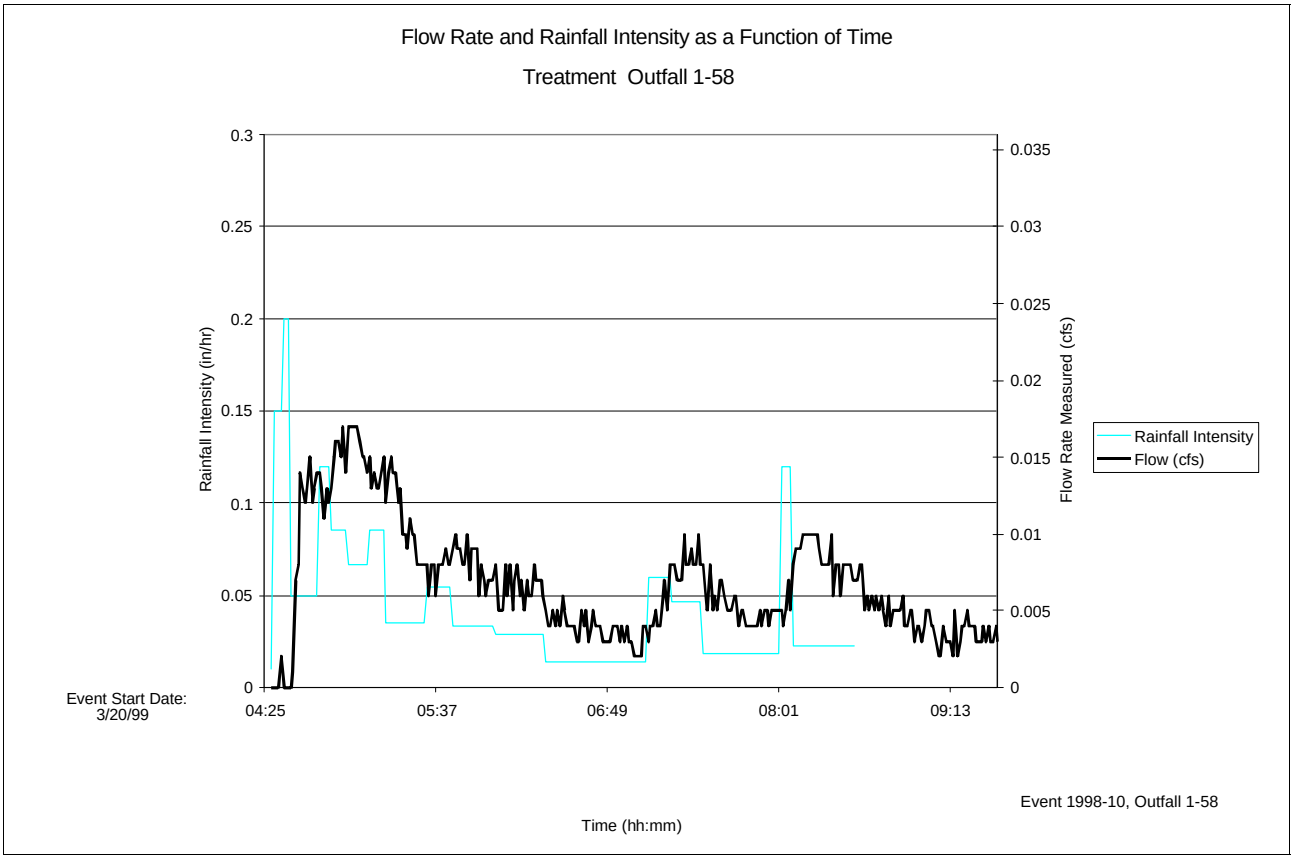
Site 1E - Litter Pickup Event No. 1998e10 - 3/20/99



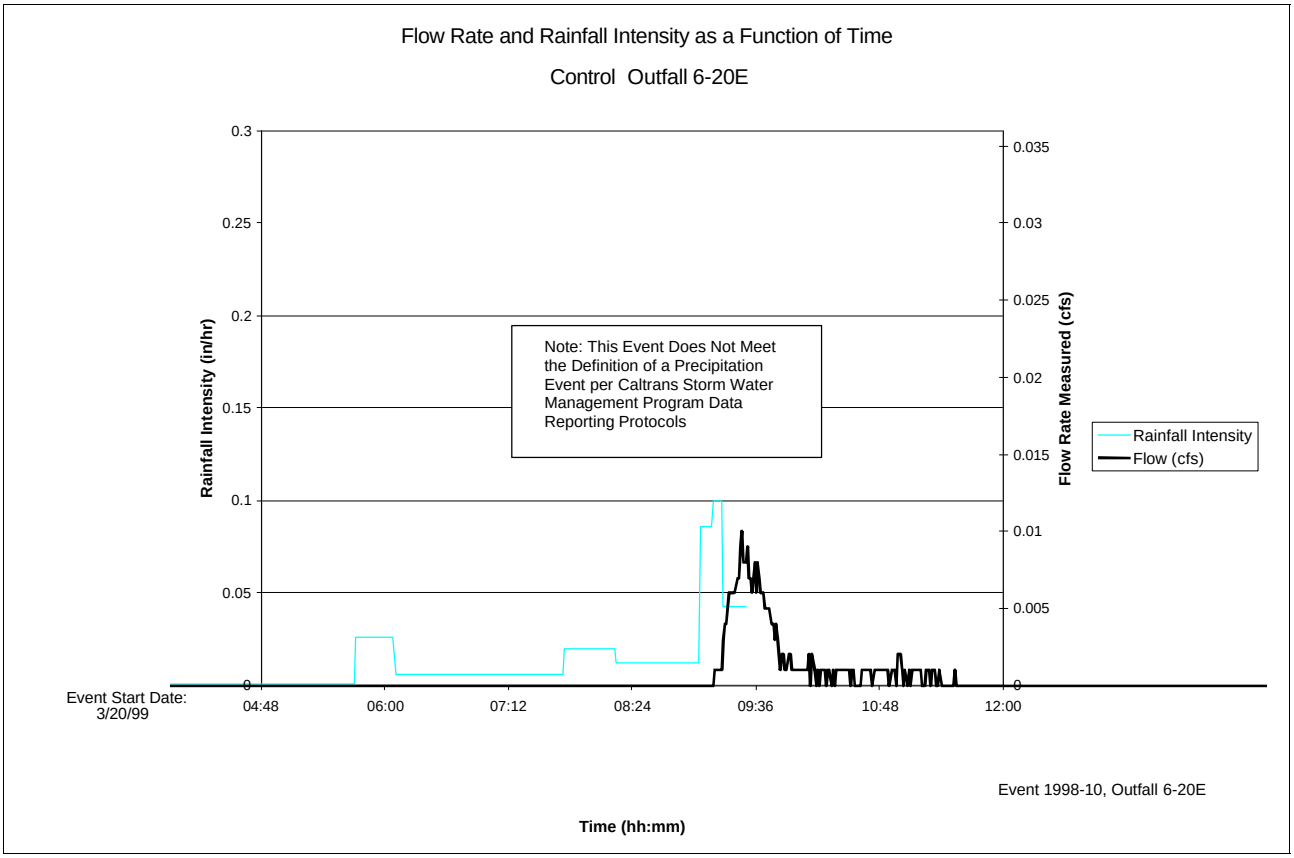


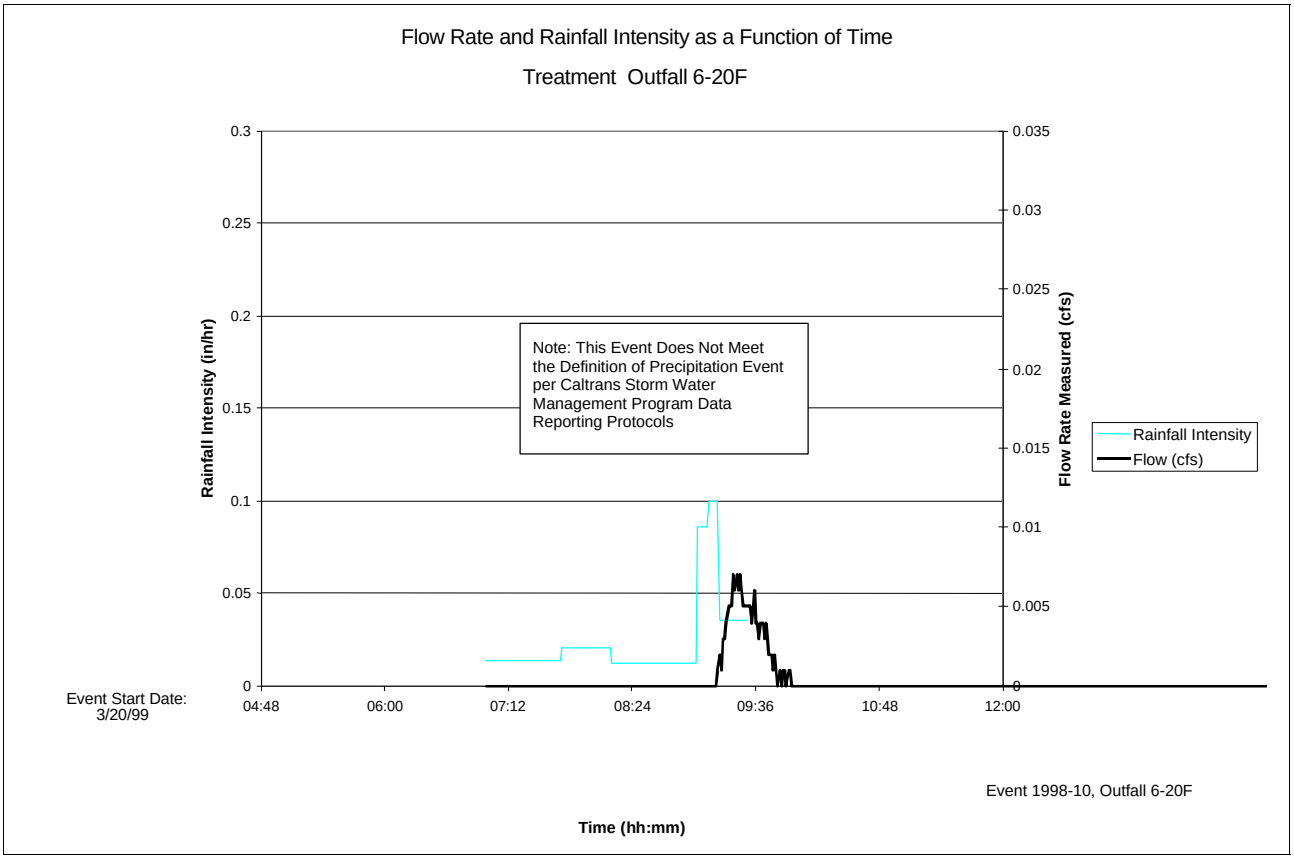
Site 1W - Street Sweeping Event No. 1998e10 - 3/20/99



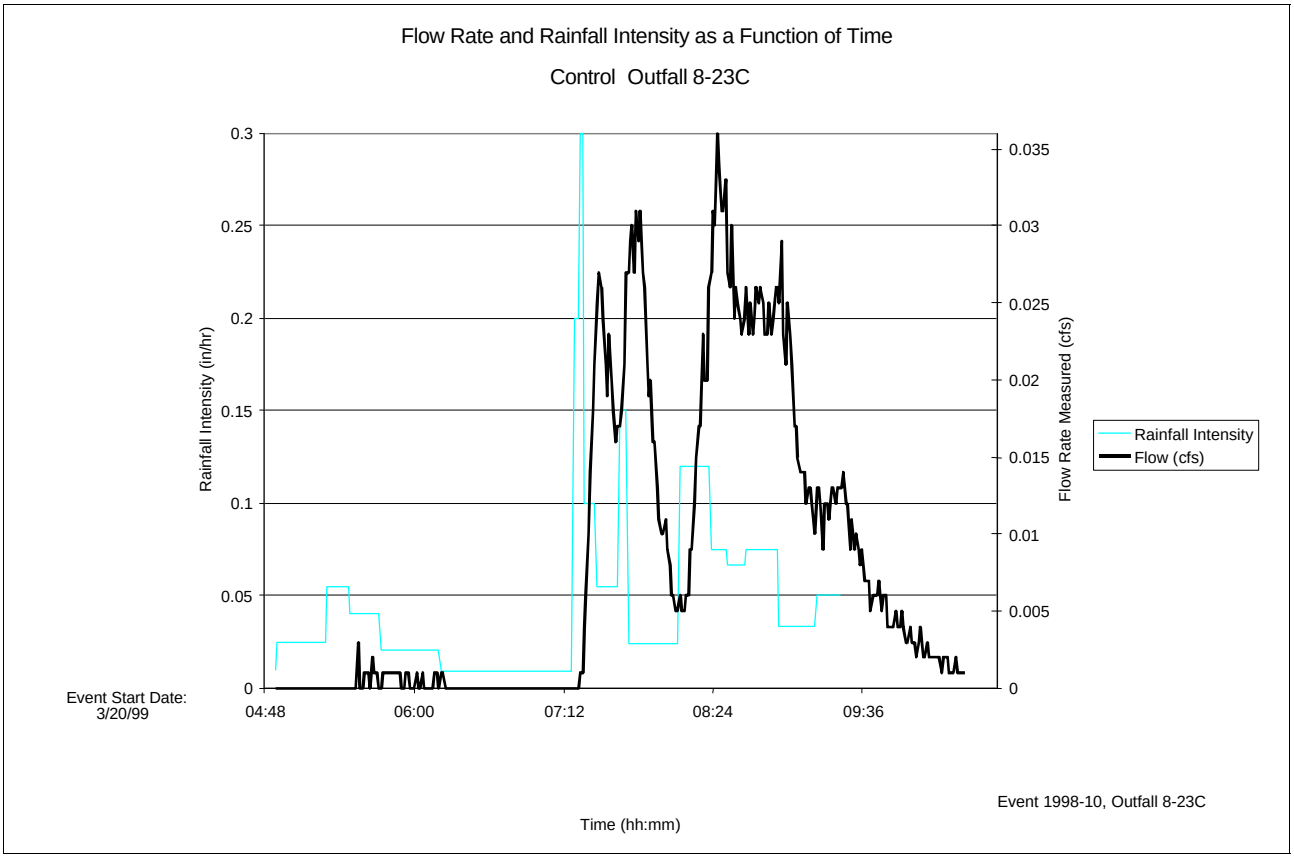


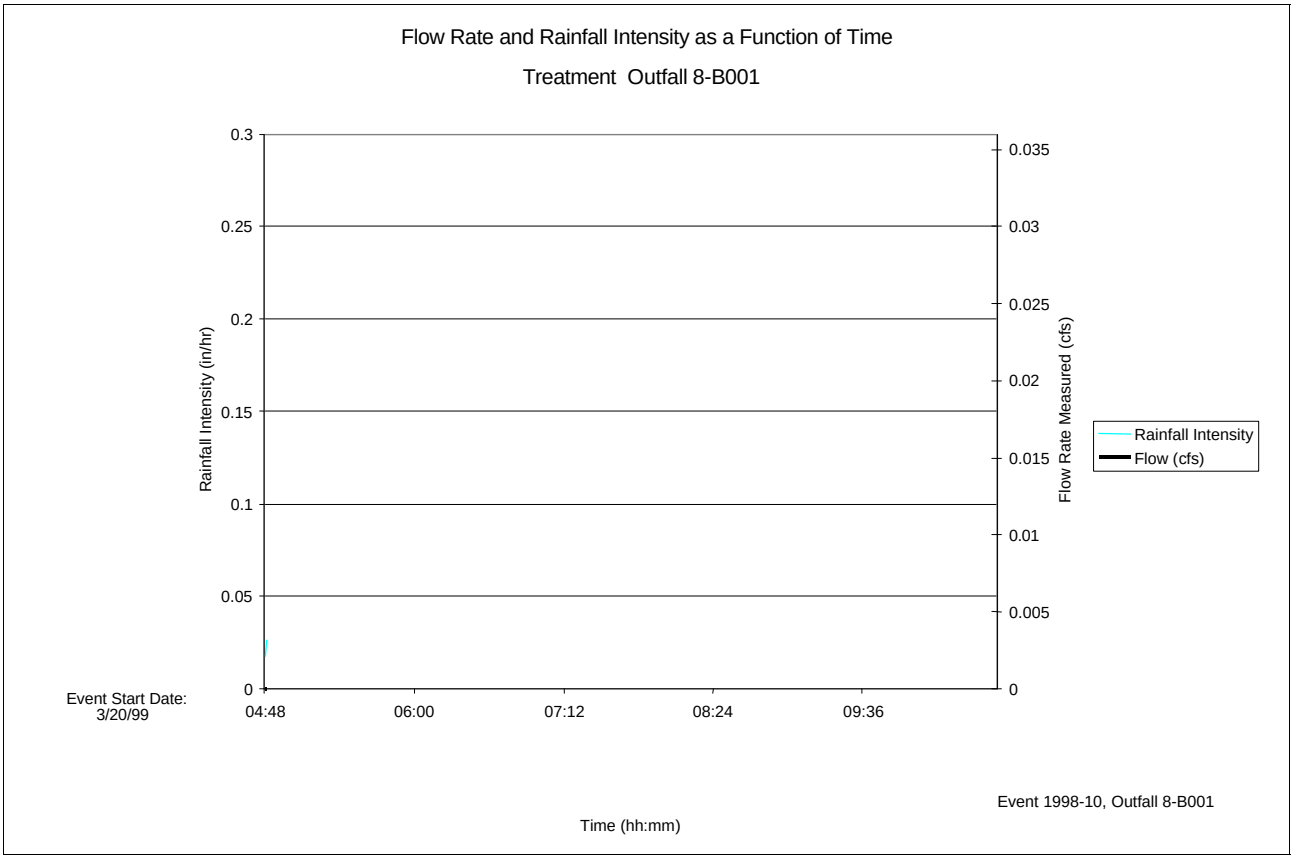
Site 6 - Modified Inlet Event No. 1998e10 - 3/20/99





Site 8 - Bicycle Grate/LID Event No. 1998e10 - 3/20/99





Site 1E - Litter Pickup

Event No. 1998e11 - 3/25/99

Flow Rate and Rainfall Intensity as a Function of Time

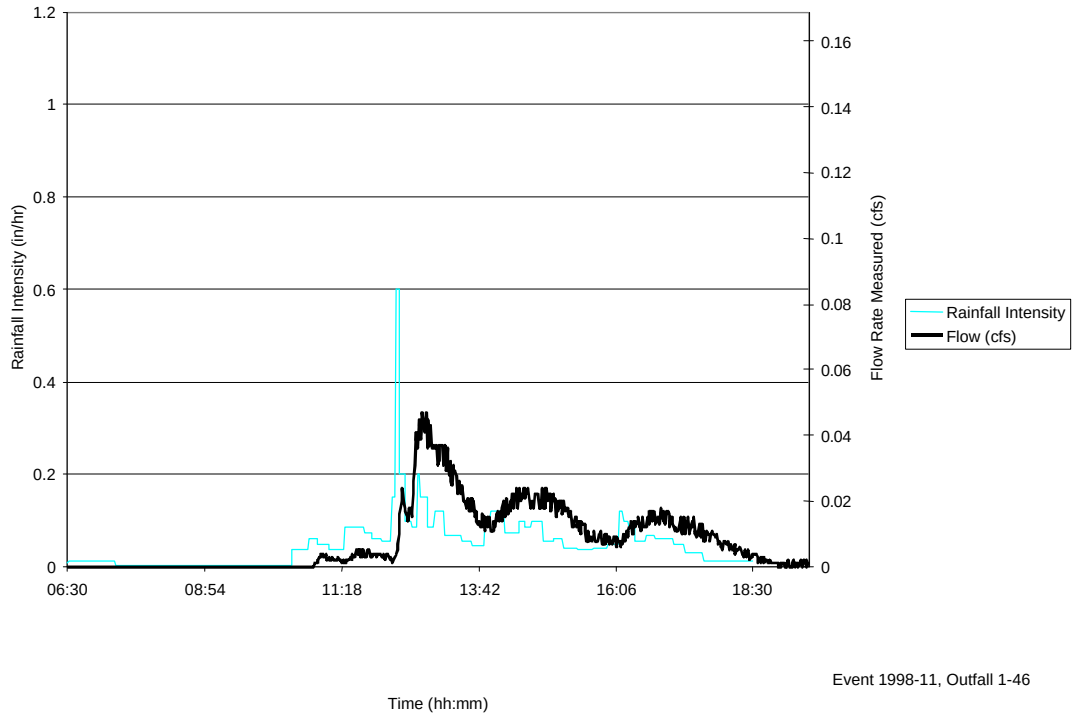
Control Outfall 1-42

No Hydrologic Data Available for this Event For this Outfall

Event Start Date:
3/25/99

Flow Rate and Rainfall Intensity as a Function of Time

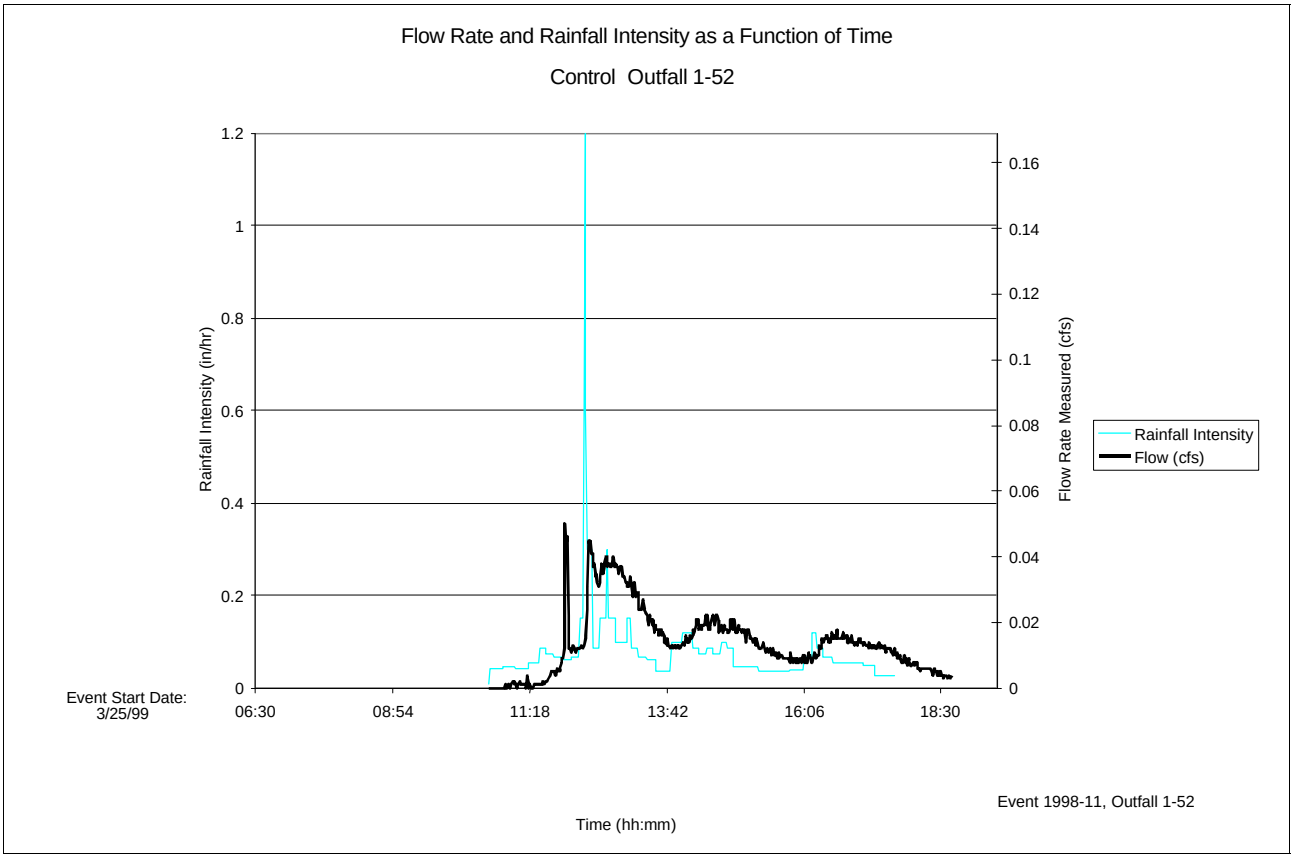
Treatment Outfall 1-46

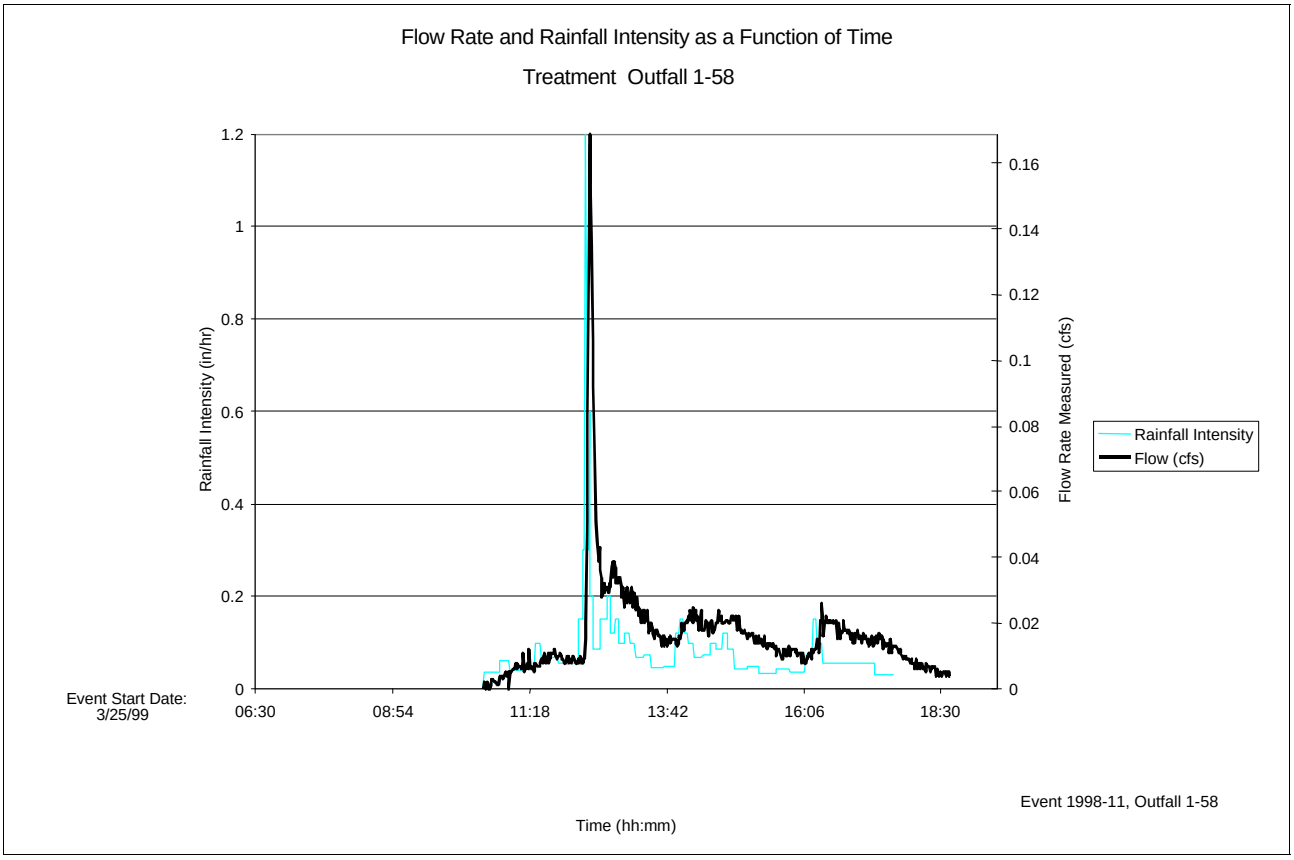


Event Start Date:
3/25/99

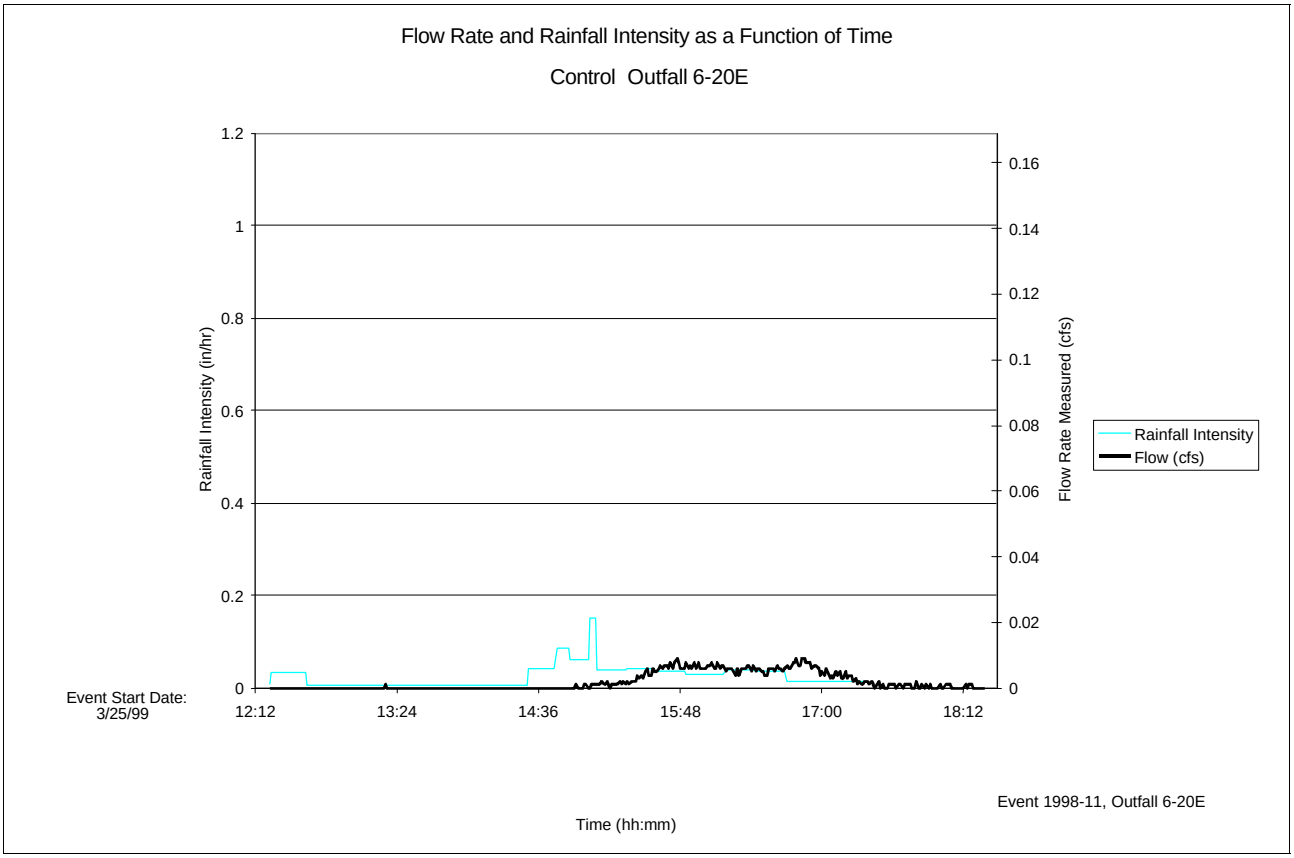
Event 1998-11, Outfall 1-46

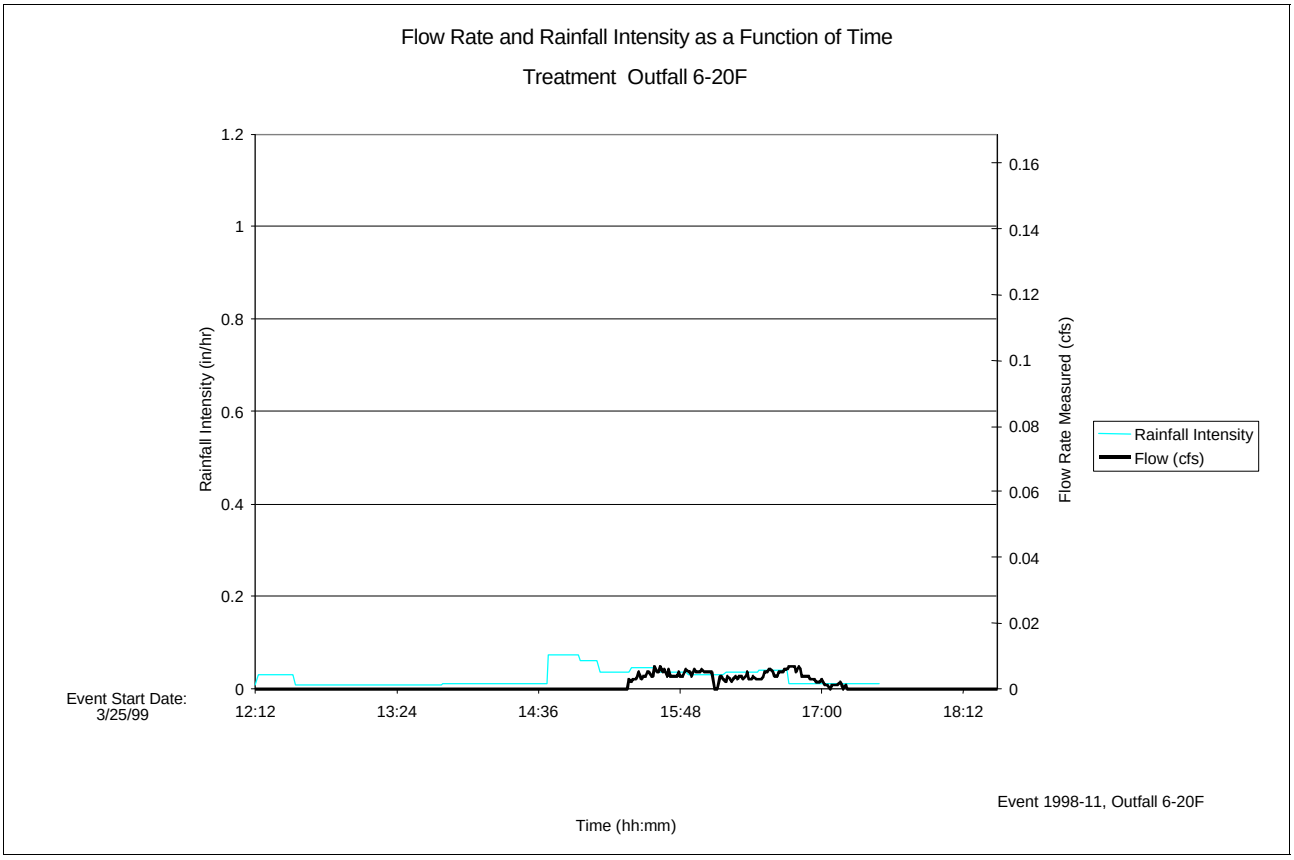
Site 1W - Street Sweeping Event No. 1998e11 - 3/25/99



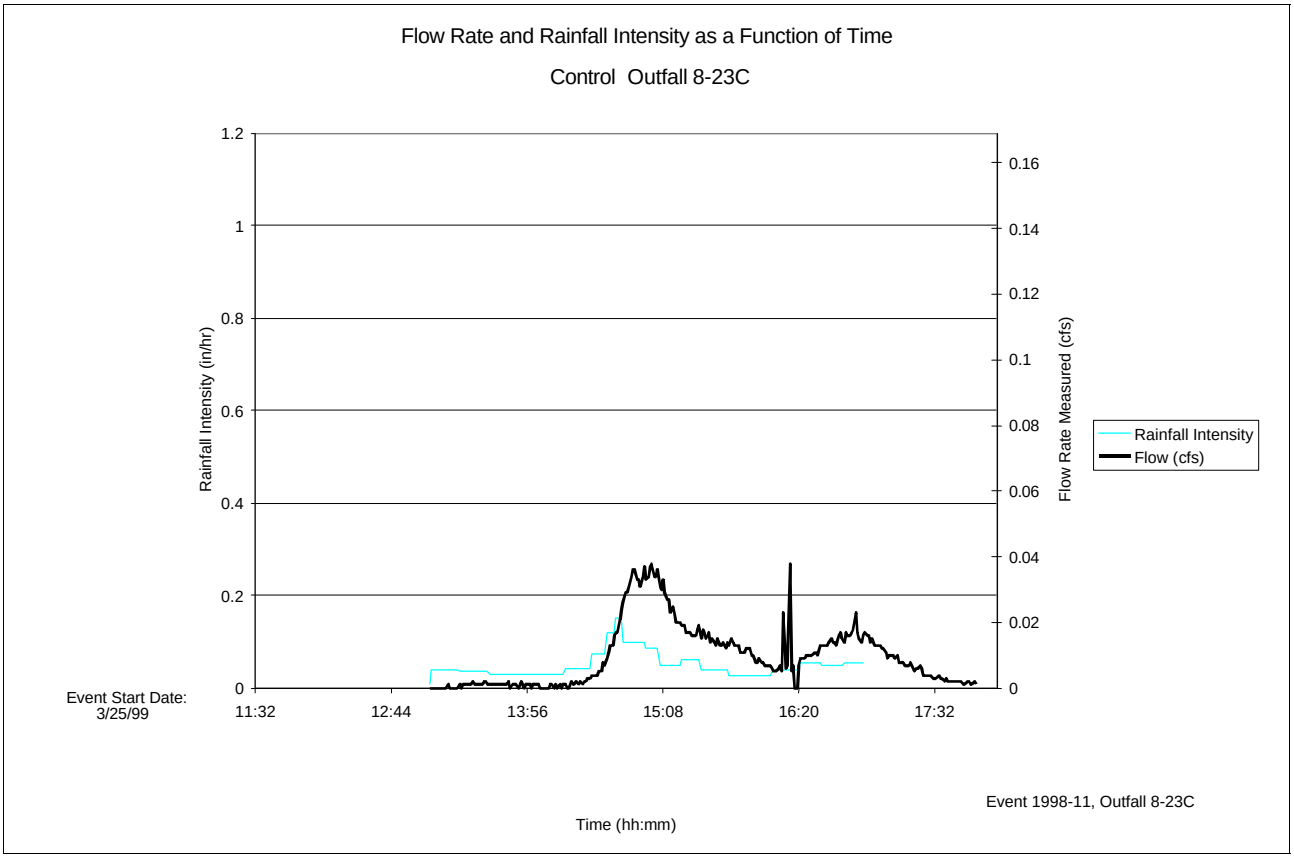


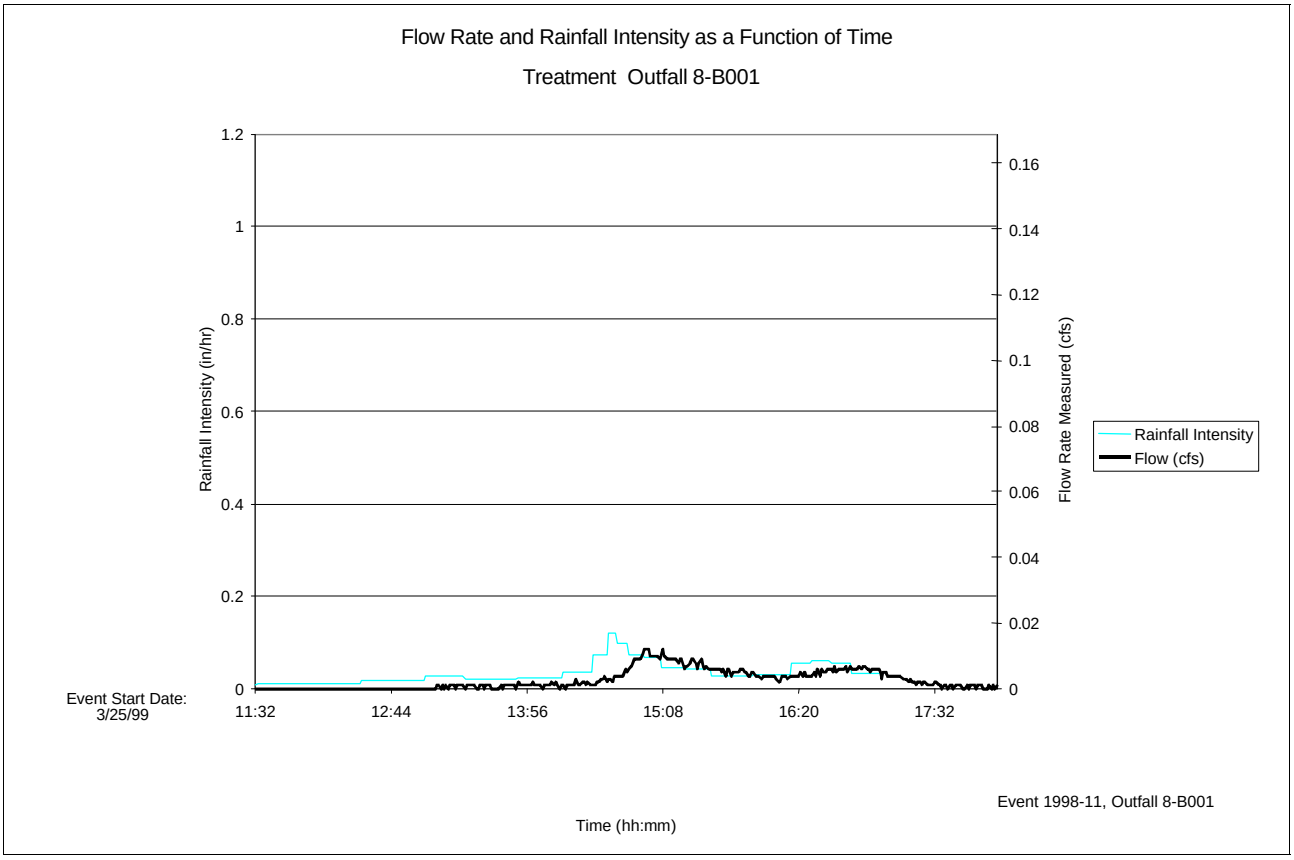
Site 6 - Modified Inlet Event No. 1998e11 - 3/25/99



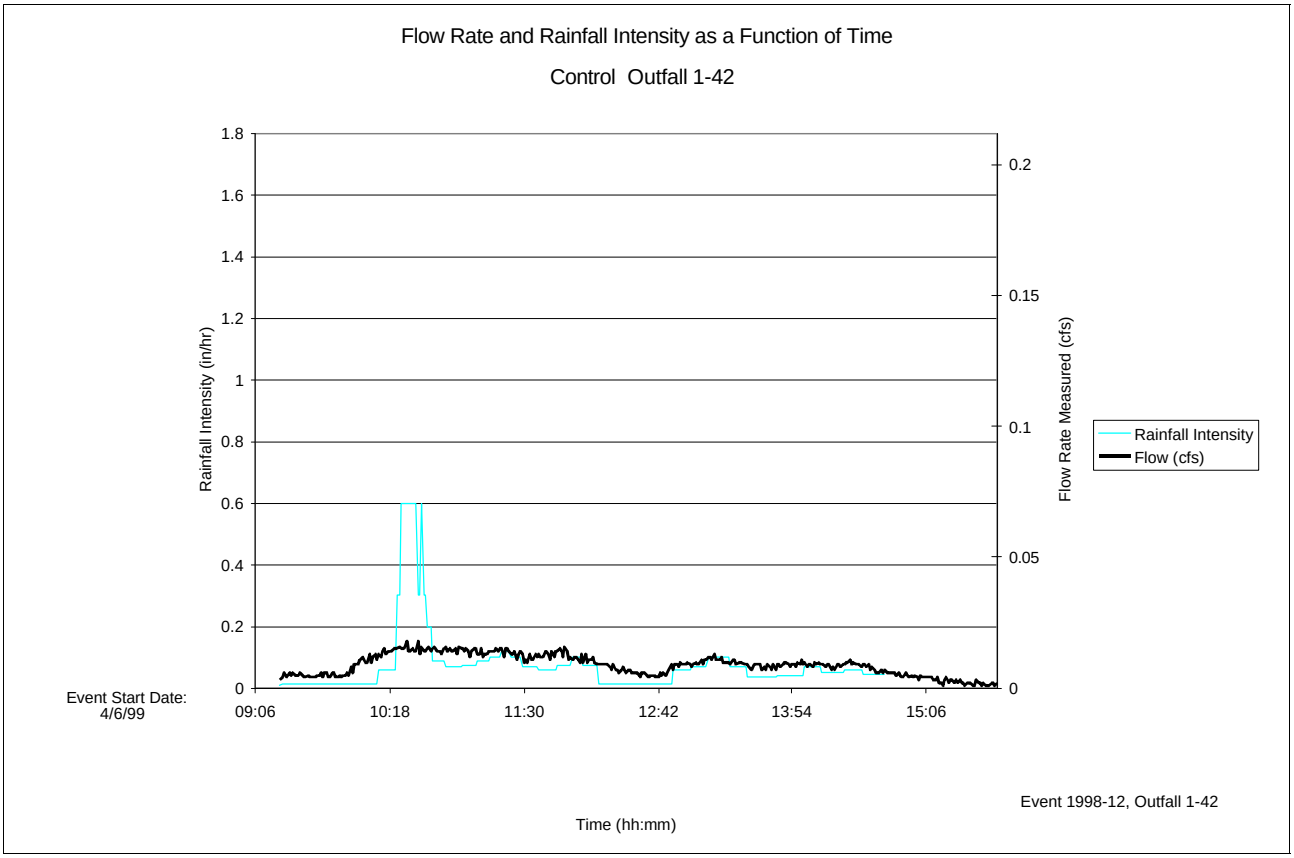


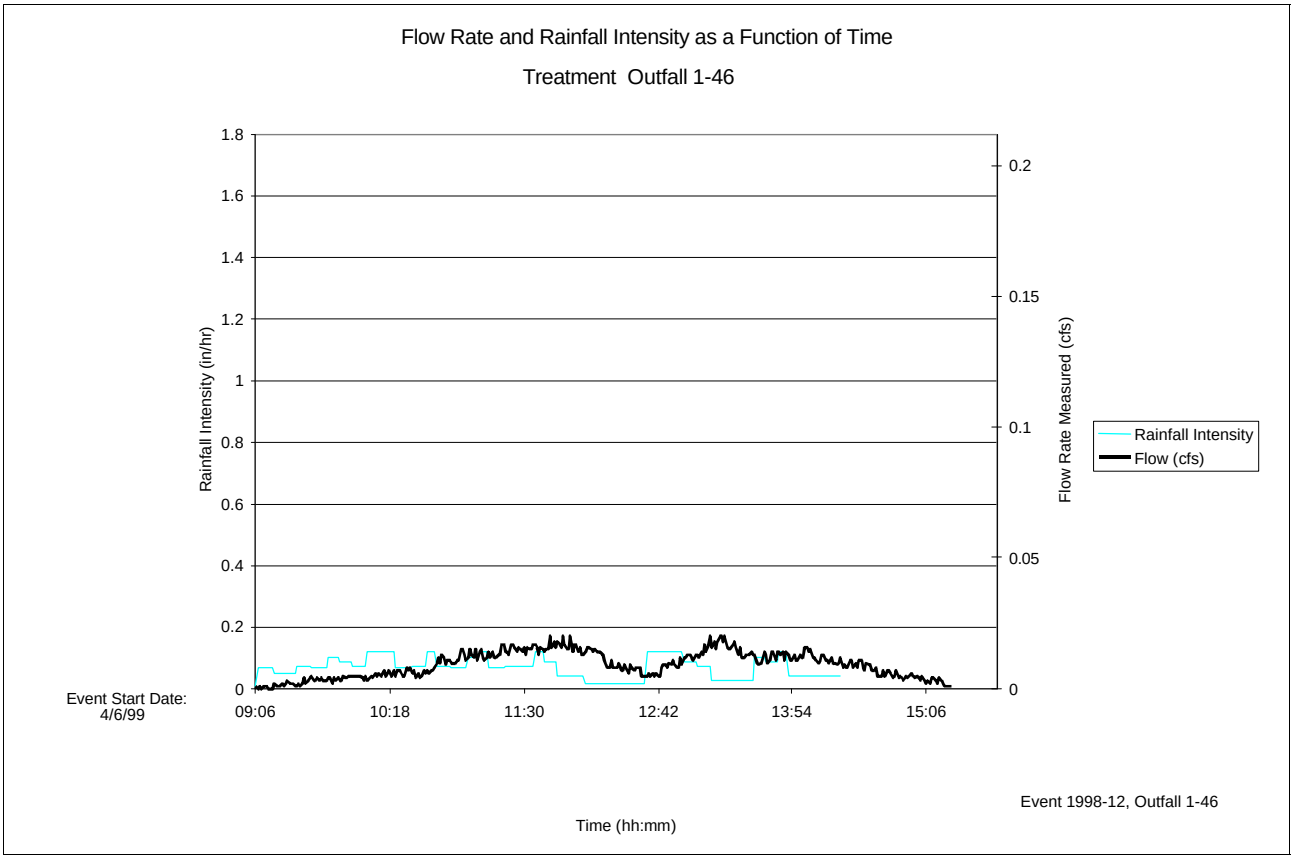
Site 8 - Bicycle Grate/LID Event No. 1998e11 - 3/25/99



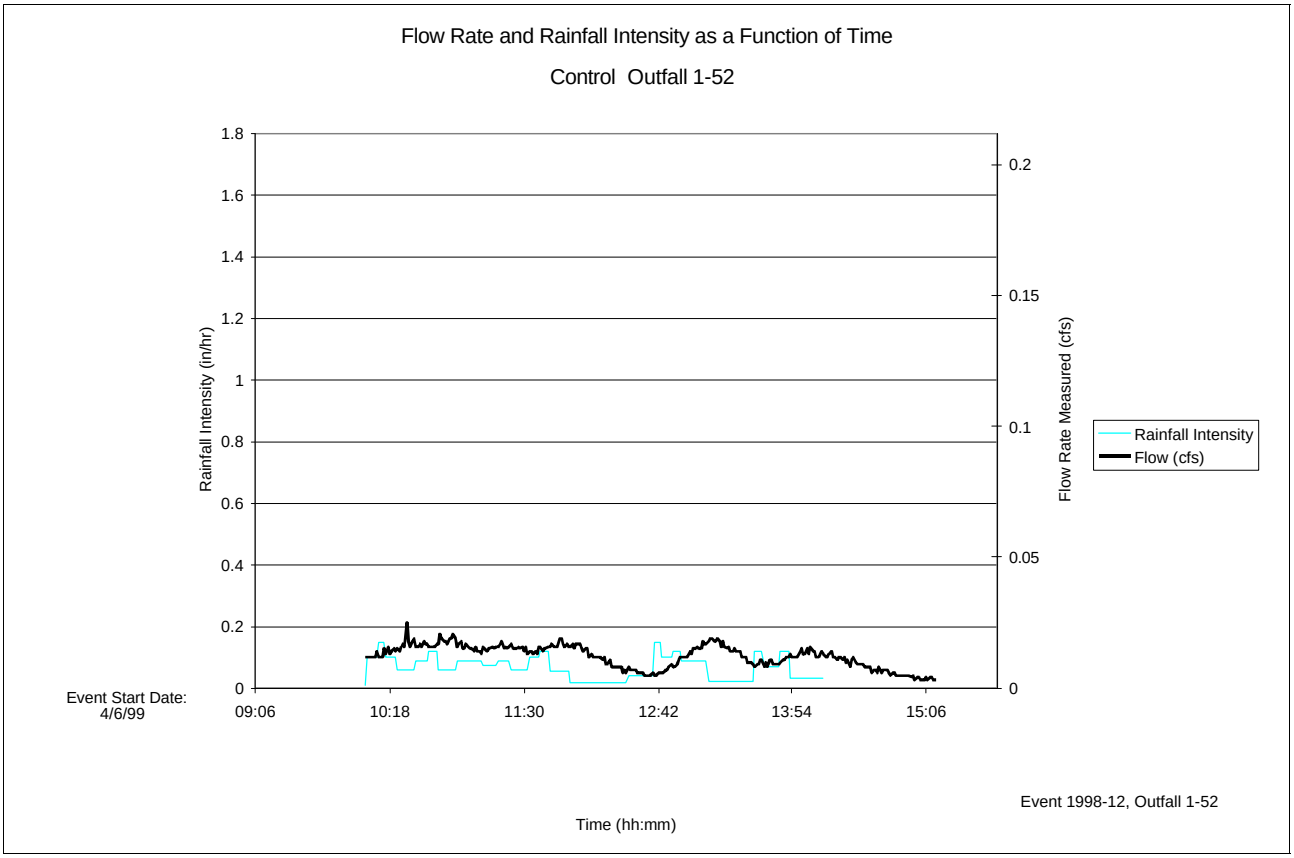


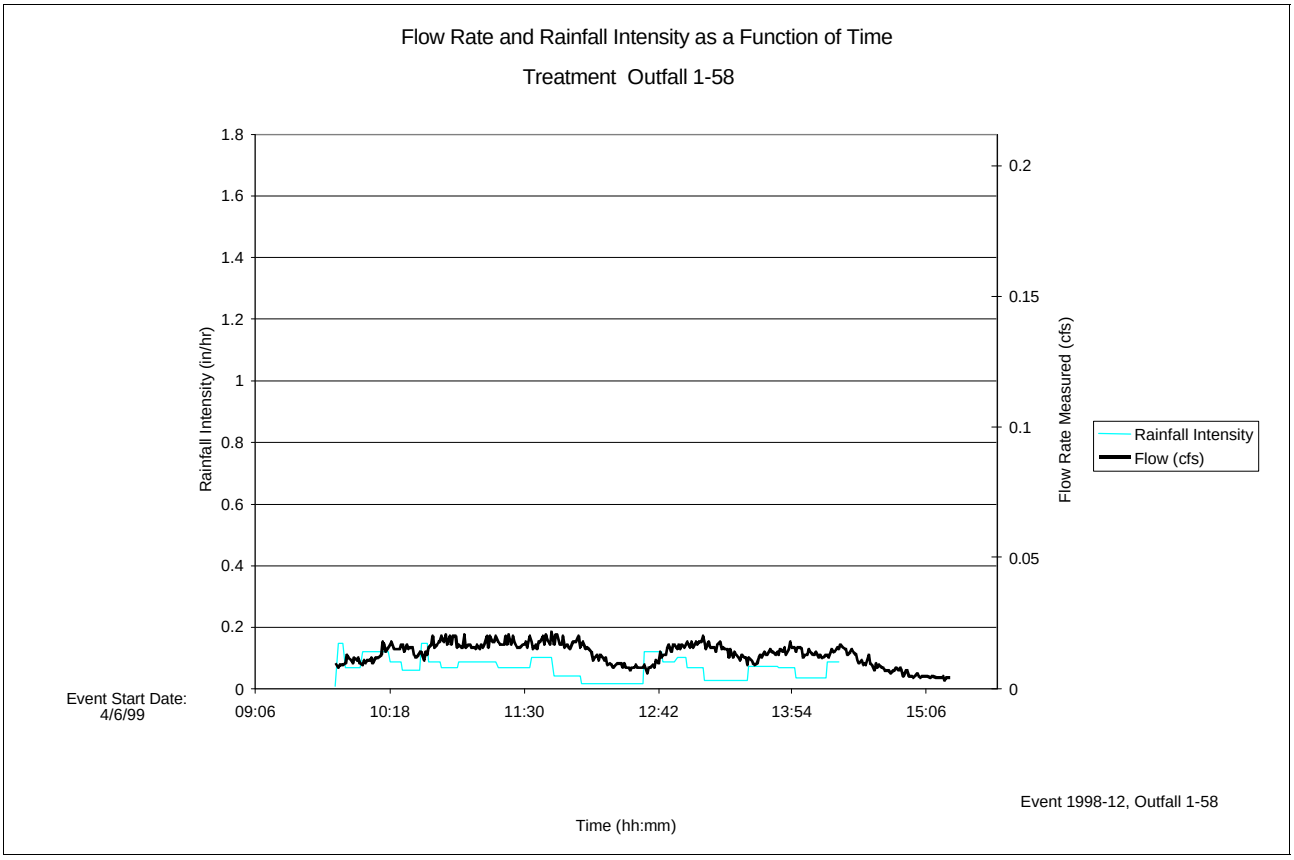
Site 1E - Litter Pickup Event No. 1998e12 - 4/6/99



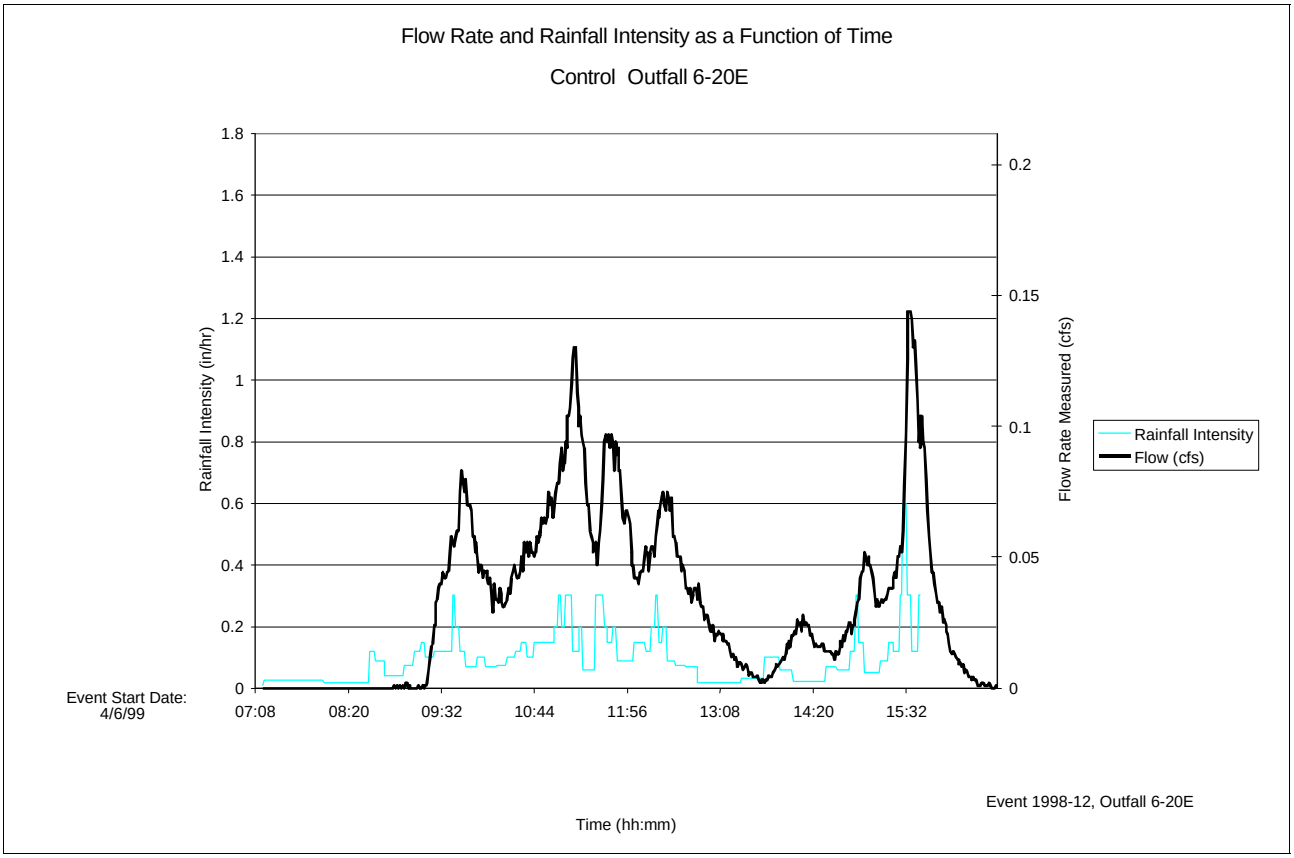


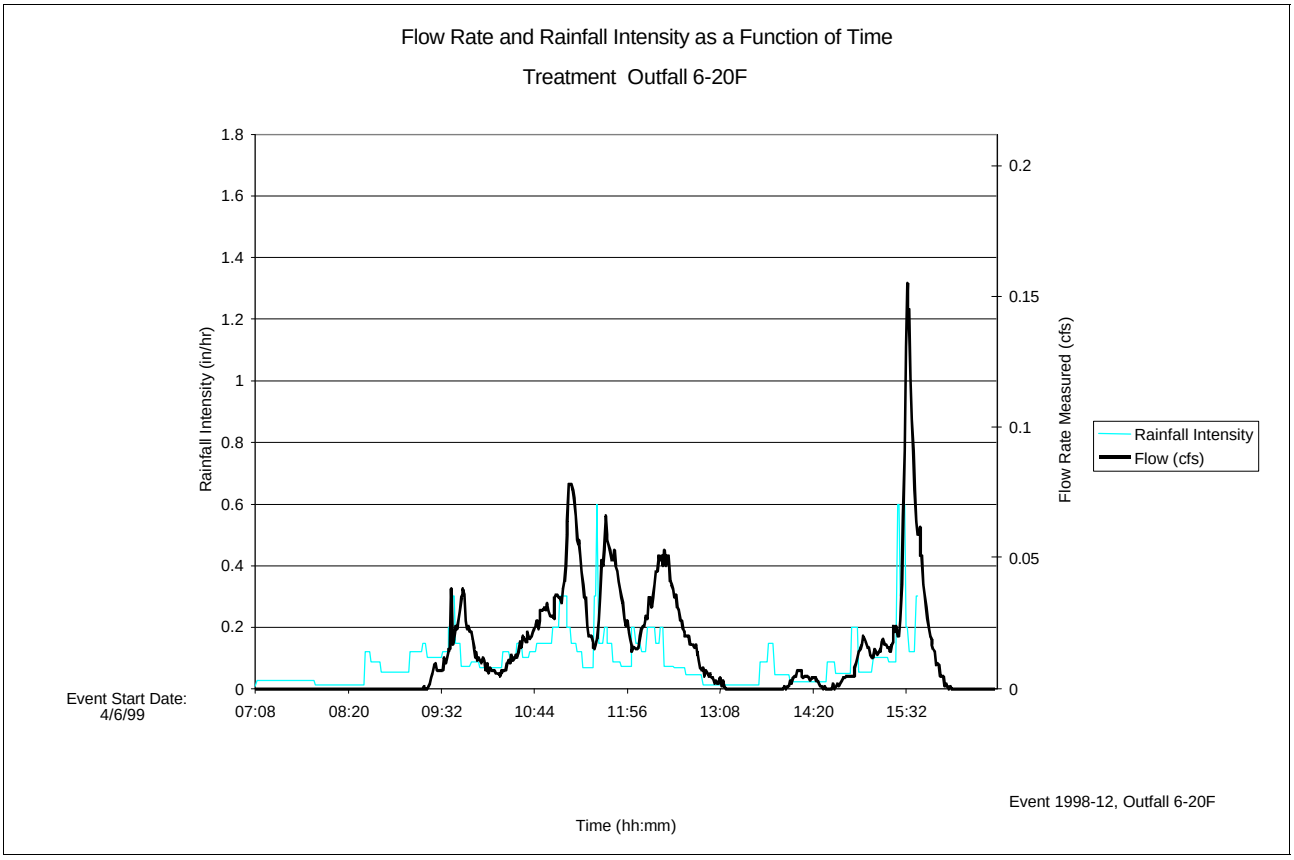
Site 1W - Street Sweeping Event No. 1998e12 - 4/6/99





Site 6 - Modified Inlet Event No. 1998e12 - 4/6/99





Site 8 - Bicycle Grate/LID Event No. 1998e12 - 4/6/99

Flow Rate and Rainfall Intensity as a Function of Time

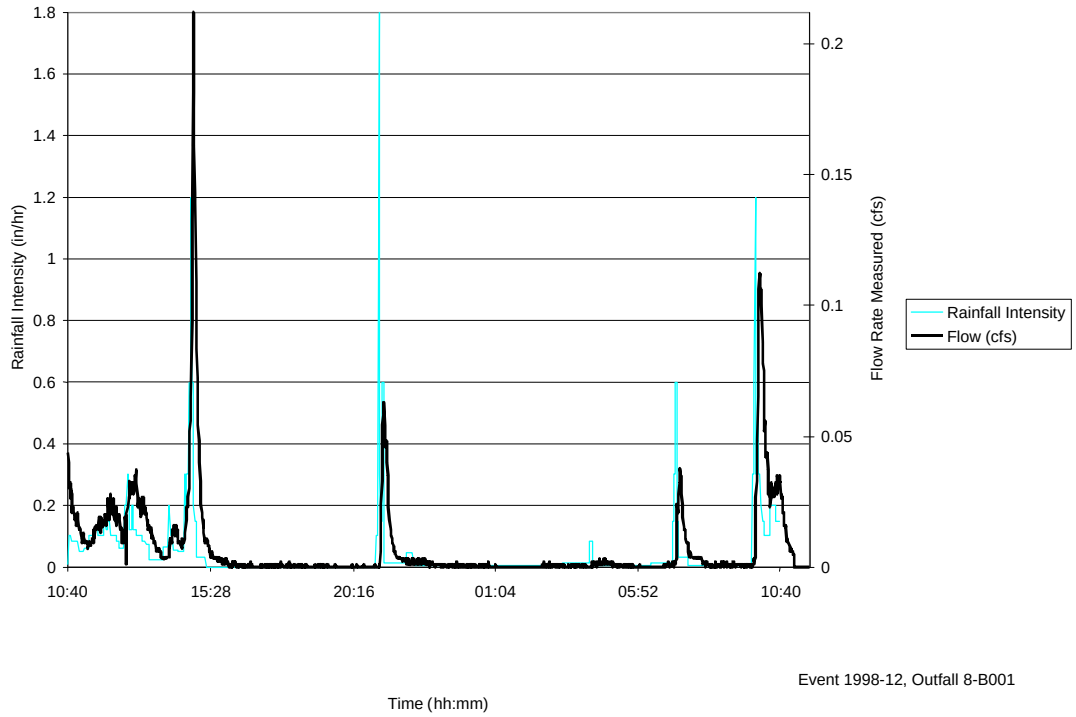
Control Outfall 8-23C

No Hydrologic Data Available for this Event For this Outfall

Event Start Date:
4/6/99

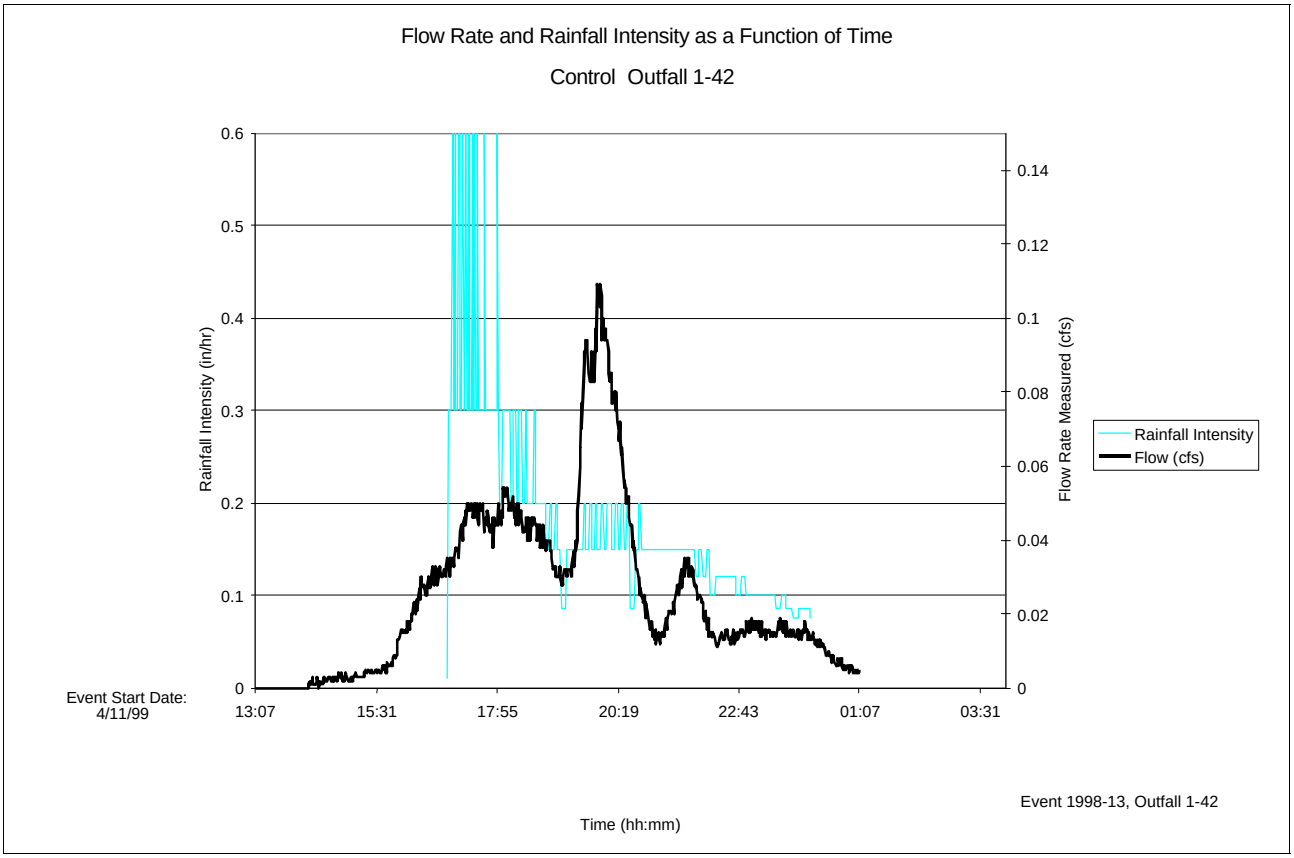
Flow Rate and Rainfall Intensity as a Function of Time

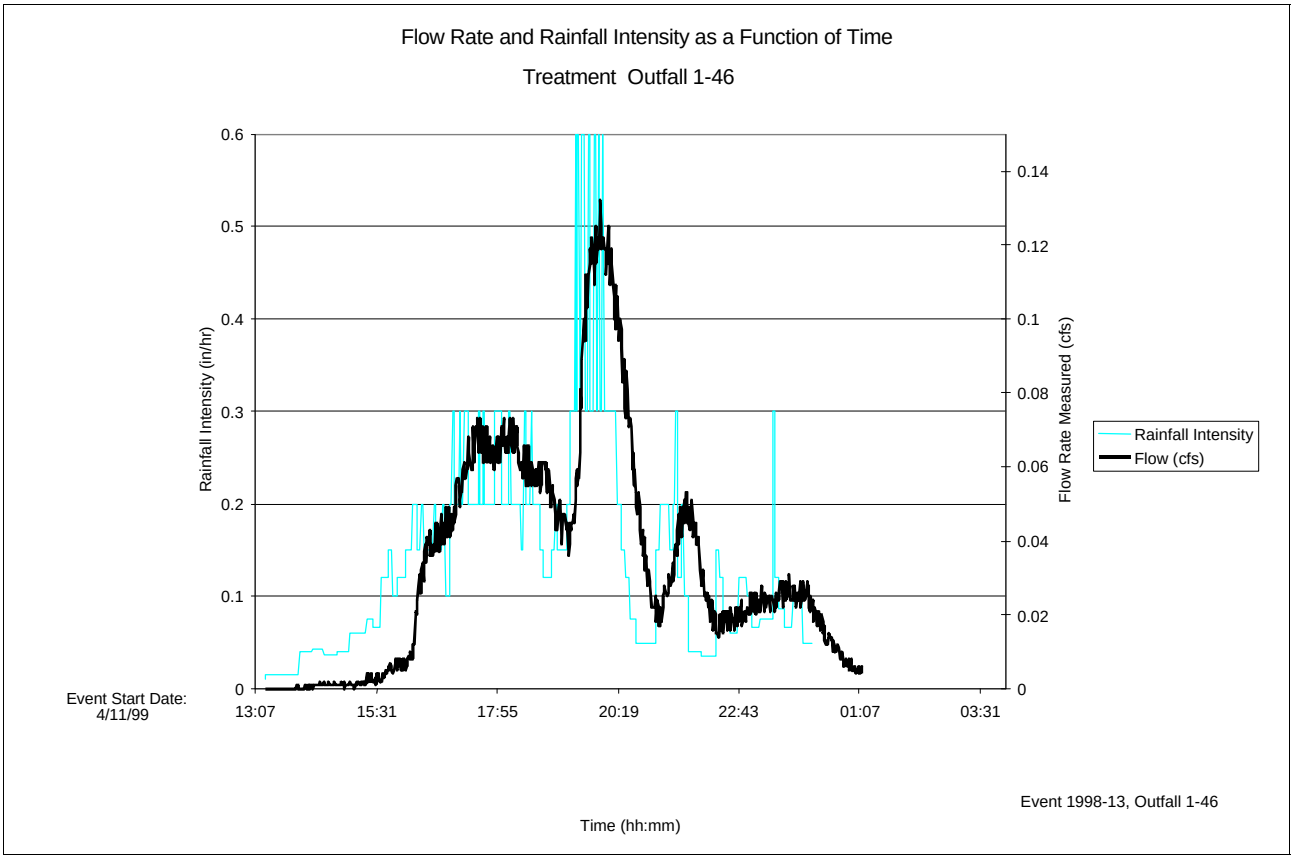
Treatment Outfall 8-B001



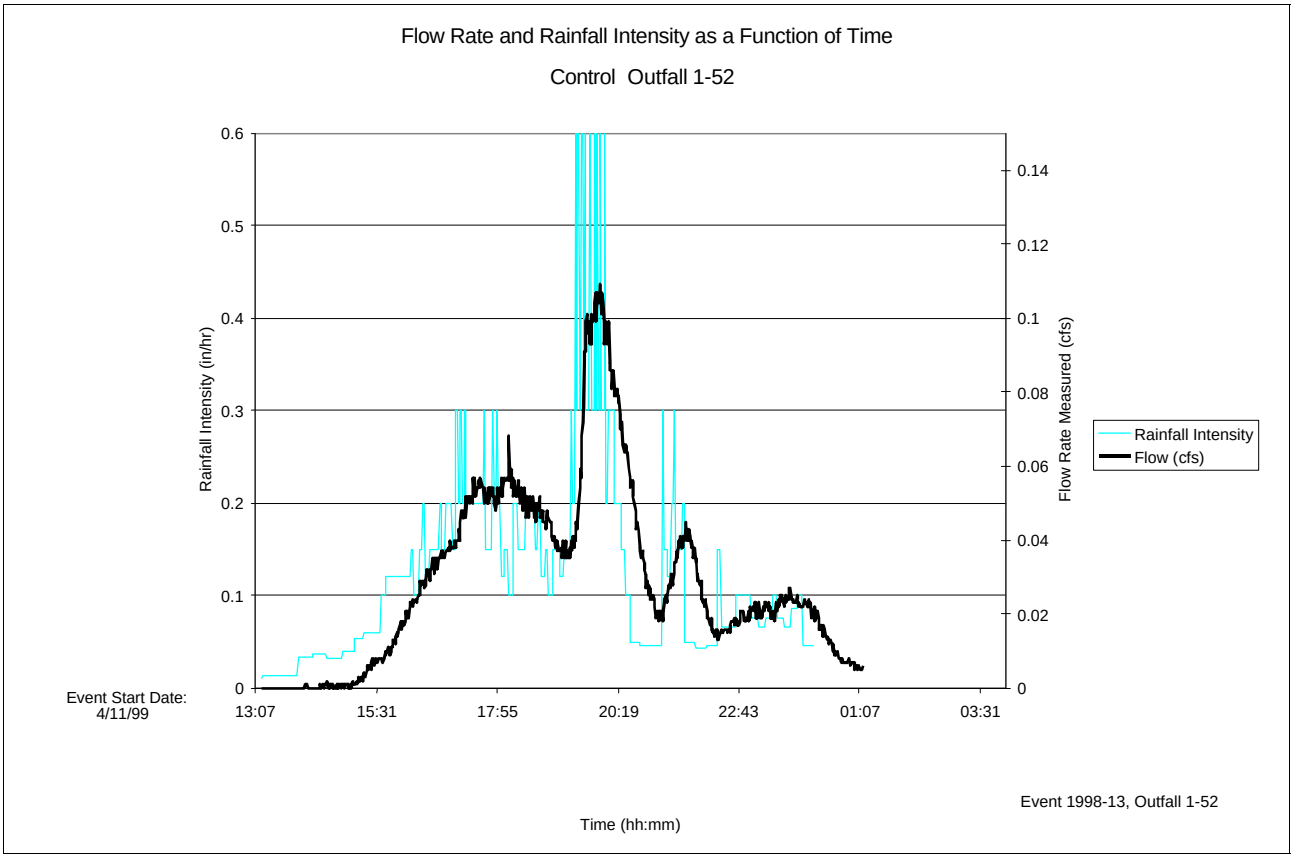
Site 1E - Litter Pickup

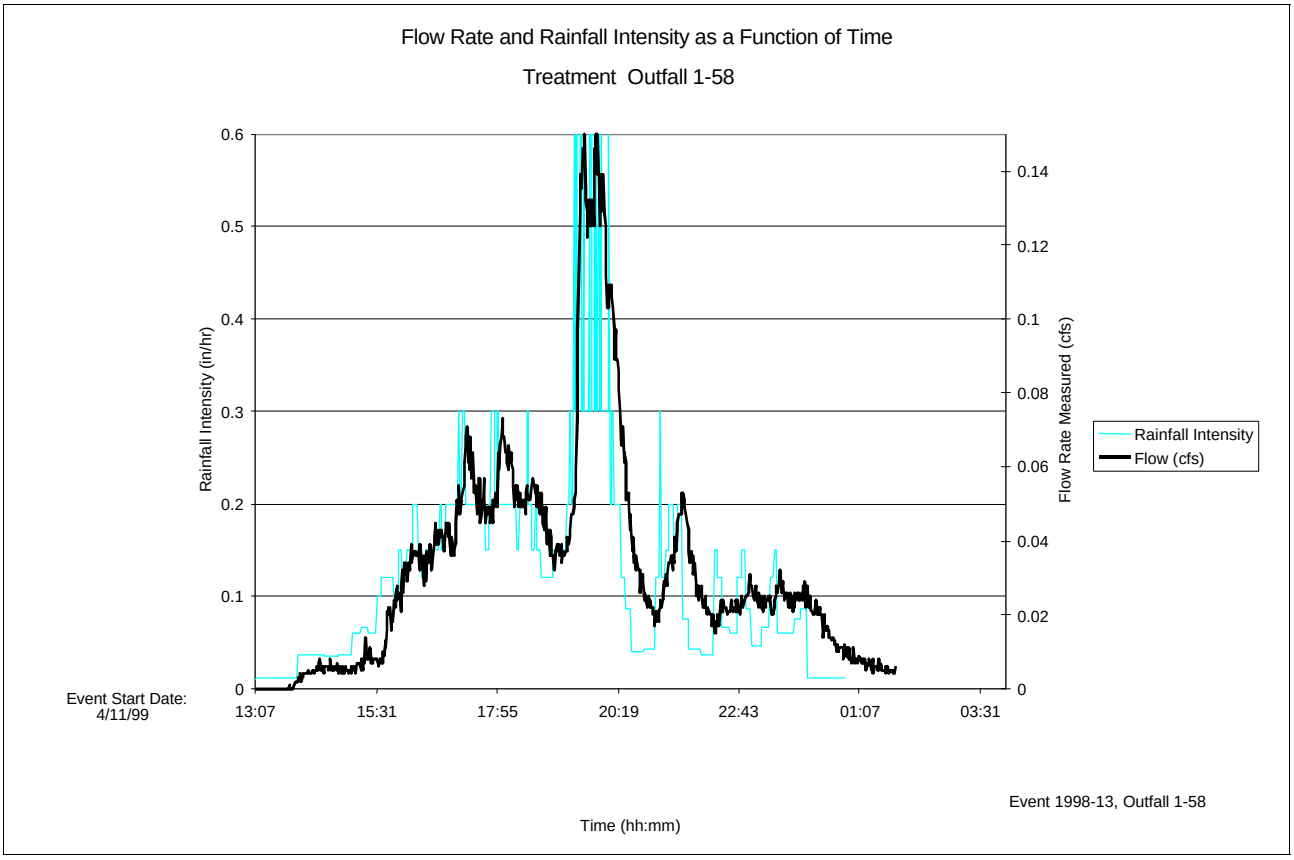
Event No. 1998e13 - 4/11/99



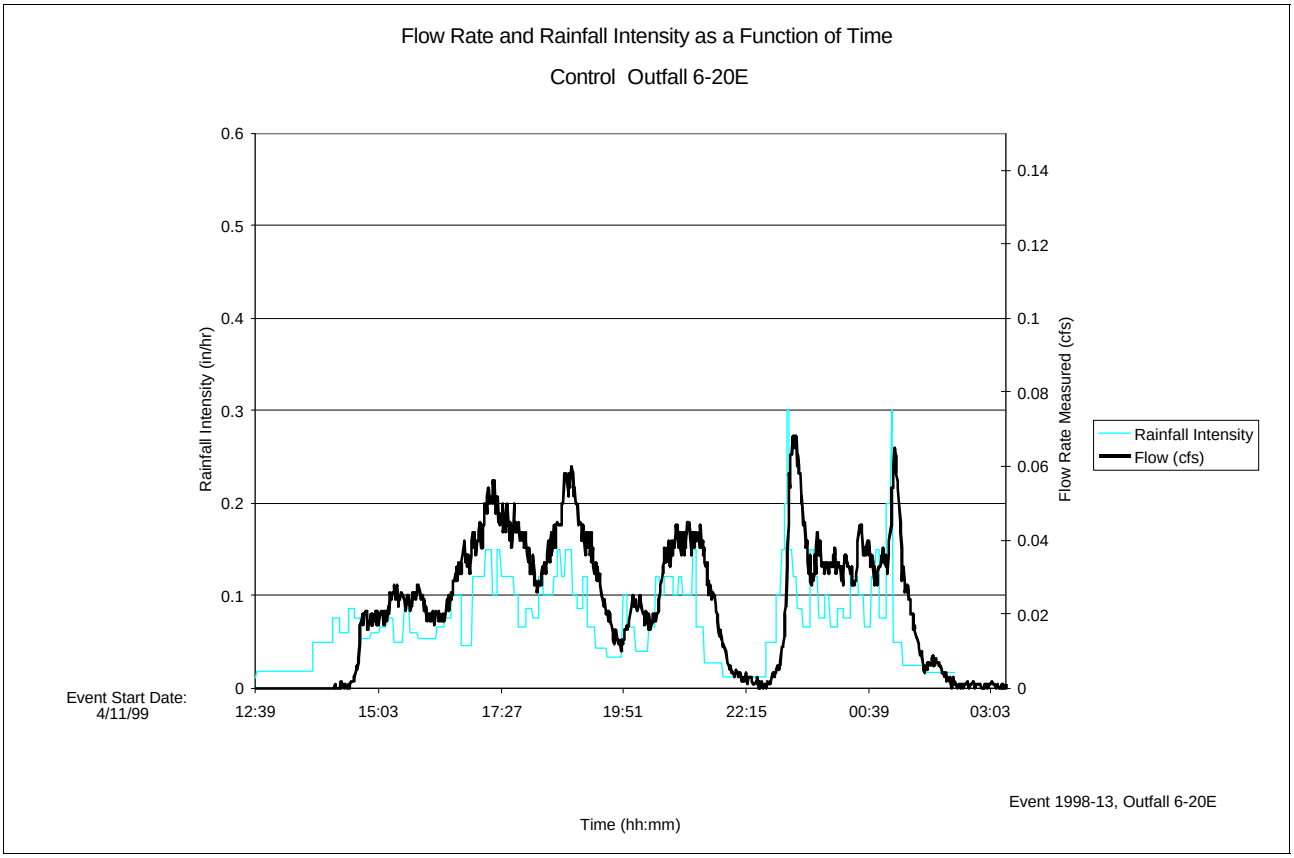


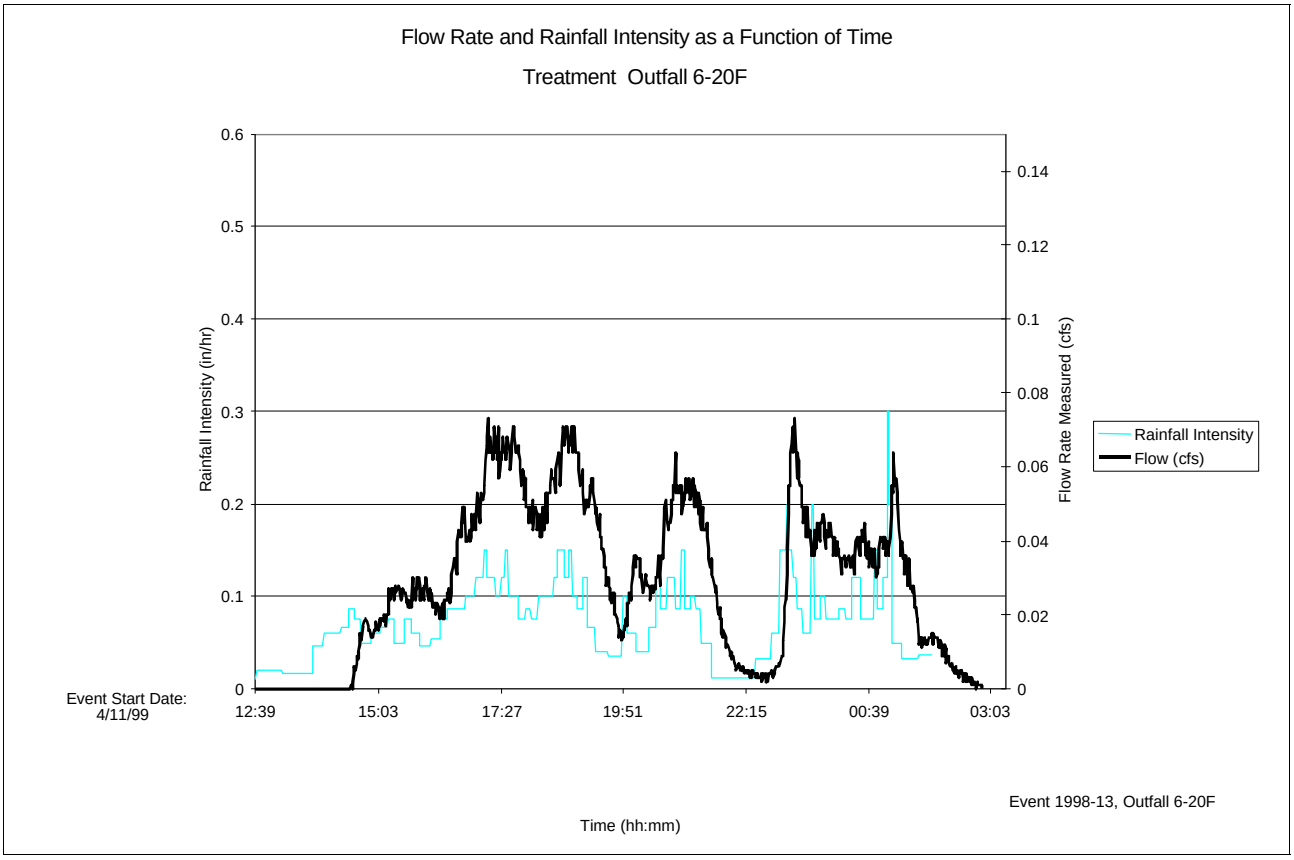
Site 1W - Street Sweeping Event No. 1998e13 - 4/11/99



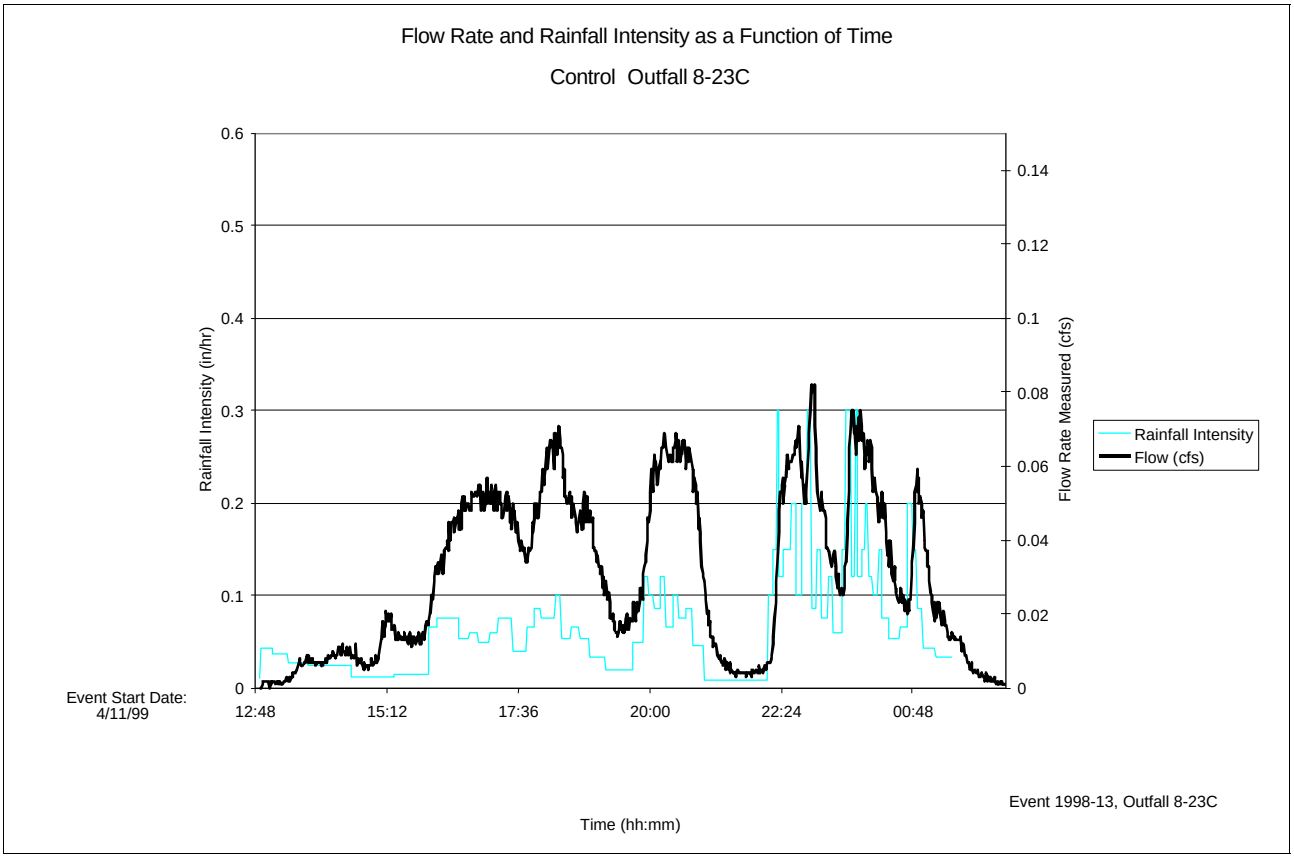


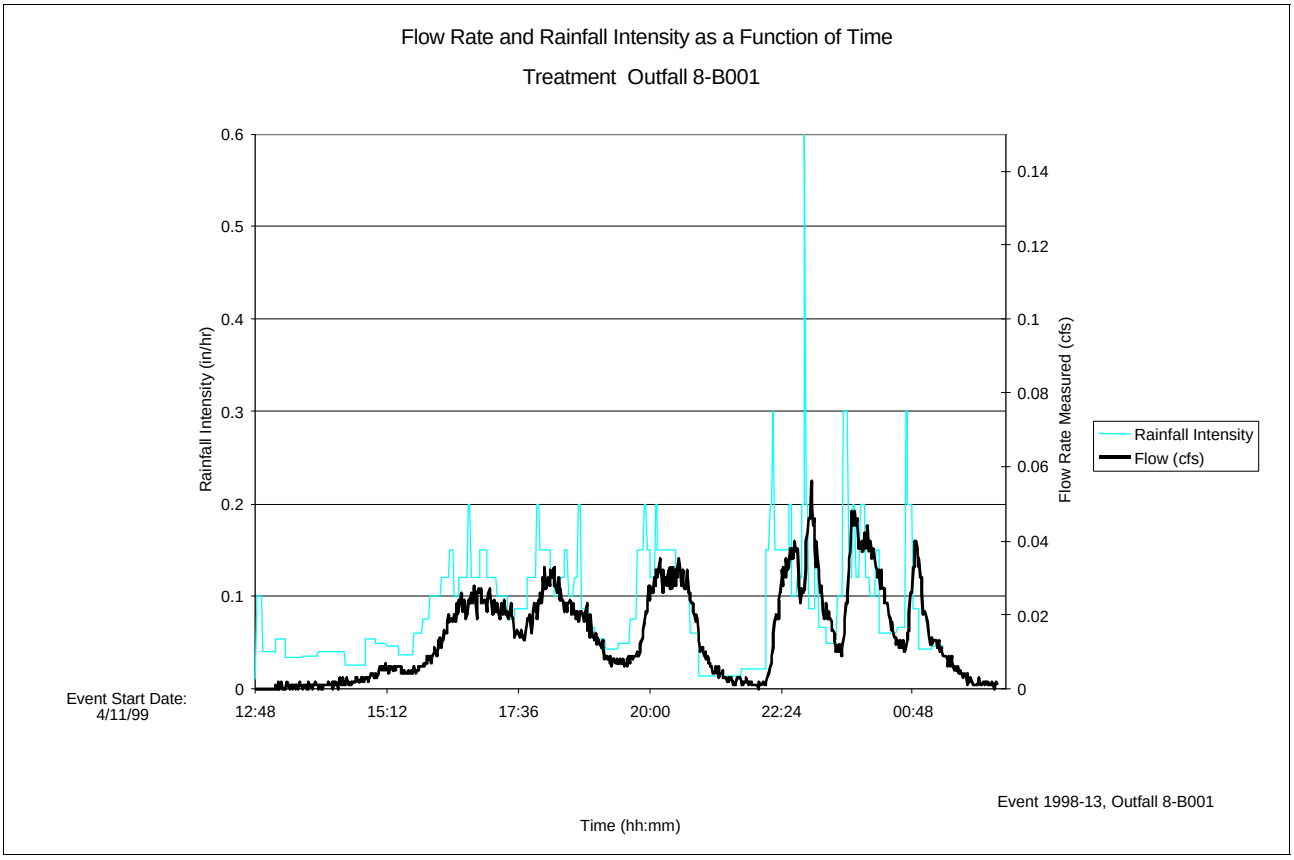
Site 6 - Modified Inlet Event No. 1998e13 - 4/11/99





Site 8 - Bicycle Grate/LID Event No. 1998e13 - 4/11/99





Site 1E - Litter Pickup

Event No. 1999e03 - 12/31/99

Flow Rate and Rainfall Intensity as a Function of Time

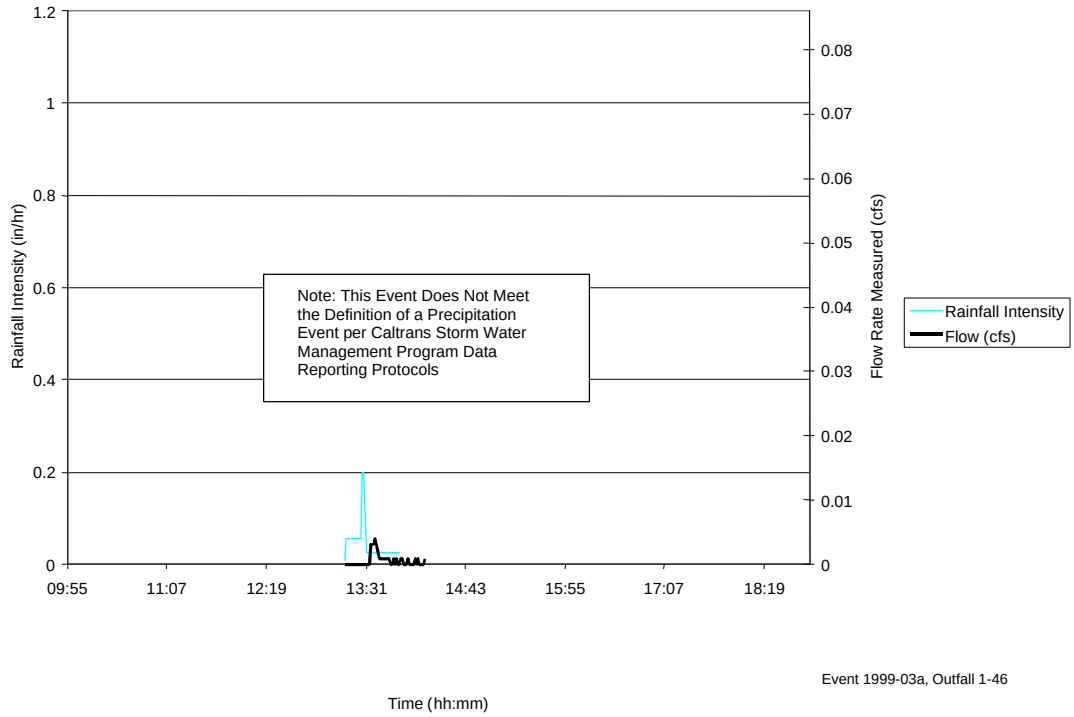
Control Outfall 1-42

No Hydrologic Data Available for this Event For this Outfall

Event Start Date:
12/31/99

Flow Rate and Rainfall Intensity as a Function of Time

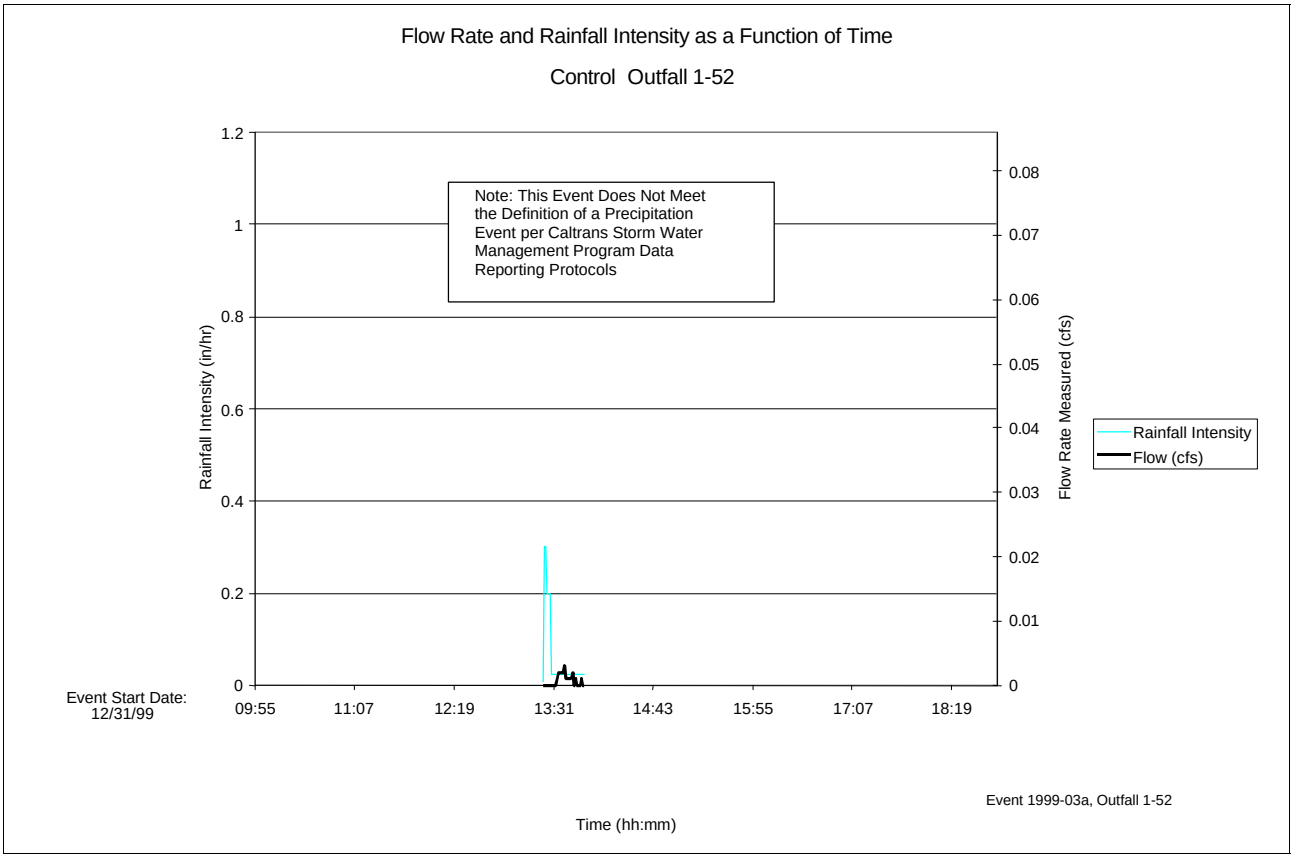
Treatment Outfall 1-46

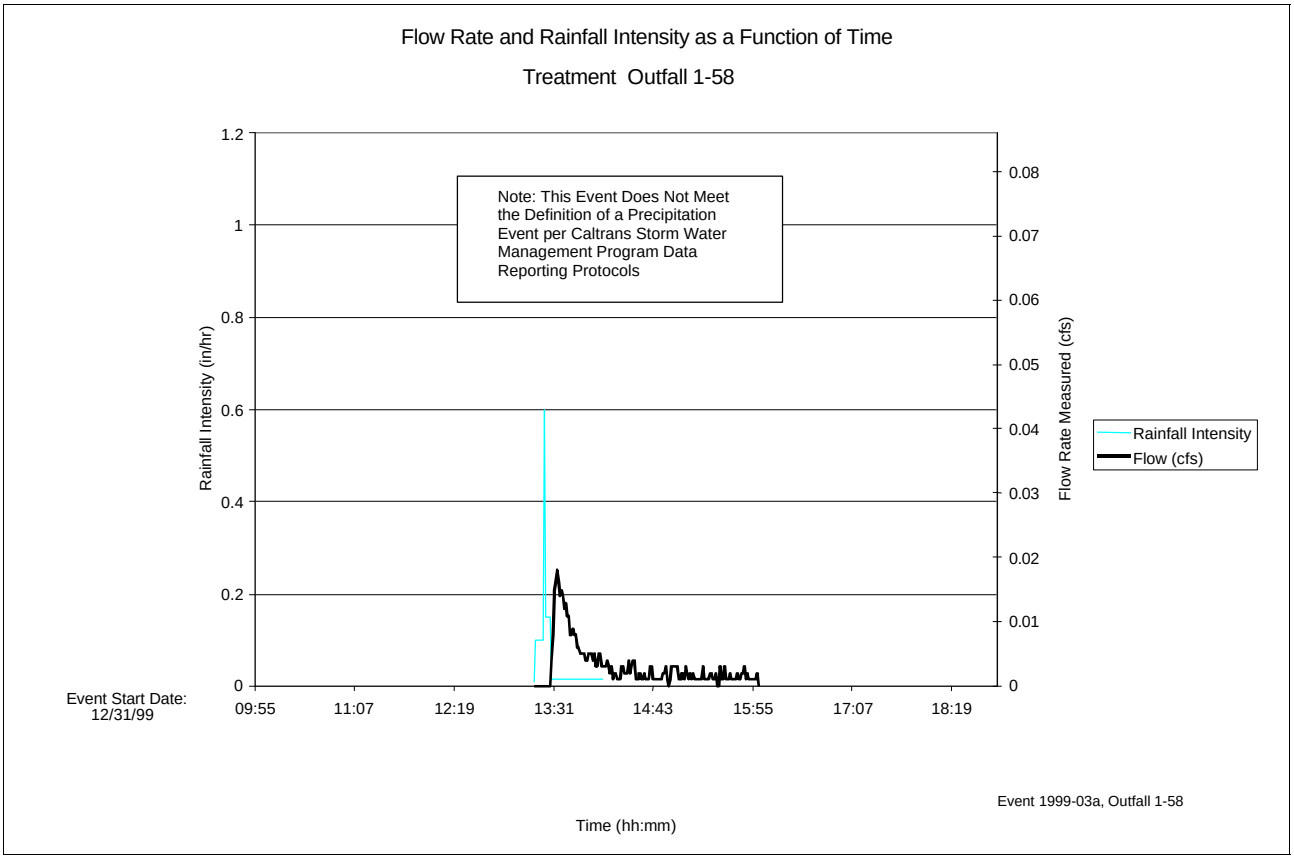


Event Start Date:
12/31/99

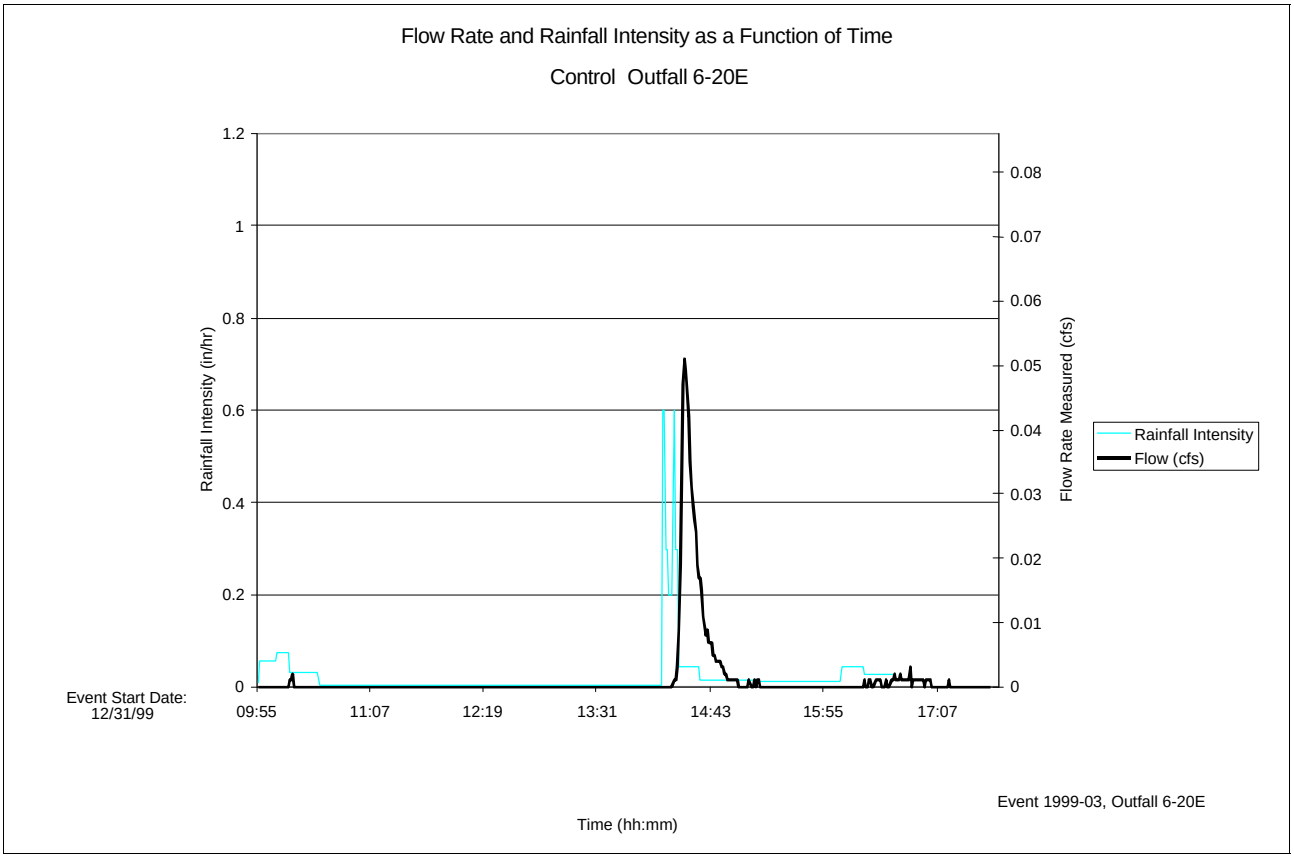
Event 1999-03a, Outfall 1-46

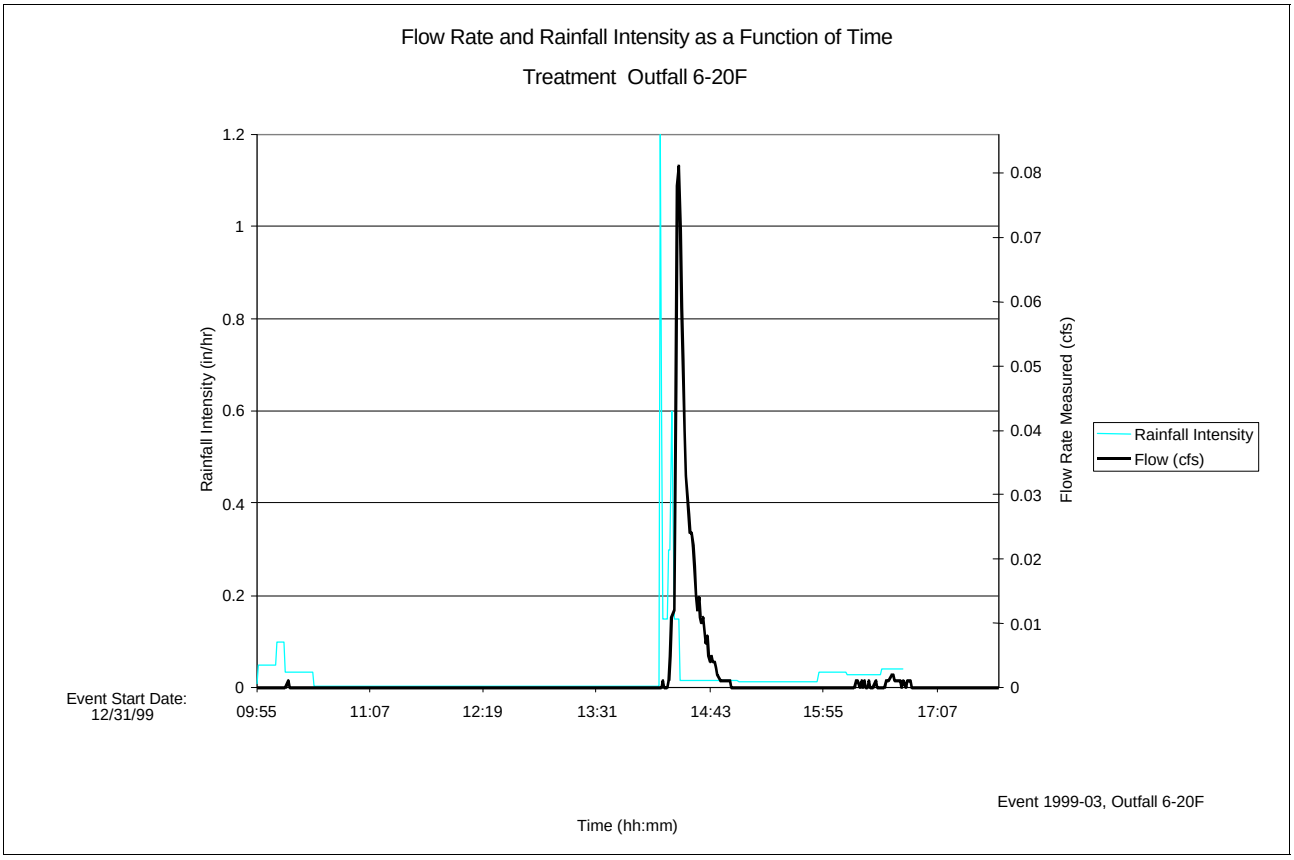
Site 1W - Street Sweeping Event No. 1999e03 - 12/31/99



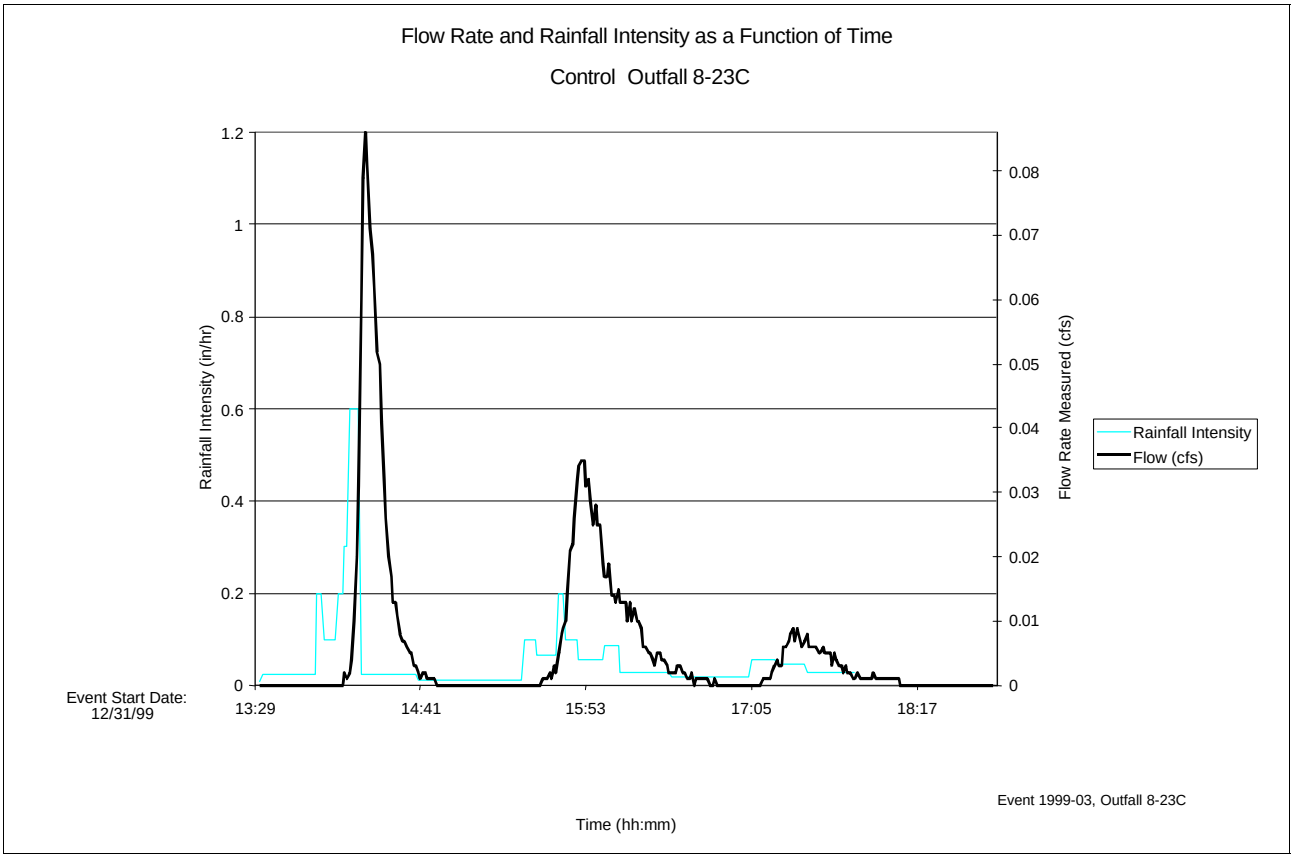


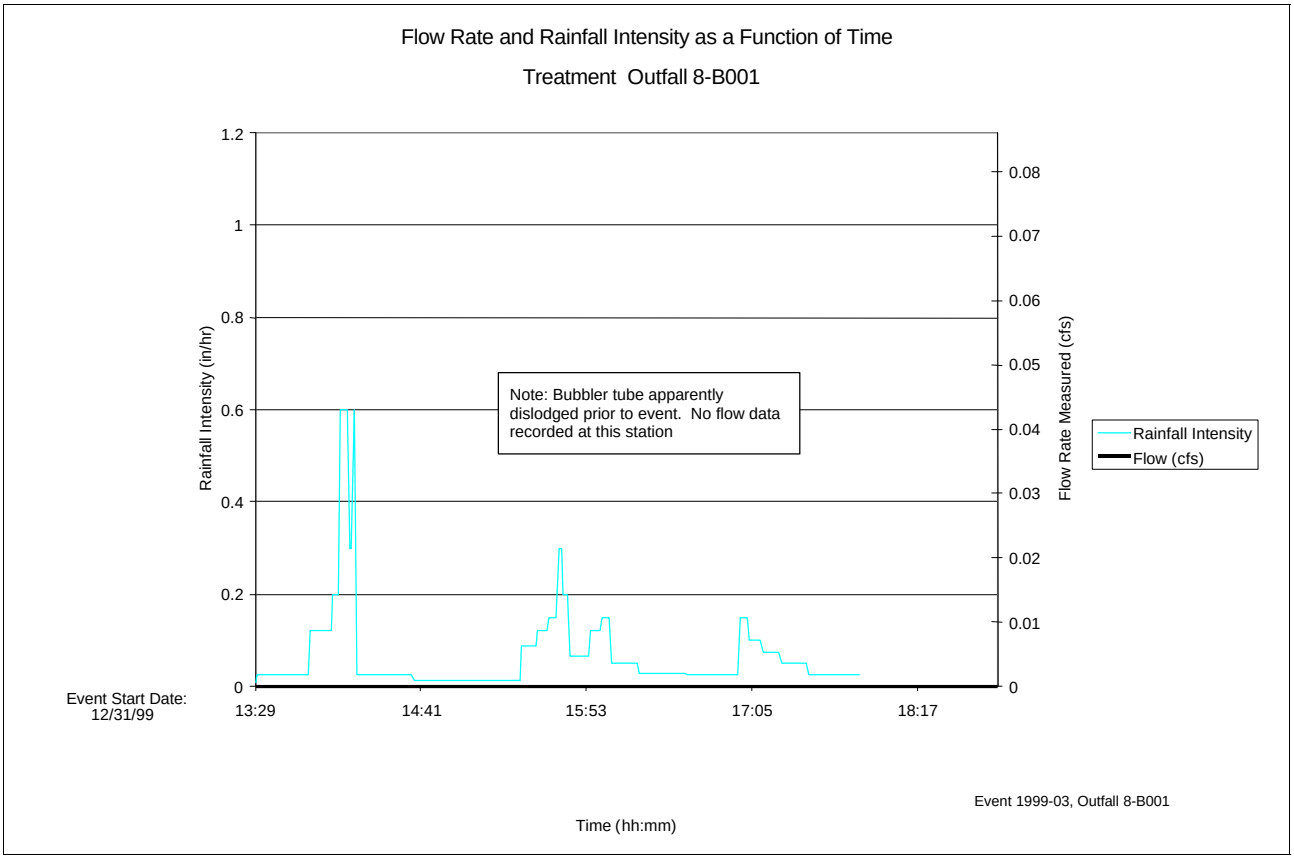
Site 6 - Modified Inlet Event No. 1999e03 - 12/31/99



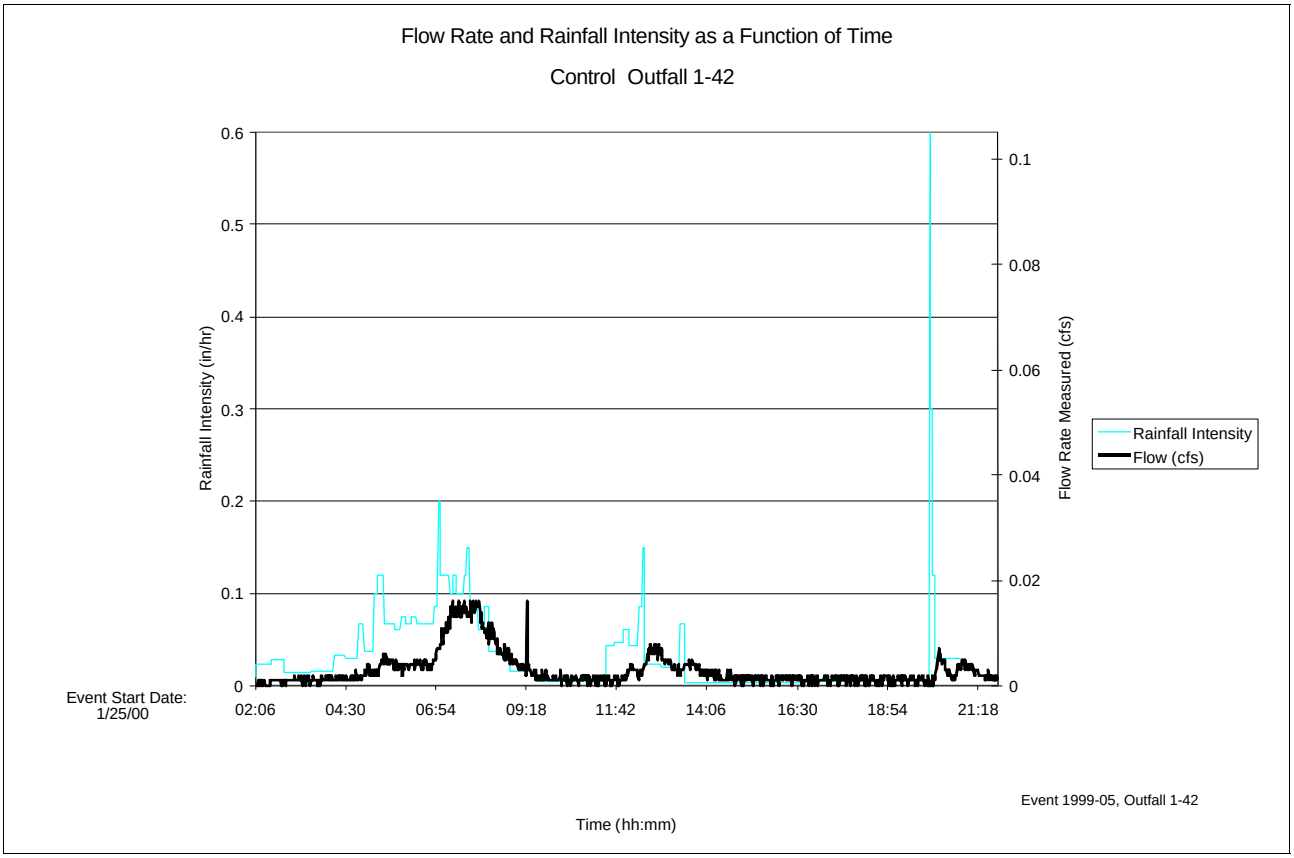


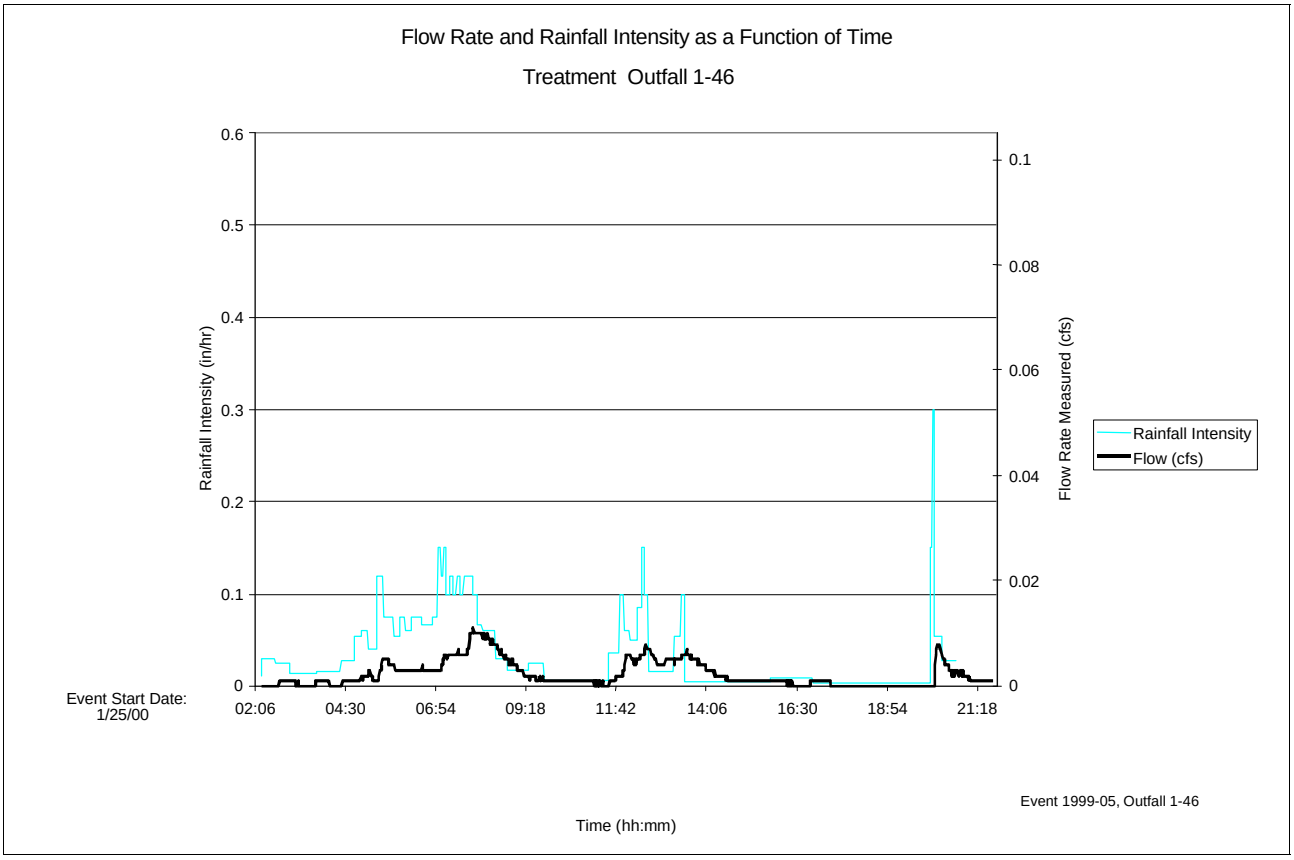
Site 8 - Bicycle Grate/LID Event No. 1999e03 - 12/31/99



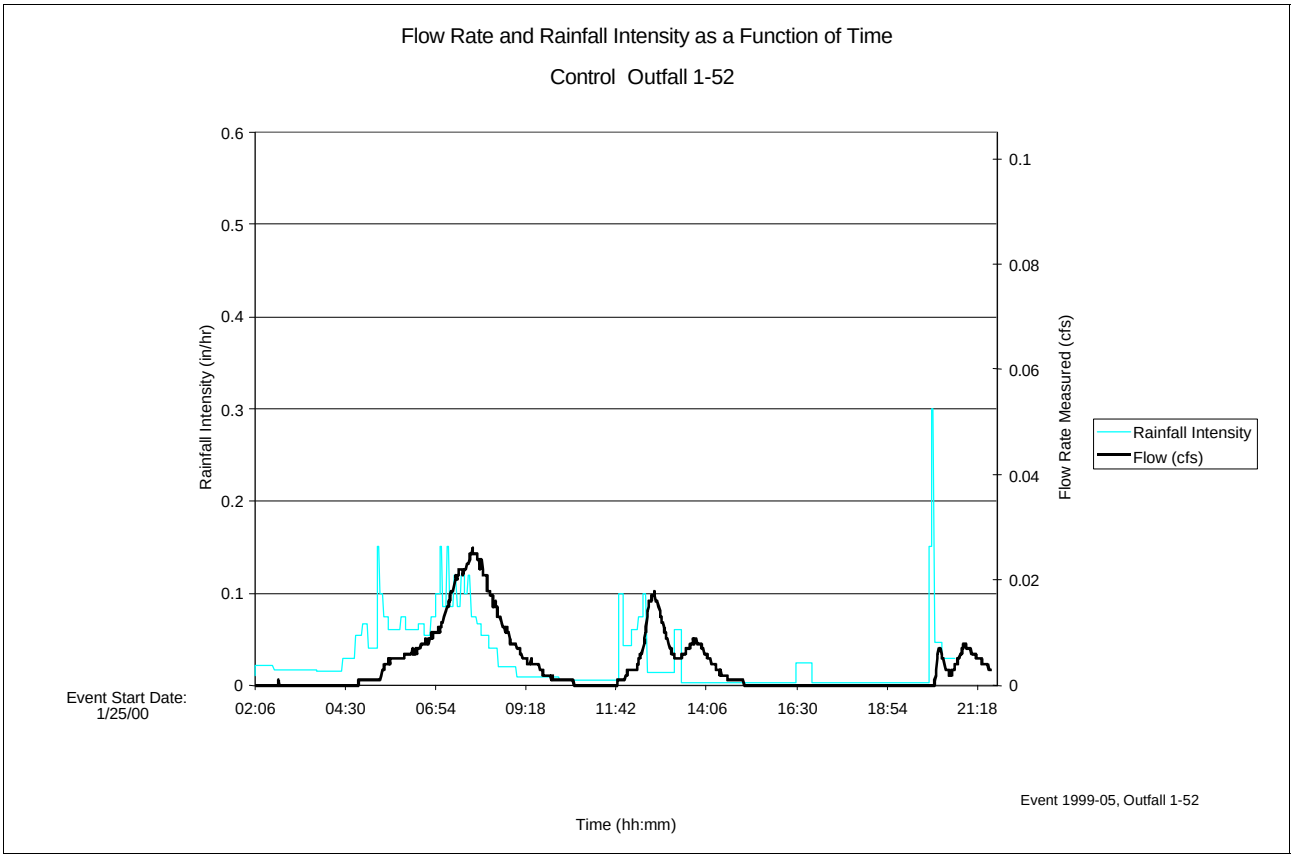


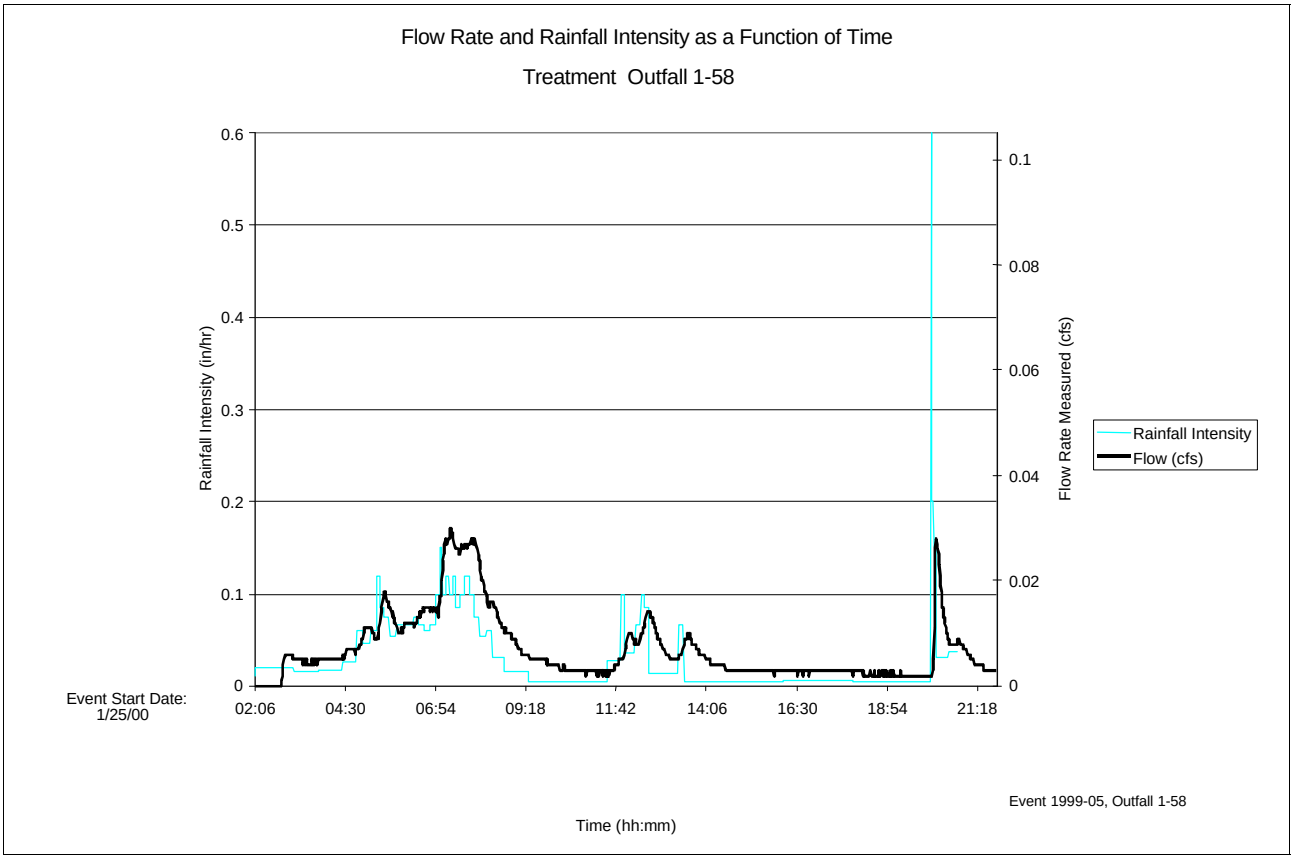
Site 1E - Litter Pickup Event No. 1999e05 - 1/25/00



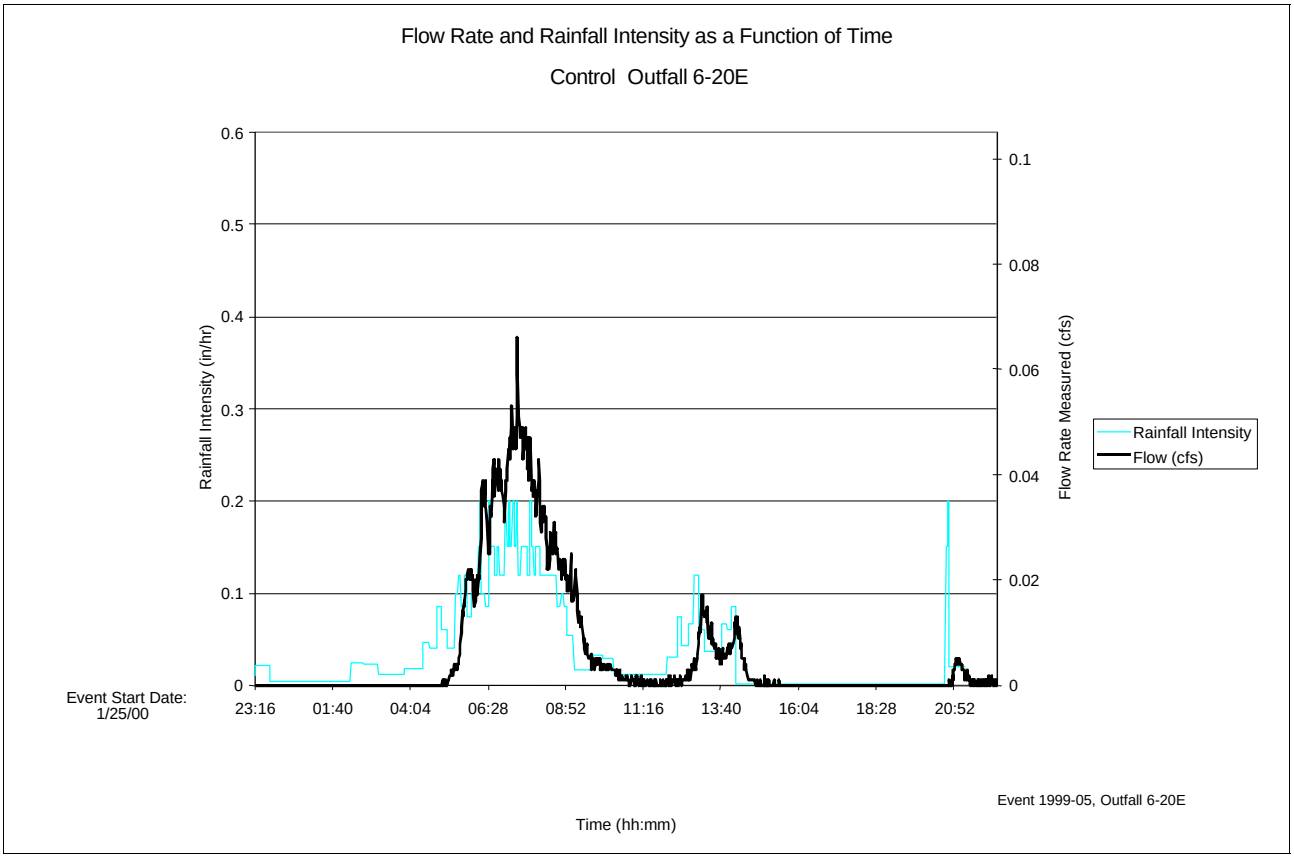


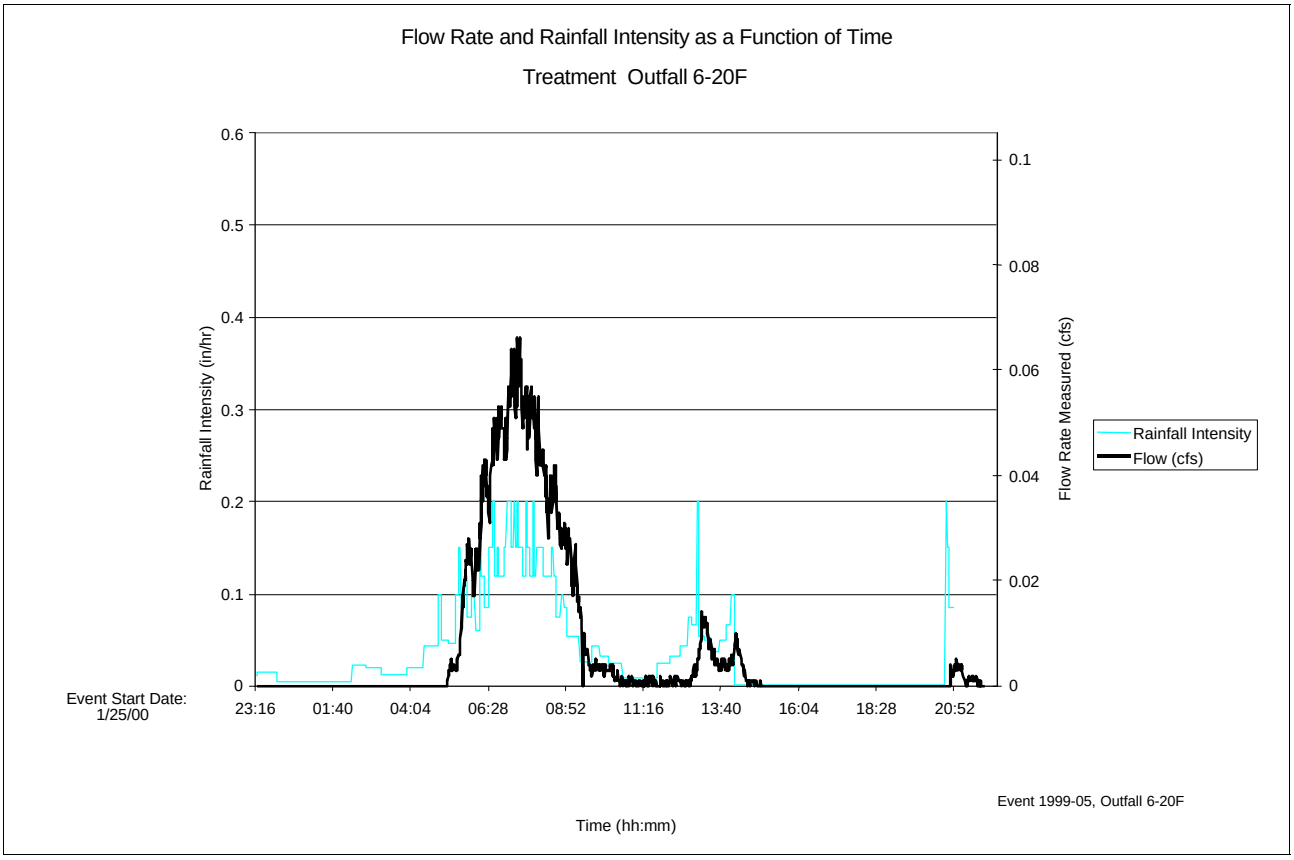
Site 1W - Street Sweeping Event No. 1999e05 - 1/25/00



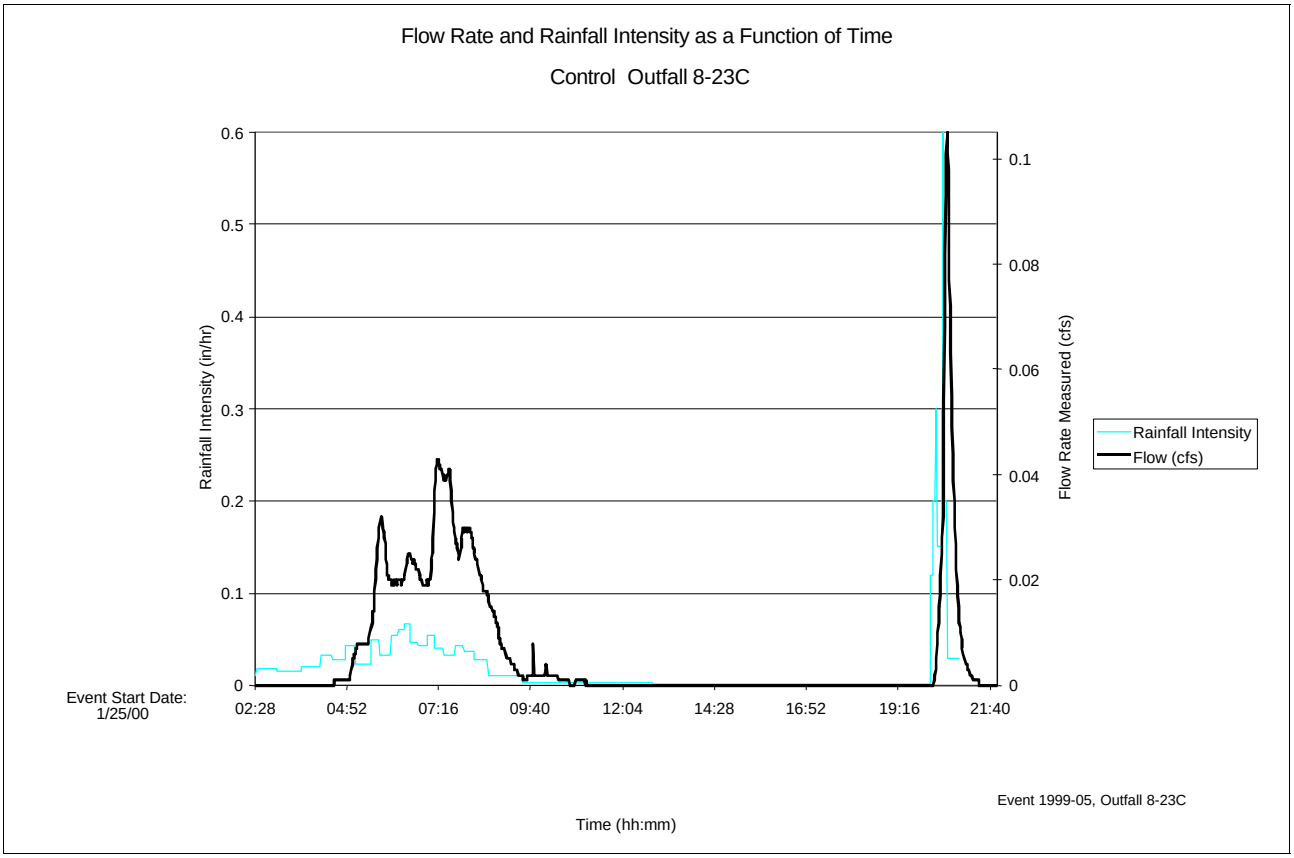


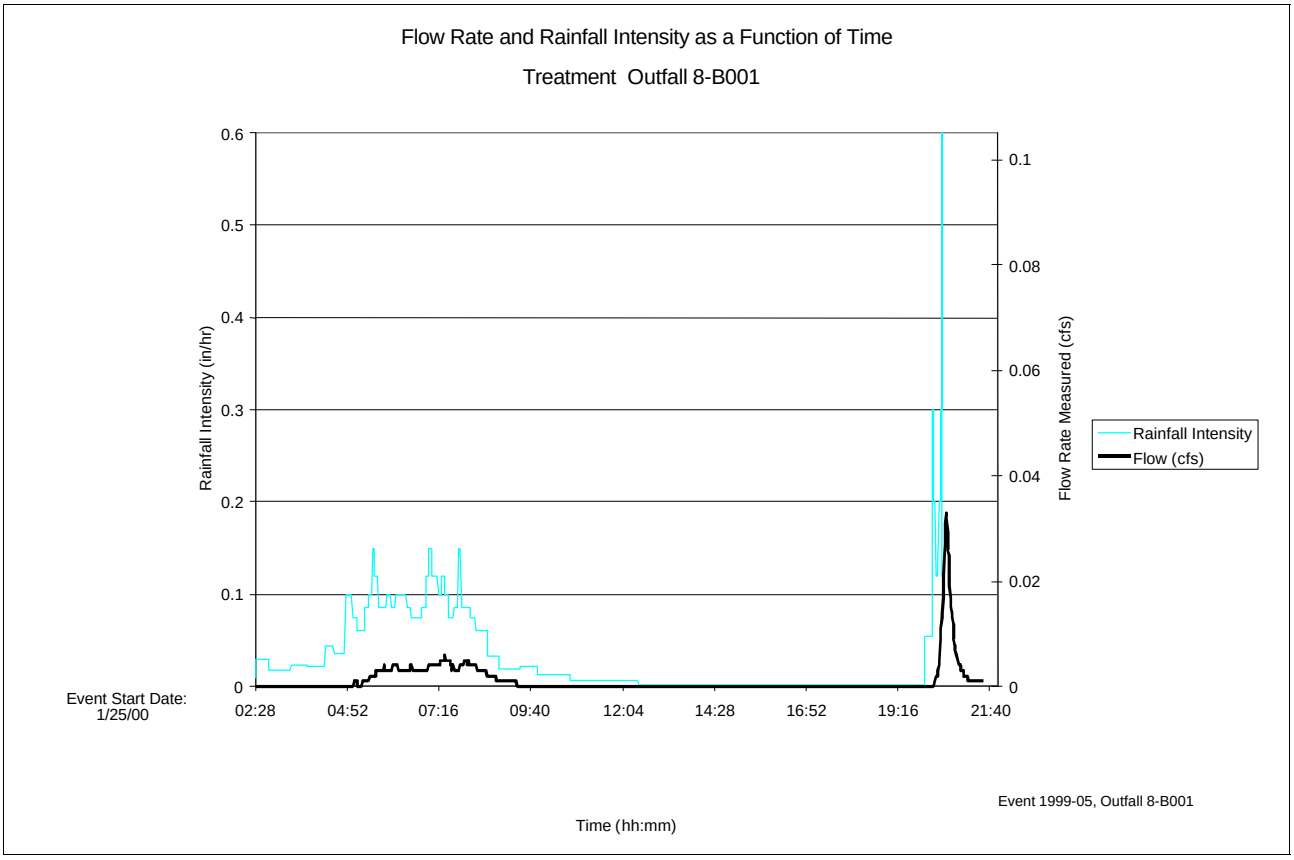
Site 6 - Modified Inlet Event No. 1999e05 - 1/25/00





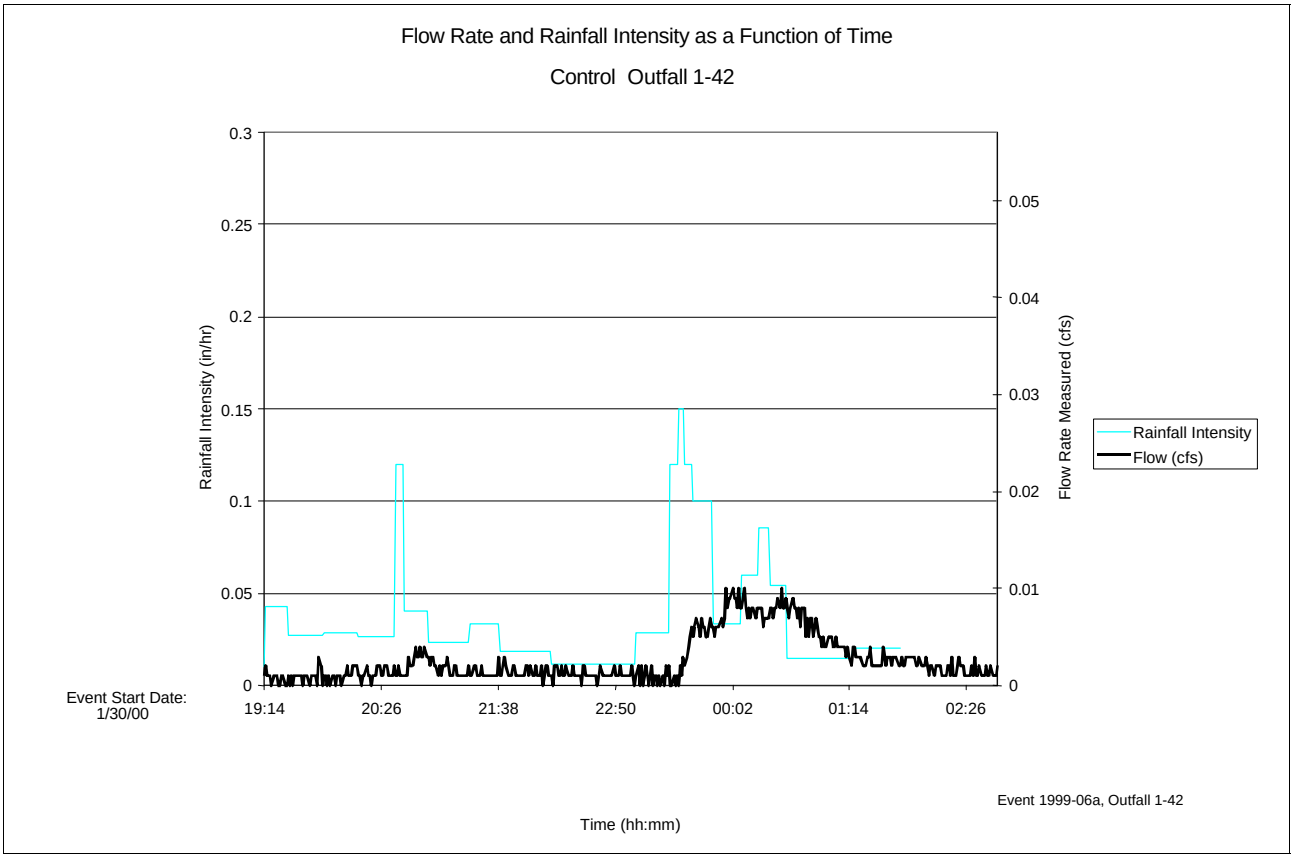
Site 8 - Bicycle Grate/LID Event No. 1999e05 - 1/25/00

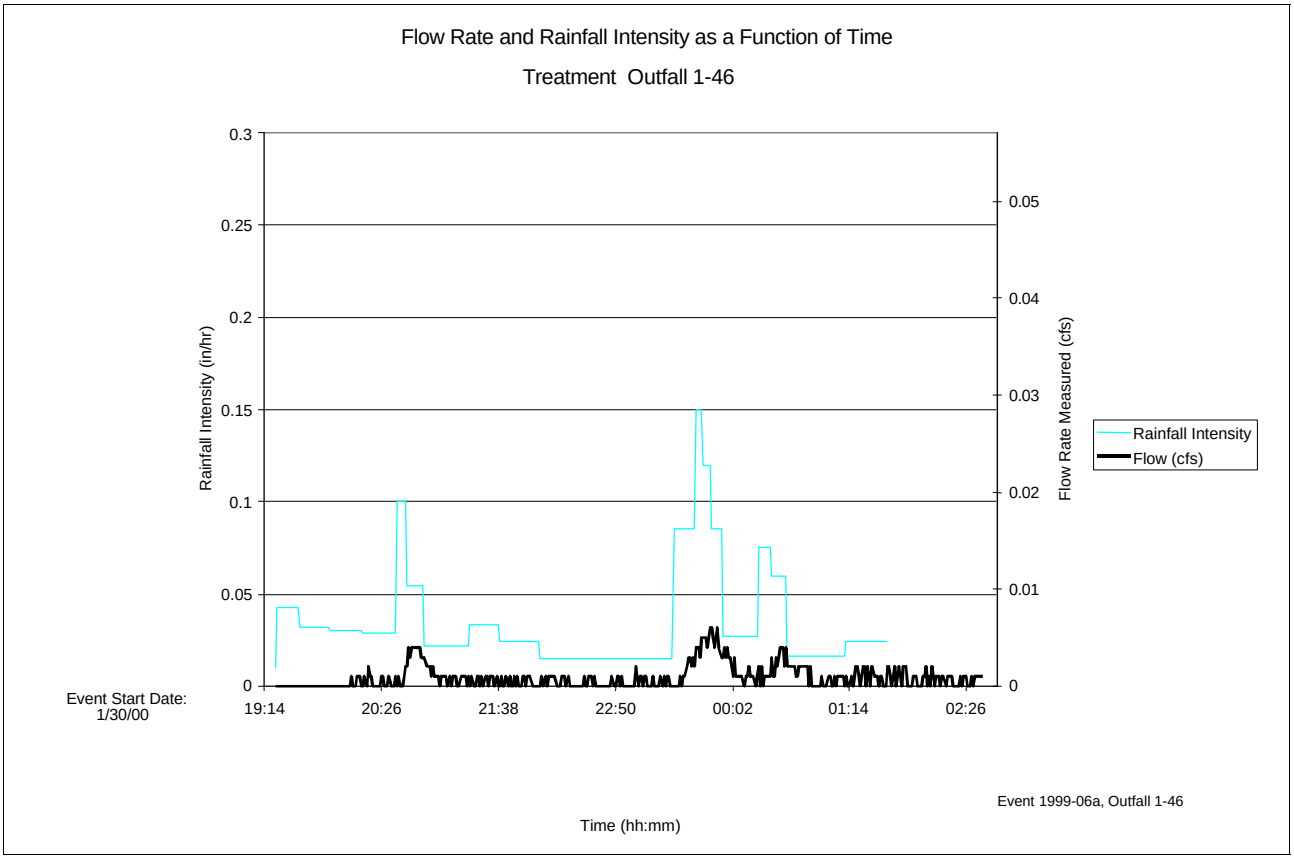




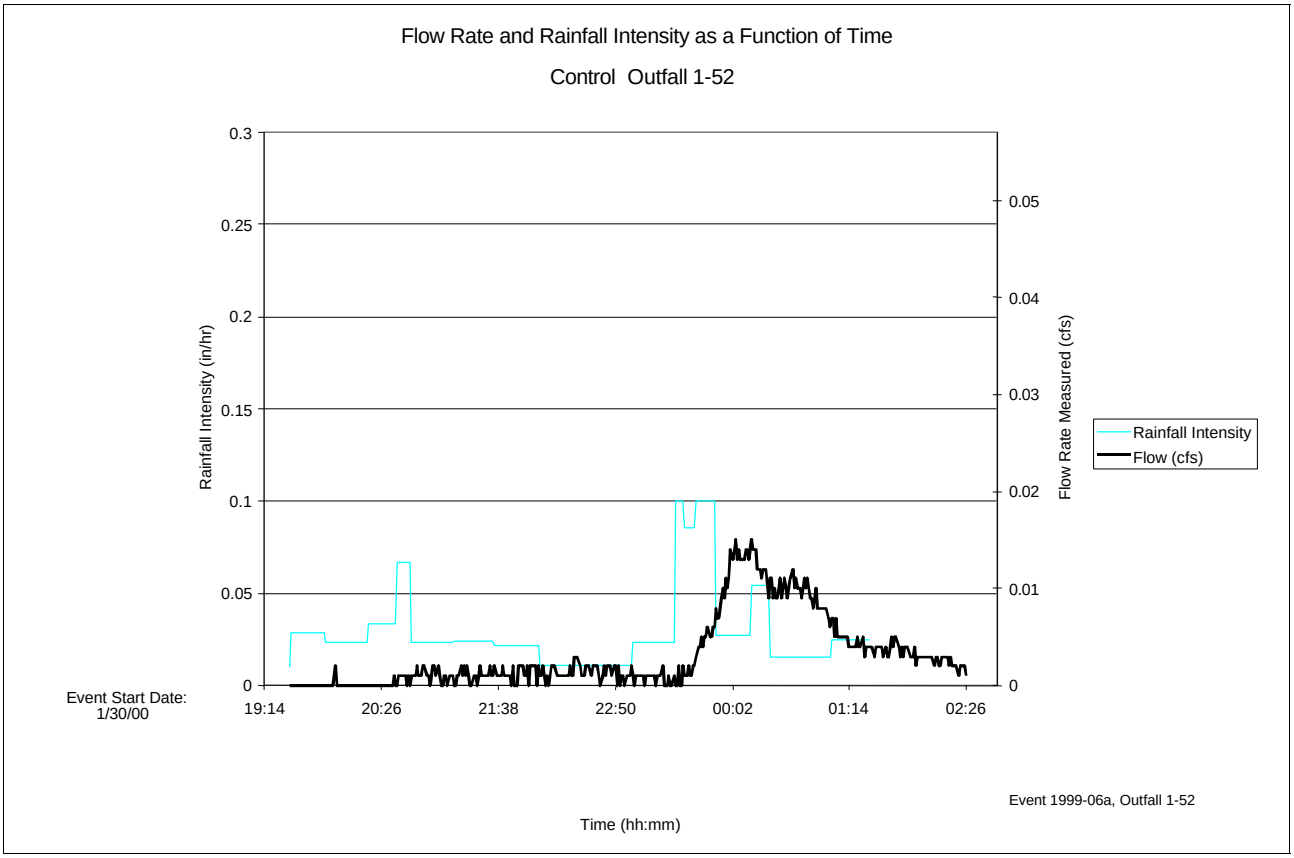
Site 1E - Litter Pickup

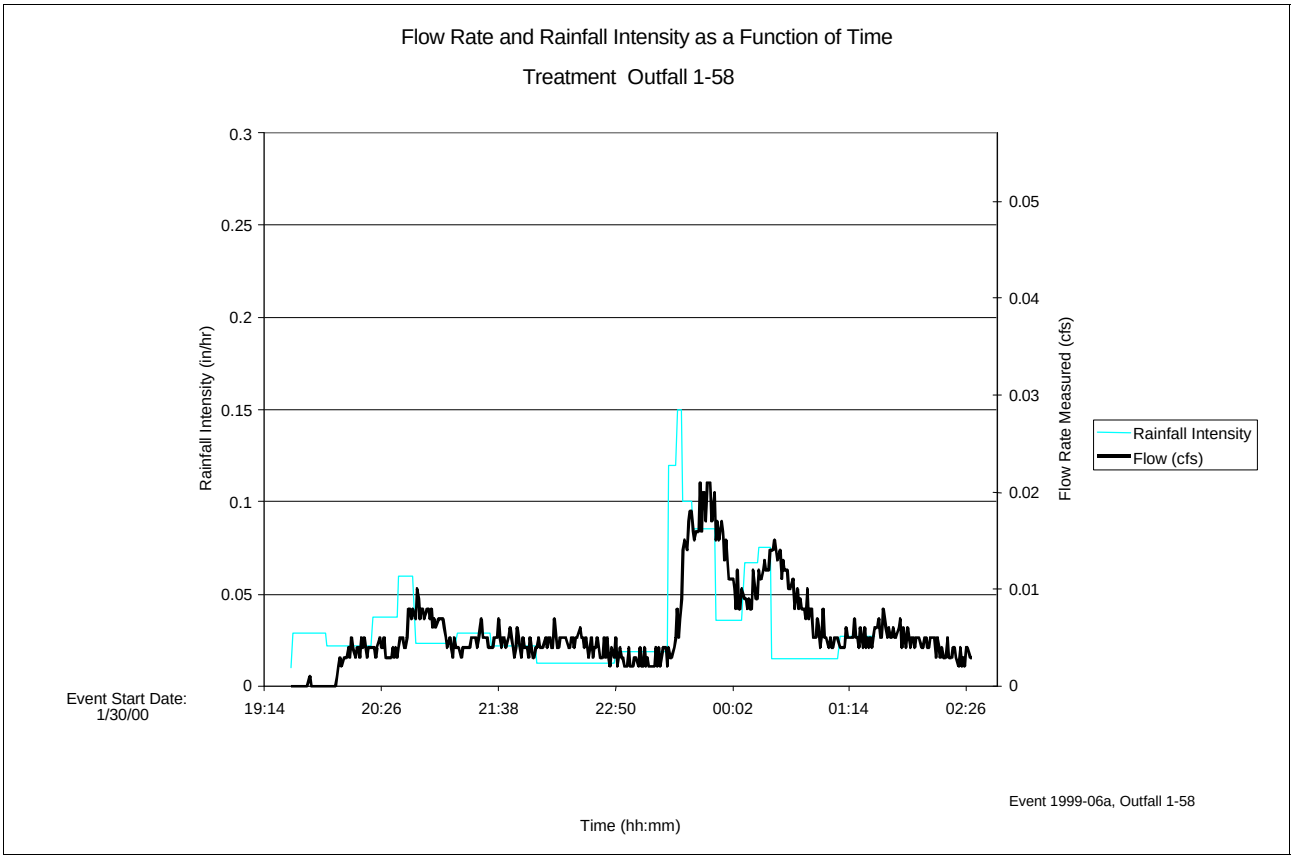
Event No. 1999e06 - 1/30/00



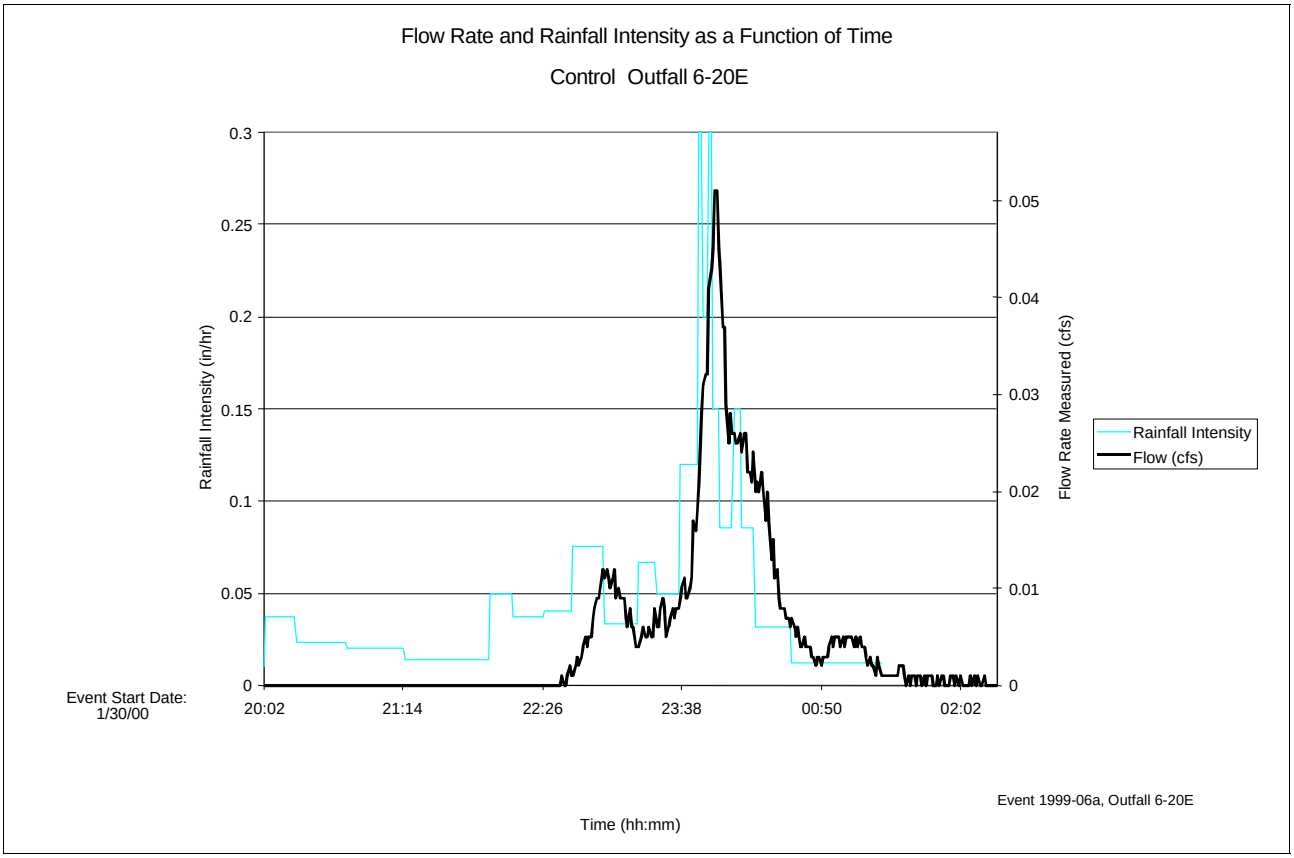


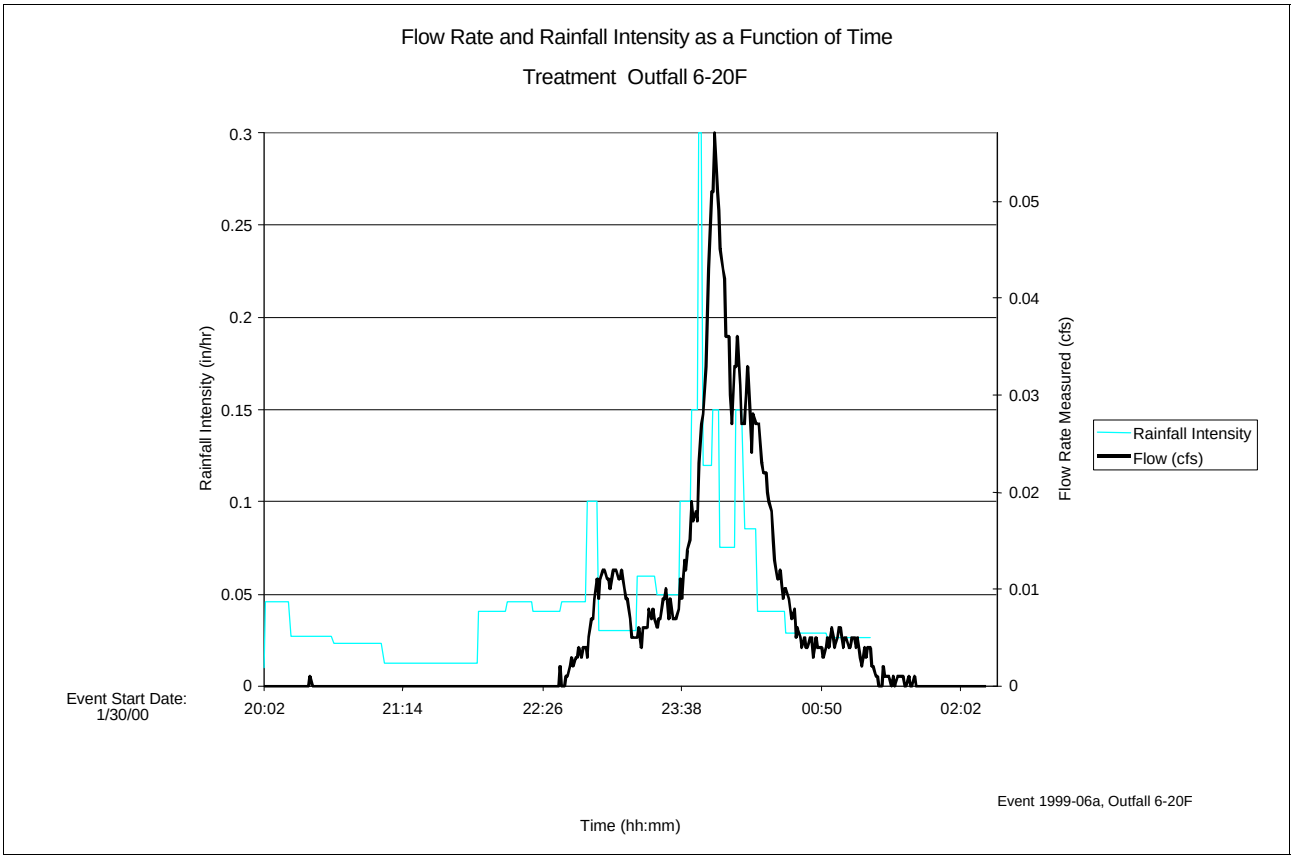
Site 1W - Street Sweeping Event No. 1999e06 - 1/30/00



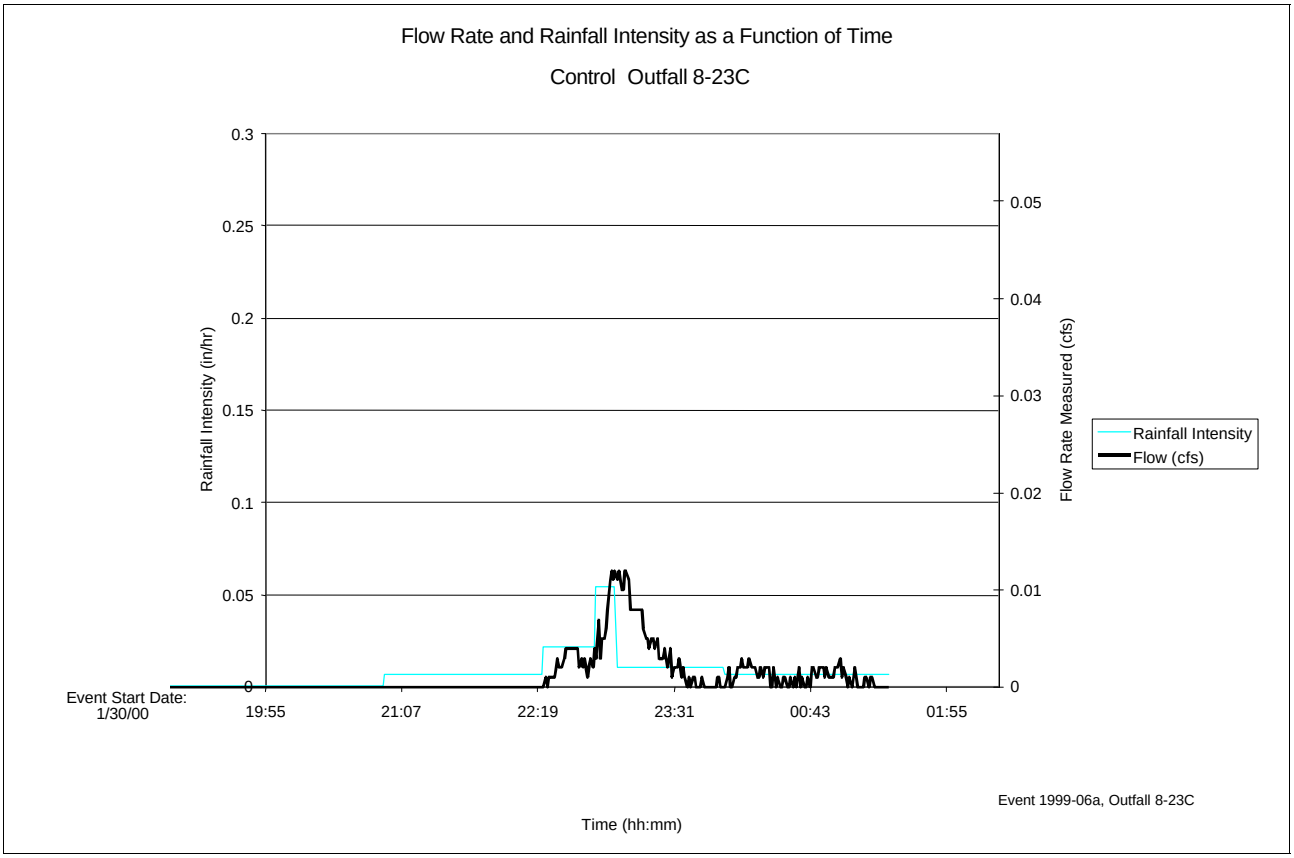


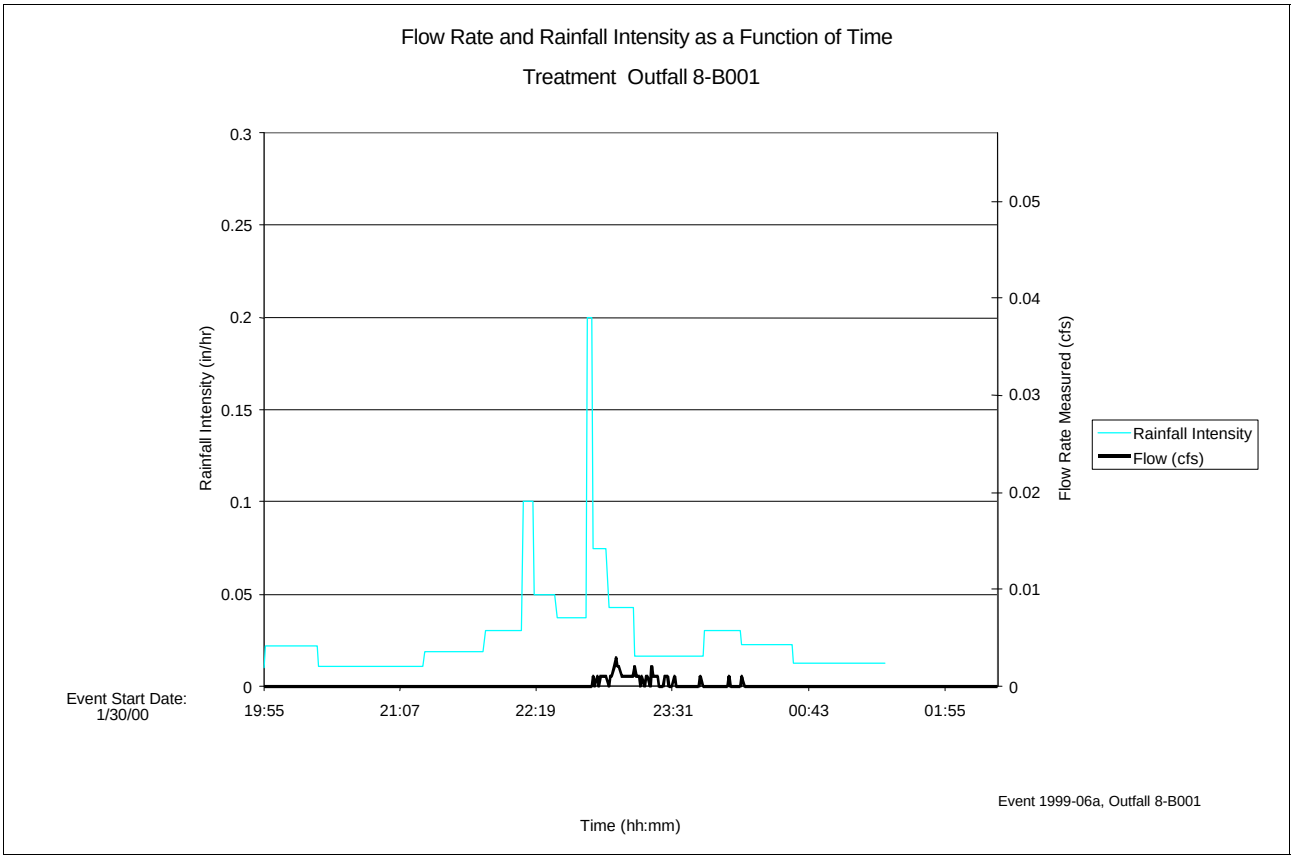
Site 6 - Modified Inlet Event No. 1999e06 - 1/30/00



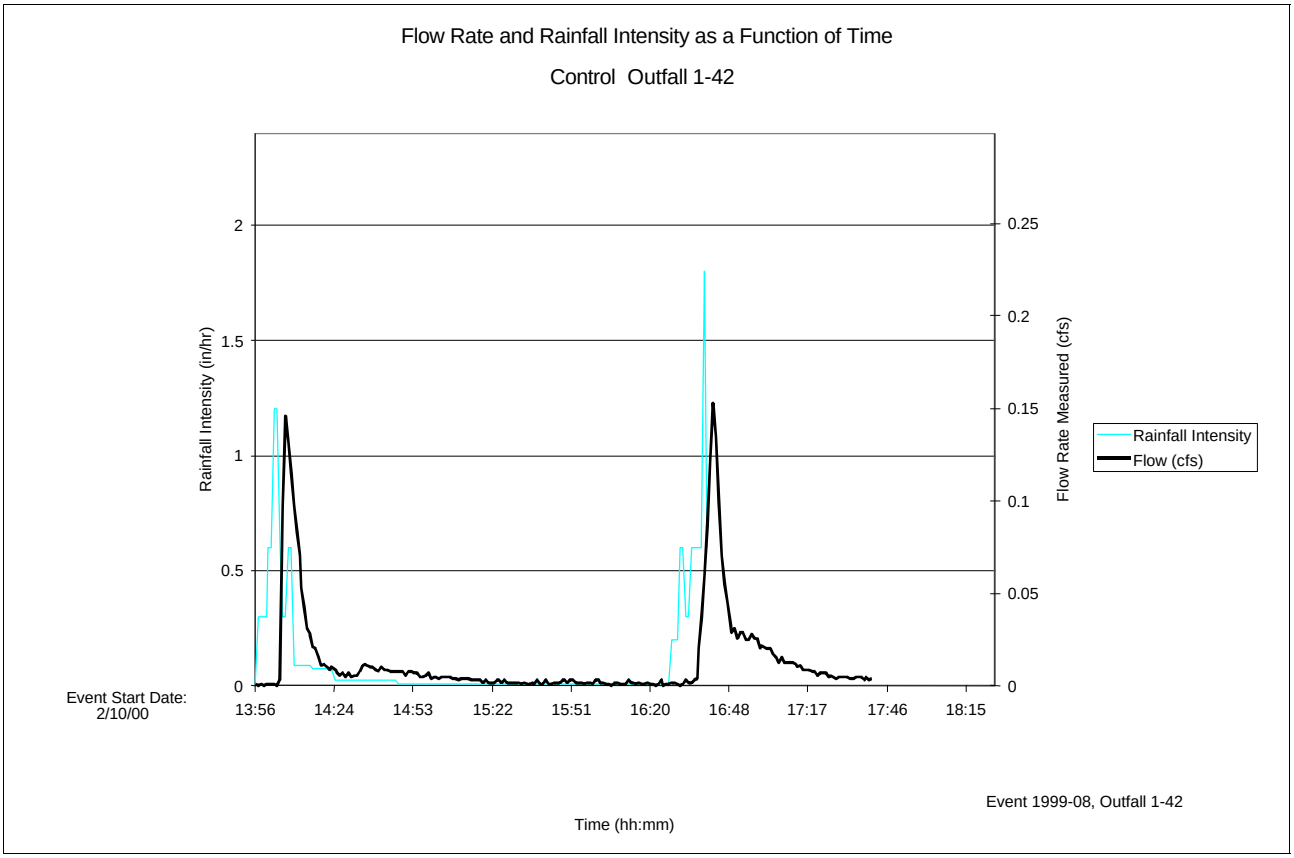


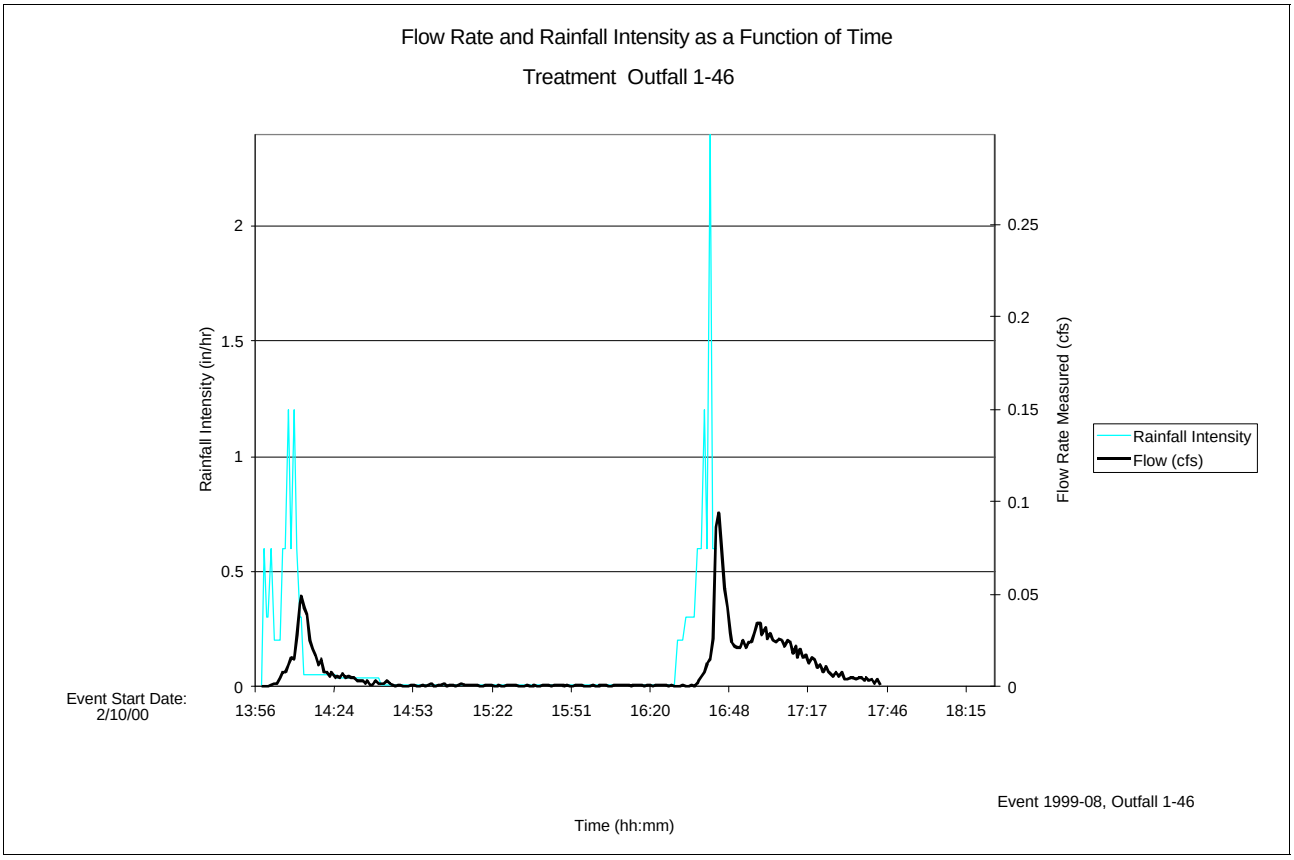
Site 8 - Bicycle Grate/LID Event No. 1999e06 - 1/30/00



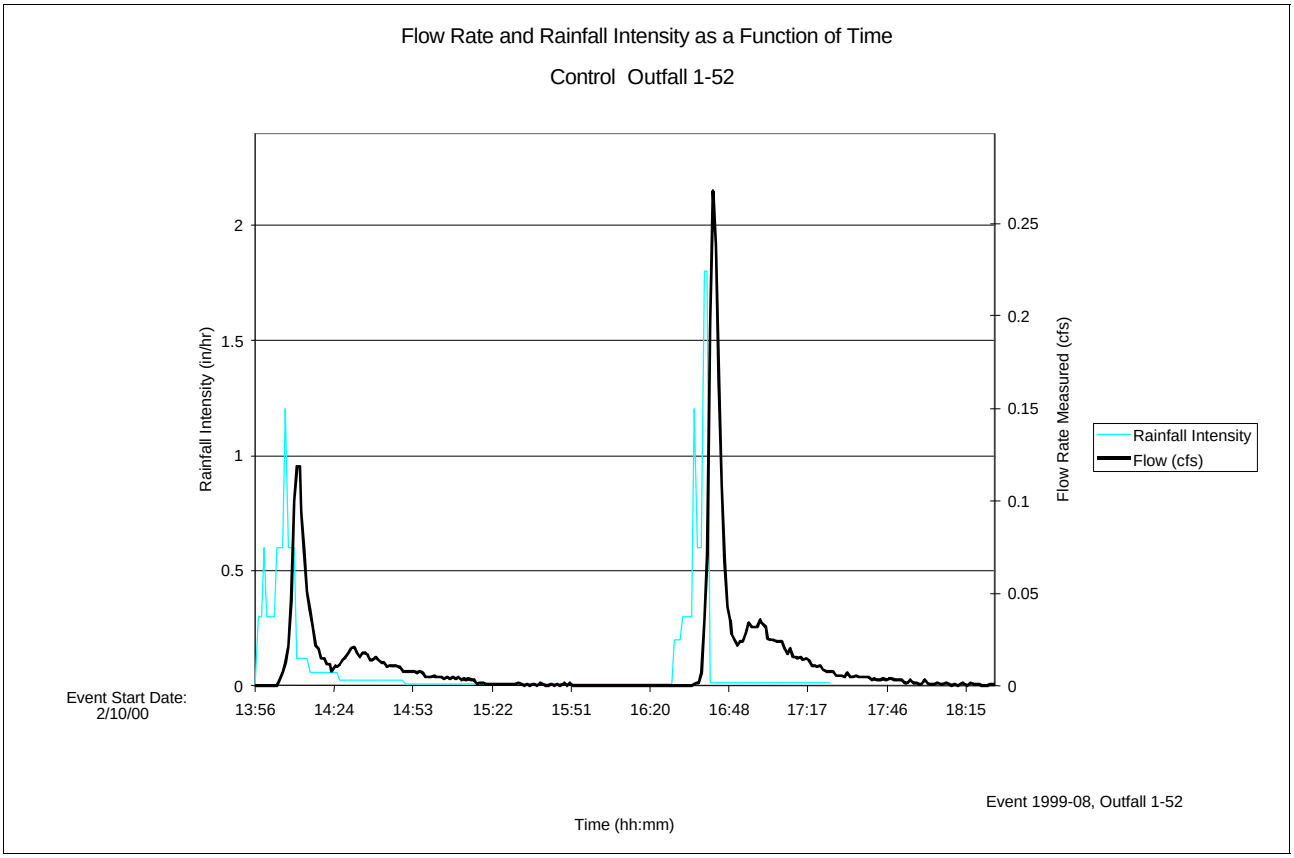


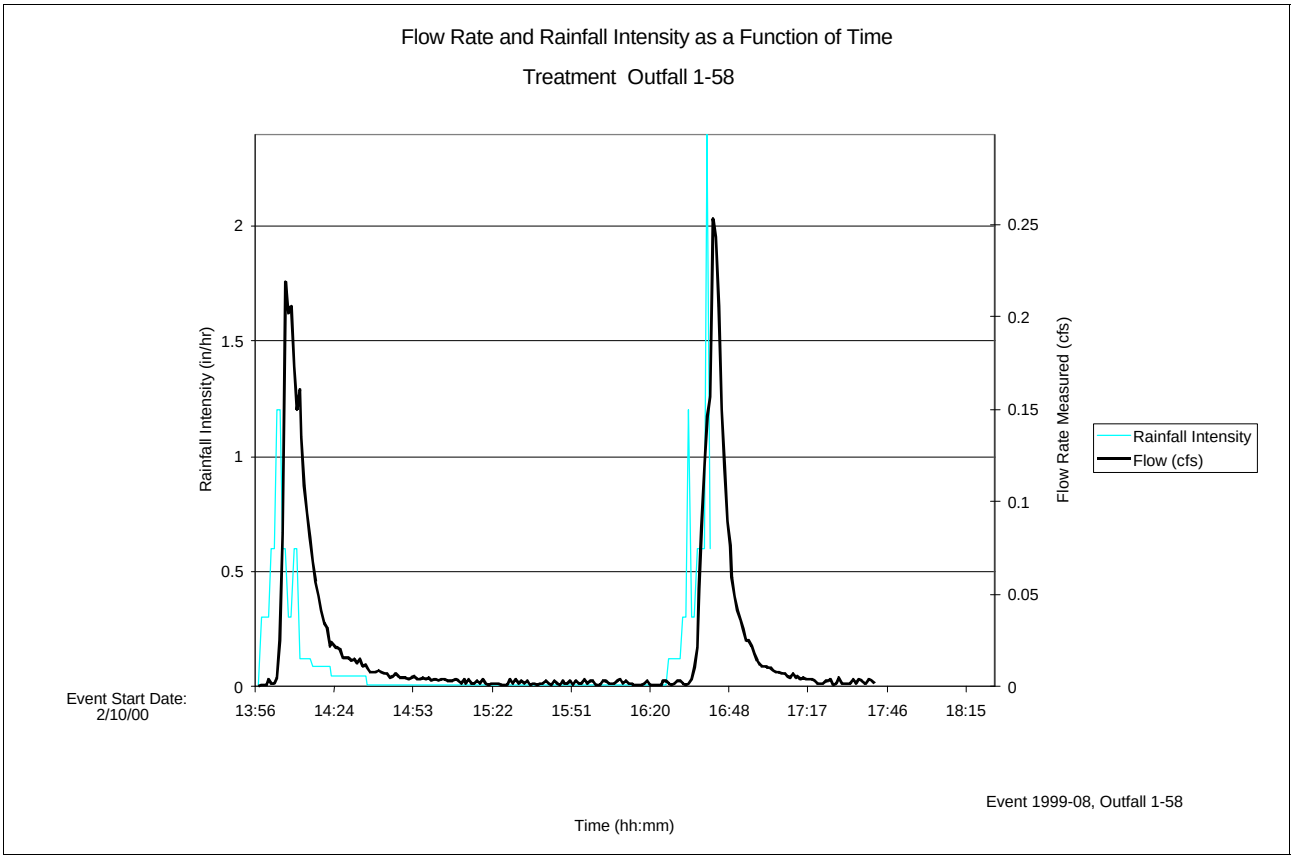
Site 1E - Litter Pickup Event No. 1999e08 - 2/10/00



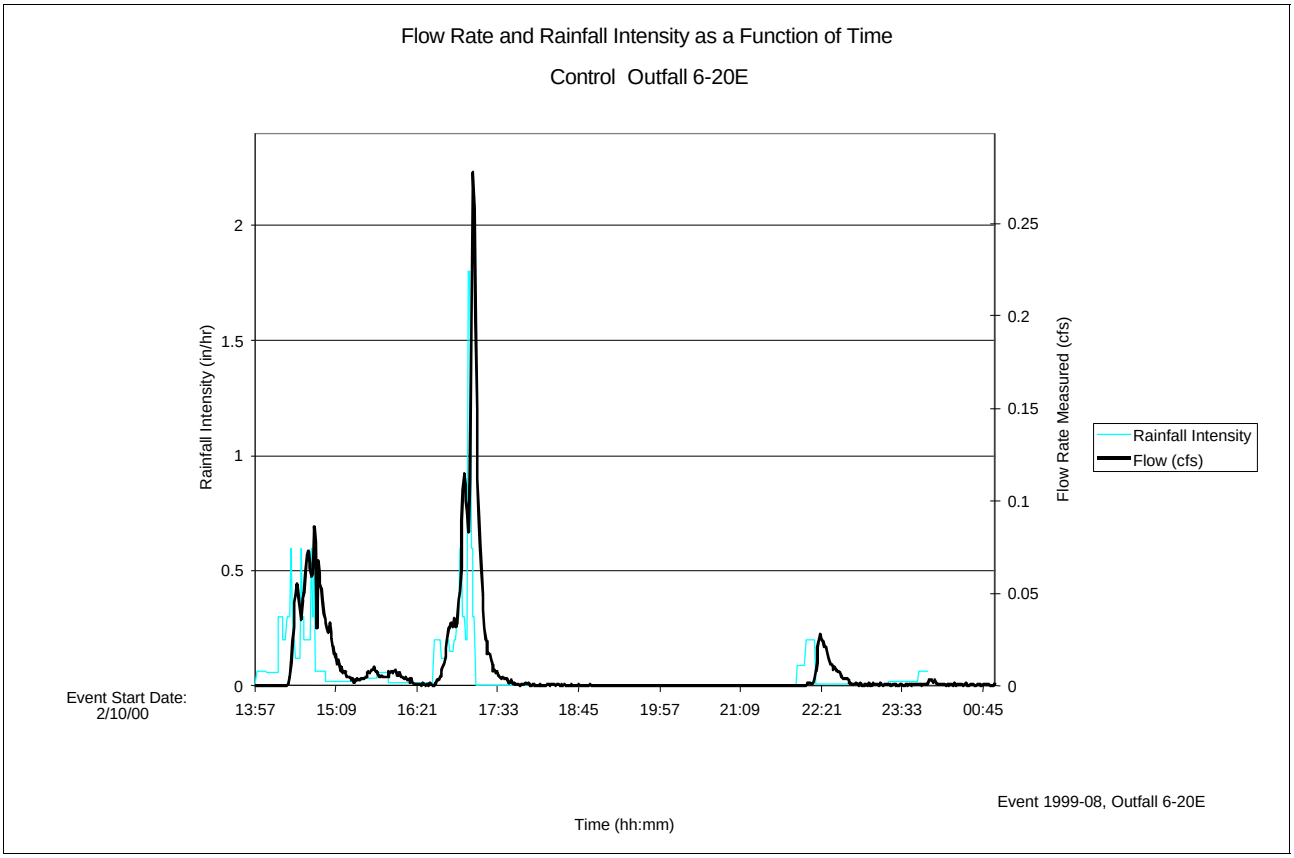


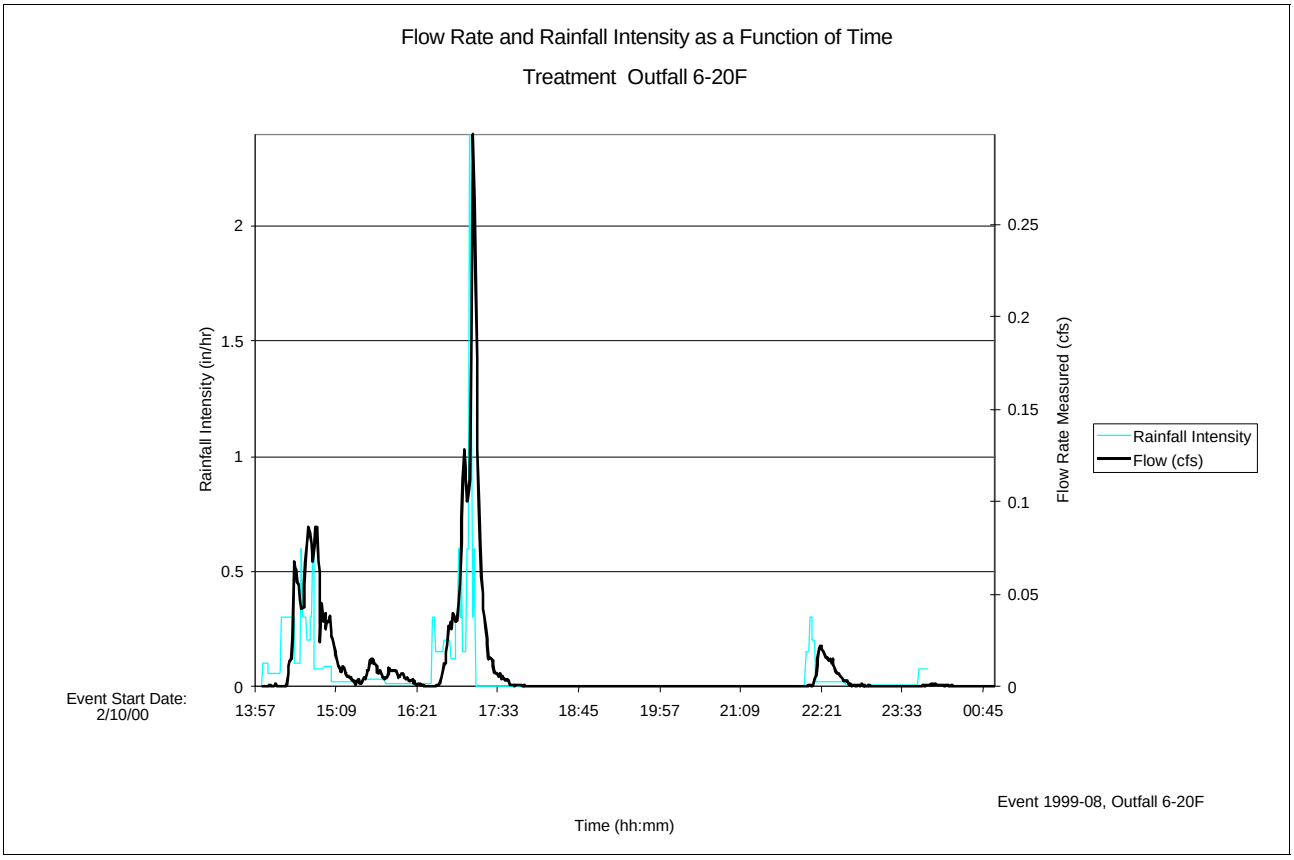
Site 1W - Street Sweeping Event No. 1999e08 - 2/10/00



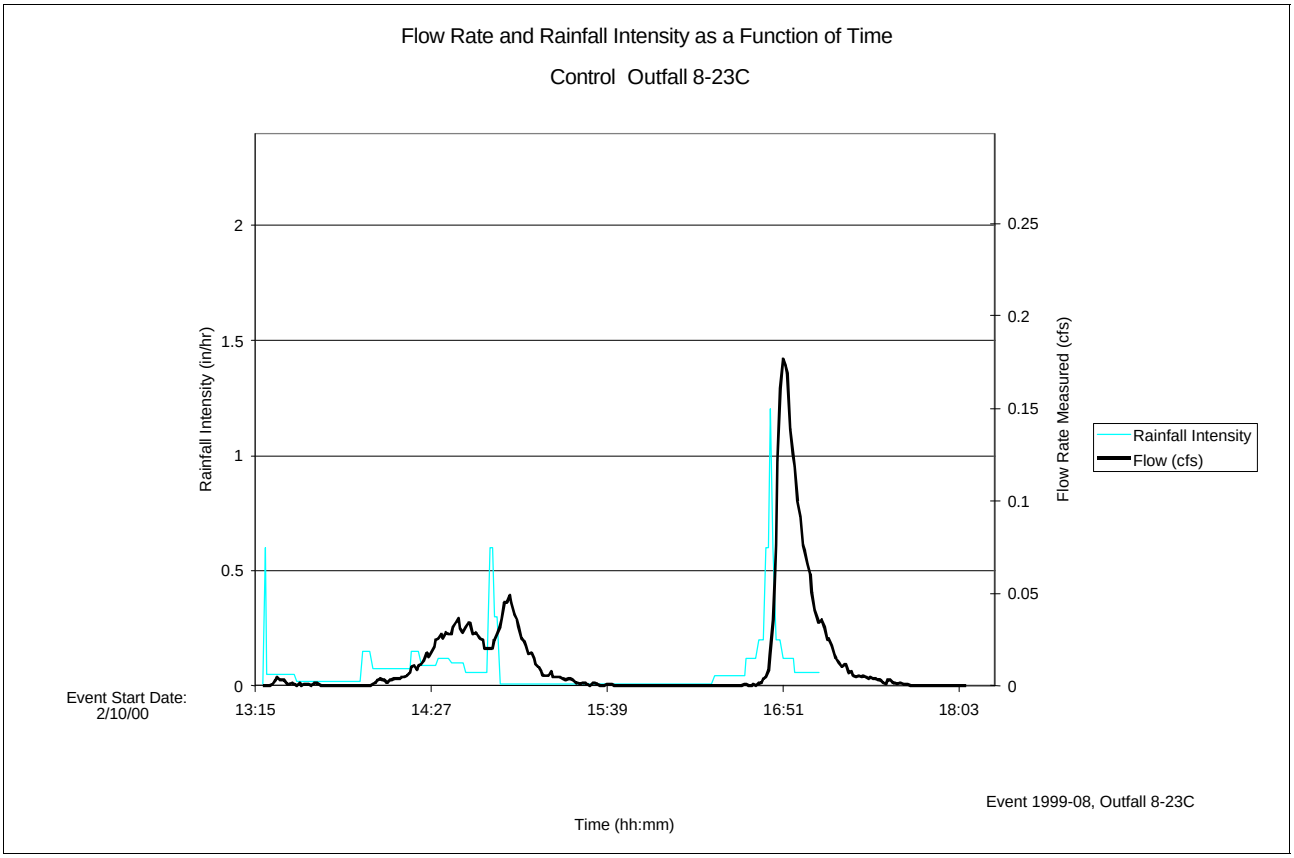


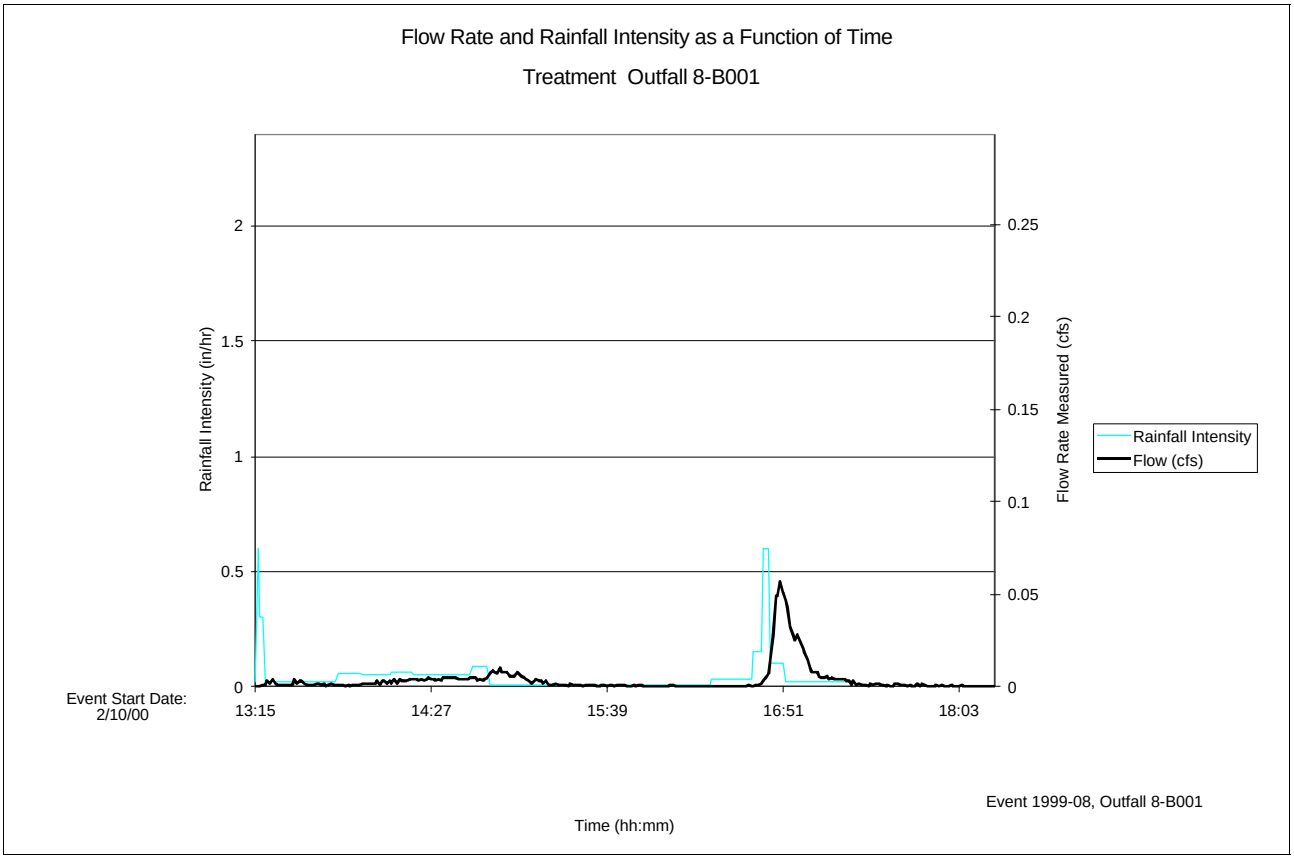
Site 6 - Modified Inlet Event No. 1999e08 - 2/10/00





Site 8 - Bicycle Grate/LID Event No. 1999e08 - 2/10/00





Site 1E - Litter Pickup Event No. 1999e09 - 2/12/00

Flow Rate and Rainfall Intensity as a Function of Time

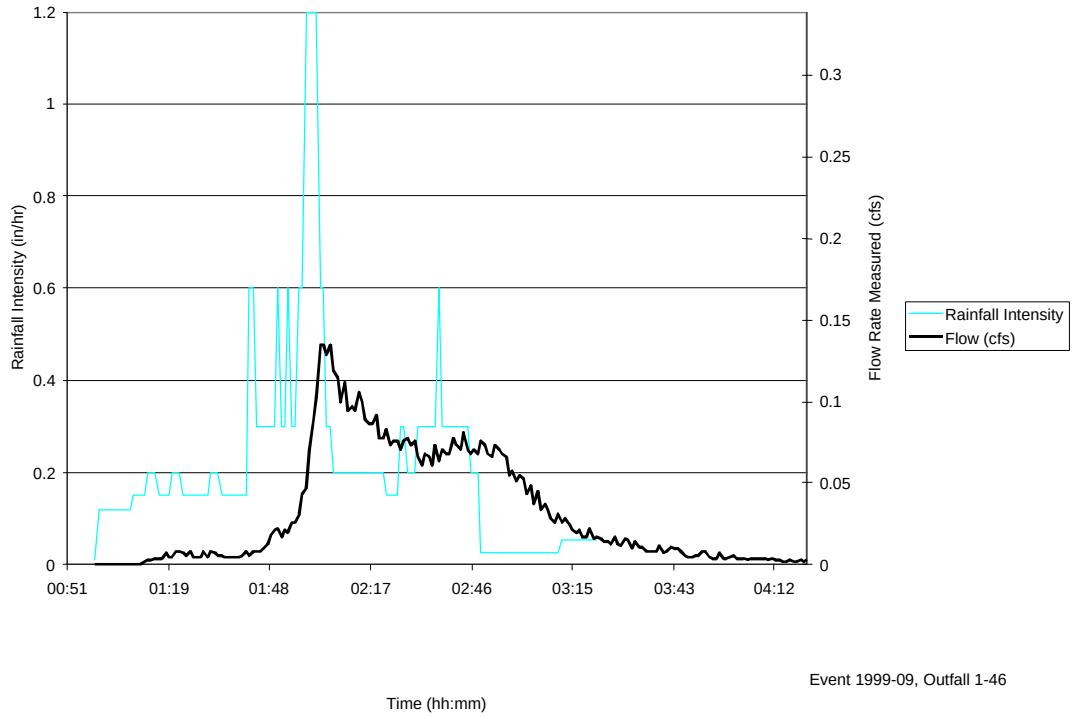
Control Outfall 1-42

No Hydrologic Data Available for this Event For this Outfall

Event Start Date:
2/12/00

Flow Rate and Rainfall Intensity as a Function of Time

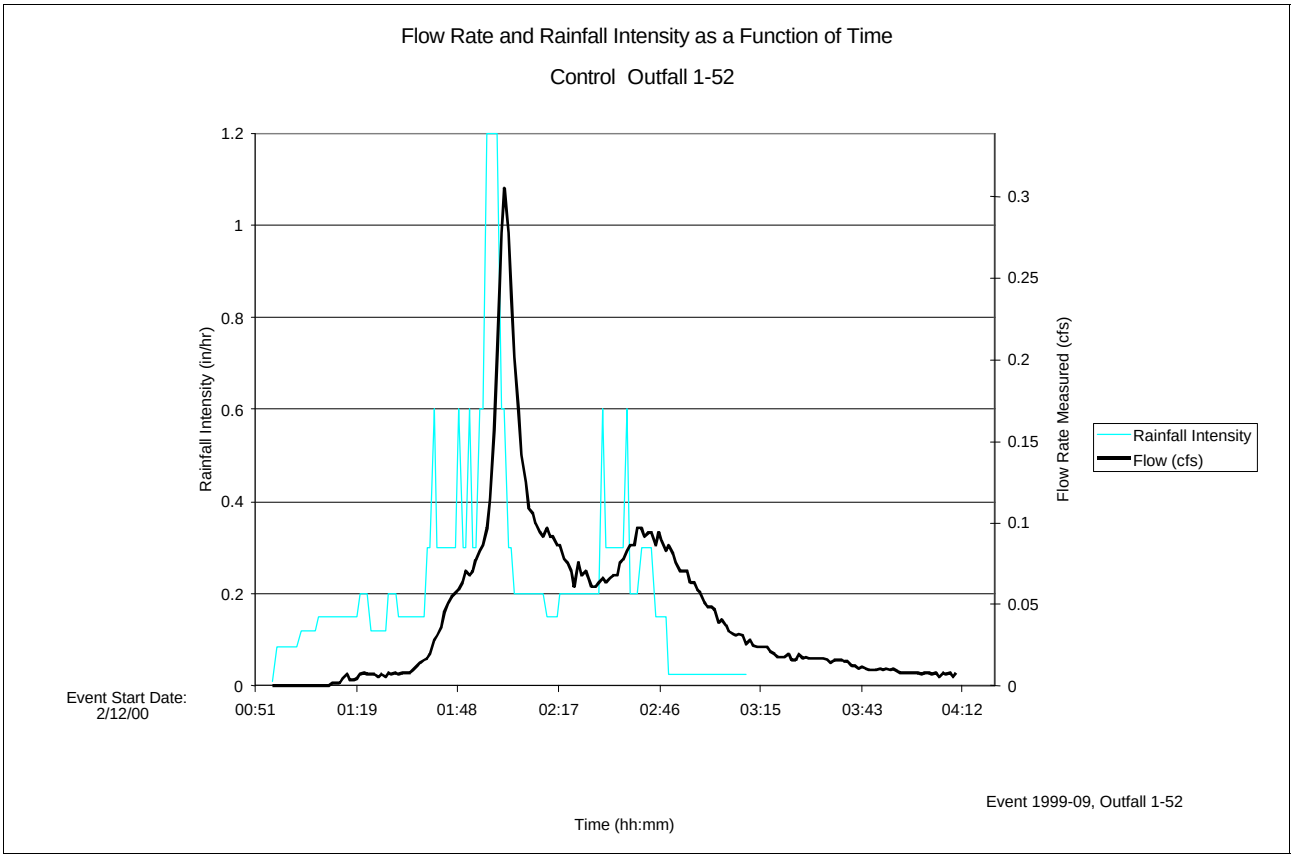
Treatment Outfall 1-46

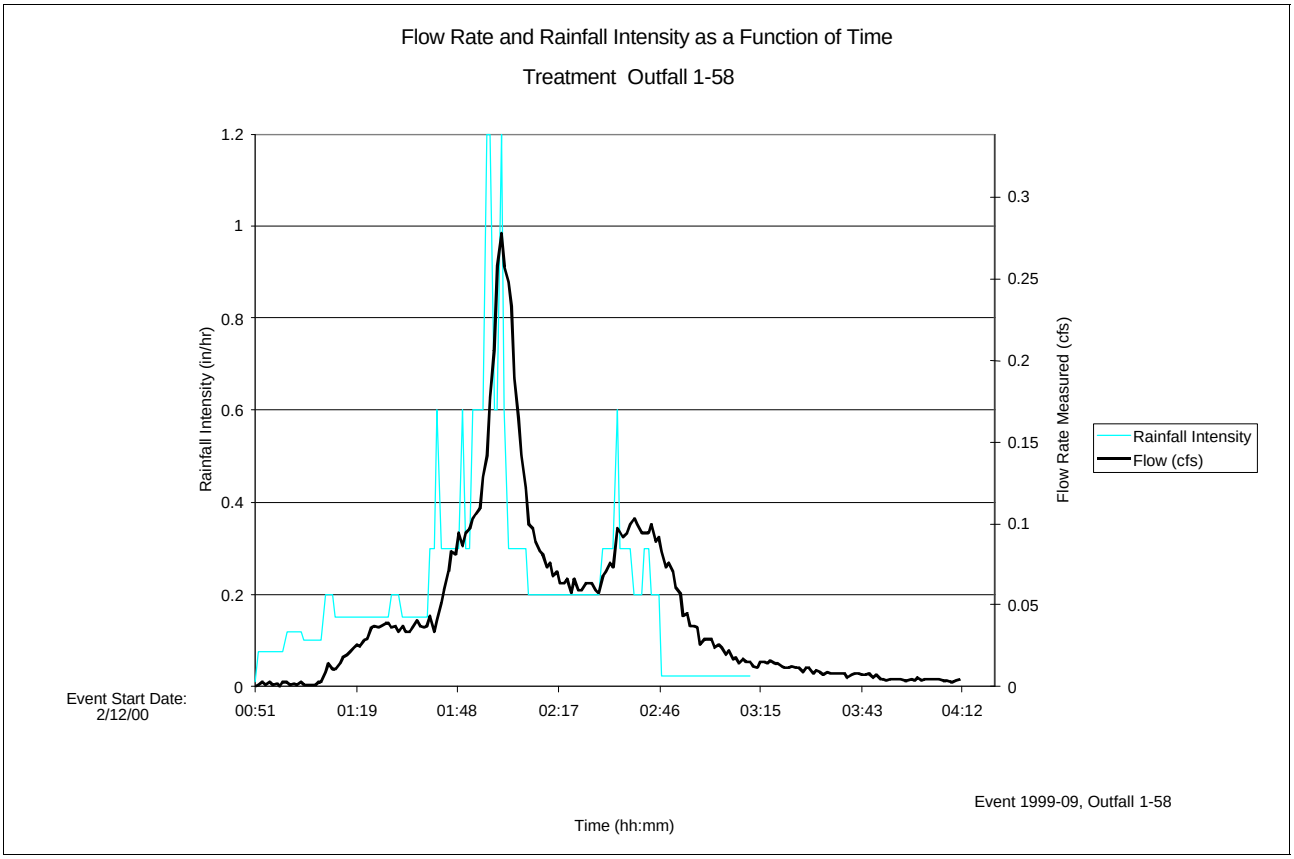


Event Start Date:
2/12/00

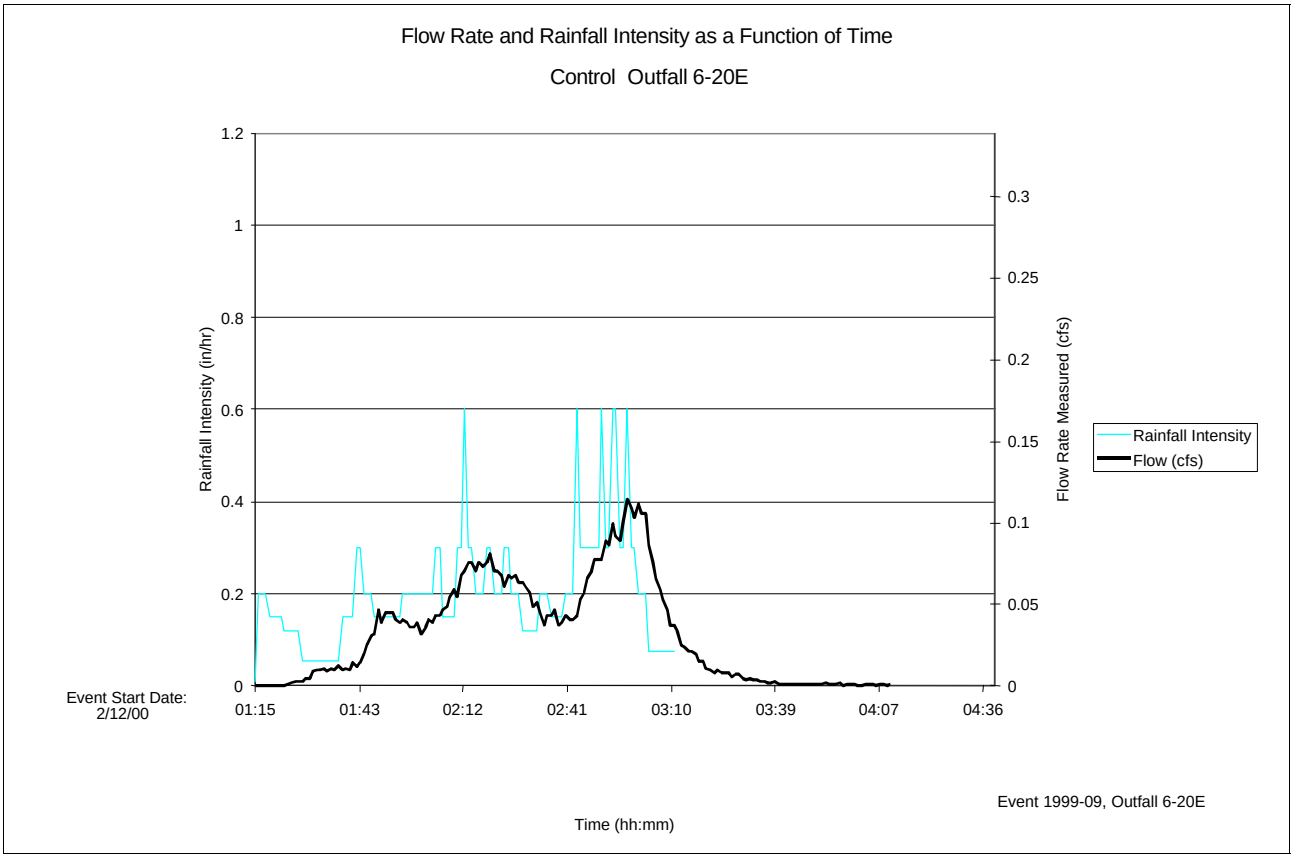
Event 1999-09, Outfall 1-46

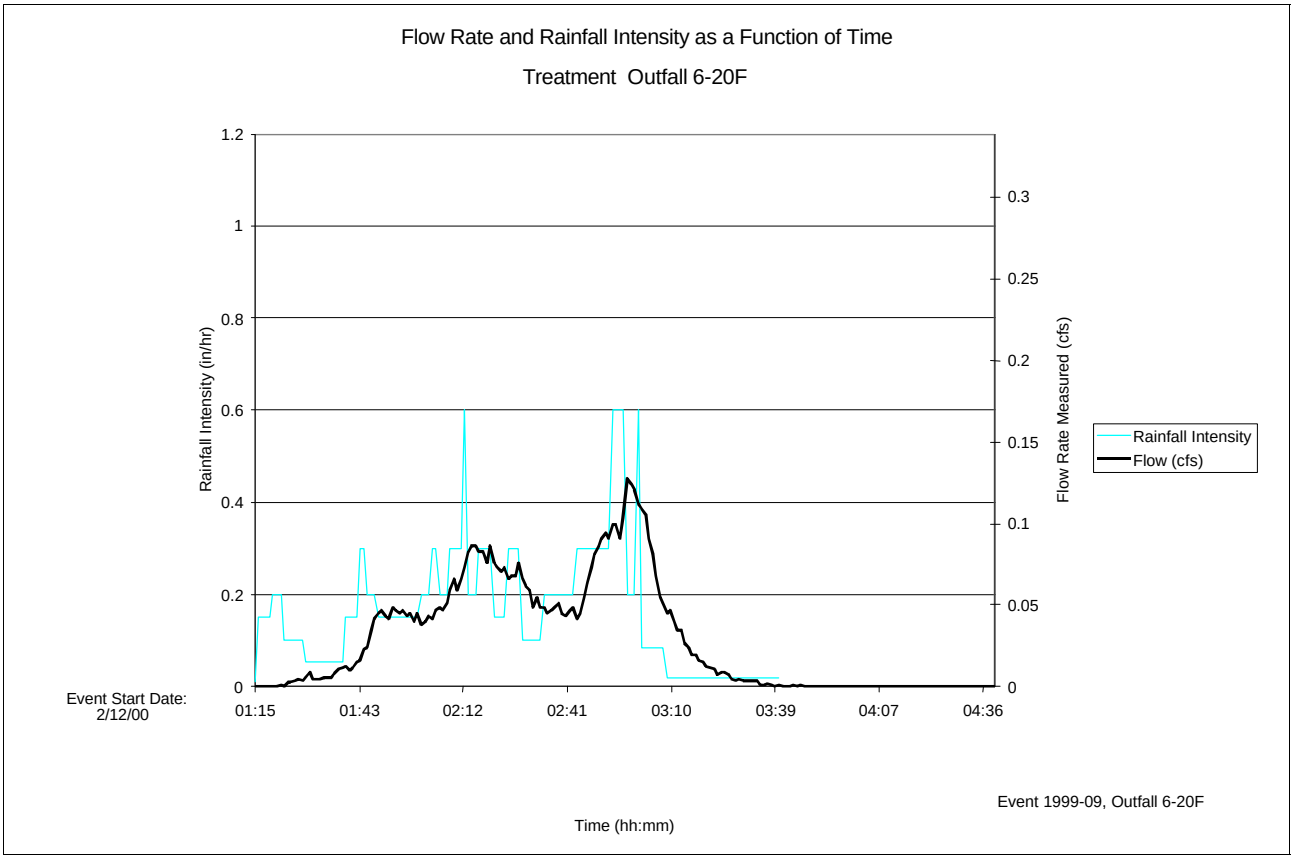
Site 1W - Street Sweeping Event No. 1999e09 - 2/12/00



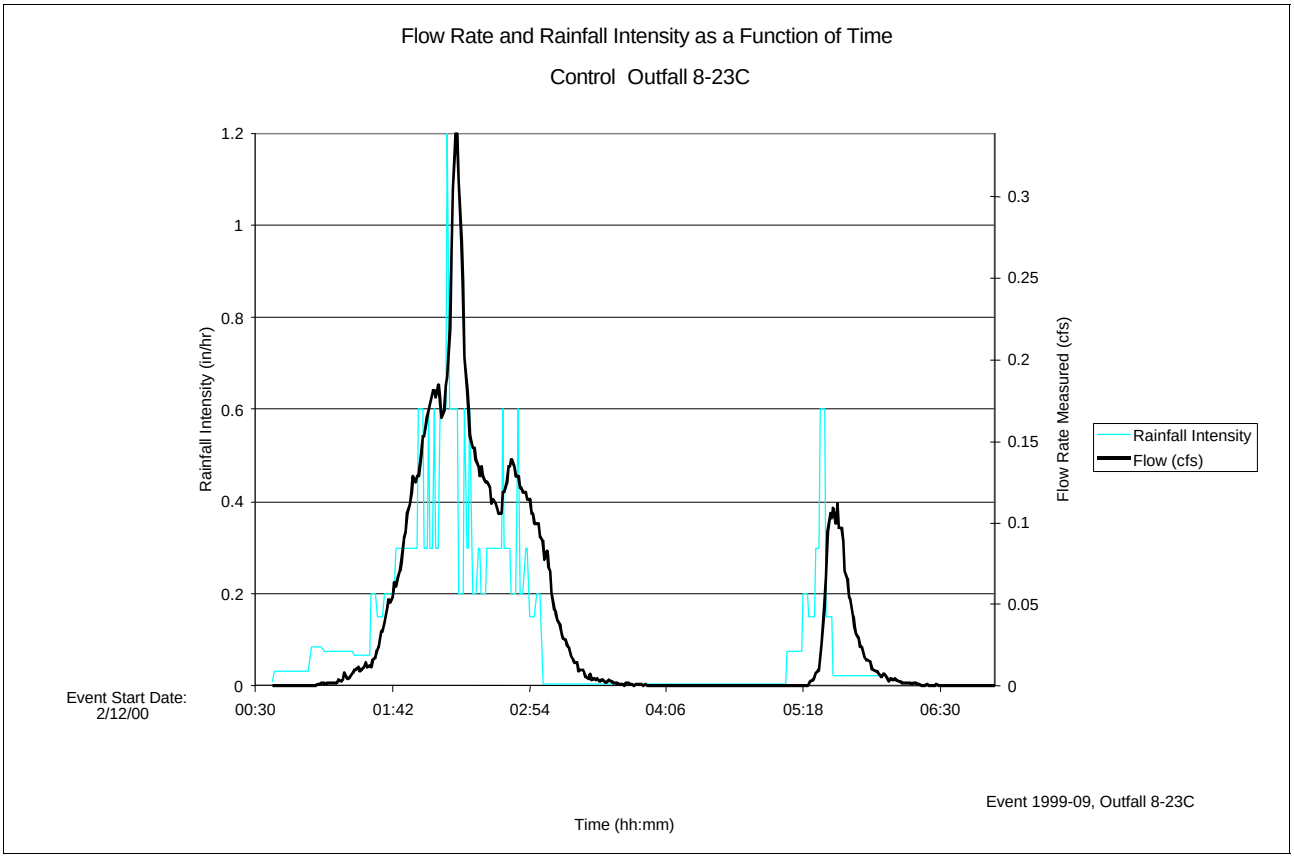


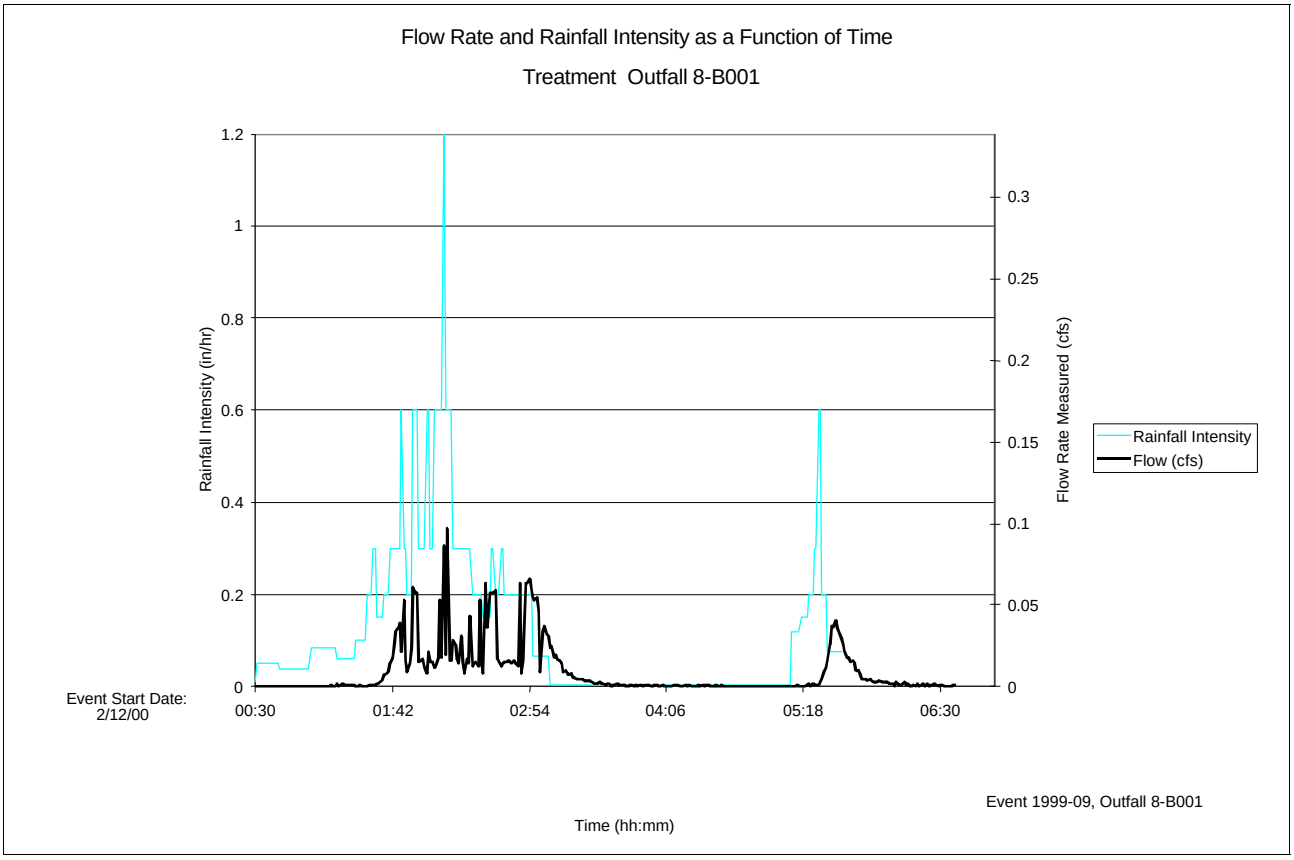
Site 6 - Modified Inlet Event No. 1999e09 - 2/12/00



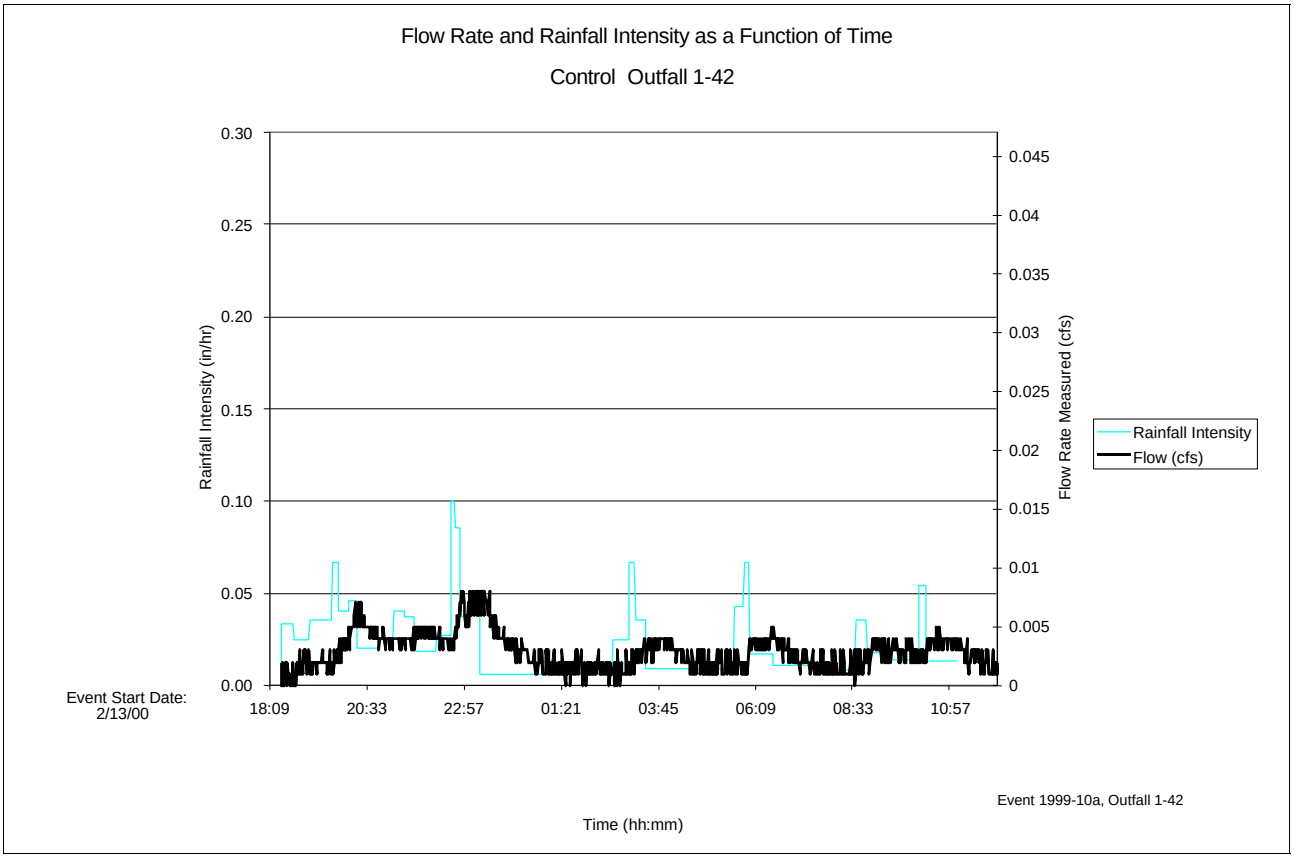


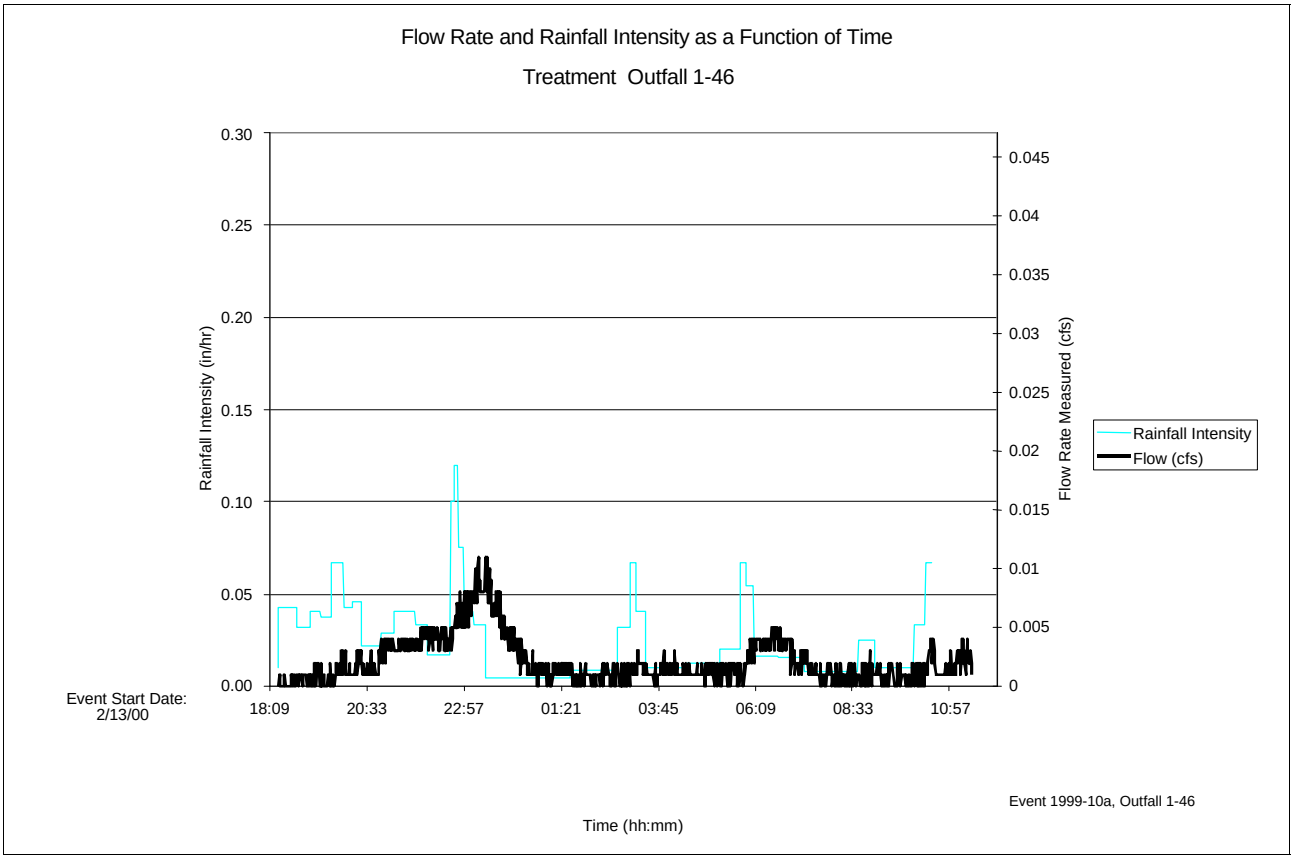
Site 8 - Bicycle Grate/LID Event No. 1999e09 - 2/12/00



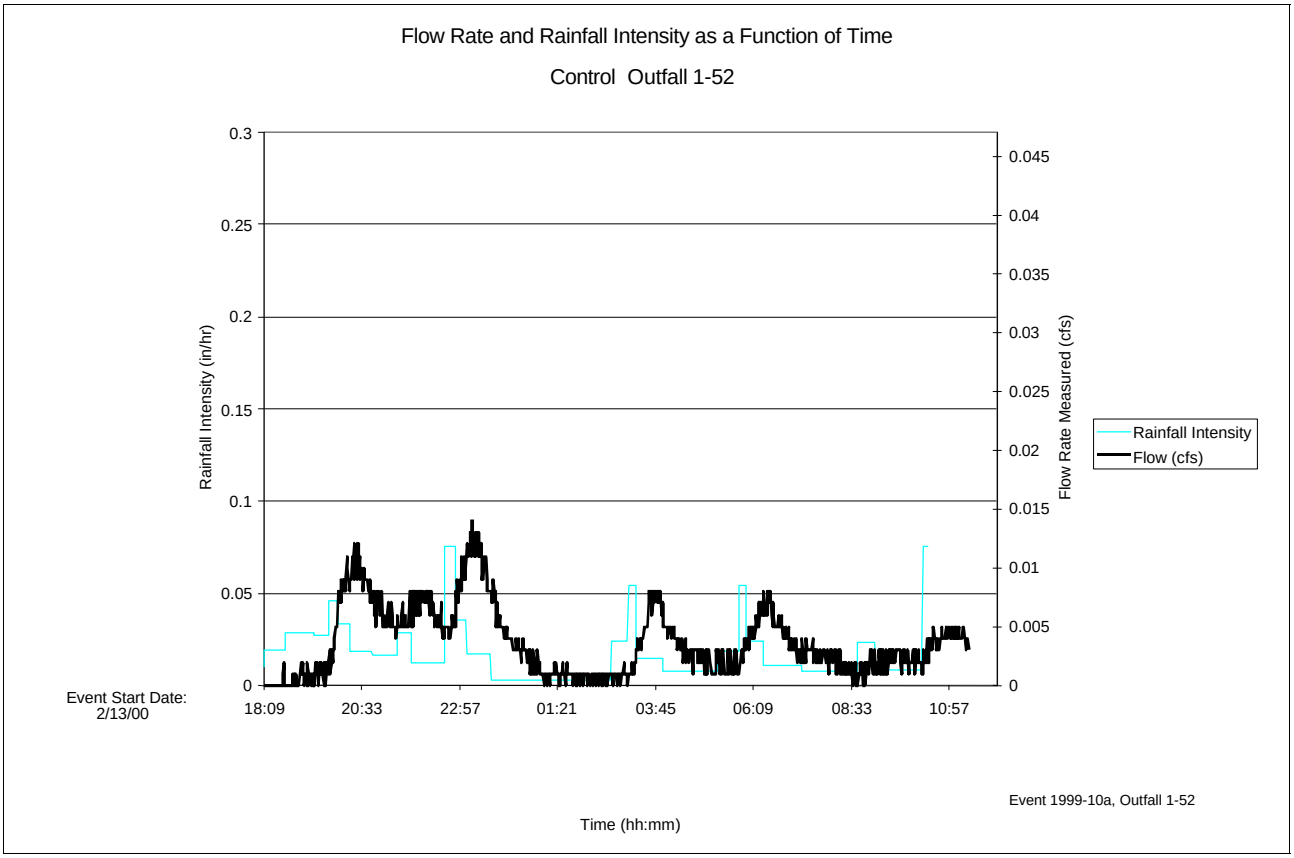


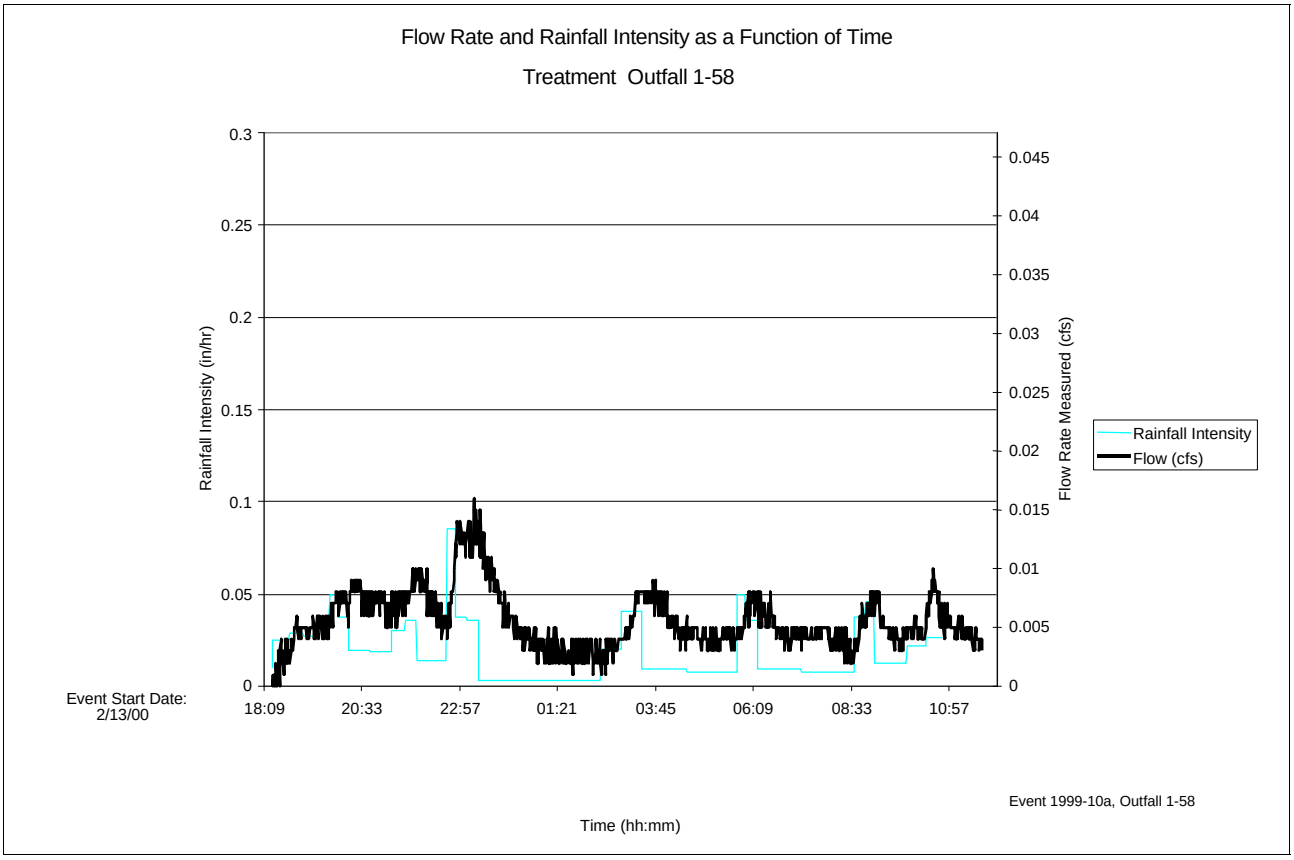
Site 1E - Litter Pickup Event No. 1999e10 - 2/13/00



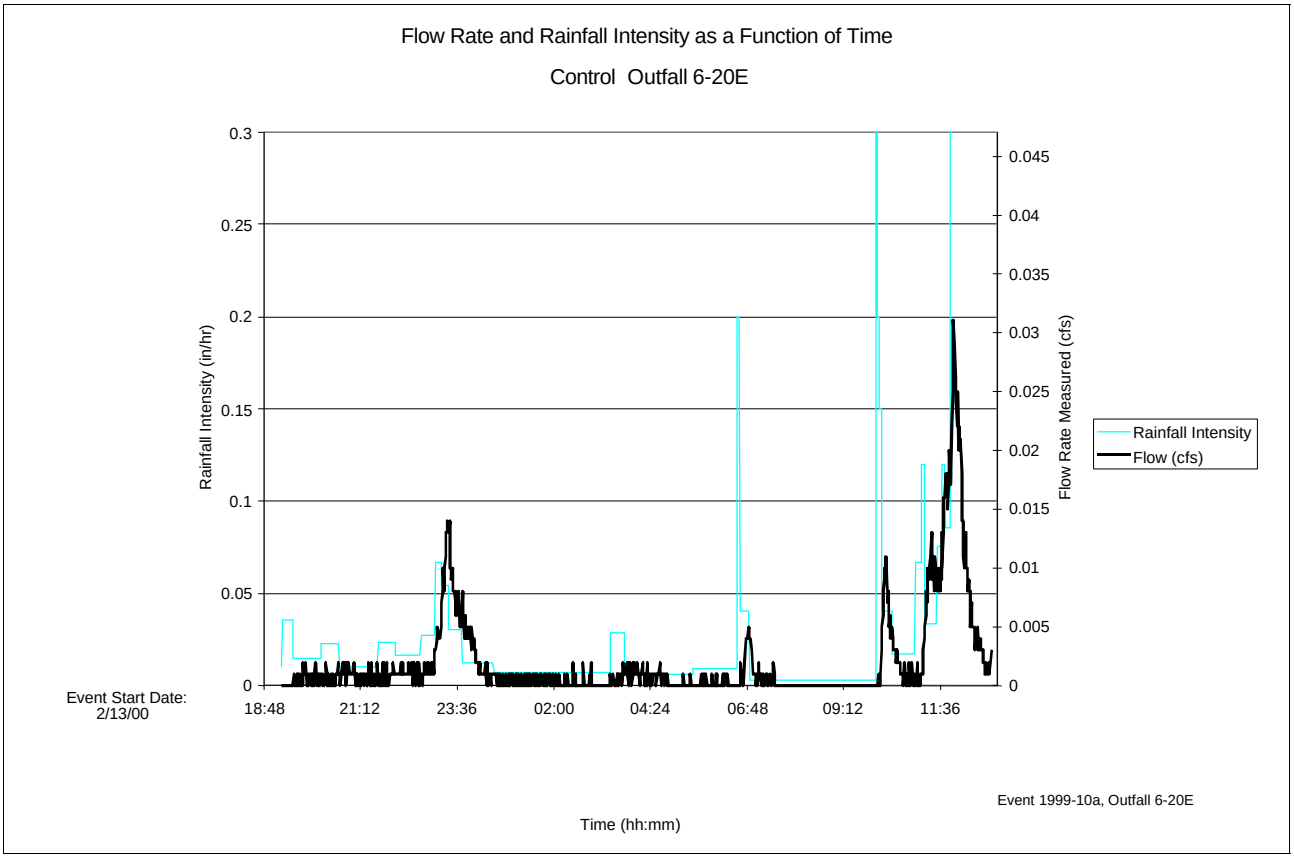


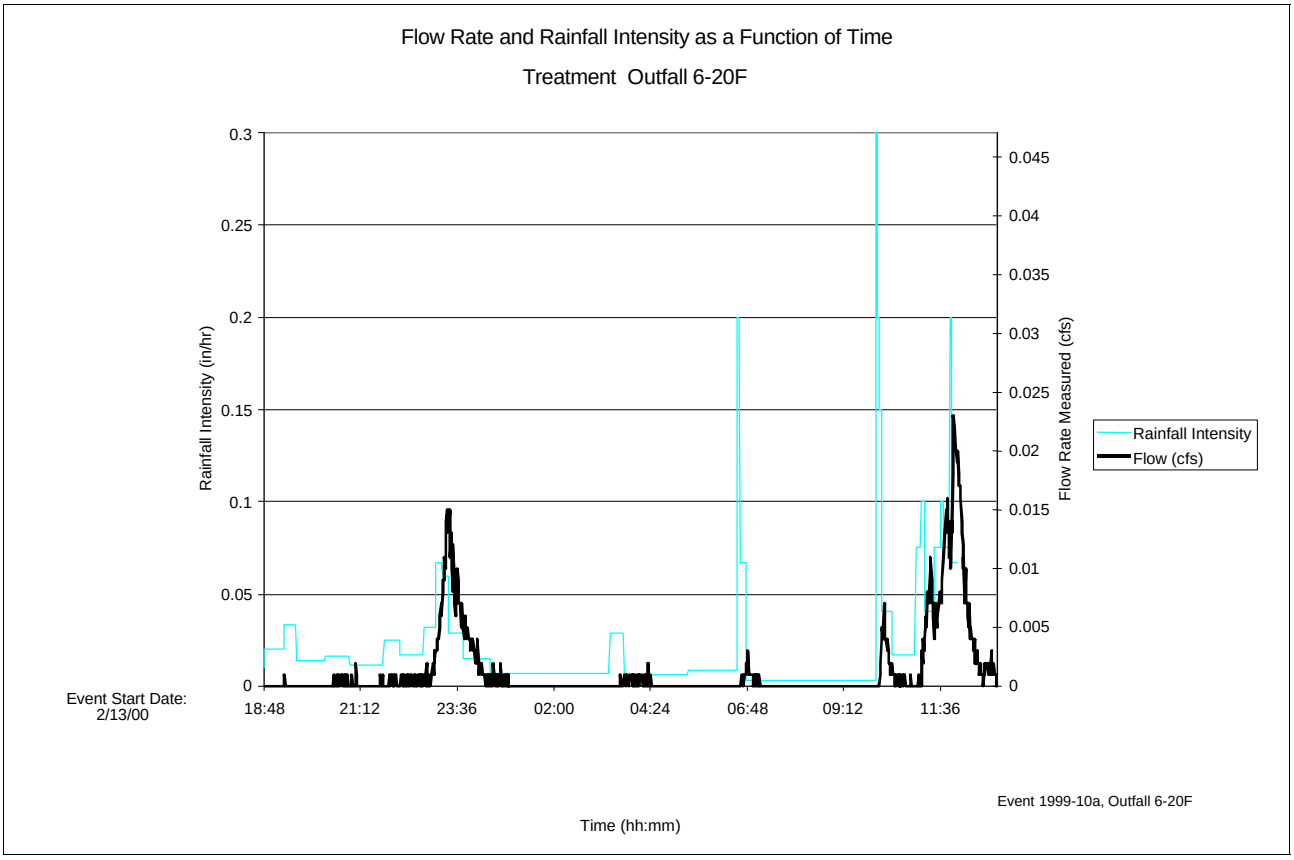
Site 1W - Street Sweeping Event No. 1999e10 - 2/13/00



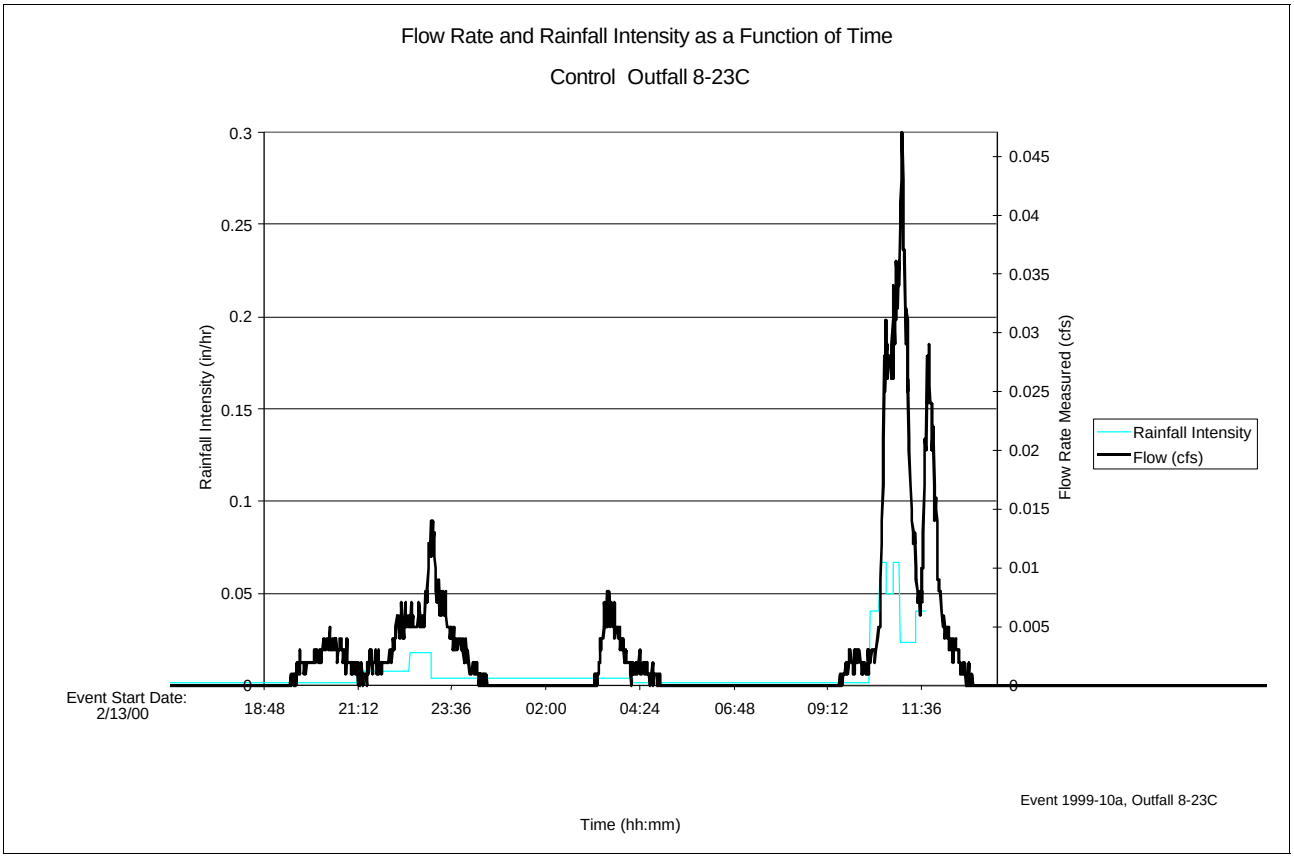


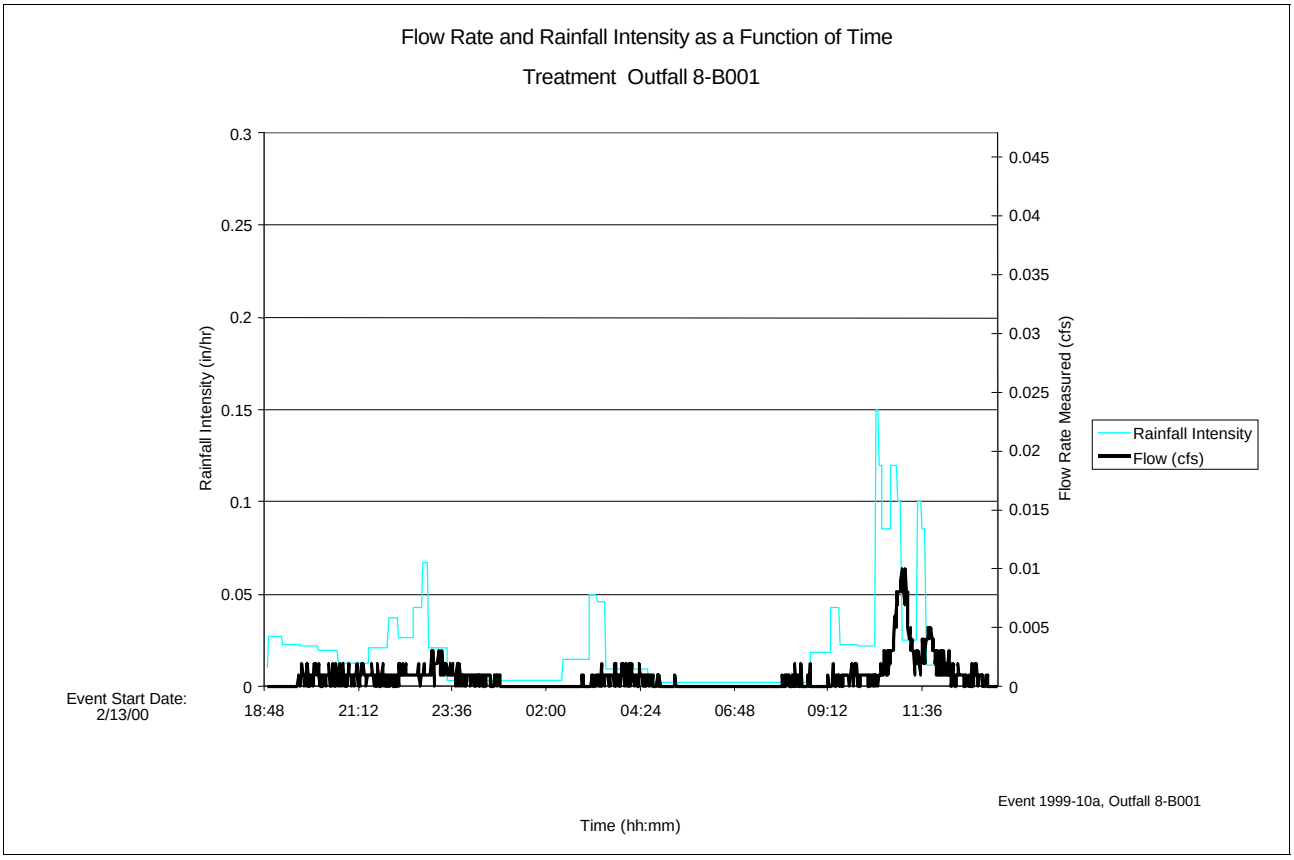
Site 6 - Modified Inlet Event No. 1999e10 - 2/13/00





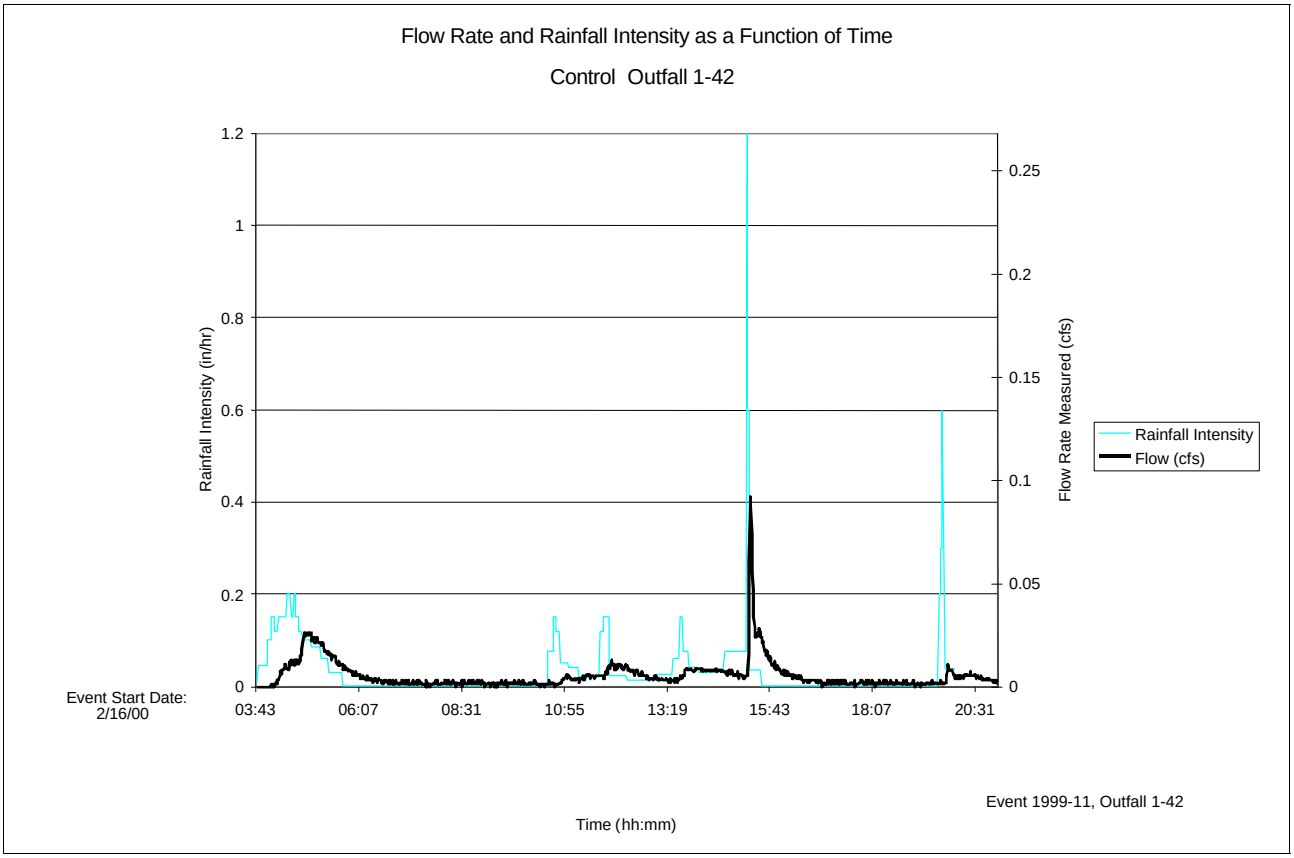
Site 8 - Bicycle Grate/LID Event No. 1999e10 - 2/13/00

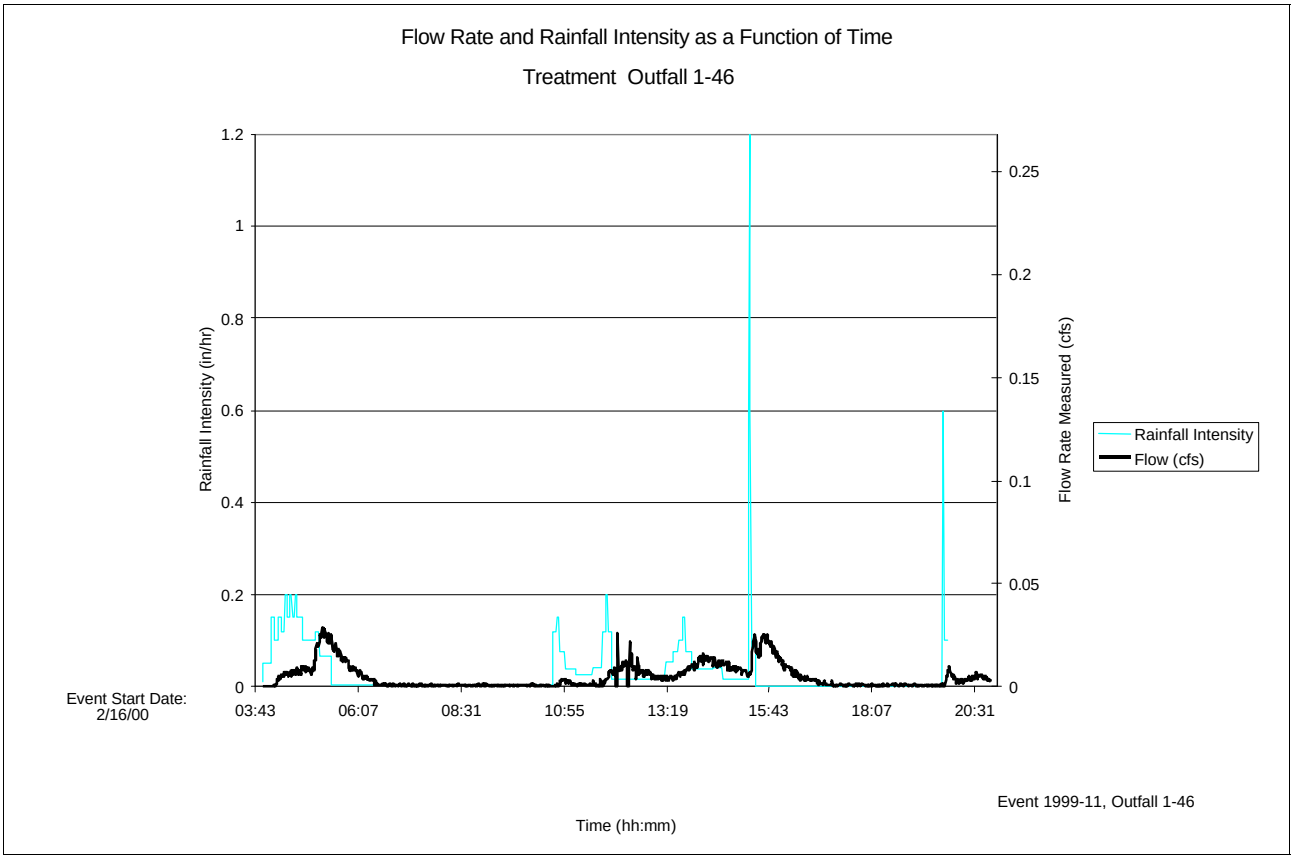




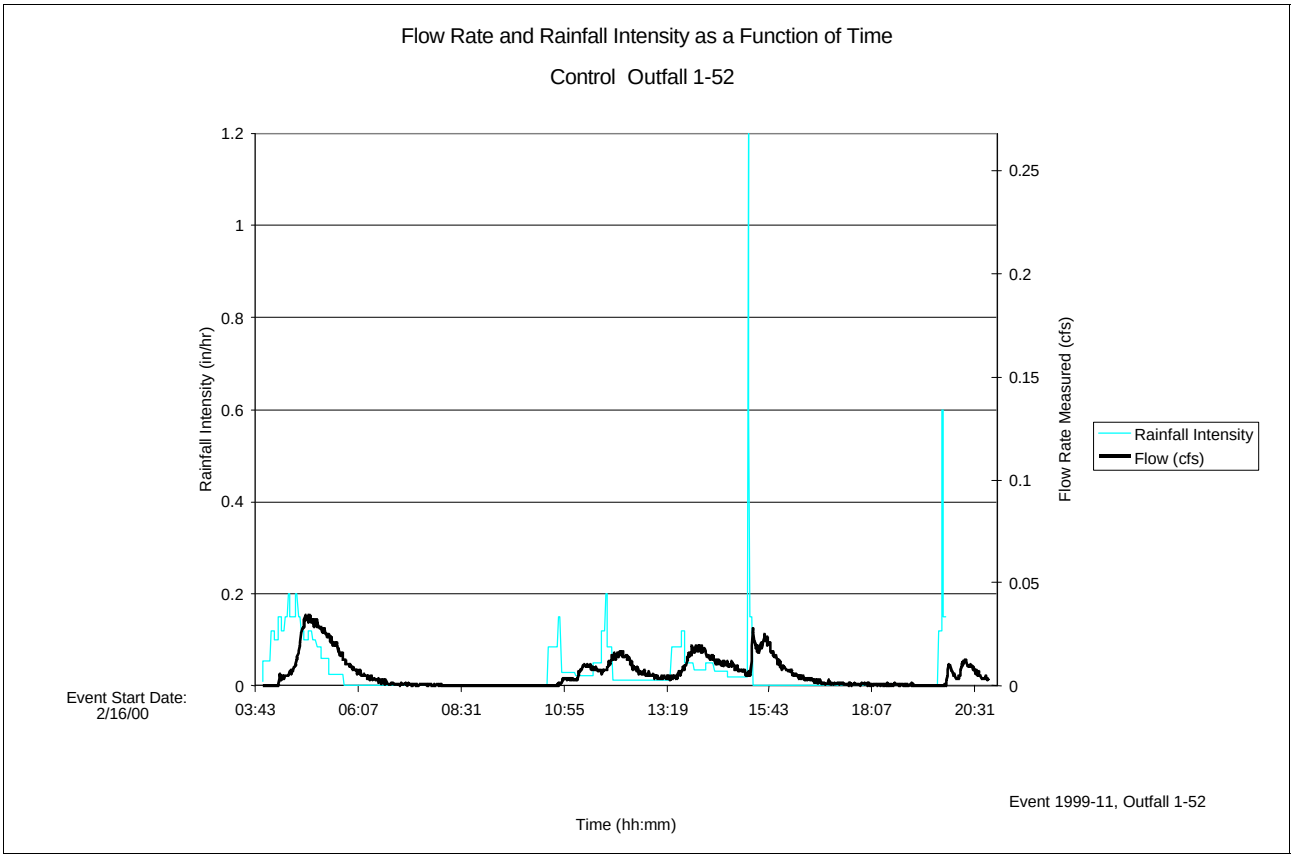
Site 1E - Litter Pickup

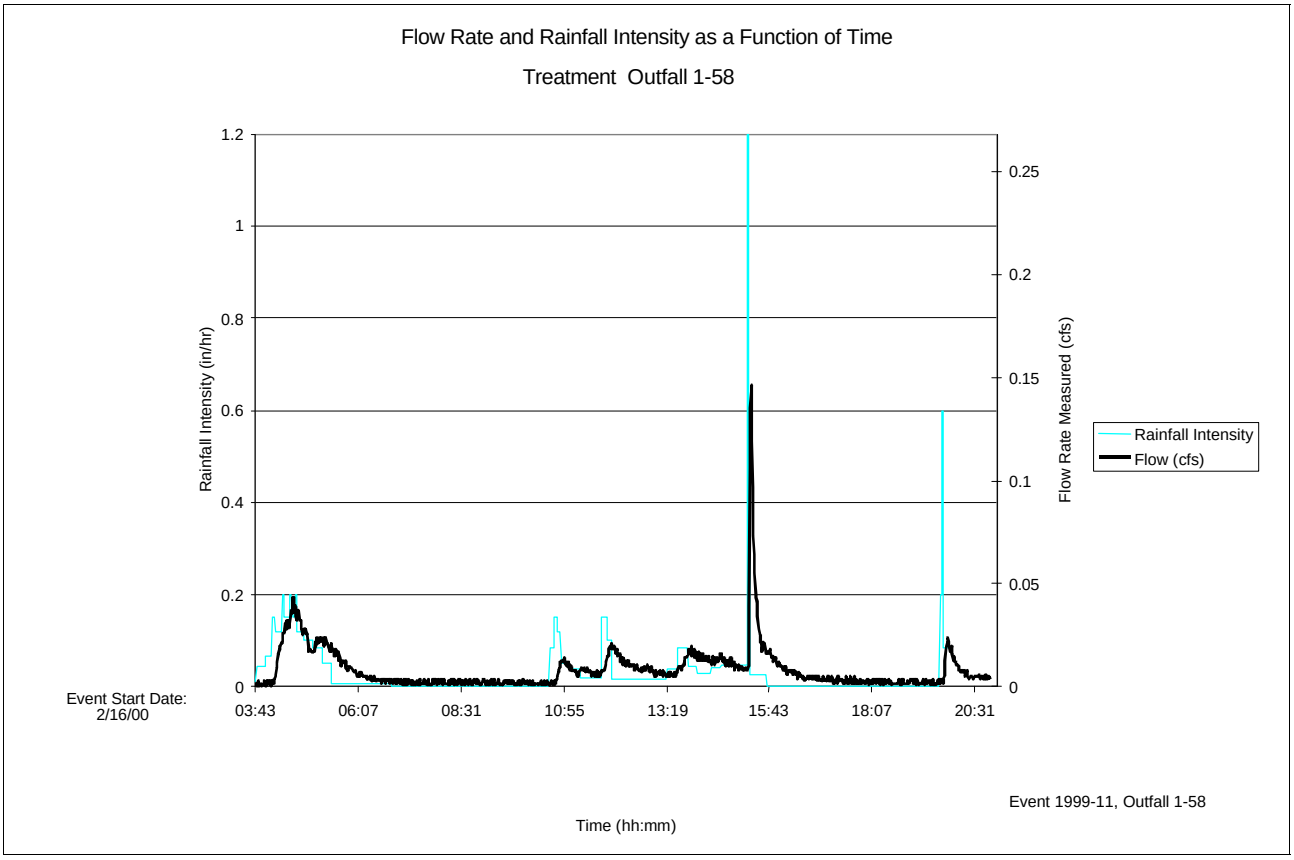
Event No. 1999e11 - 2/16/00



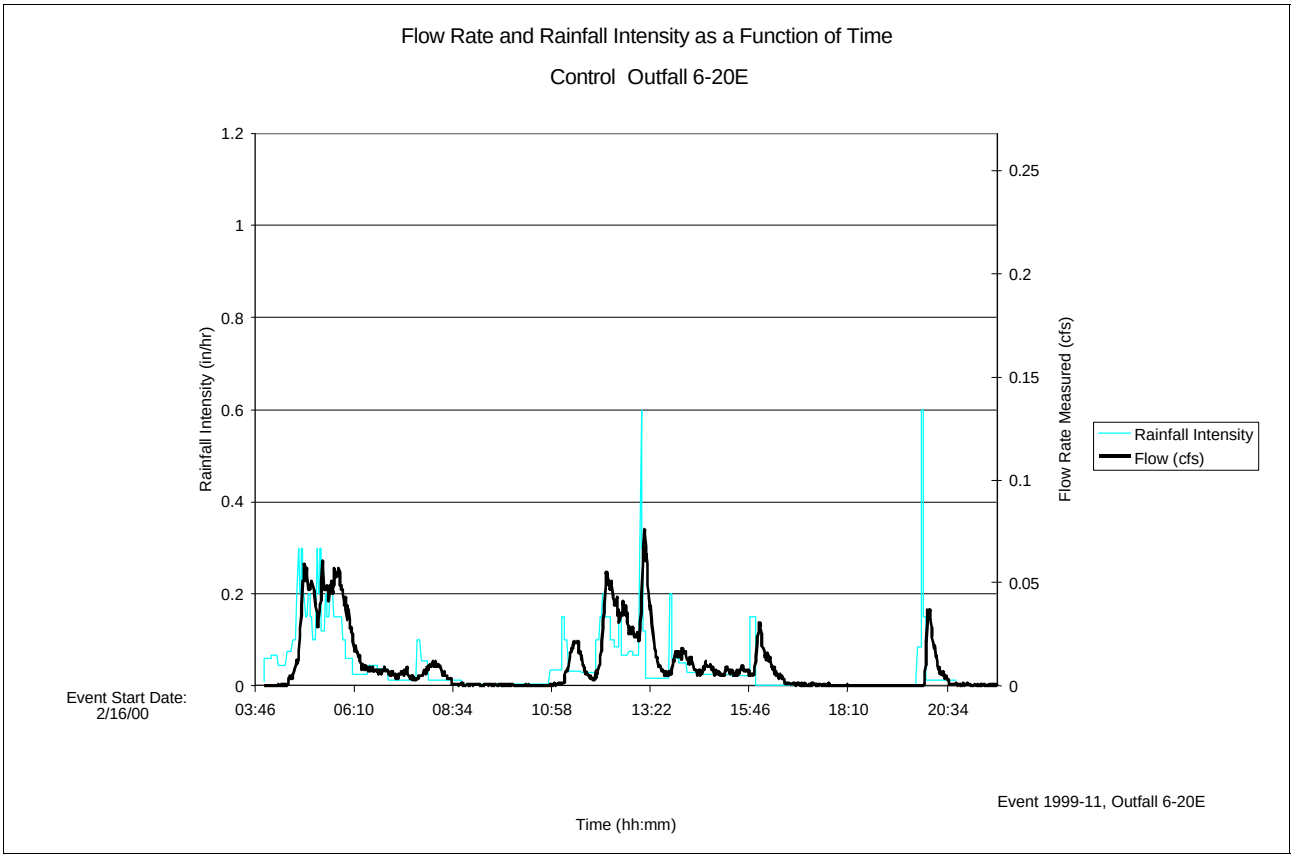


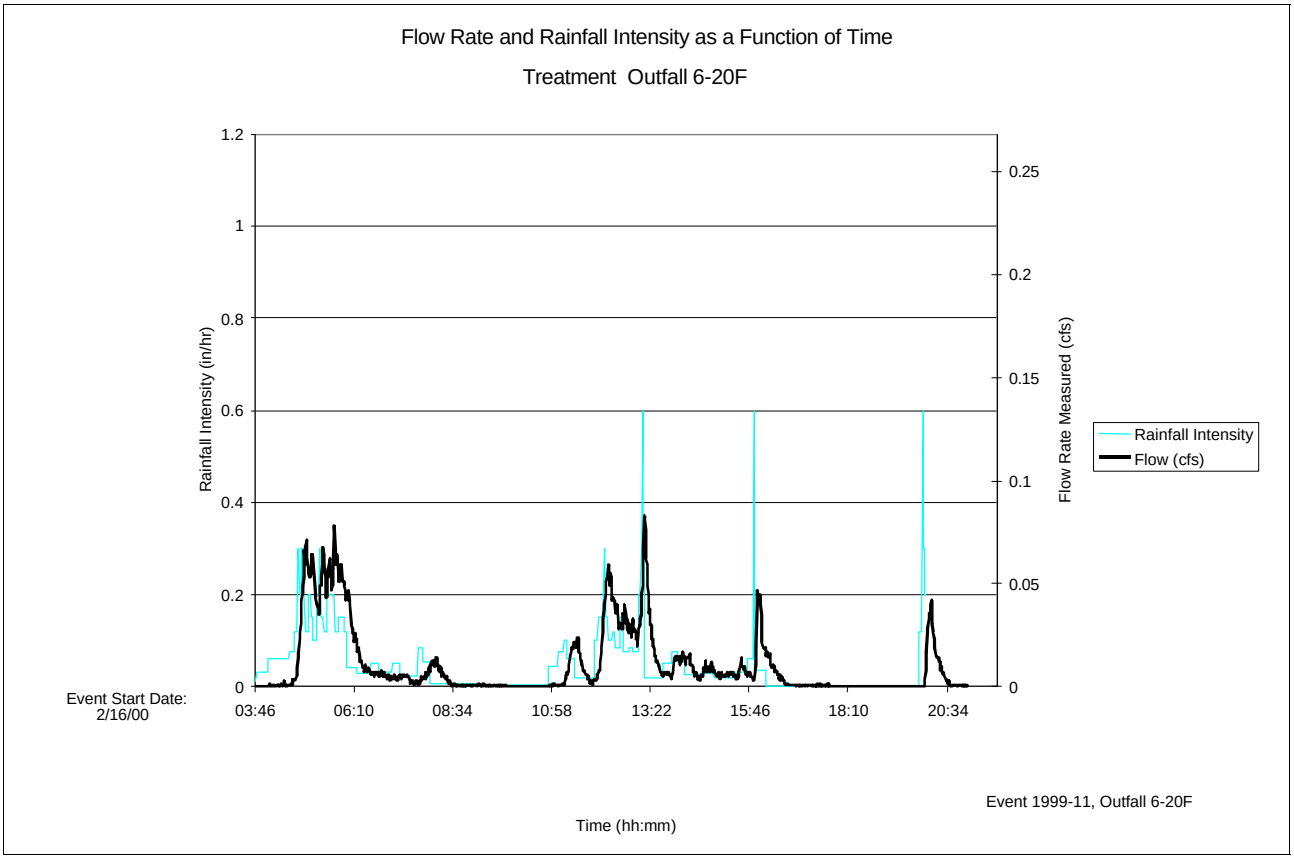
Site 1W - Street Sweeping Event No. 1999e11 - 2/16/00



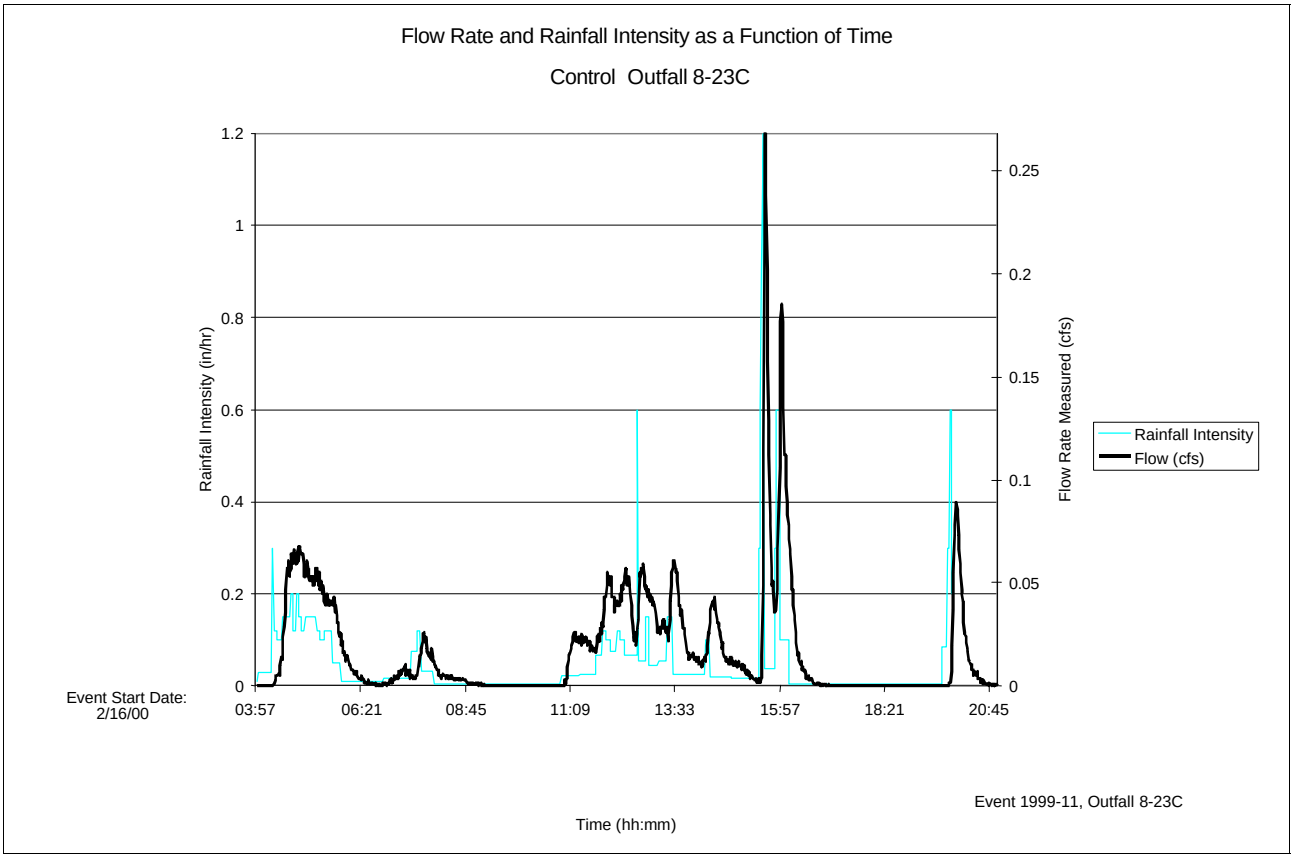


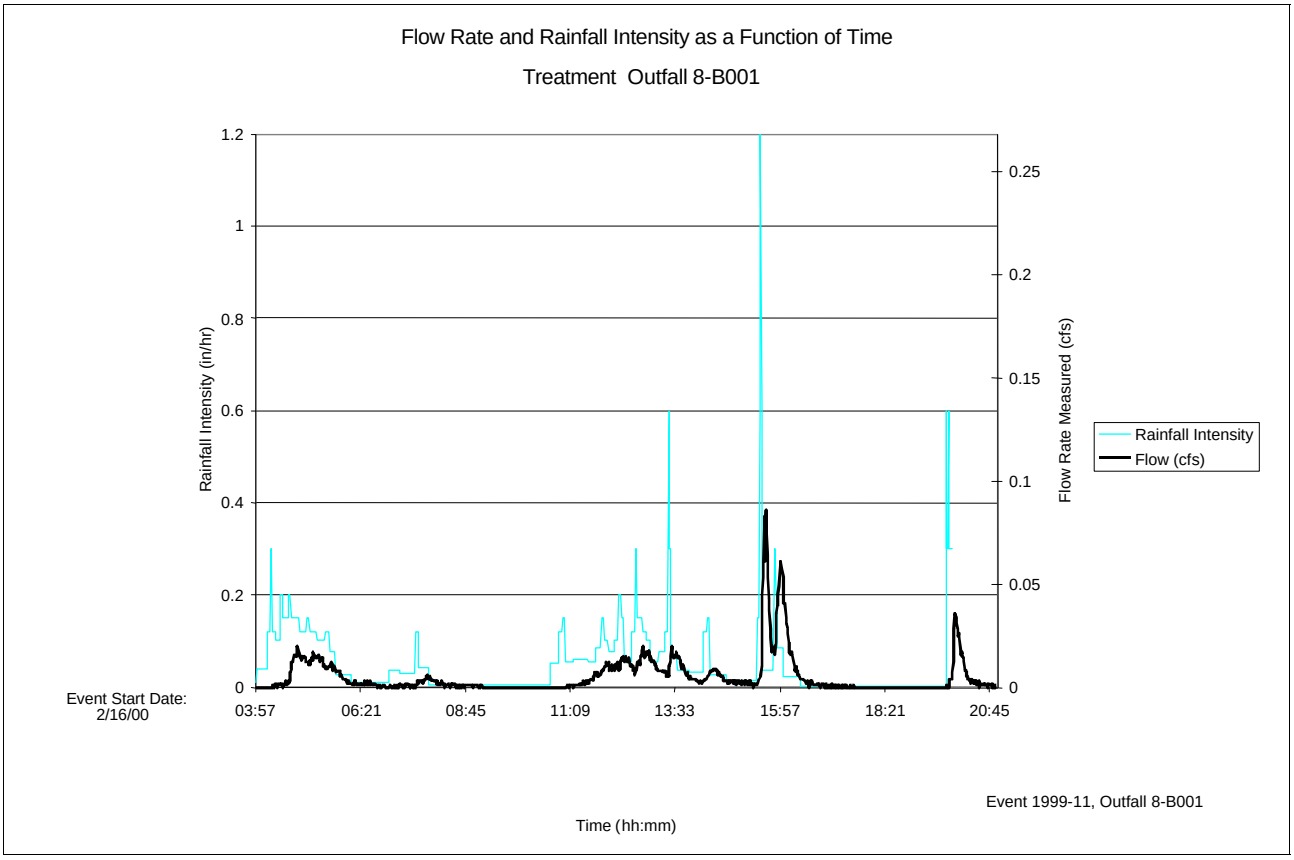
Site 6 - Modified Inlet Event No. 1999e11 - 2/16/00





Site 8 - Bicycle Grate/LID Event No. 1999e11 - 2/16/00





Site 1E - Litter Pickup Event No. 1999e12 - 2/20/00

Flow Rate and Rainfall Intensity as a Function of Time

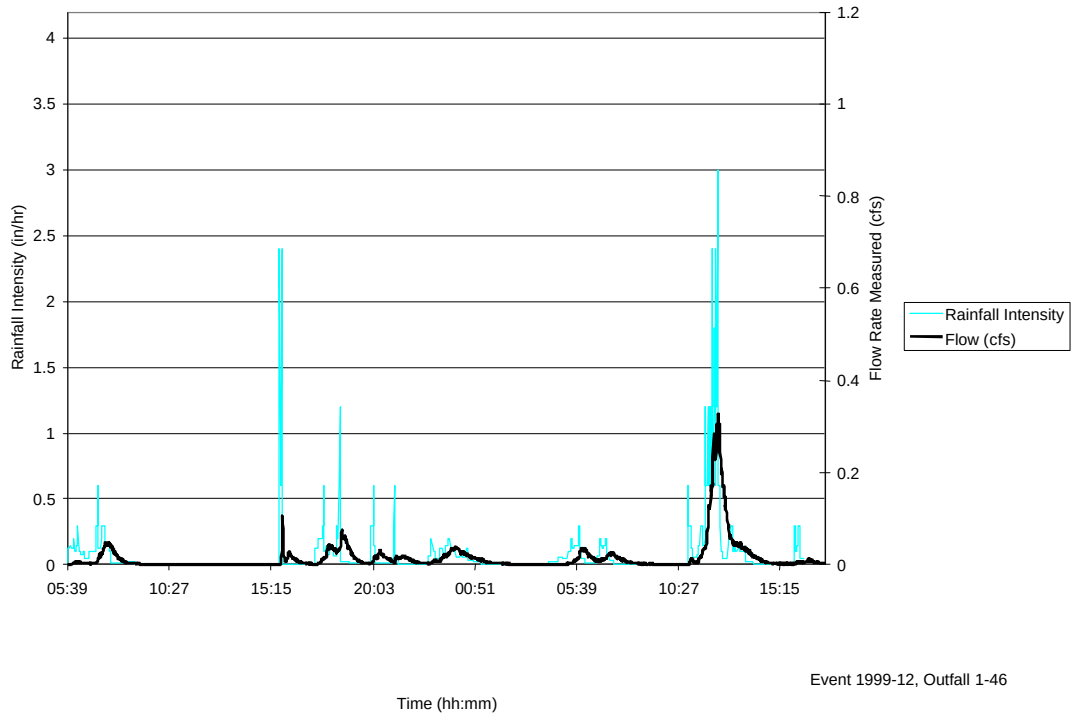
Control Outfall 1-42

No Hydrologic Data Available for this Event For this Outfall

Event Start Date:
2/20/00

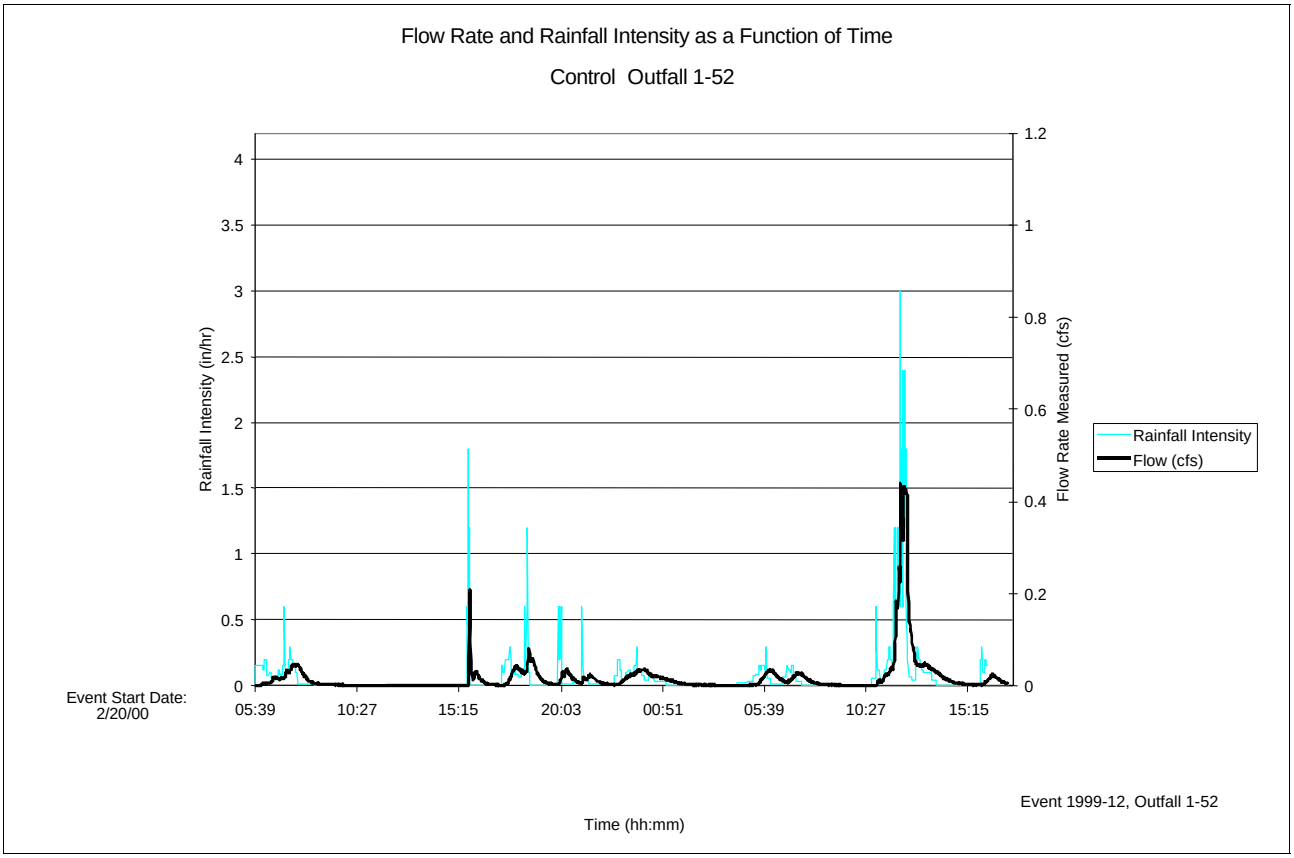
Flow Rate and Rainfall Intensity as a Function of Time

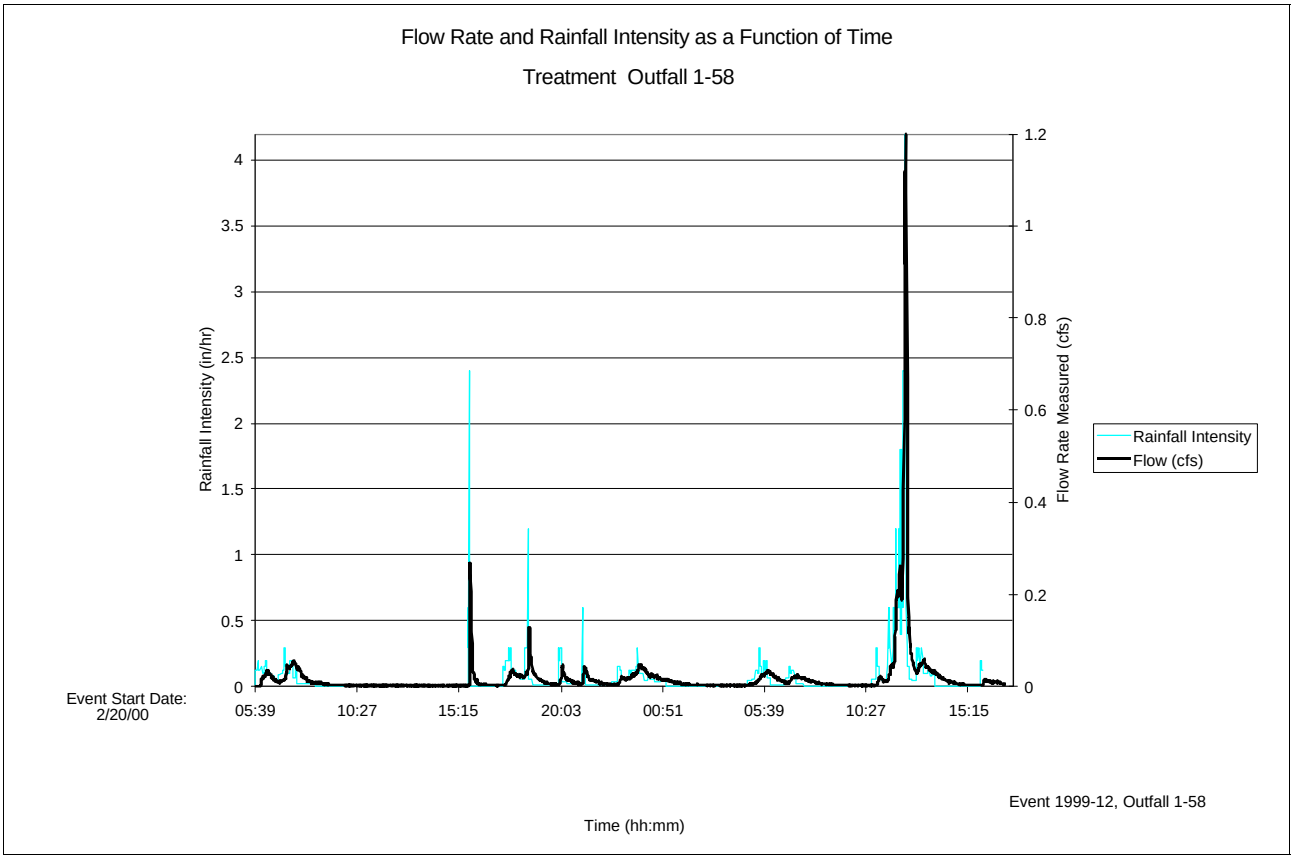
Treatment Outfall 1-46



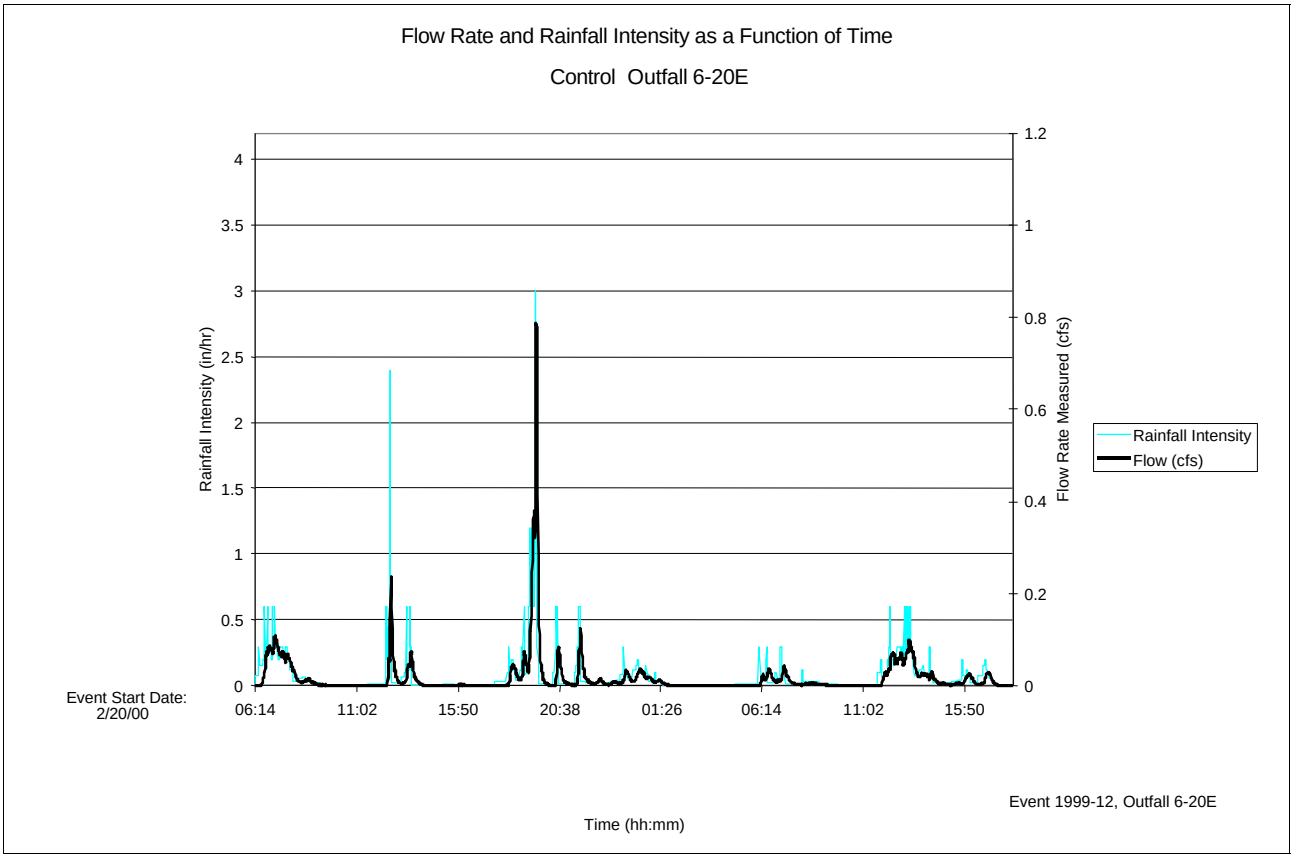
Event Start Date:
2/20/00

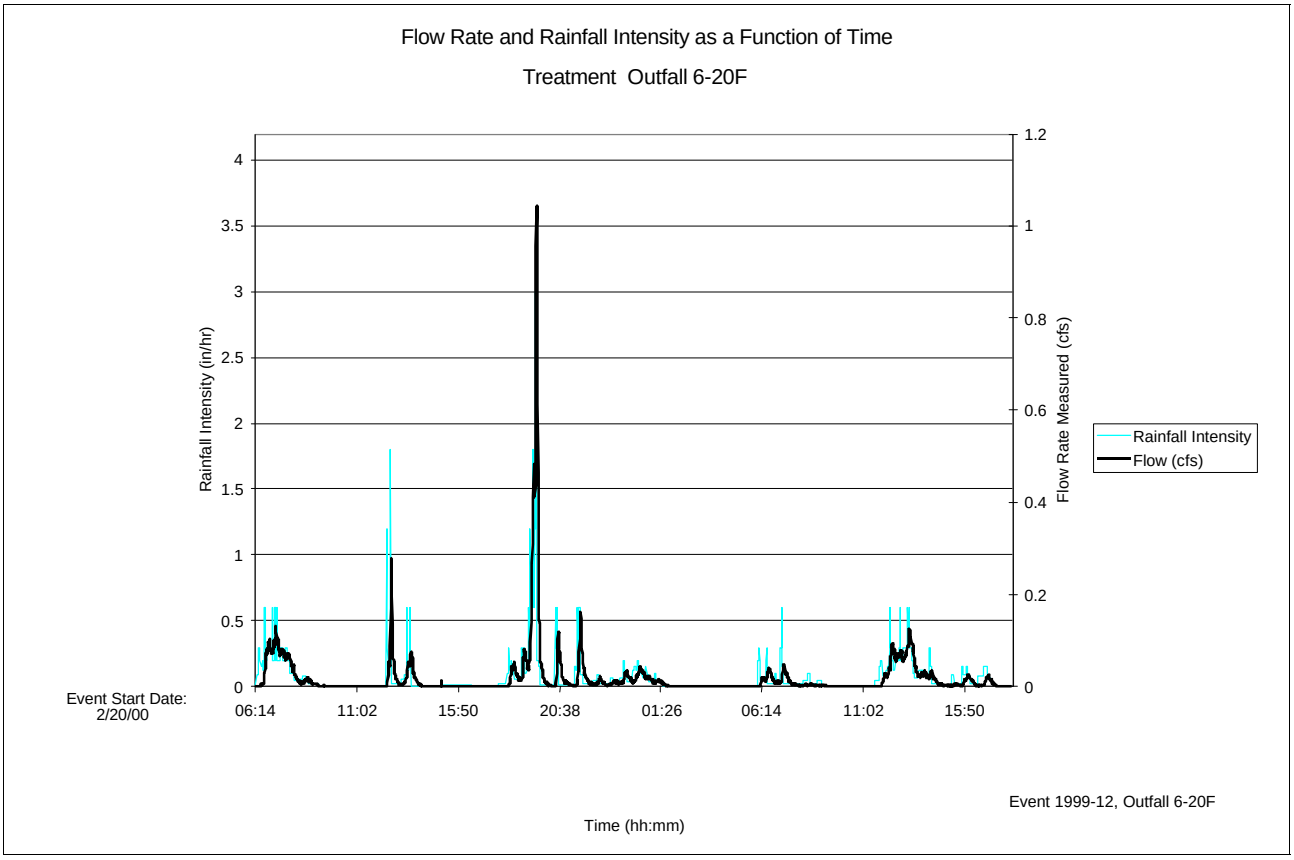
Site 1W - Street Sweeping Event No. 1999e12 - 2/20/00



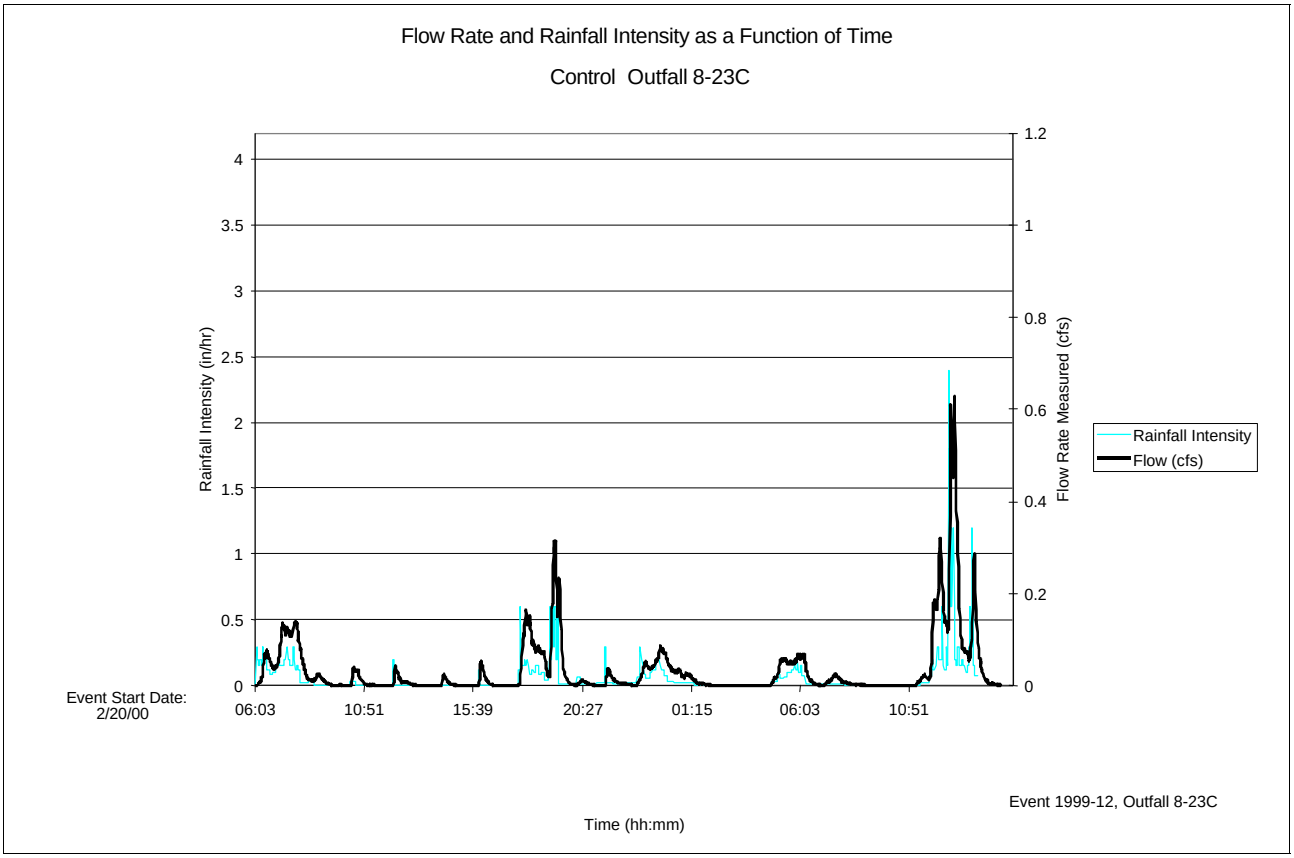


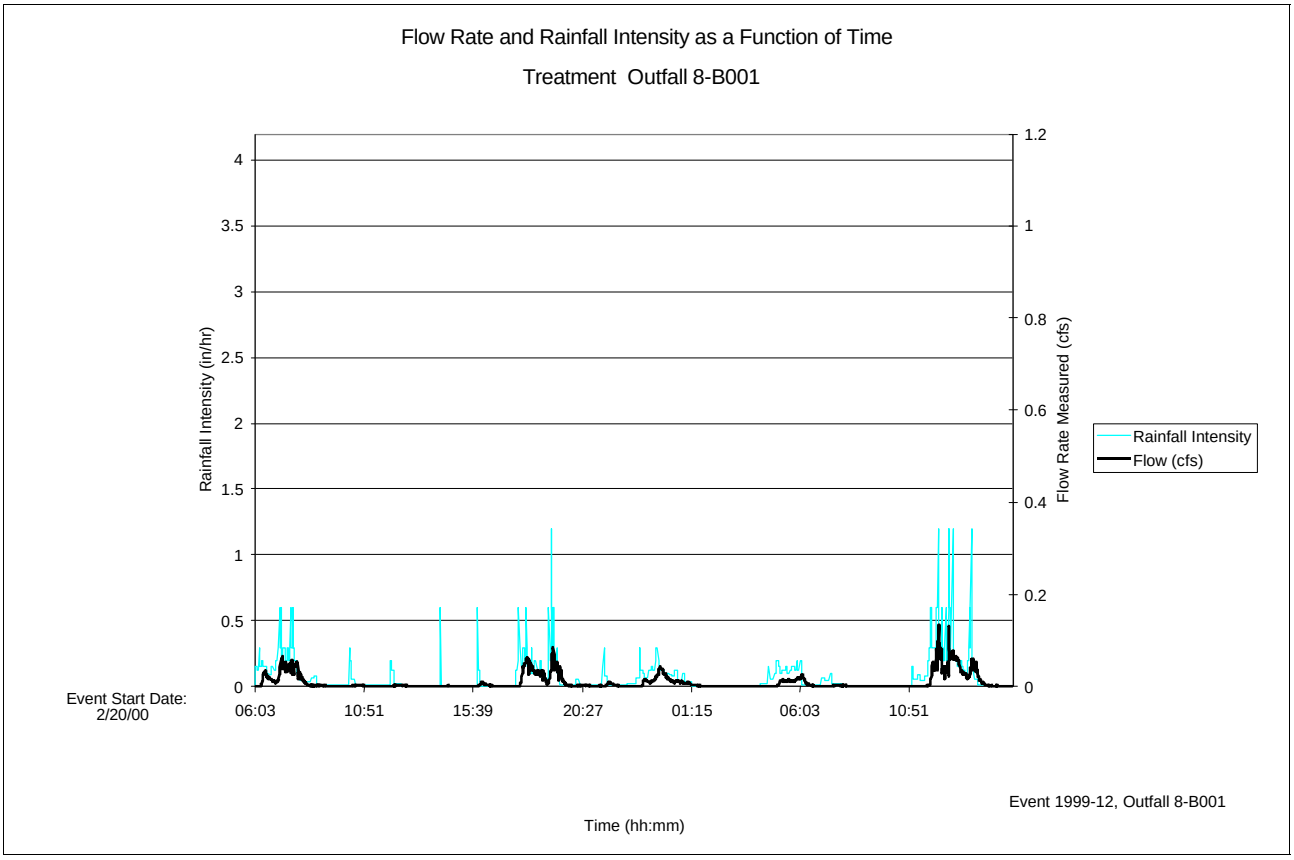
Site 6 - Modified Inlet Event No. 1999e12 - 2/20/00





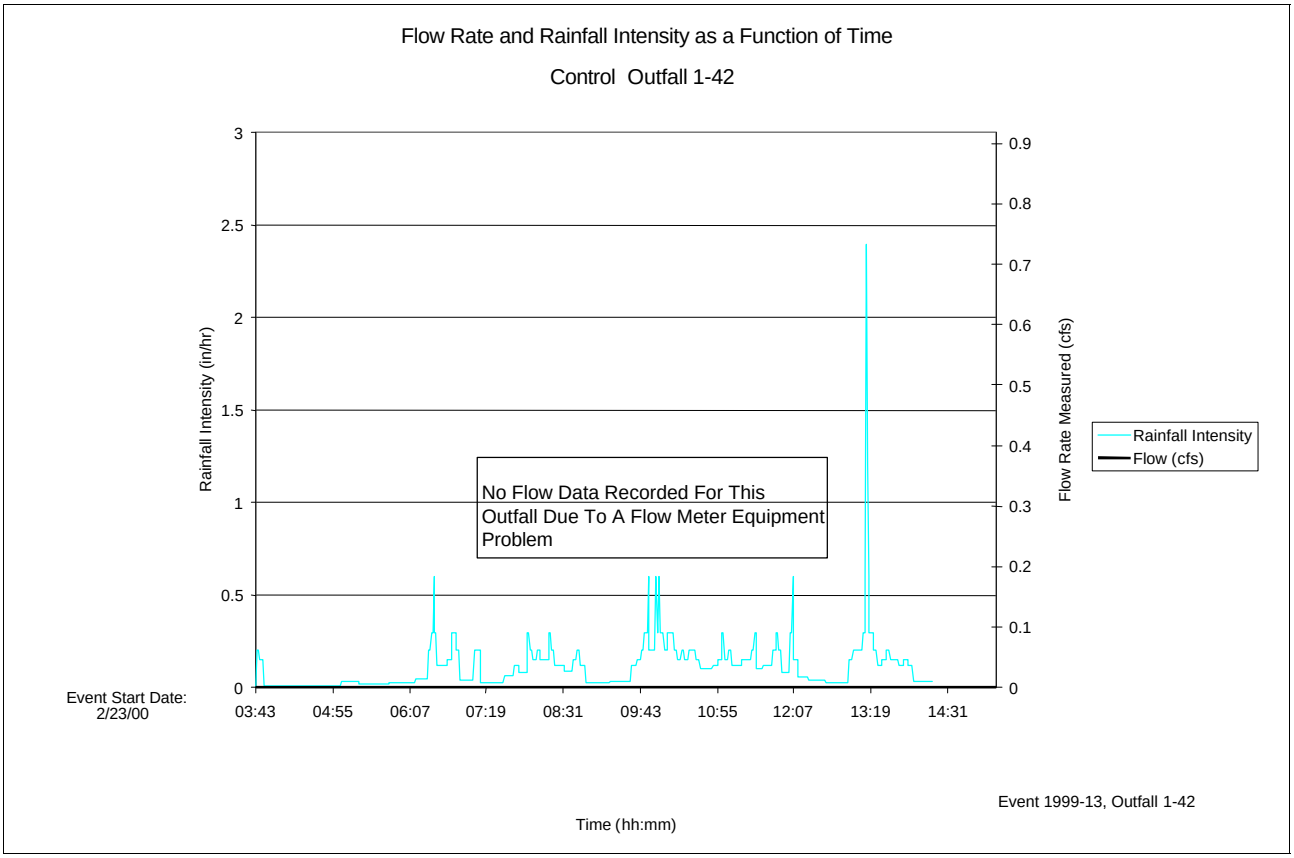
Site 8 - Bicycle Grate/LID Event No. 1999e12 - 2/20/00

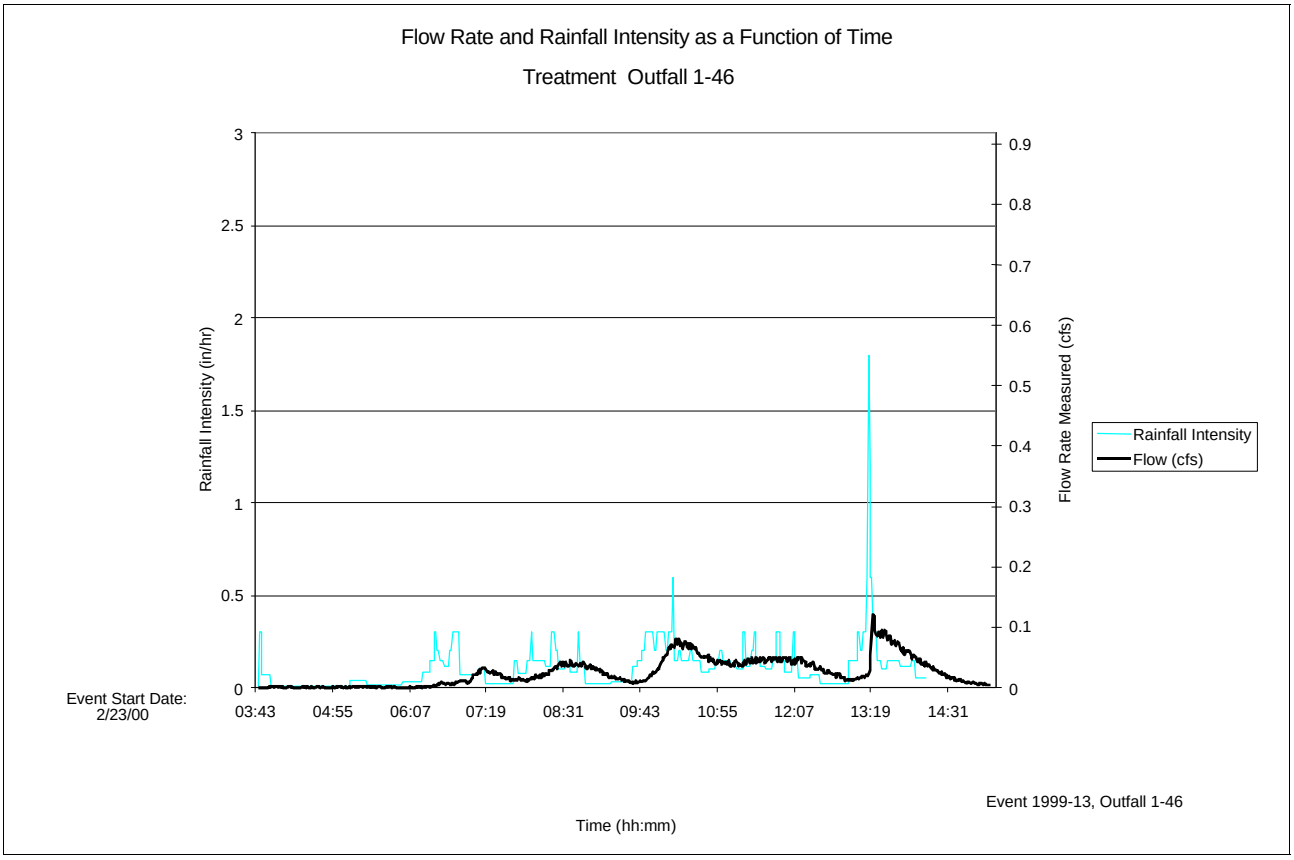




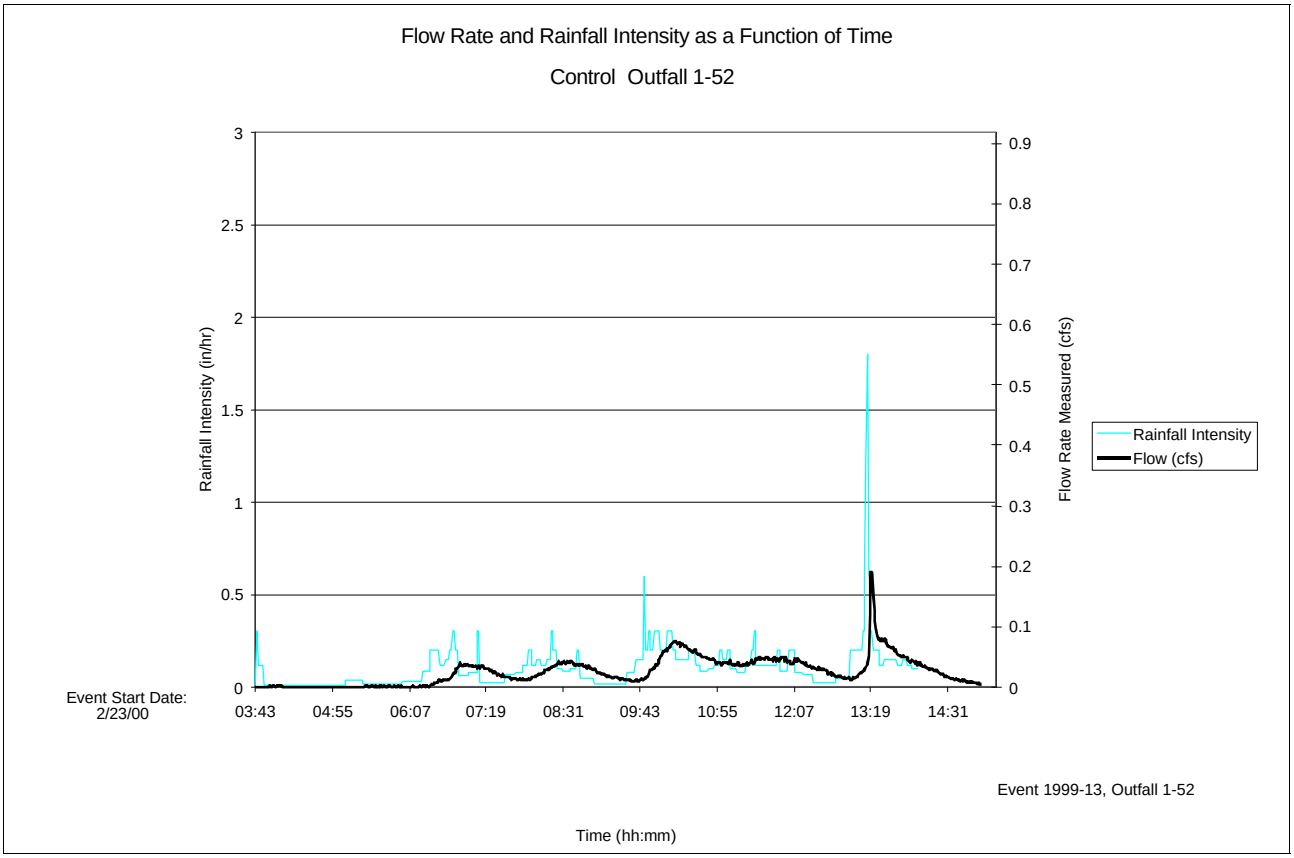
Site 1E - Litter Pickup

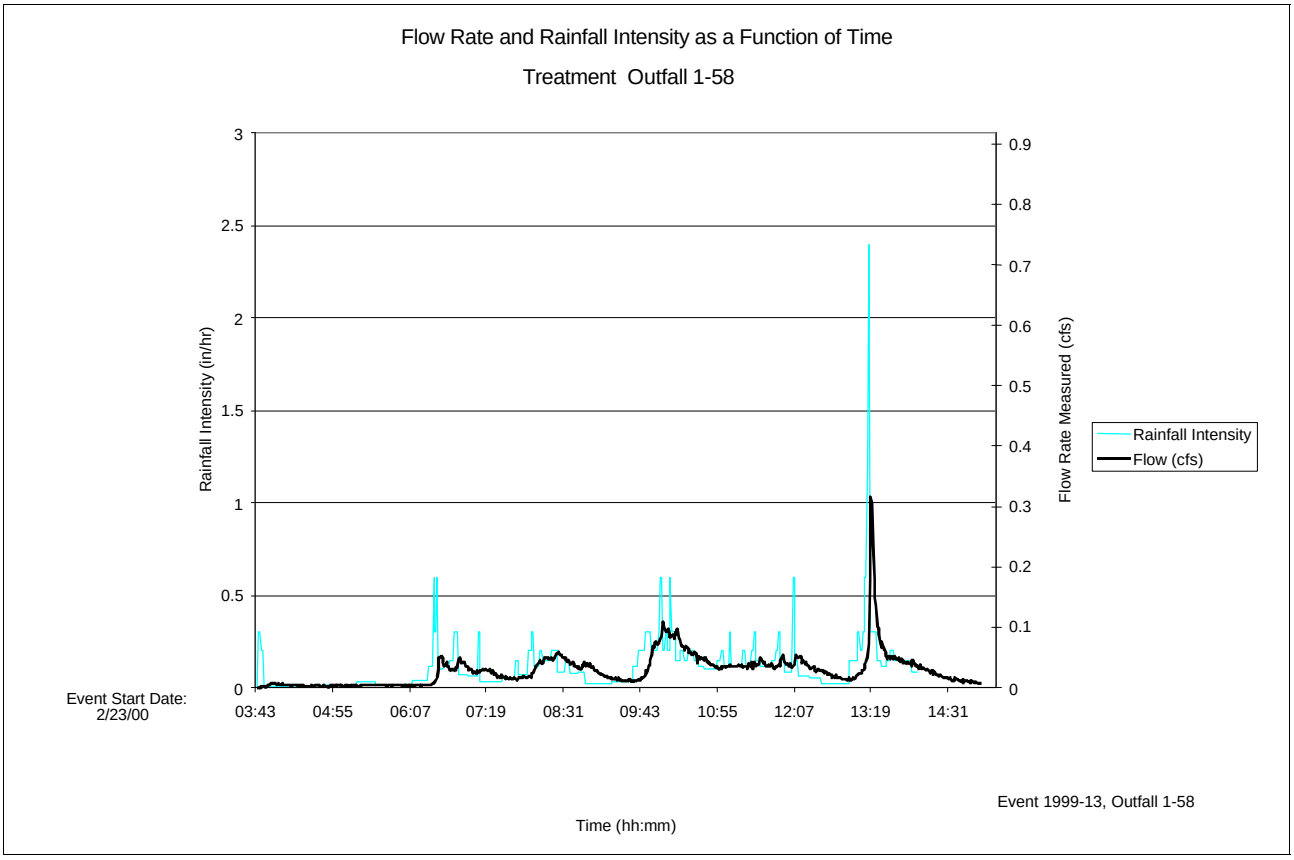
Event No. 1999e13 - 2/23/00



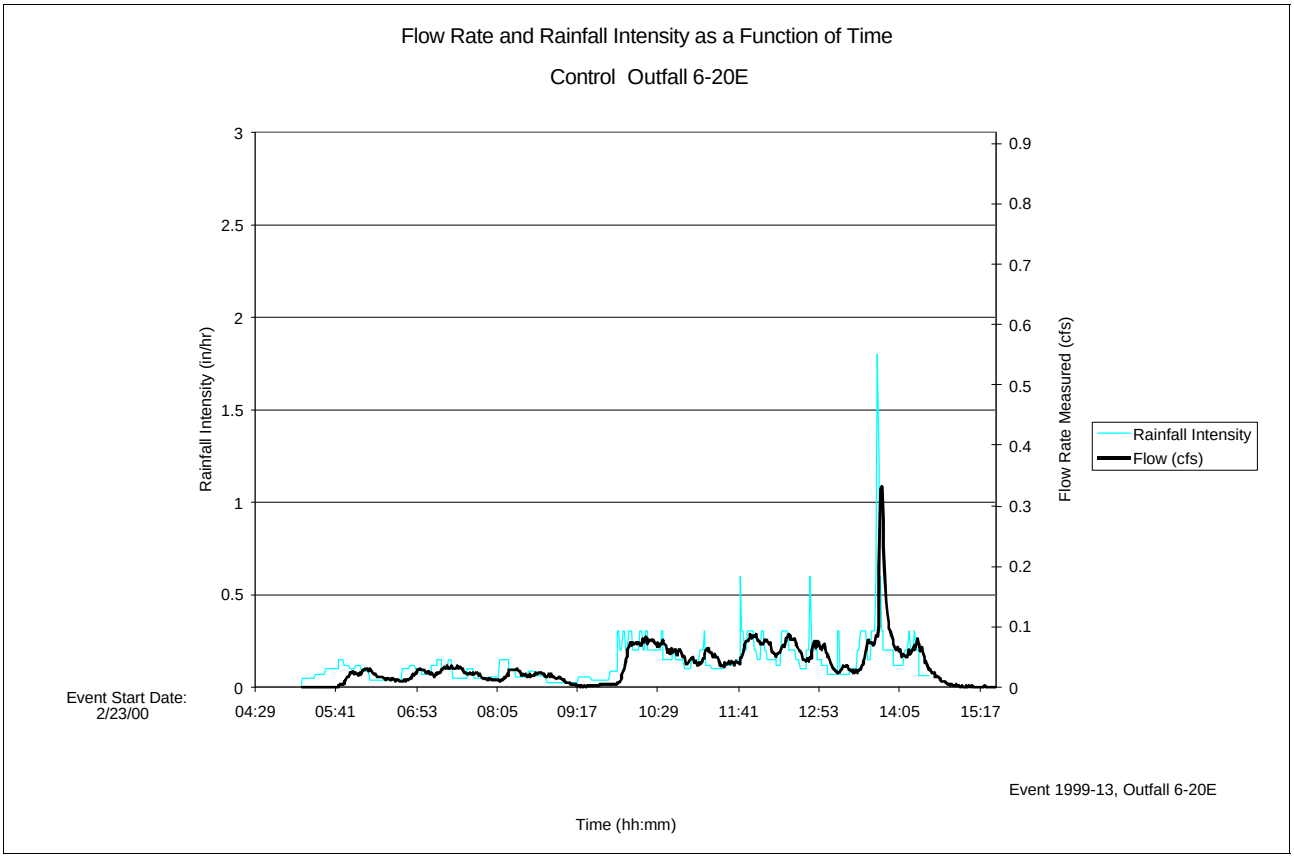


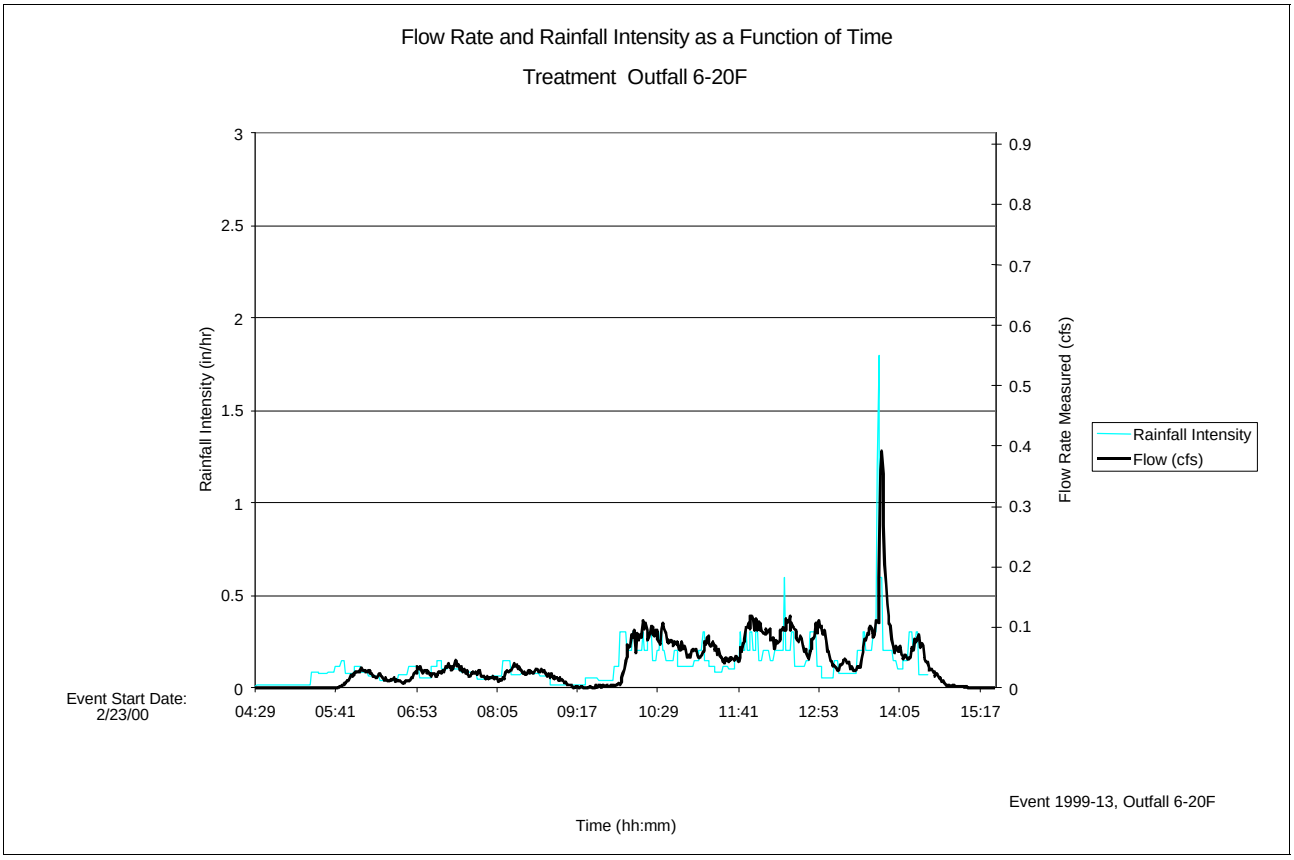
Site 1W - Street Sweeping Event No. 1999e13 - 2/23/00



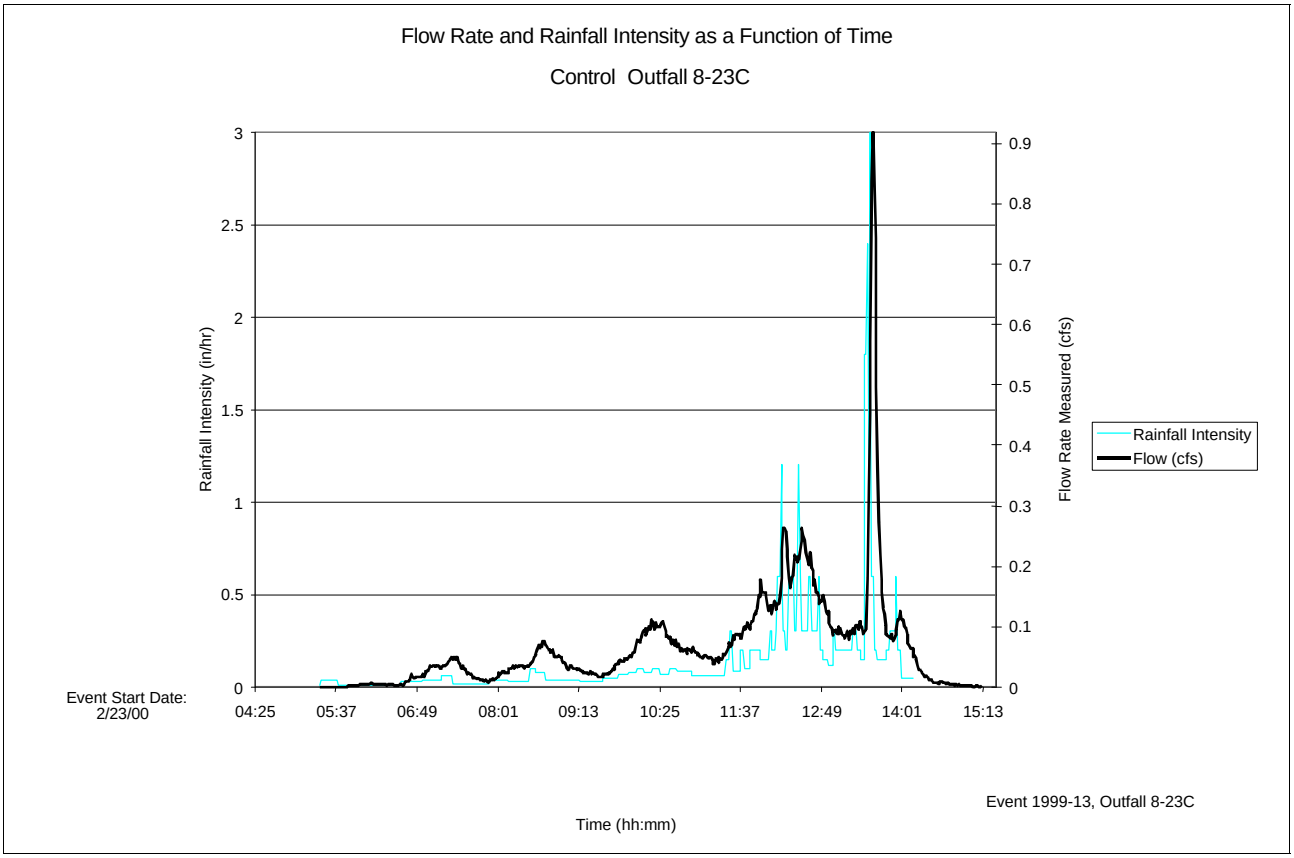


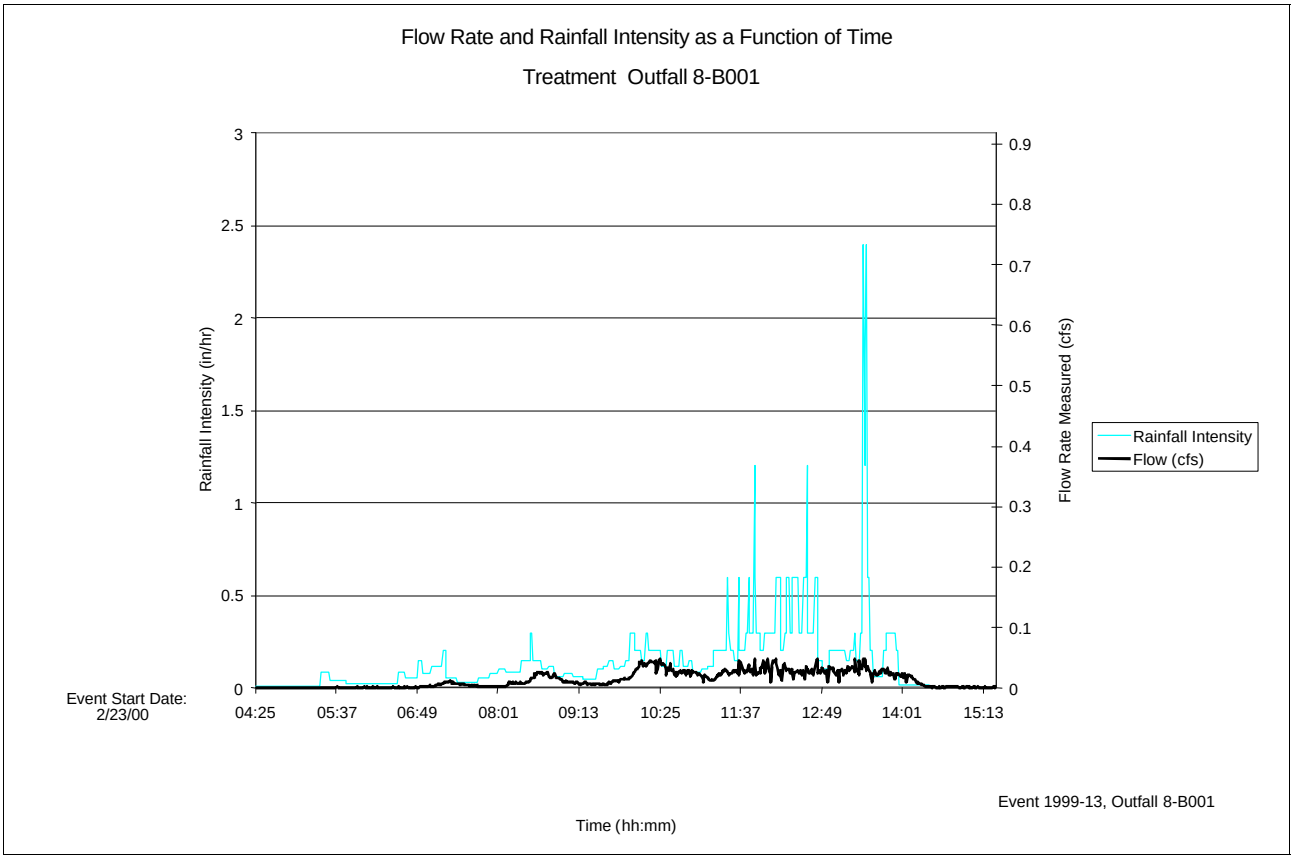
Site 6 - Modified Inlet Event No. 1999e13 - 2/23/00





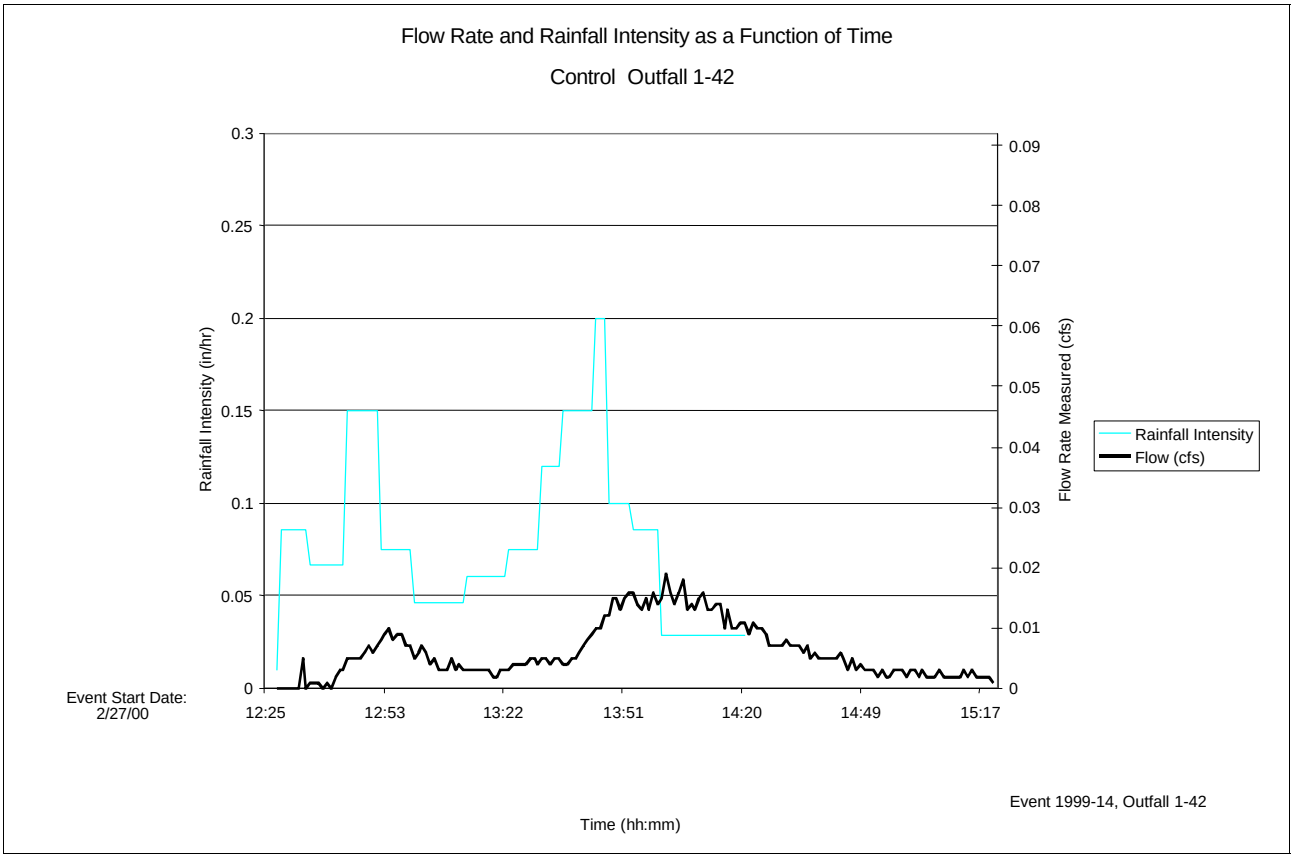
Site 8 - Bicycle Grate/LID Event No. 1999e13 - 2/23/00

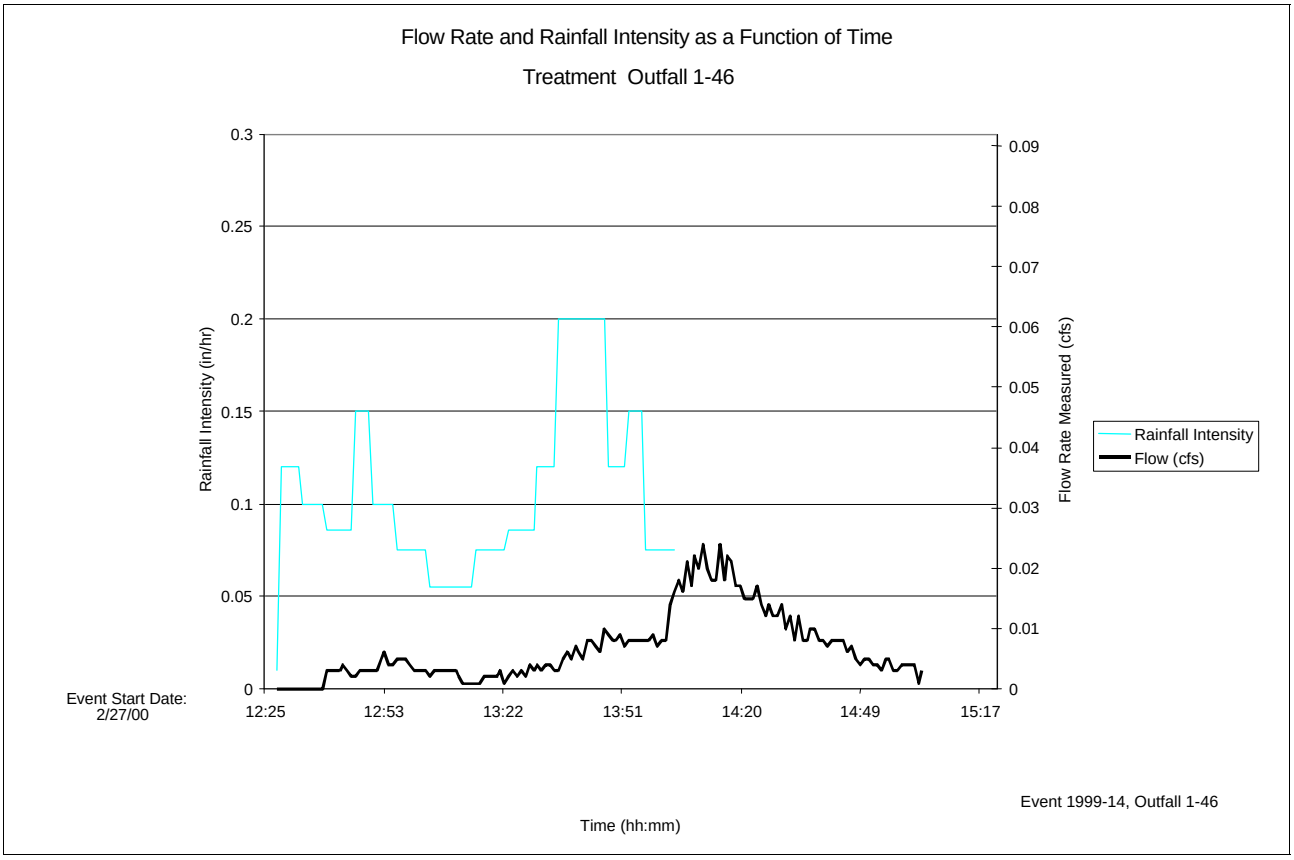




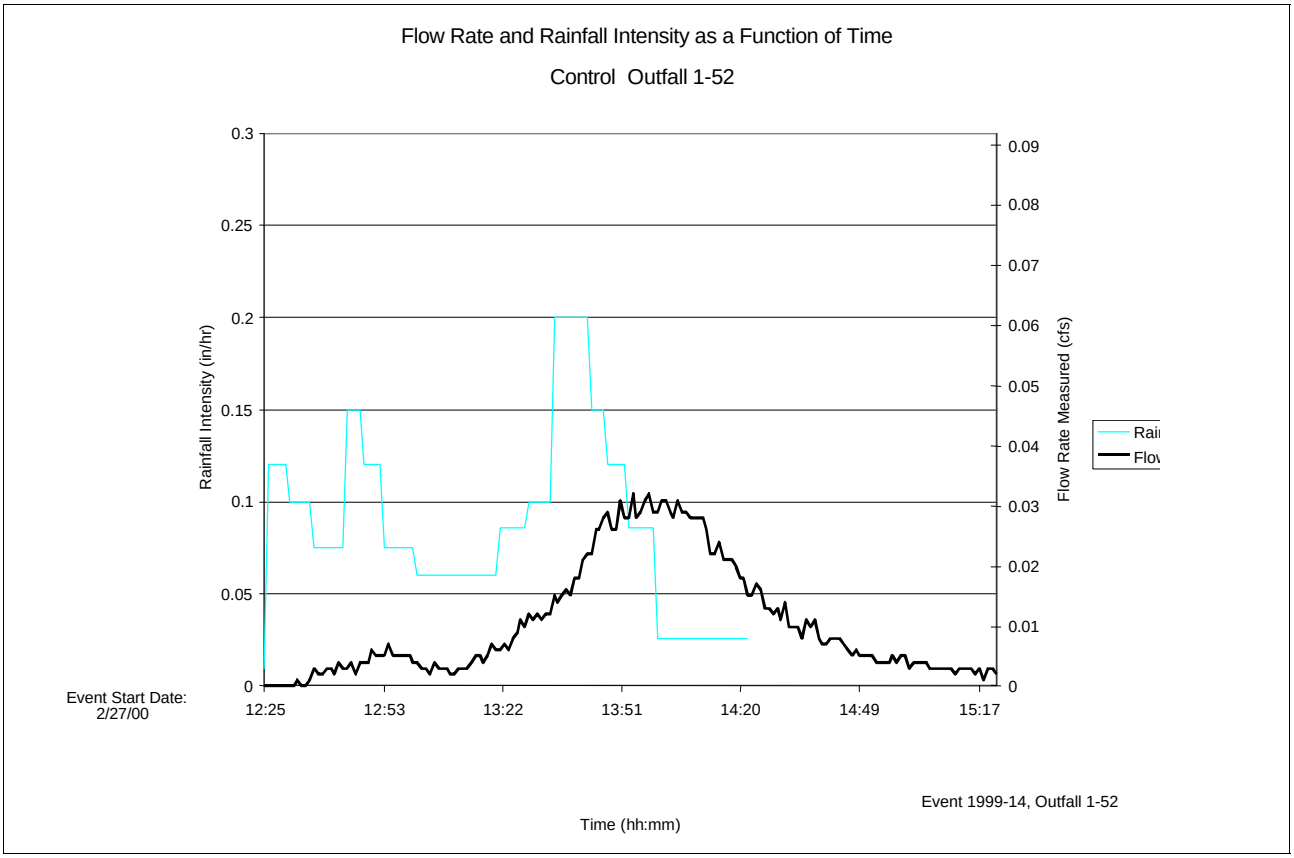
Site 1E - Litter Pickup

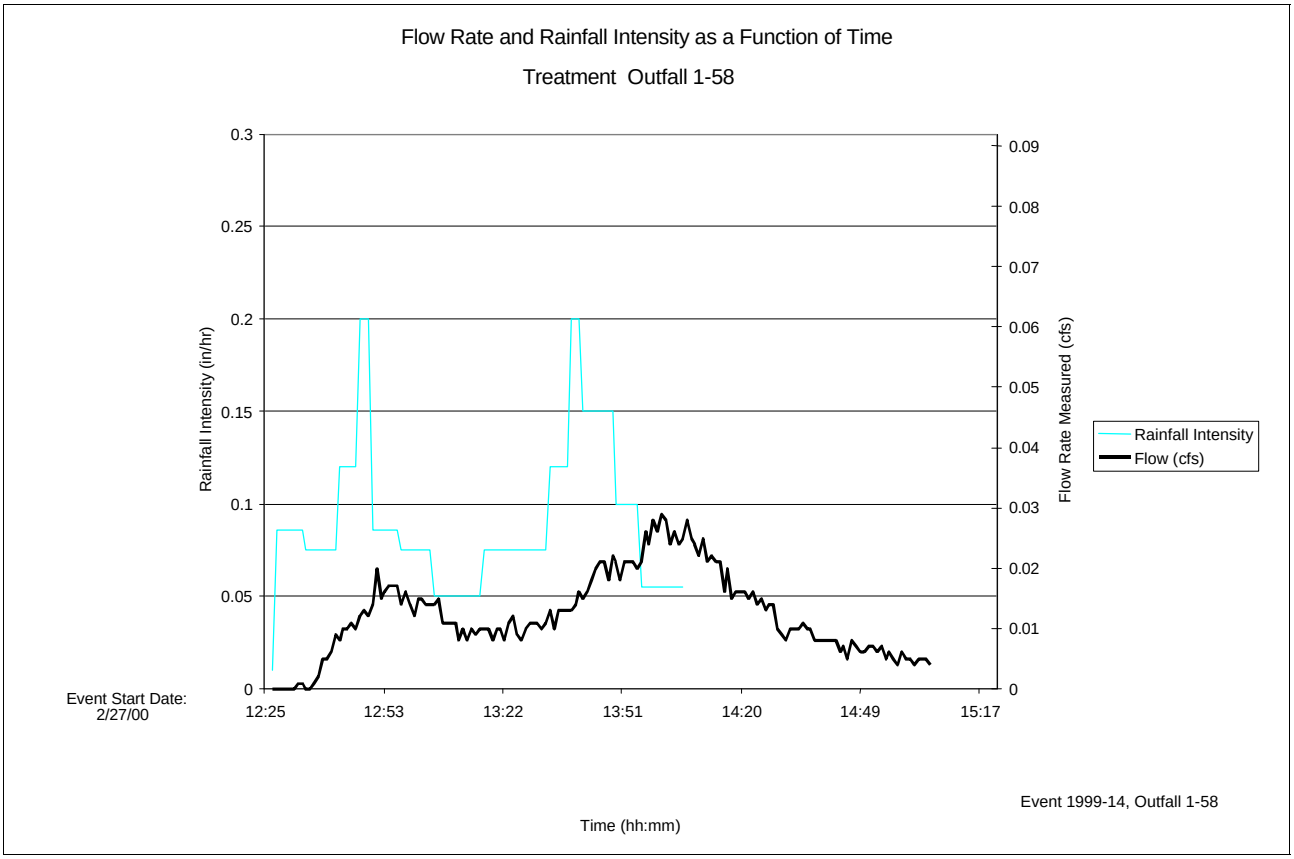
Event No. 1999e14 - 2/27/00



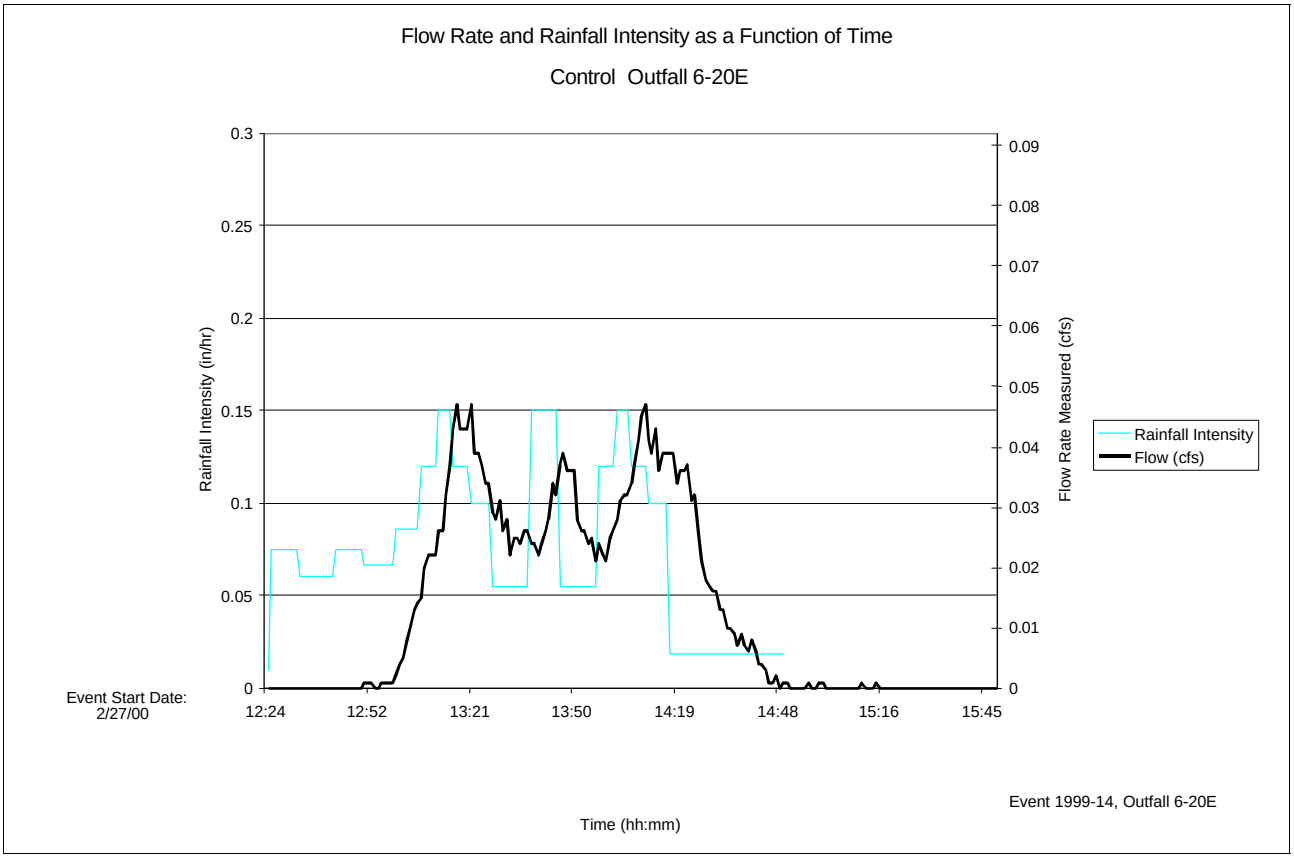


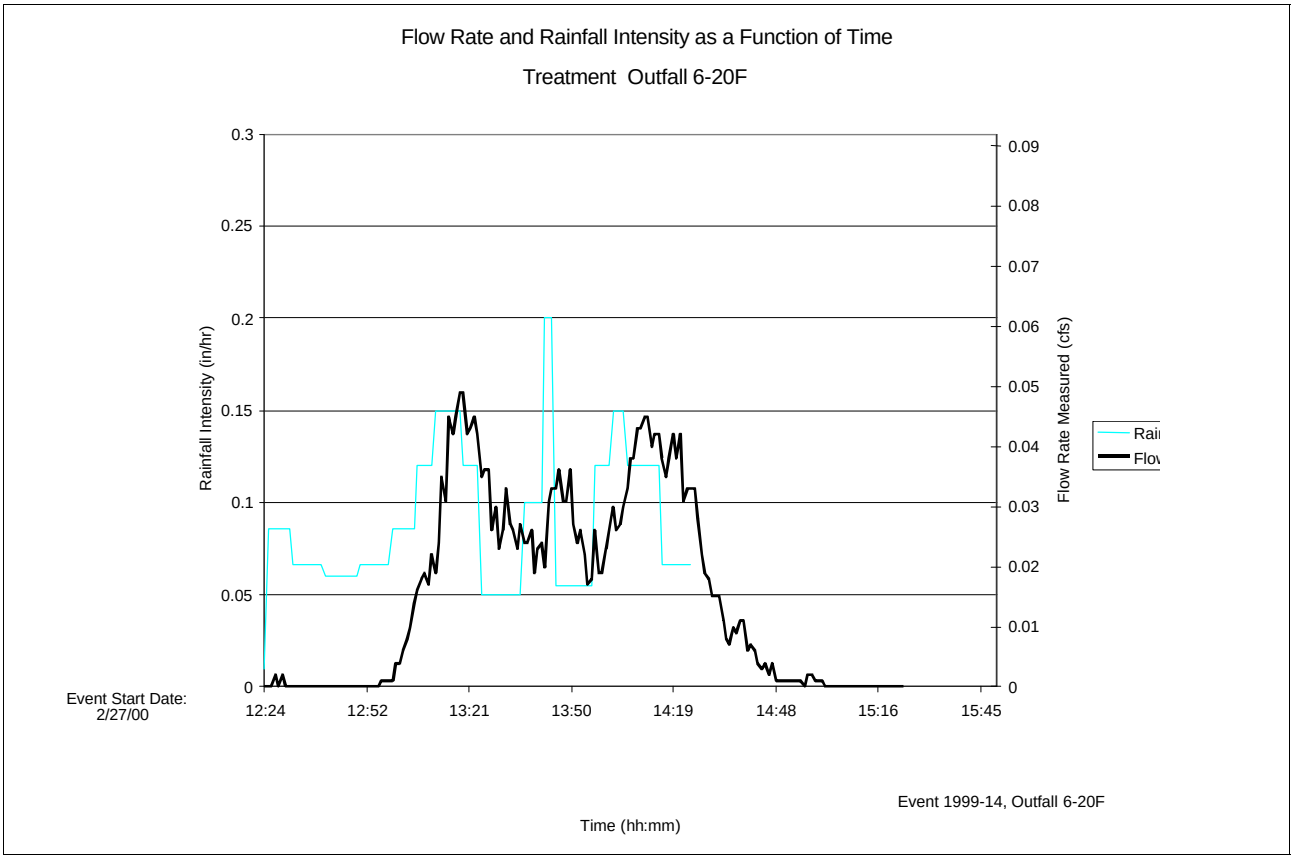
Site 1W - Street Sweeping Event No. 1999e14 - 2/27/00



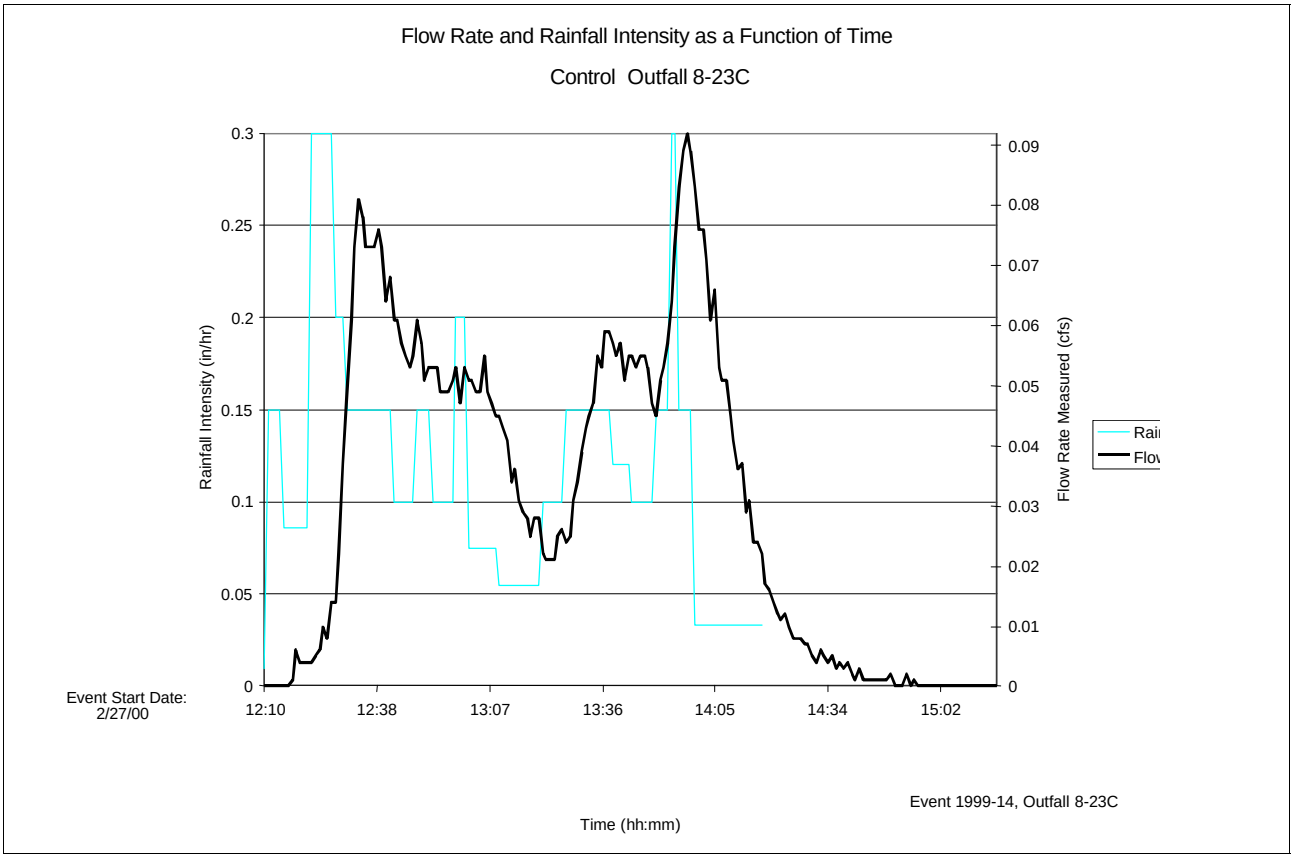


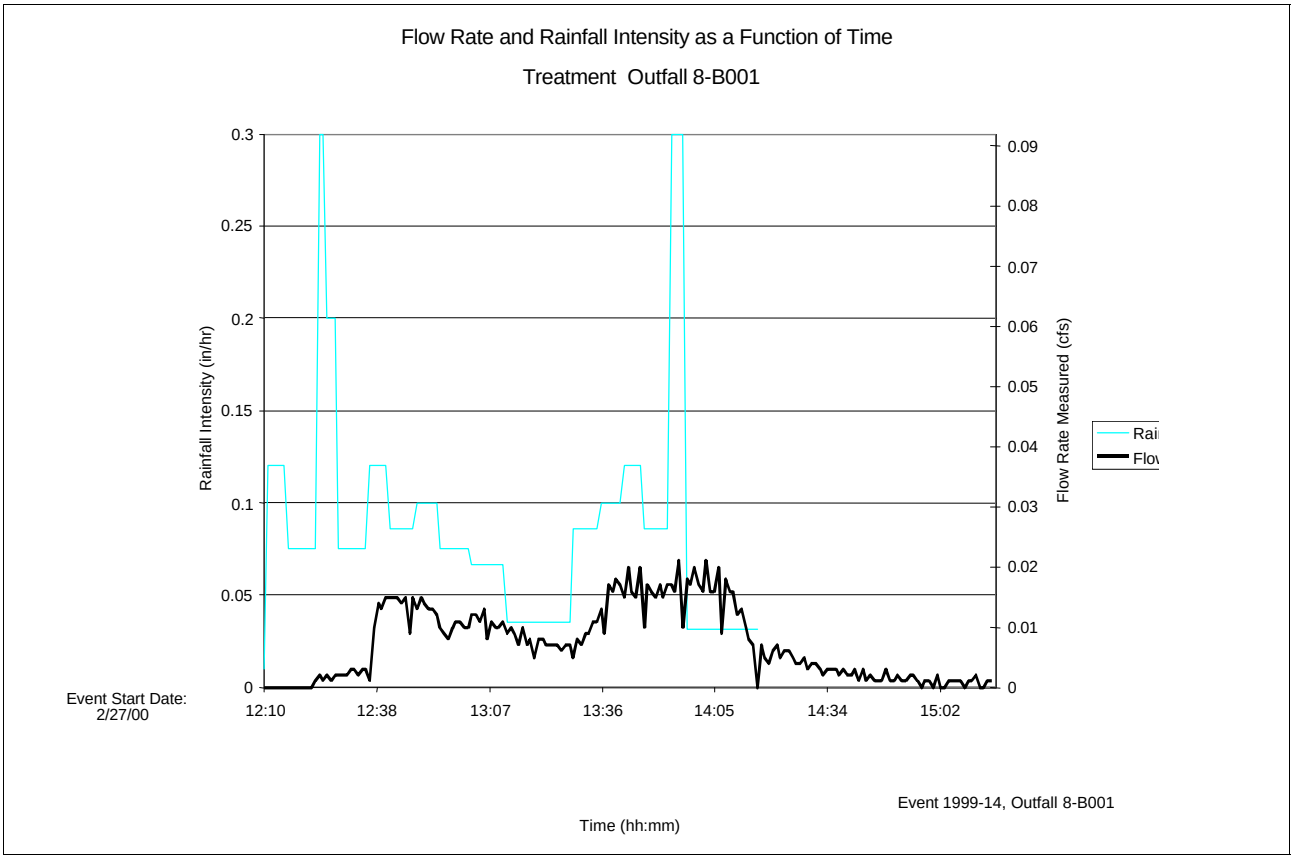
Site 6 - Modified Inlet Event No. 1999e14 - 2/27/00



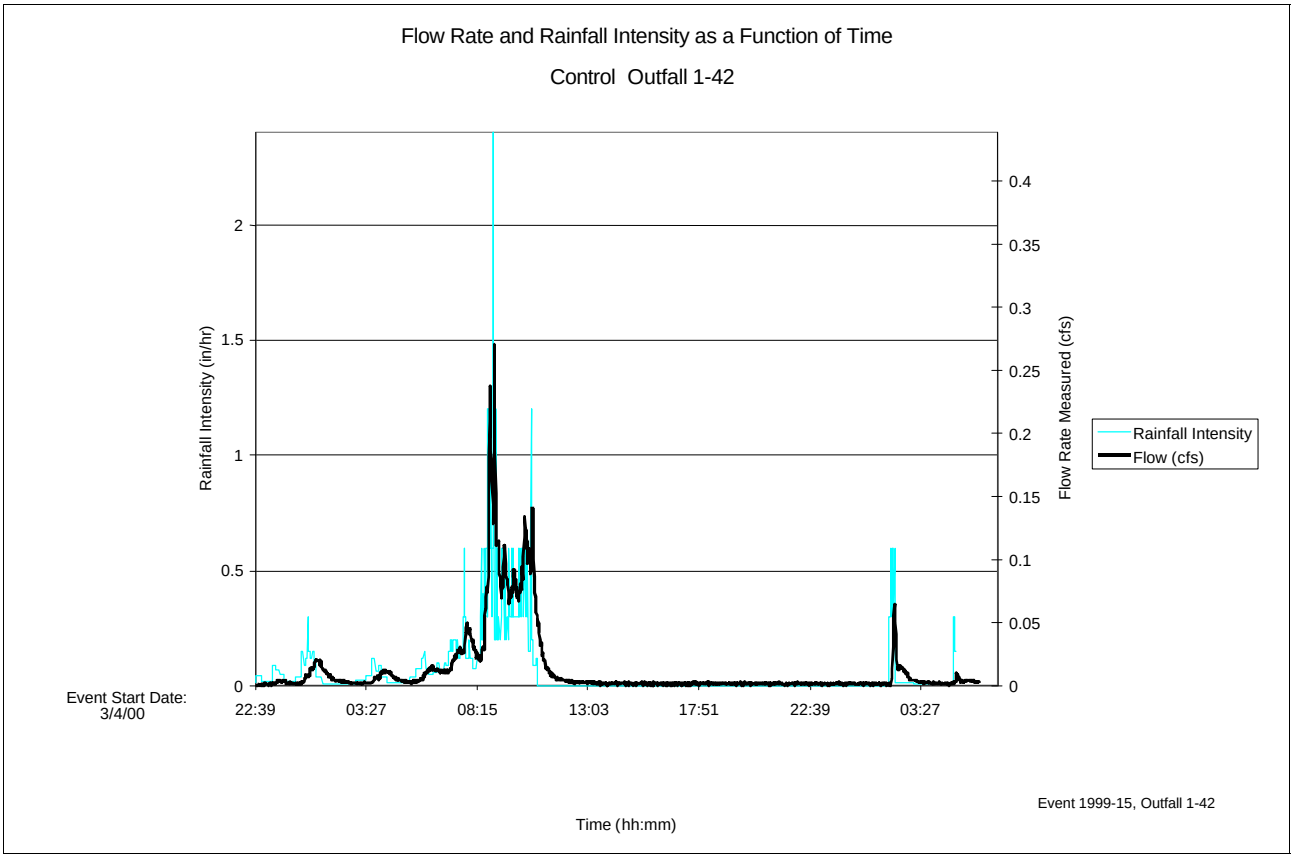


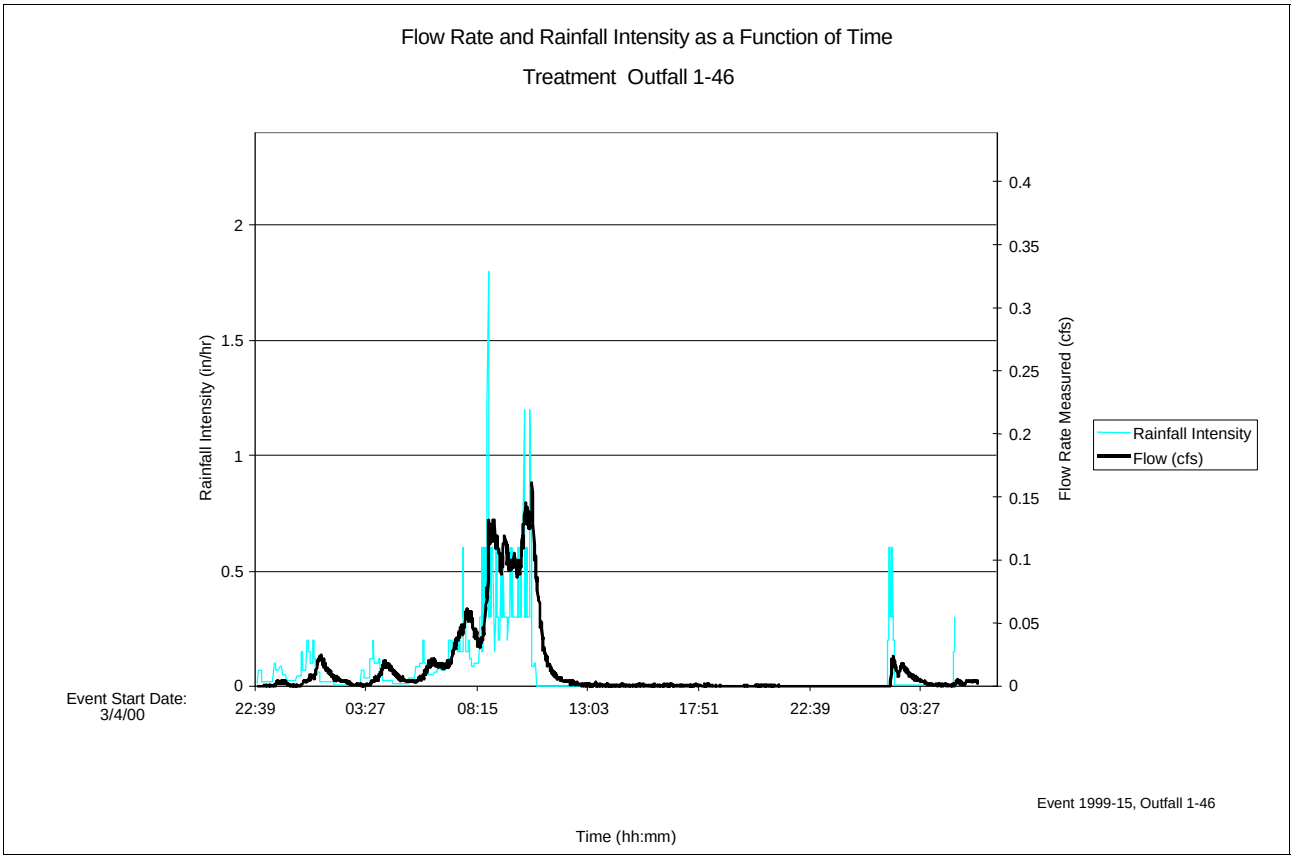
Site 8 - Bicycle Grate/LID Event No. 1999e14 - 2/27/00



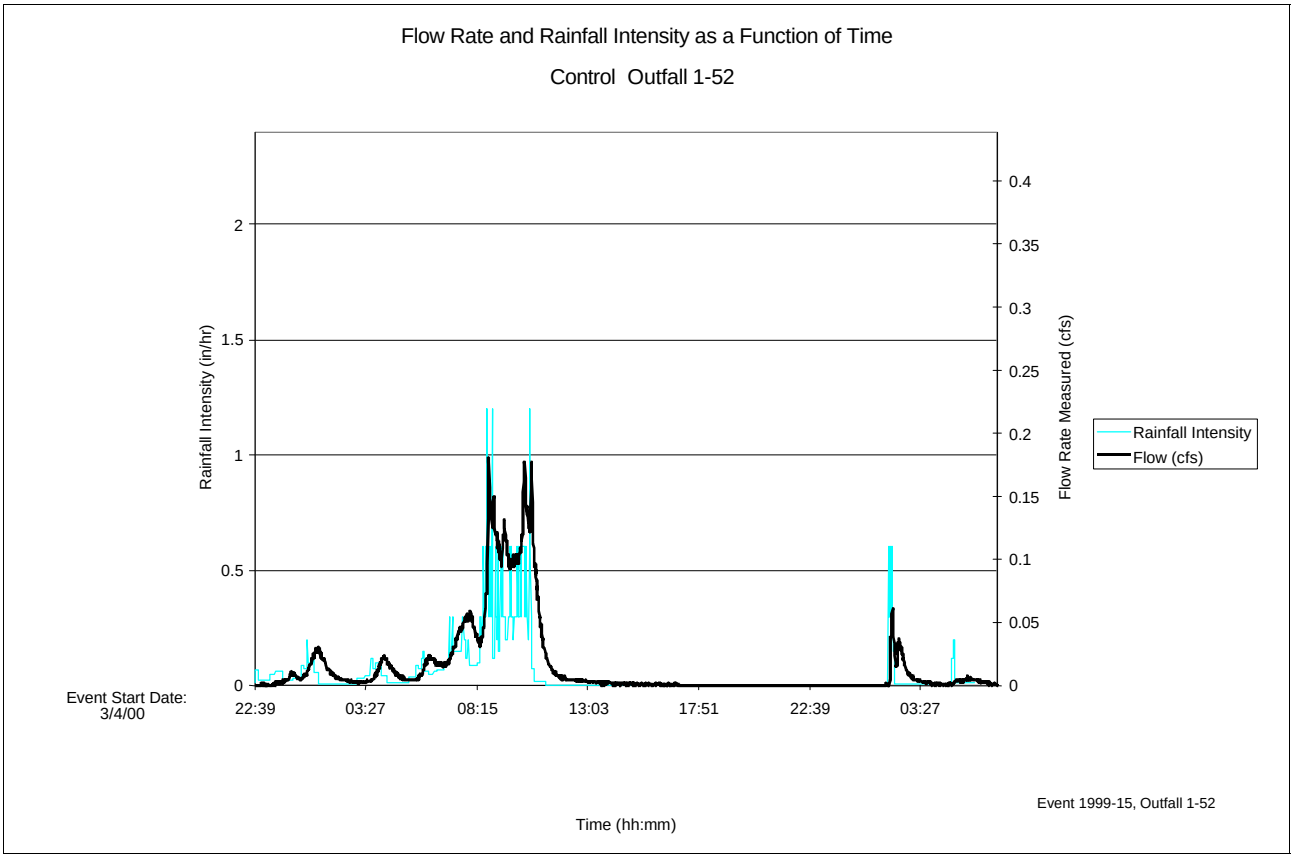


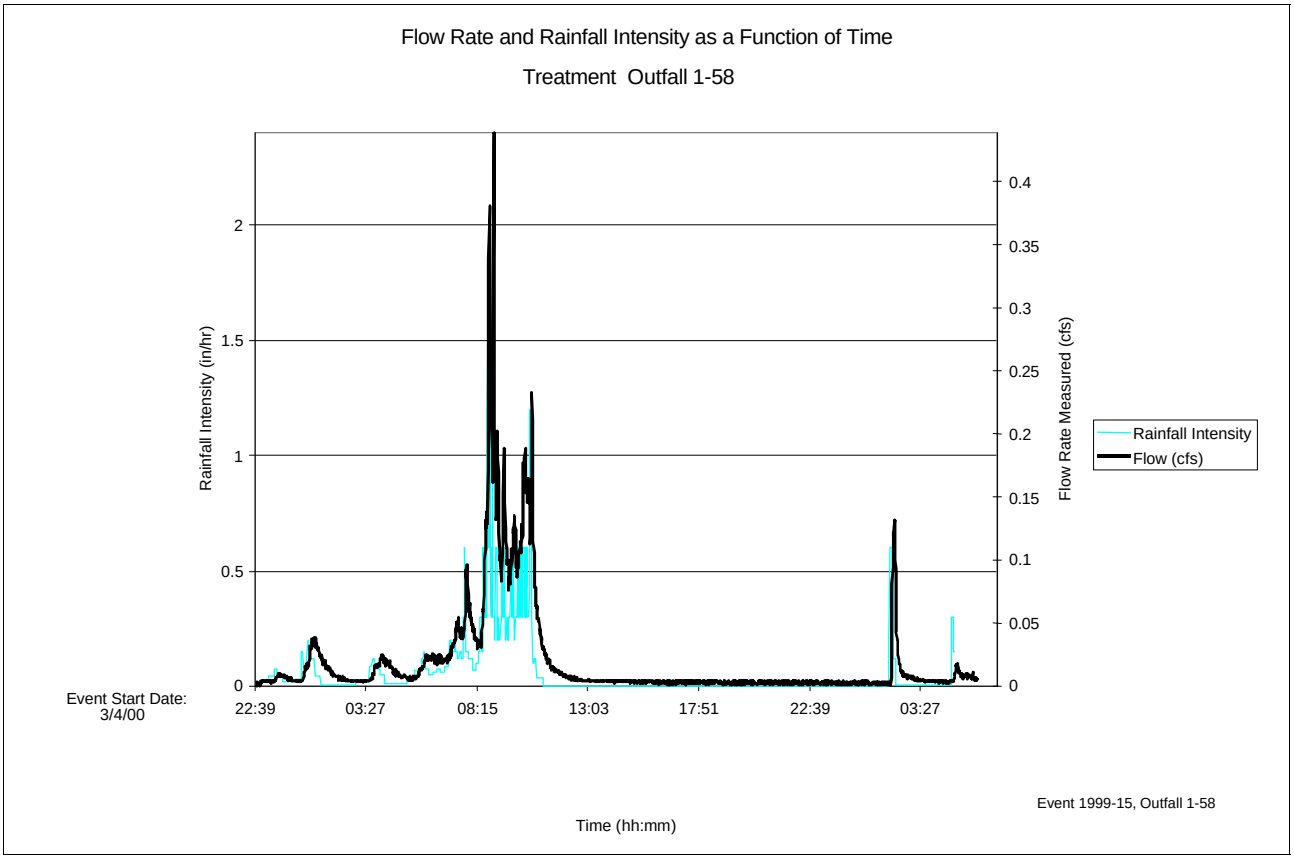
Site 1E - Litter Pickup Event No. 1999e15 - 3/4/00



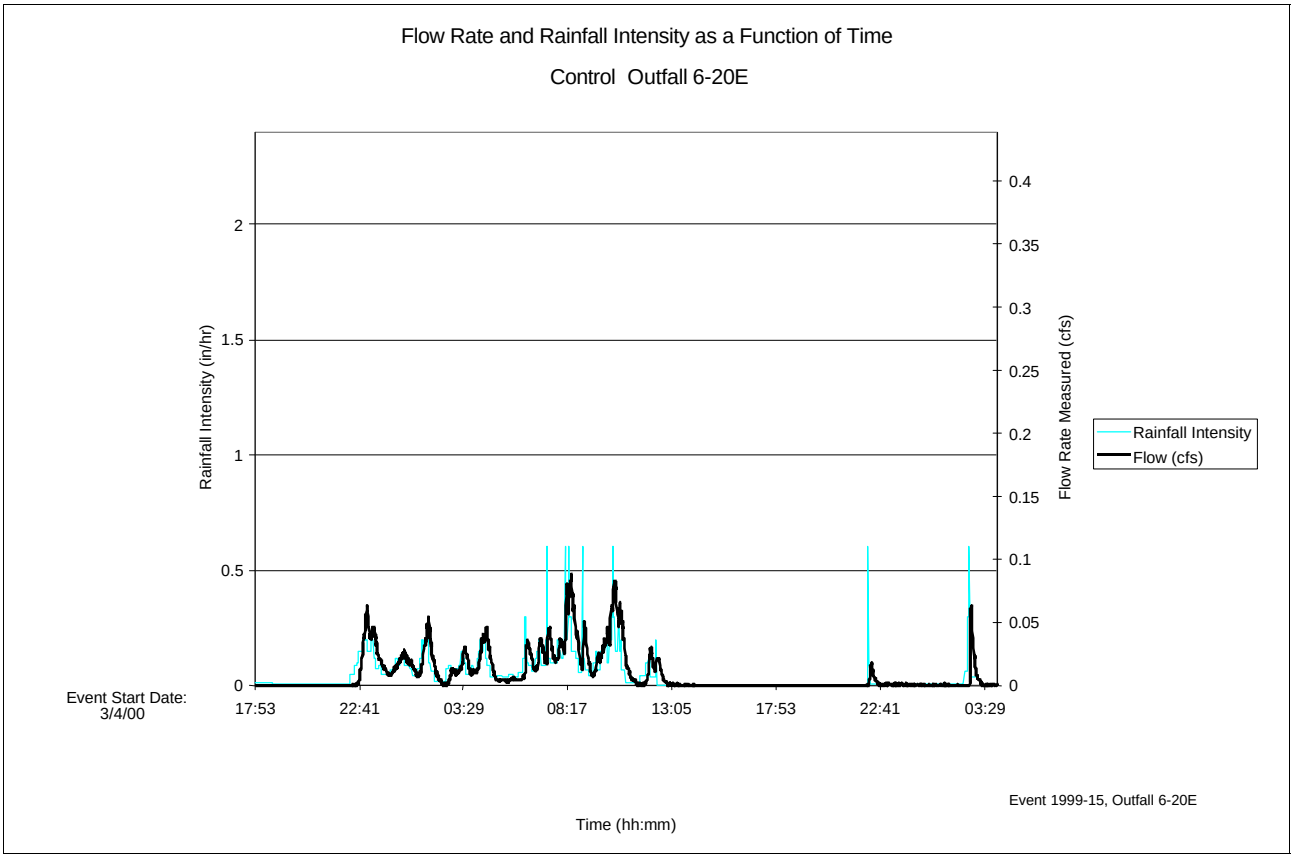


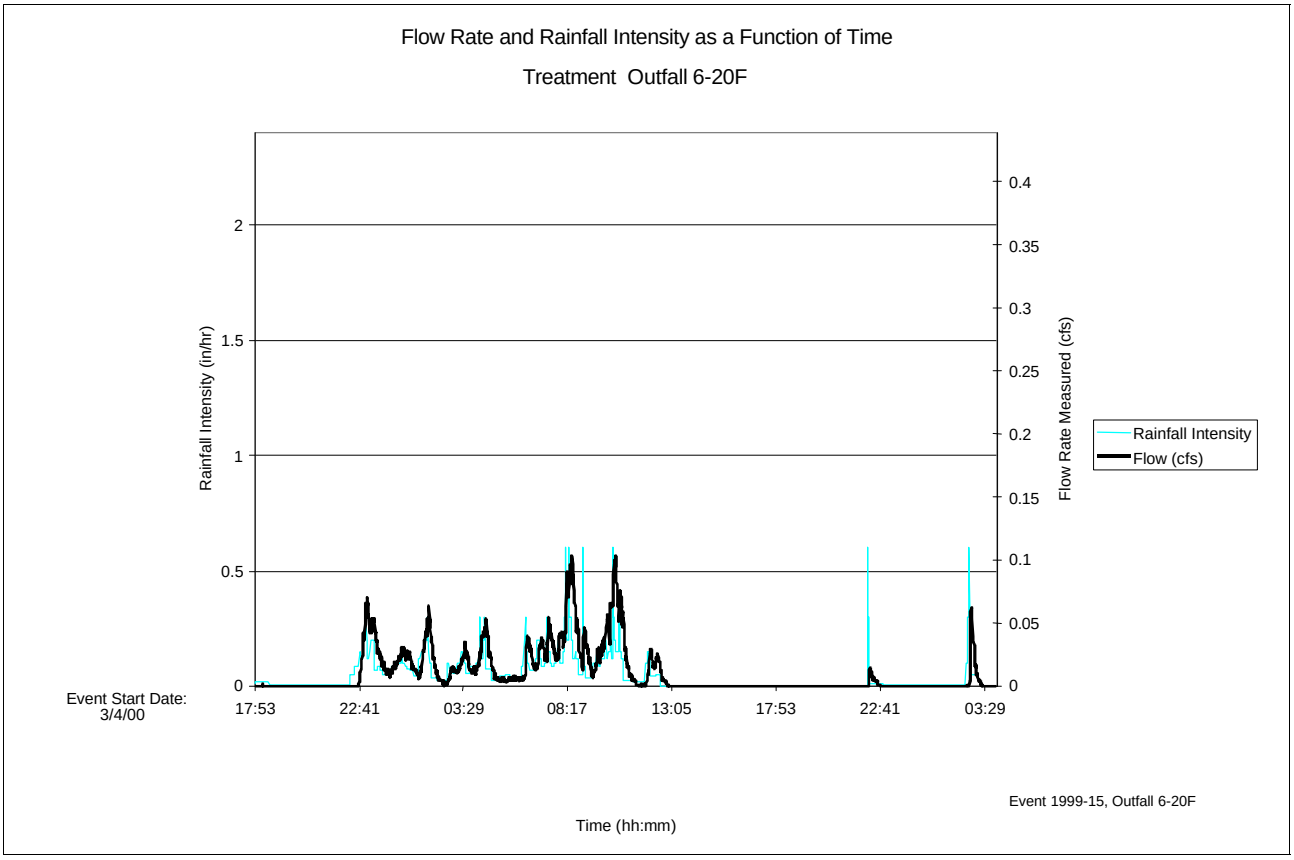
Site 1W - Street Sweeping Event No. 1999e15 - 3/4/00



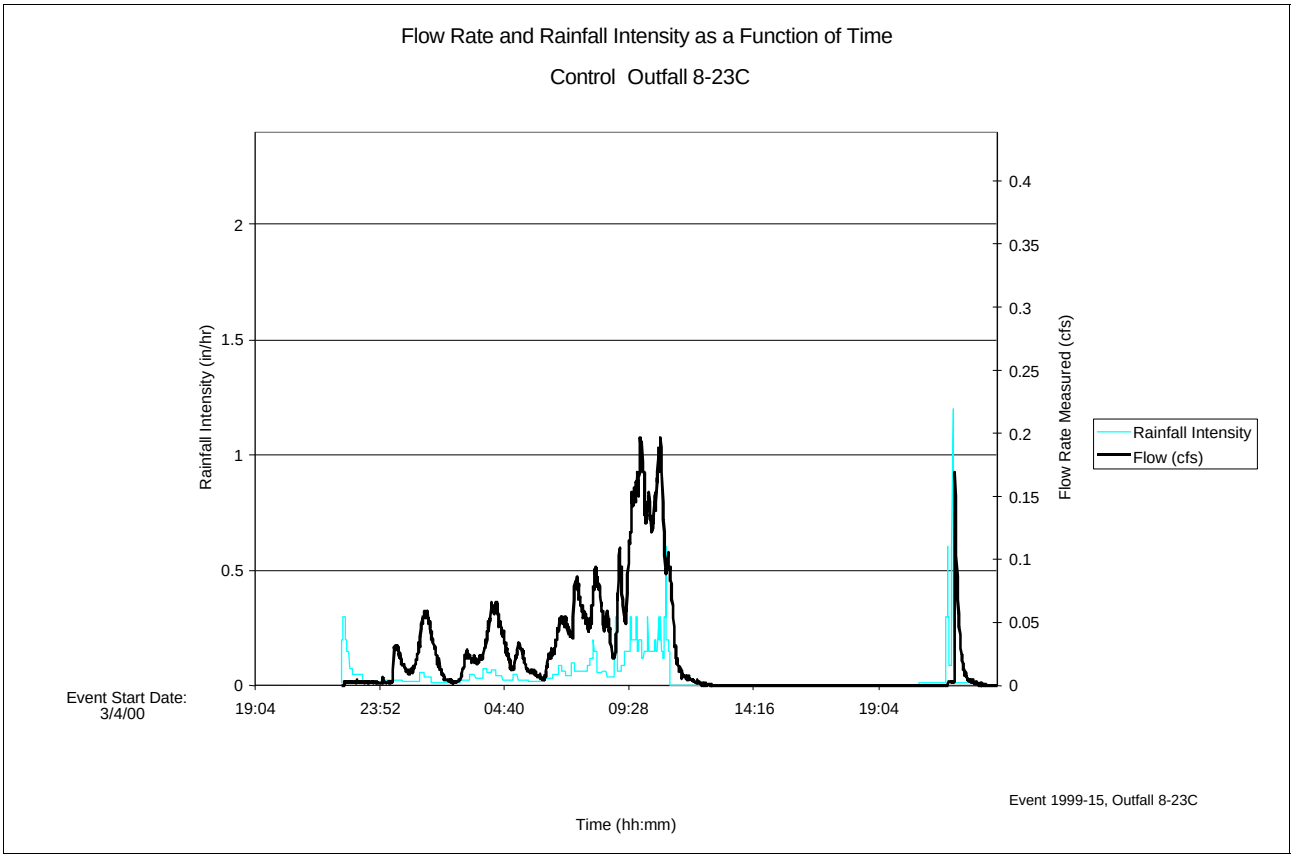


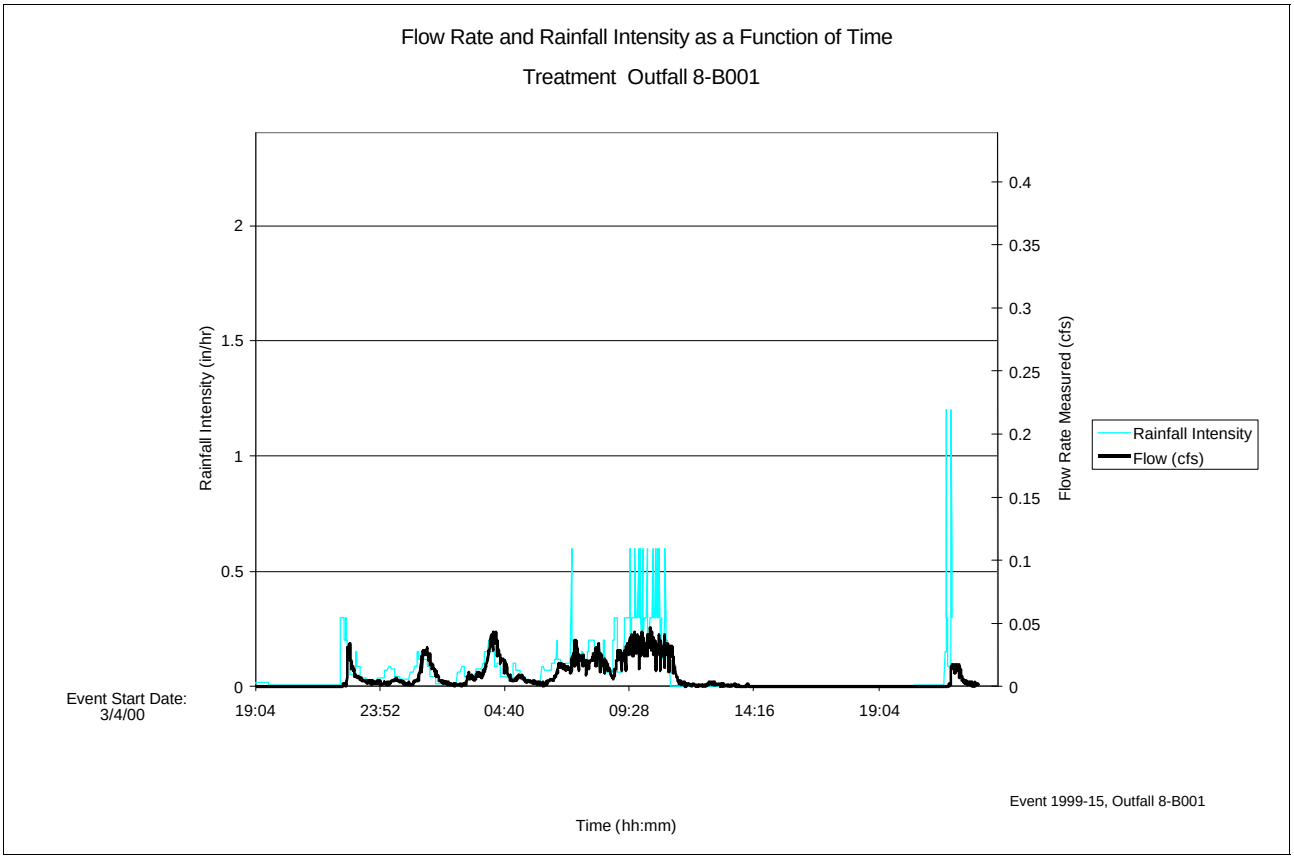
Site 6 - Modified Inlet Event No. 1999e15 - 3/4/00





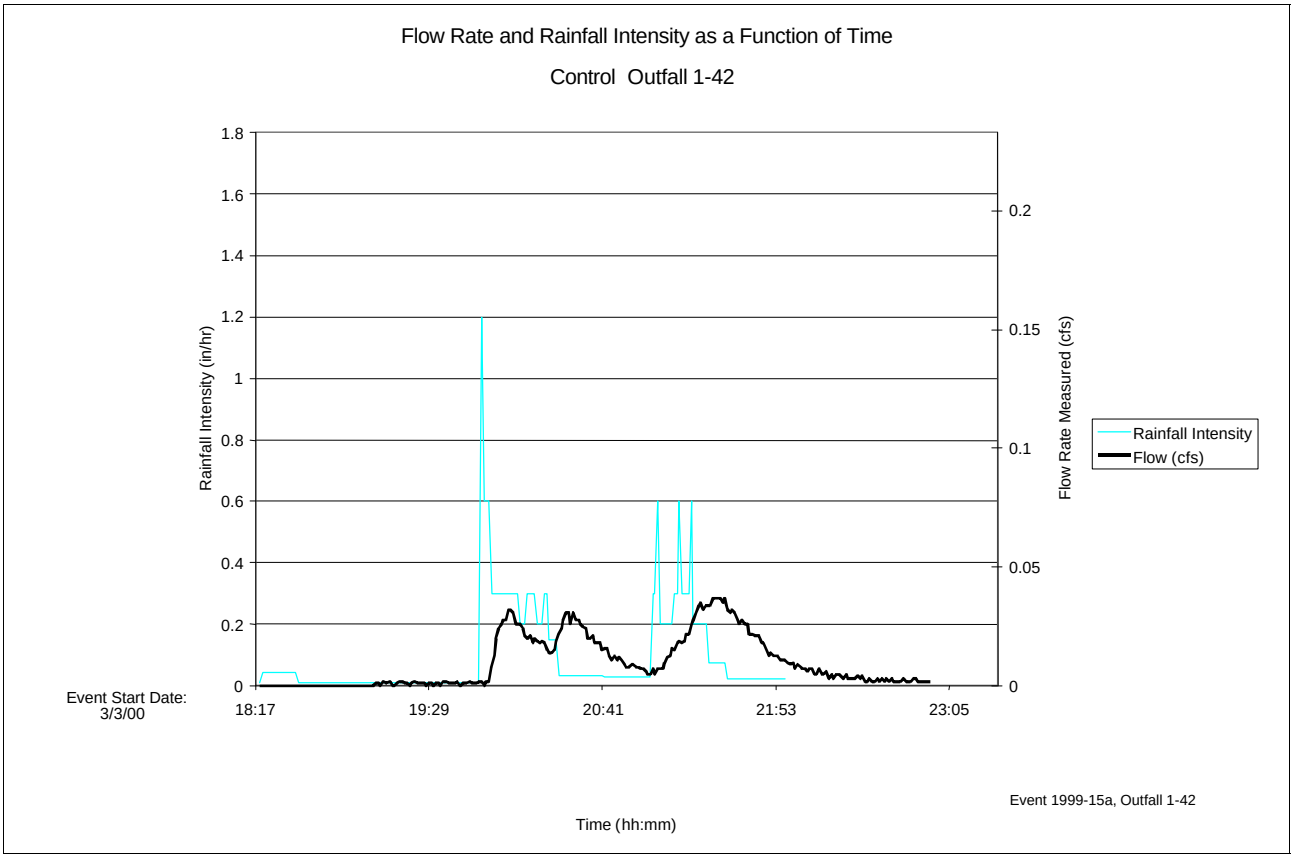
Site 8 - Bicycle Grate/LID Event No. 1999e15 - 3/4/00

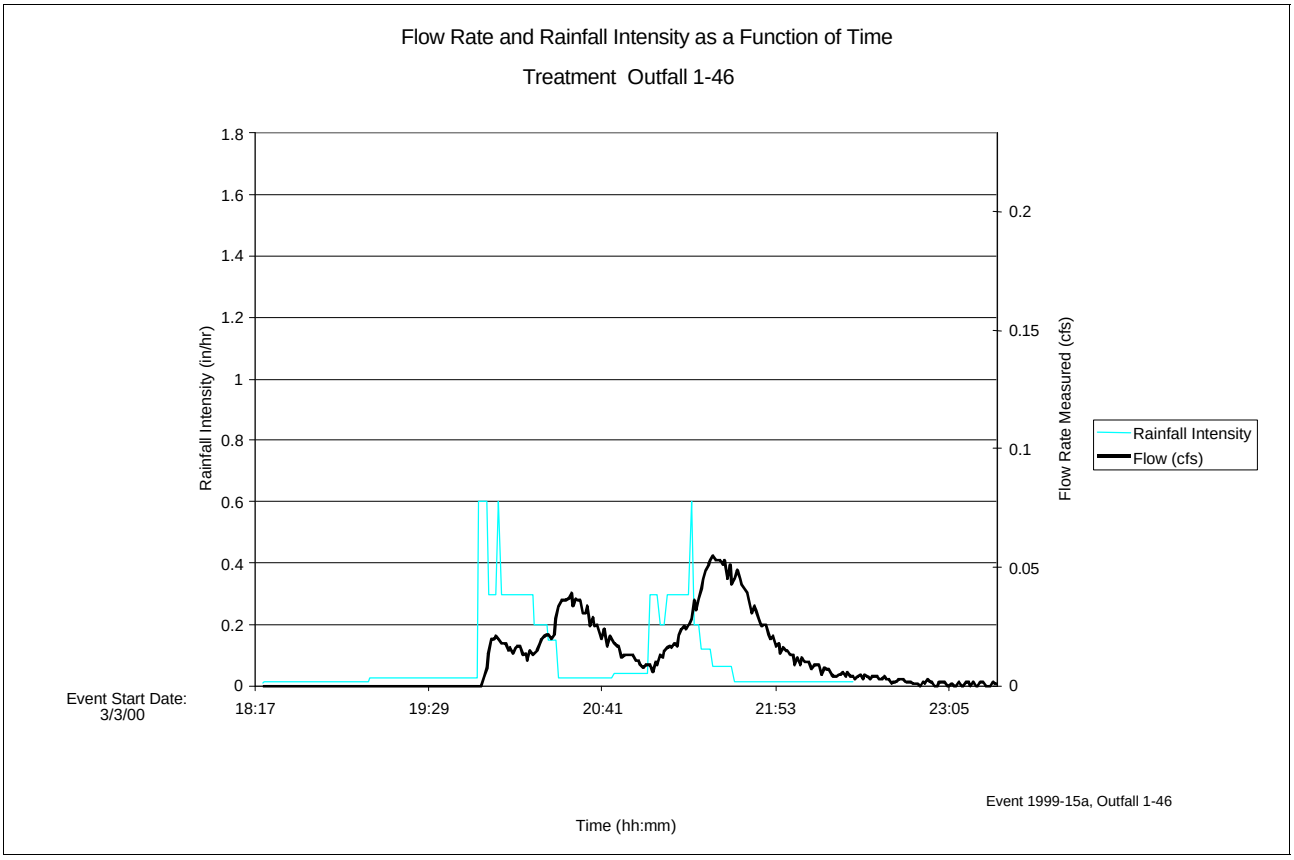




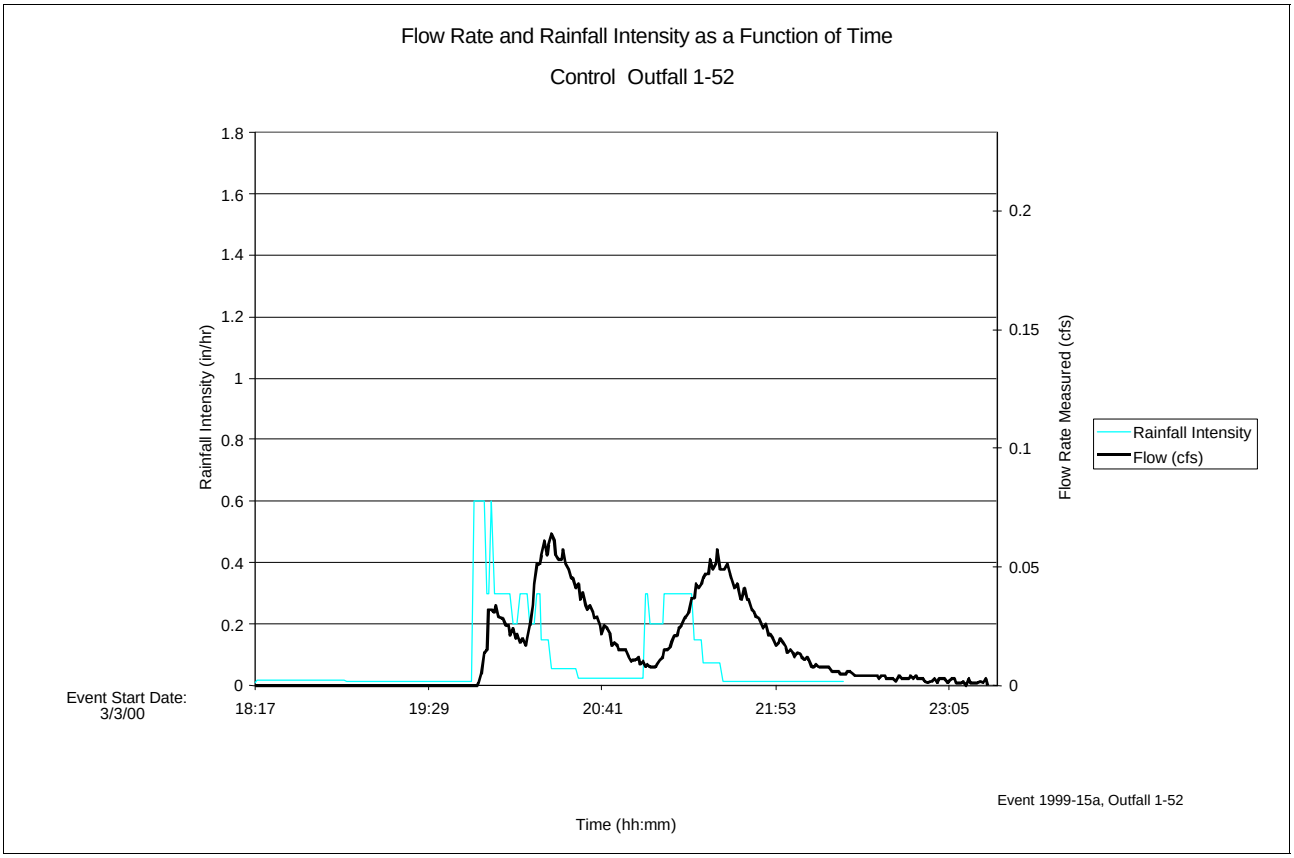
Site 1E - Litter Pickup

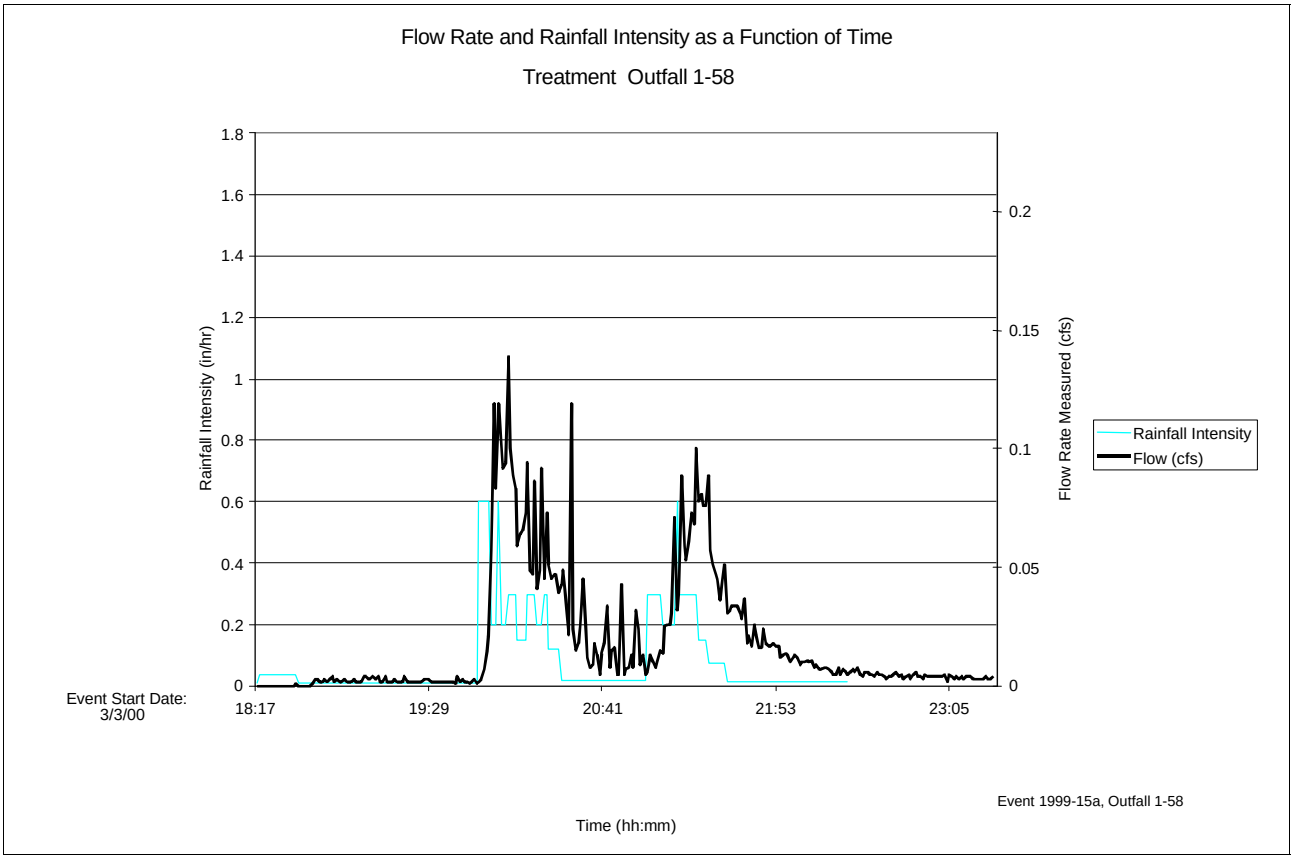
Event No. 1999e15a - 3/3/00



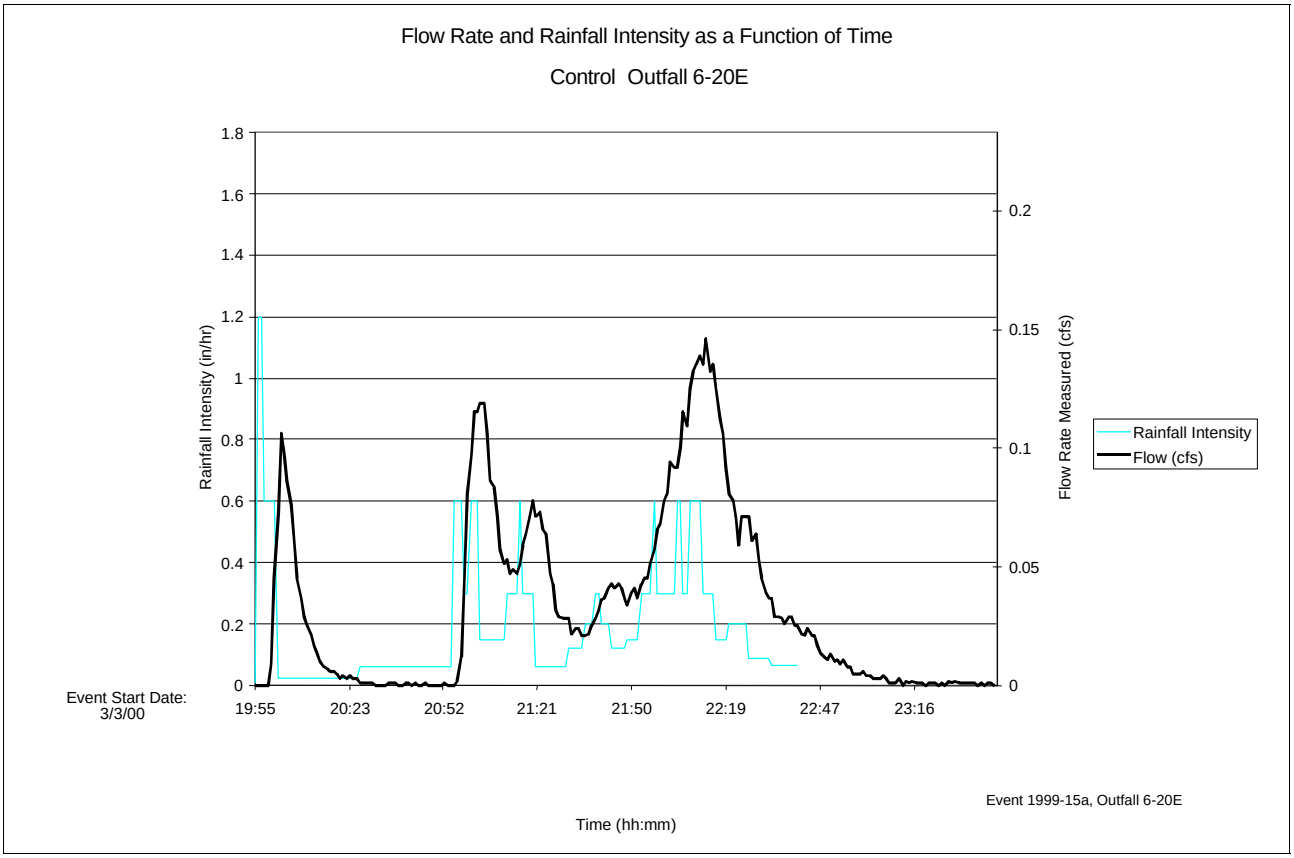


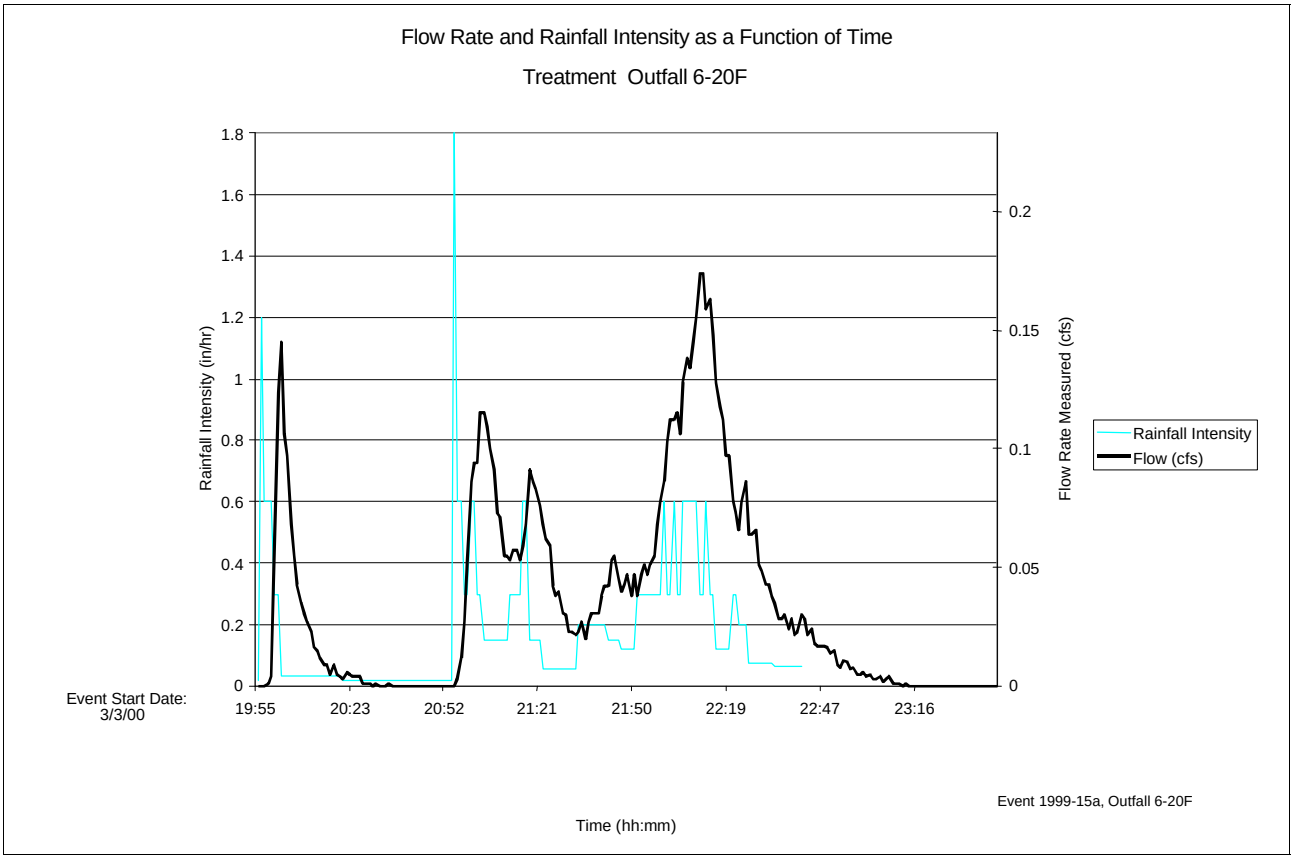
Site 1W - Street Sweeping Event No. 1999e15a - 3/3/00



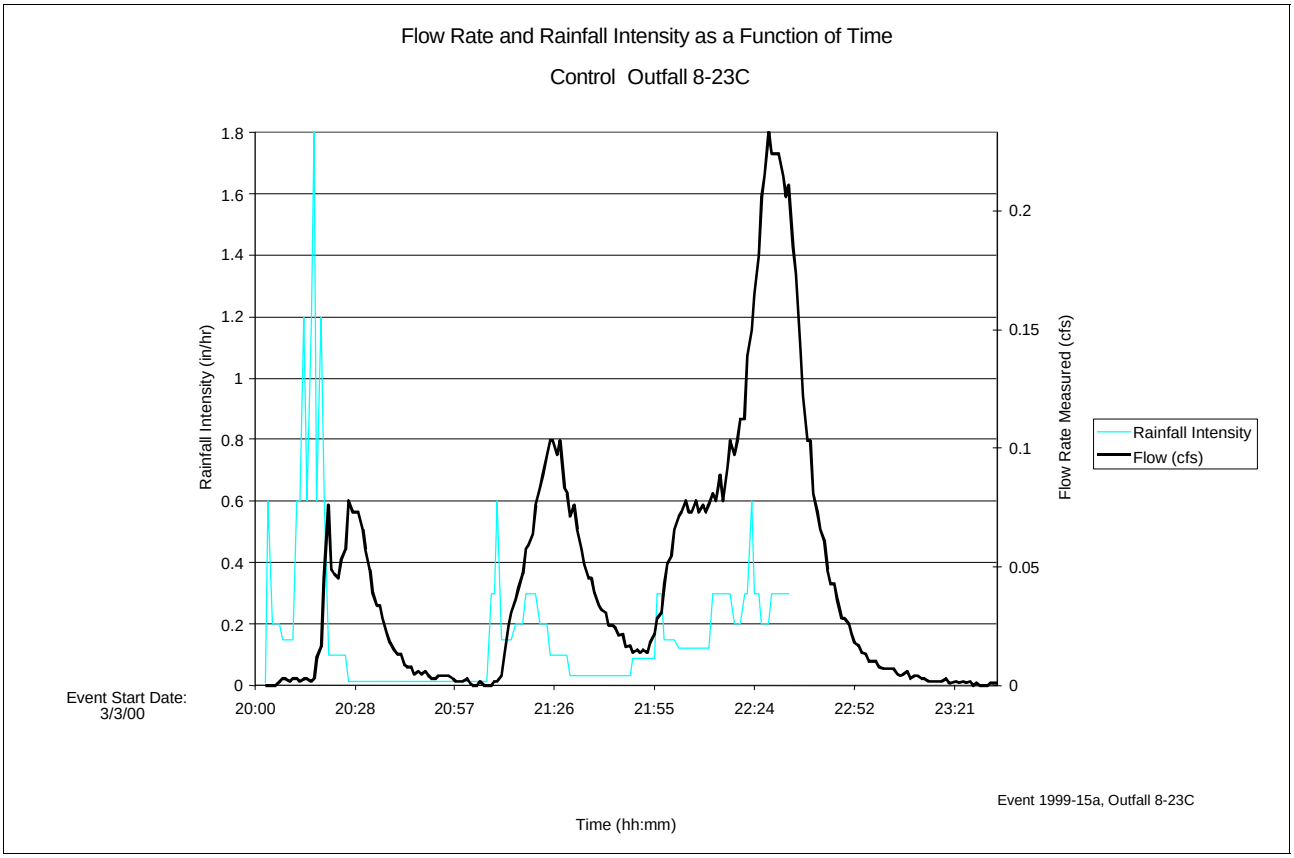


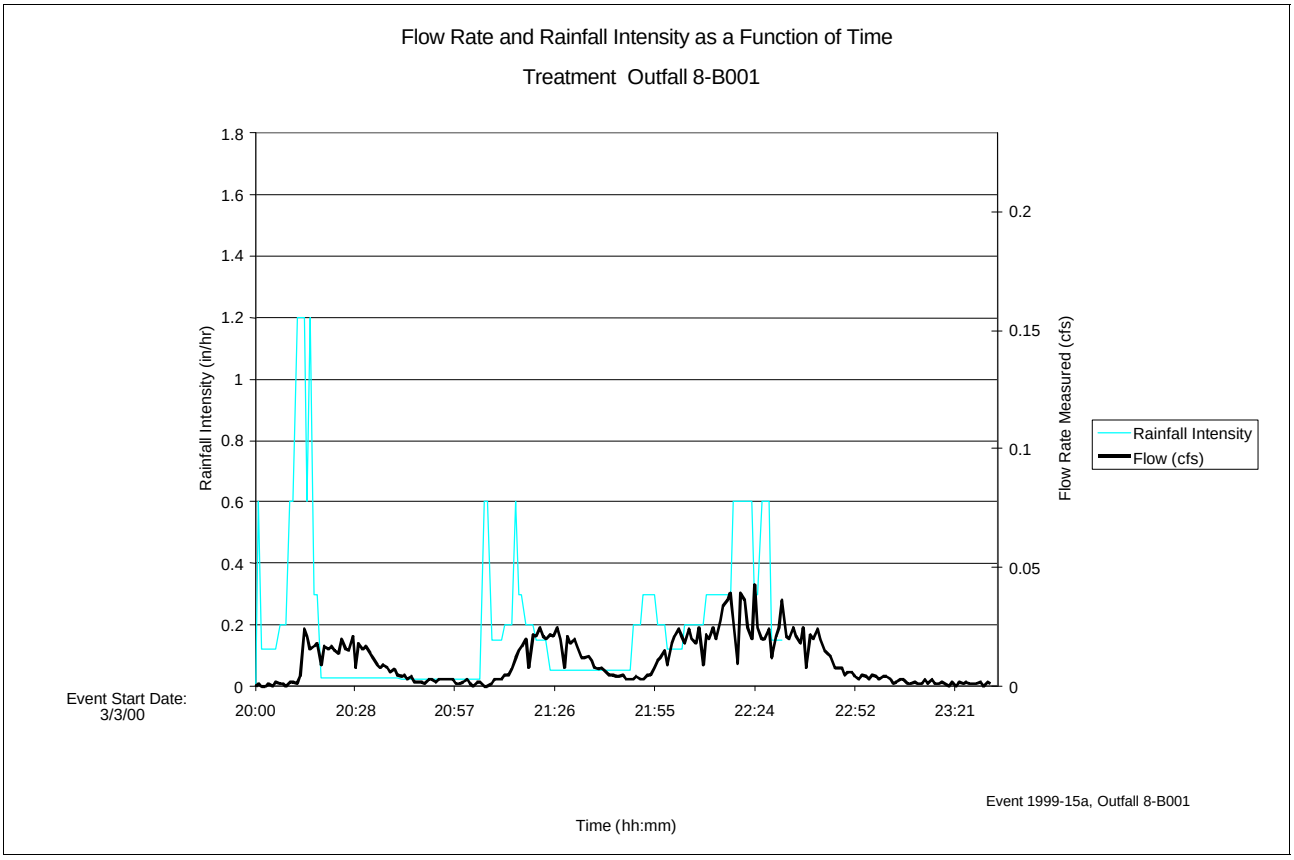
Site 6 - Modified Inlet Event No. 1999e15a - 3/3/00



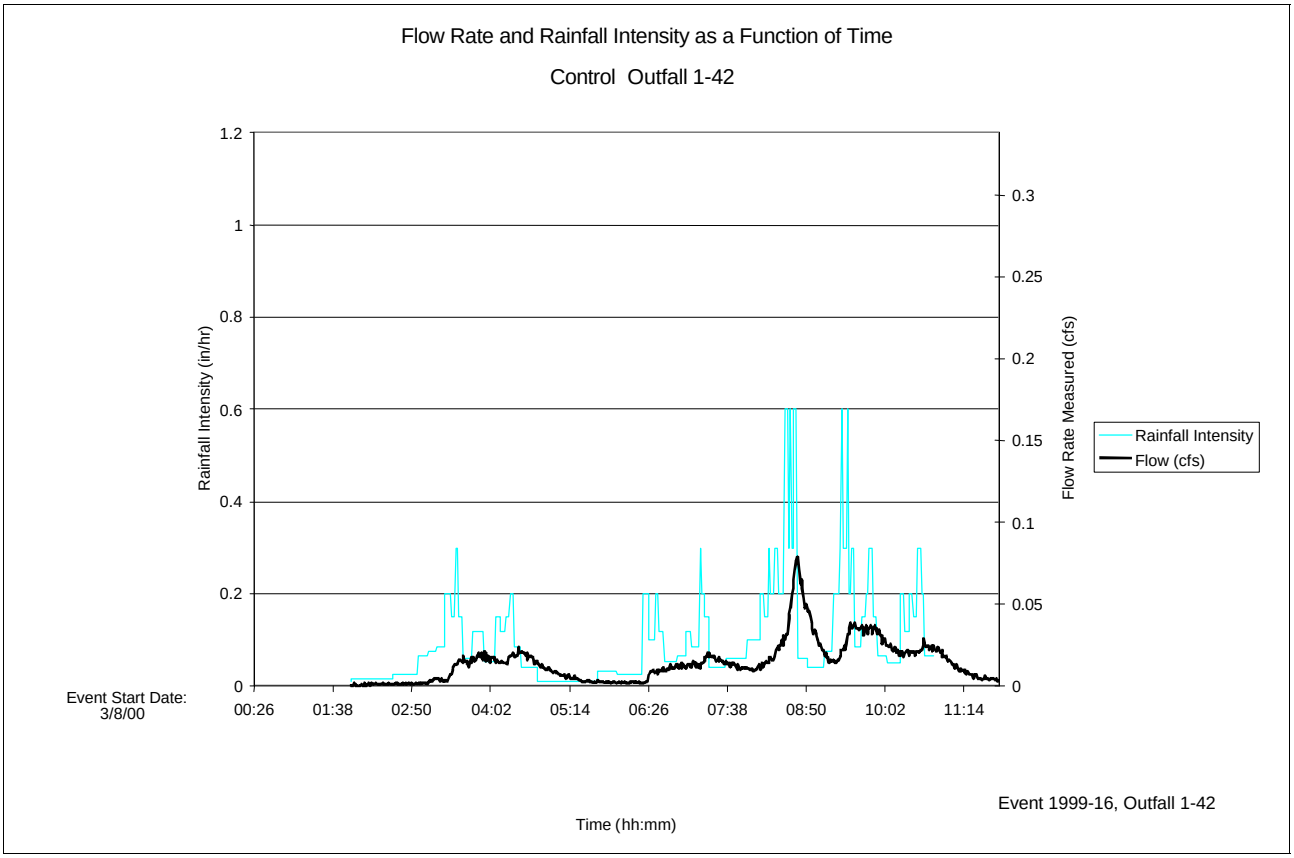


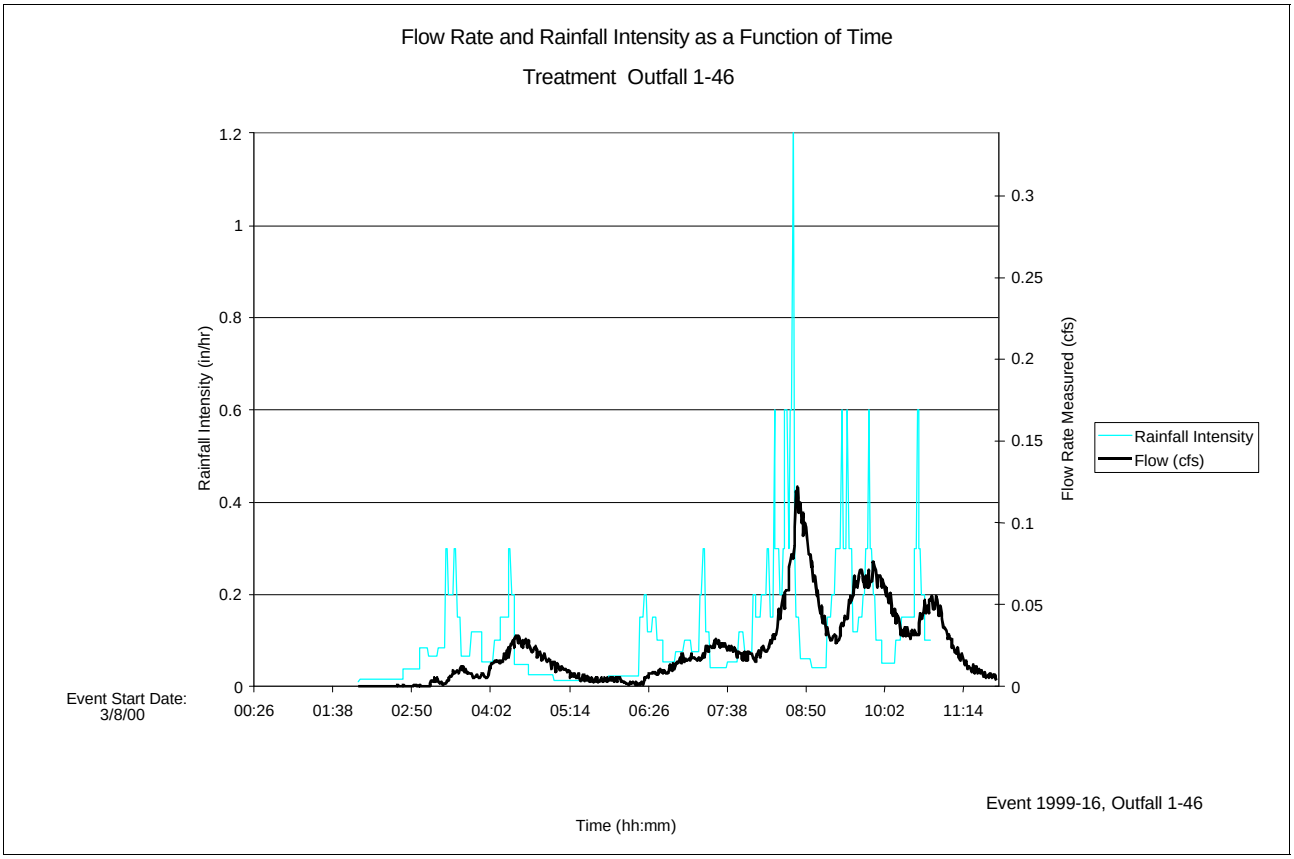
Site 8 - Bicycle Grate/LID Event No. 1999e15a - 3/3/00



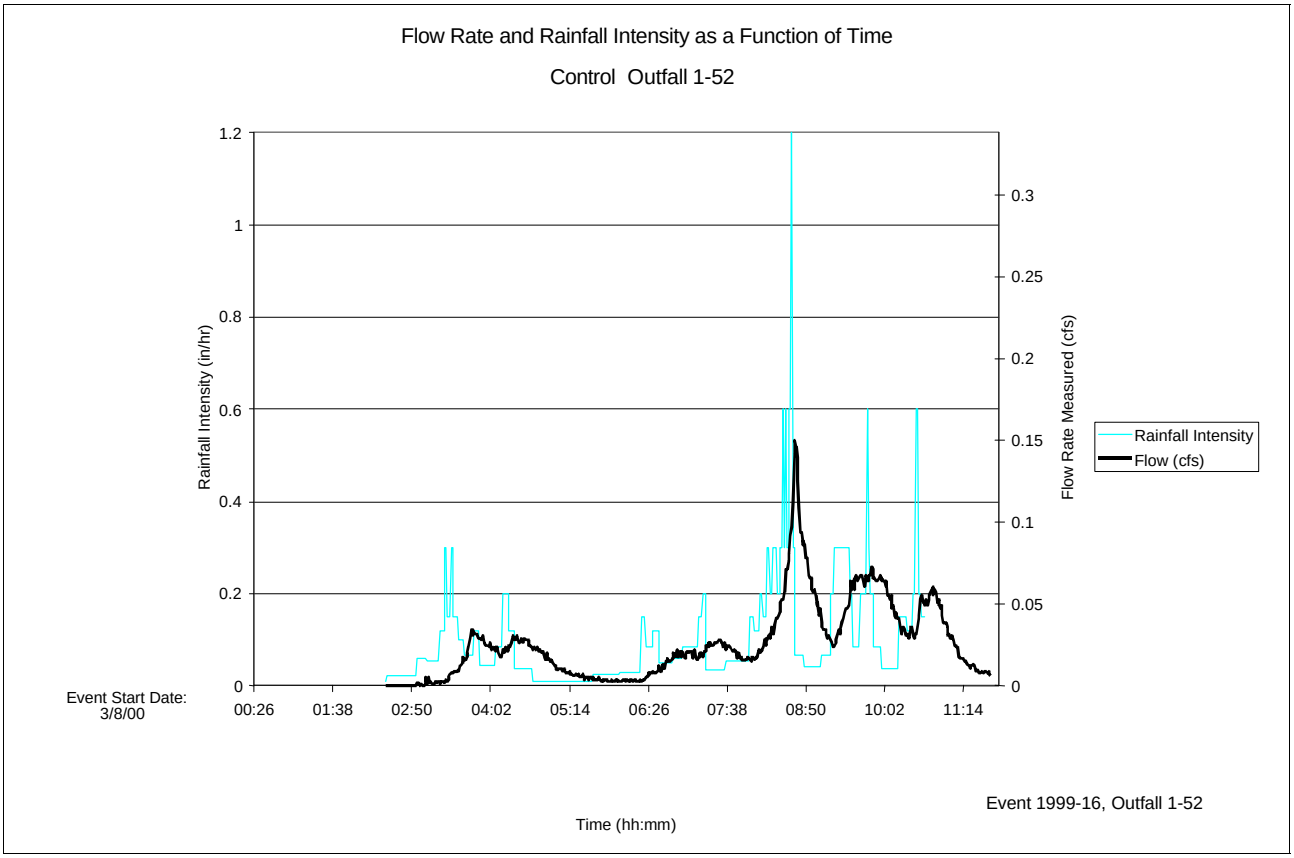


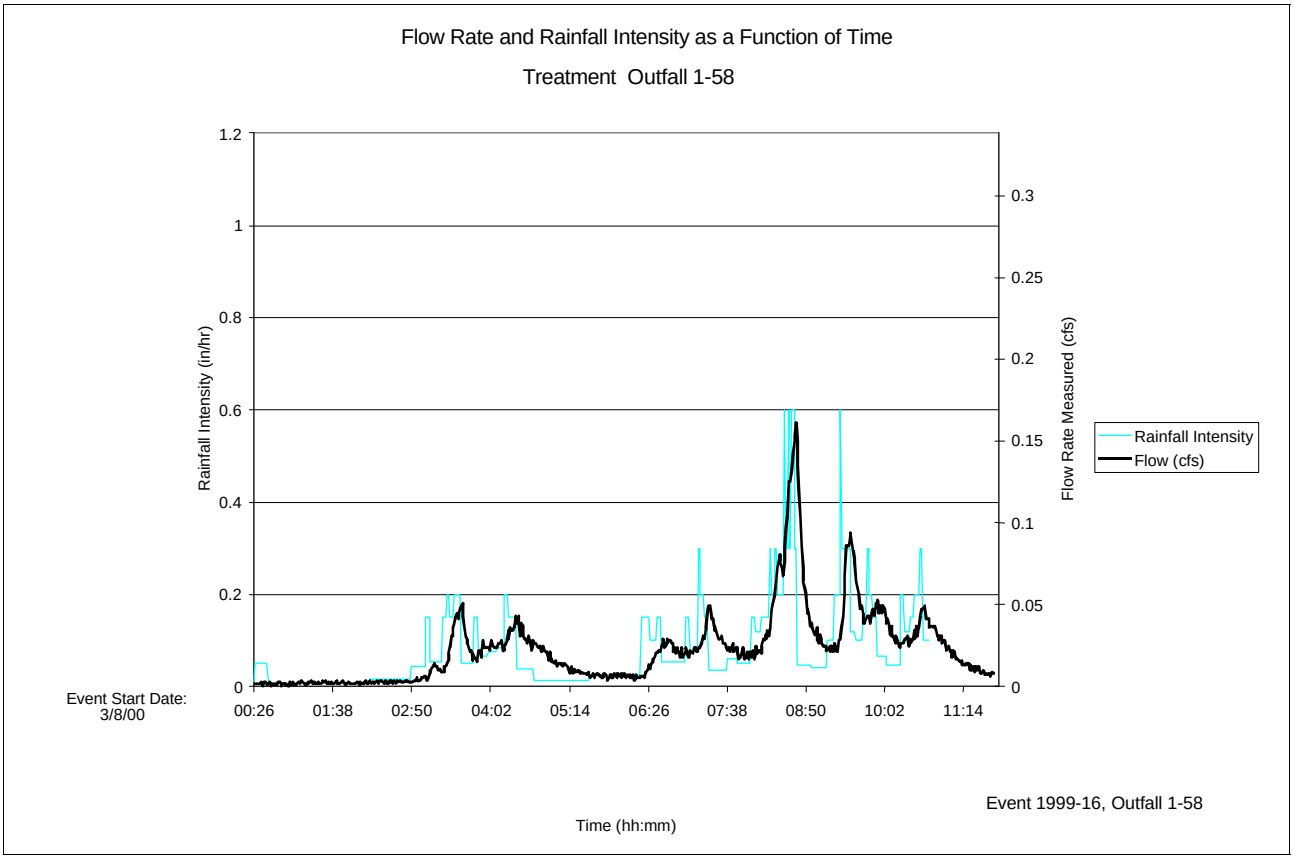
Site 1E - Litter Pickup Event No. 1999e16 - 3/8/00



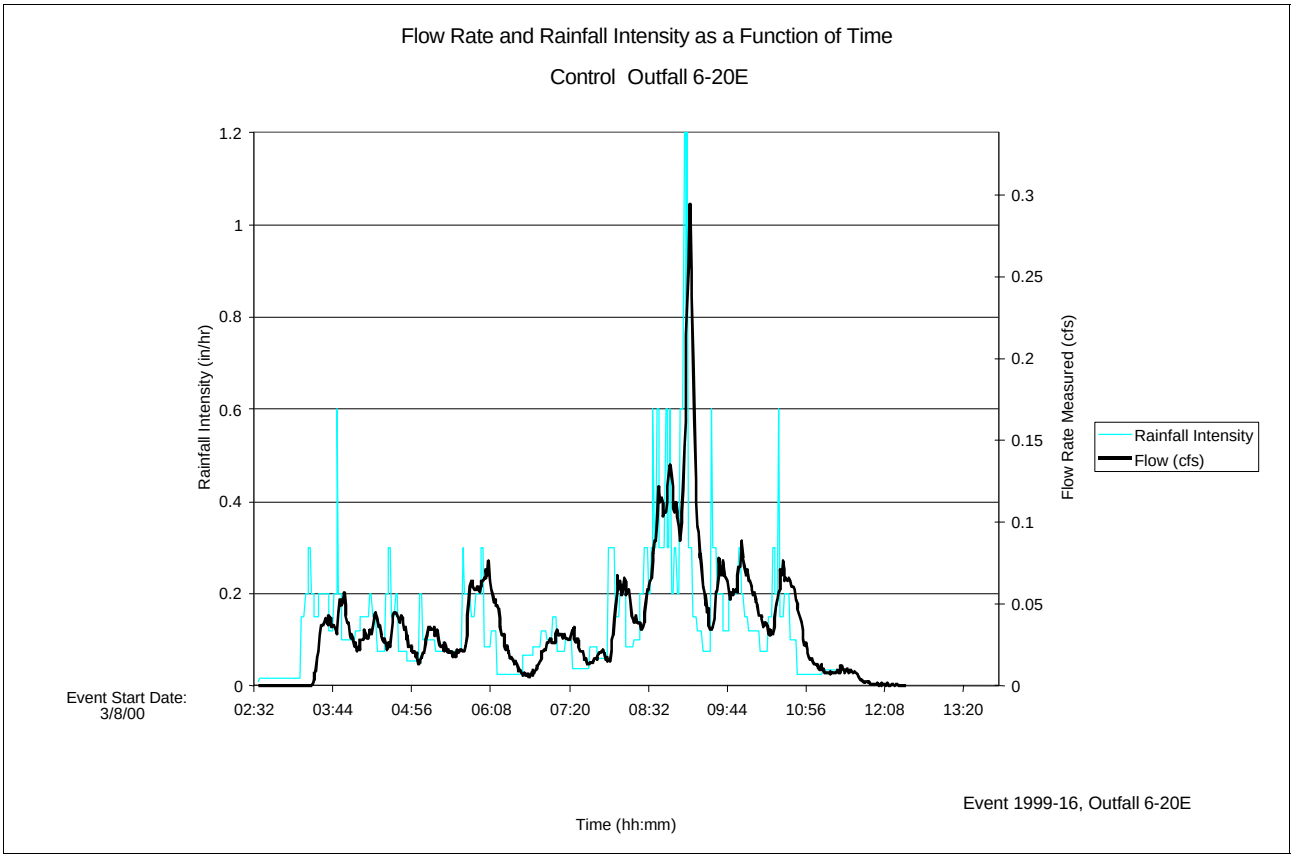


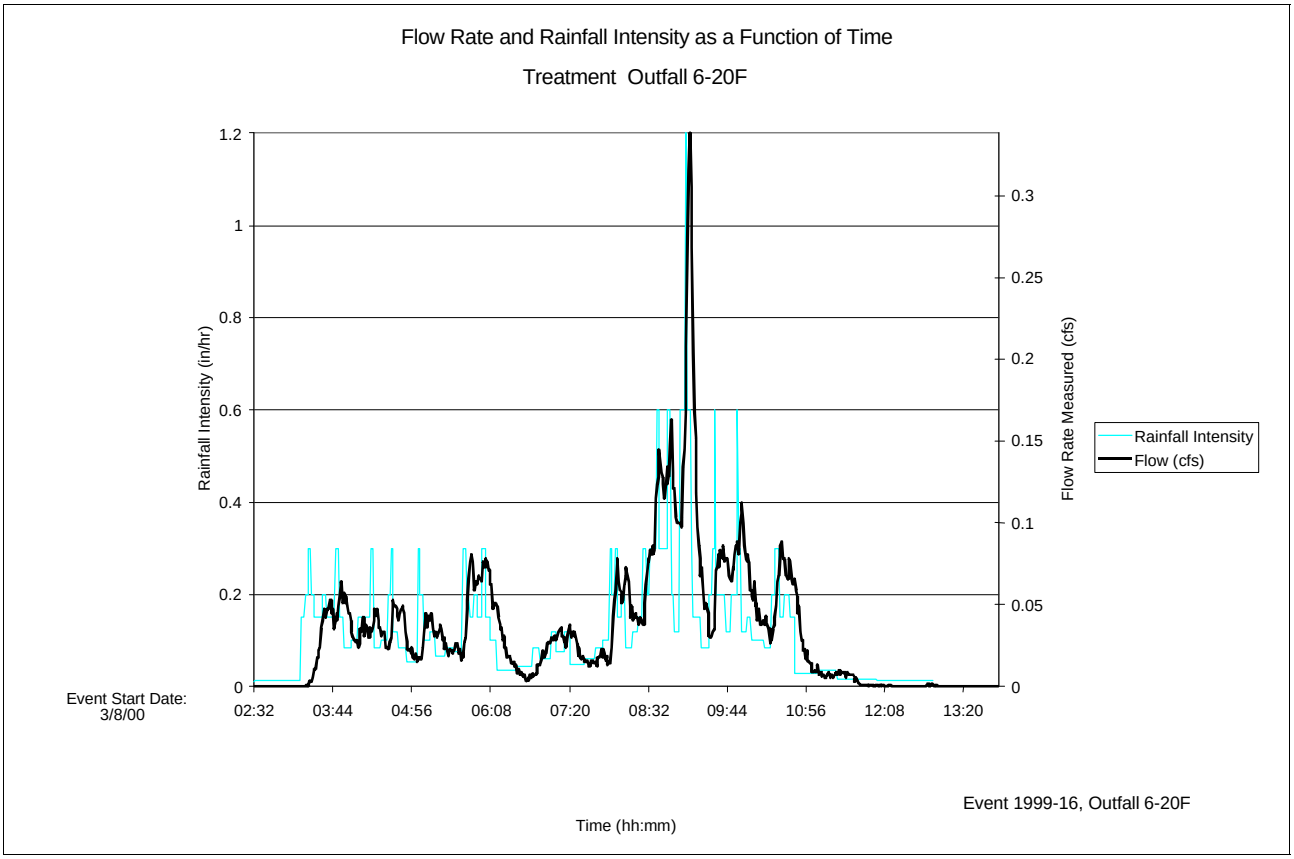
Site 1W - Street Sweeping Event No. 1999e16 - 3/8/00



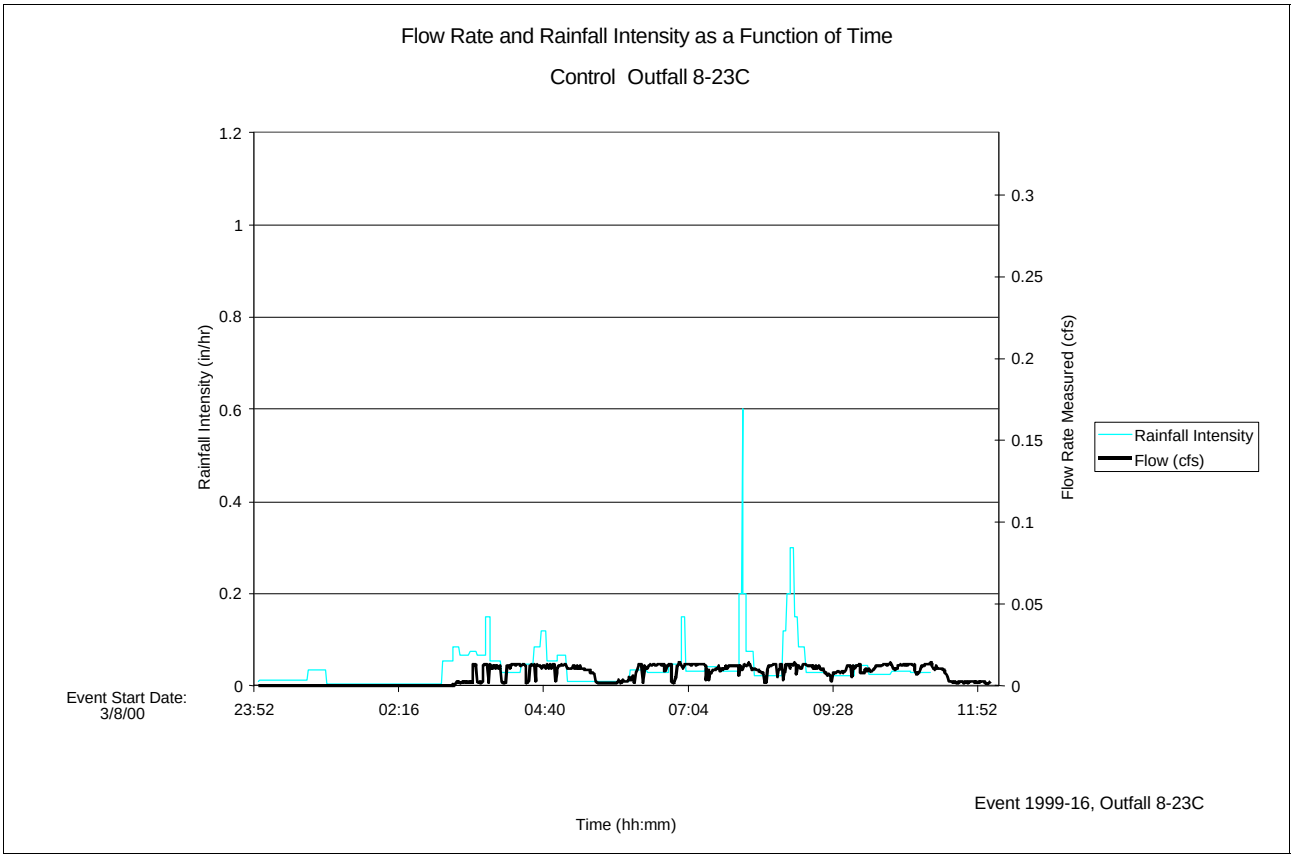


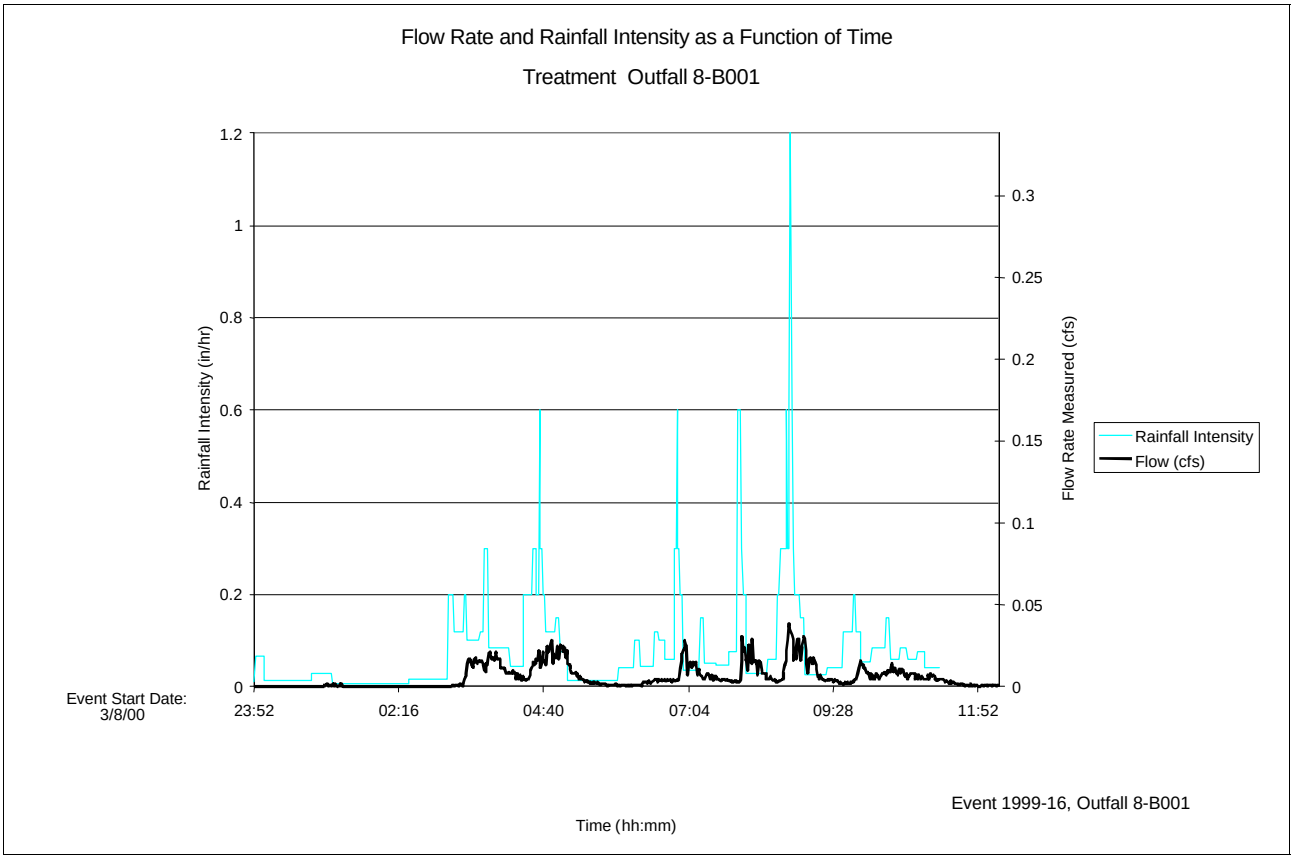
Site 6 - Modified Inlet Event No. 1999e16 - 3/8/00





Site 8 - Bicycle Grate/LID Event No. 1999e16 - 3/8/00





1.0 INTRODUCTION

This Standard Operating Procedure (SOP) applies to measuring solid mass accumulation at 24 drain inlets in conjunction with the Litter Management Pilot Study (LMPS). This SOP describes the schedule of implementation, site locations, procedures, necessary equipment, and the requirements of personnel performing the solids accumulation measurements. The intent of the inlet deposition monitoring is to evaluate seasonal fluctuations of solids within drain inlets.

2.0 SITE LOCATIONS

Inlet deposition monitoring will be performed at 24 inlets, 6 inlets at each of four LMPS sites. Directions to each site are provided in Attachment 1.

3.0 SCHEDULE

Inlet deposition monitoring will generally be performed at a frequency of once every four weeks from June through August 1999 and once every two weeks from September 1999 to April 2000. Projected dates of implementation are provided in Attachment 2. The schedule has been developed to account for holidays and not to conflict with the LMPS street sweeping schedule as the subcontractor (California Street Maintenance) uses the same barrier vehicle for both activities.

4.0 PROCEDURES

4.1 PREMOBILIZATION

- Identify the drain inlet to be monitored from Figures 2.1 through 2.4 for Sites 1E, 1W, 6, and 8 on the scheduled day.
- Collect and pack all required equipment, listed in Attachment 3 of this SOP, within the field vehicle.
- Verify the meeting time and location of the traffic control support vehicle (Truck Mounted Crash Cushion [TMCC]) and personnel.

TMCC Contact Information:
California Street Maintenance
Rick Anderson (626) 961-9326

4.2 MOBILIZATION

Drive to the Site as guided by the directions provided in Attachment 1.

Drain inlets are located on the highway shoulders (within the right of way). Inlets to be monitored have been labeled with the appropriate inlet identification number, red lines painted twenty feet before and after the inlet, and labels indicating “Do Not Clean” (in red paint). Upon arriving at a designated inlet, the field vehicle should pull forward past the inlet to the red spray

painted line and the TMCC should pull up to the red spray painted line prior to the inlet. The positioning of vehicles in this manner is intended to provide temporary protection from traffic. The TMCC should have the crash cushion in the proper horizontal configuration and the Flashing Arrow Sign (FAS) should indicate "caution" ahead during monitoring activities. At inlets where the field crew deems feasible, cones and a "Shoulder Work Ahead" sign should be placed behind the TMCC during monitoring activities.

Full shoulder closure is not required for "Short-Term Operations" (activities under 10 minutes) as defined in Caltrans Division of Maintenance manual (Chapter 8 – "Protection of Workers"). The inlet deposition monitoring falls under this definition but all relevant requirements, such as working near moving traffic and protective vehicles, within Caltrans Division of Maintenance manual (Chapter 8 – "Protection of Workers") must be followed.

4.3 MONITORING PROCEDURES

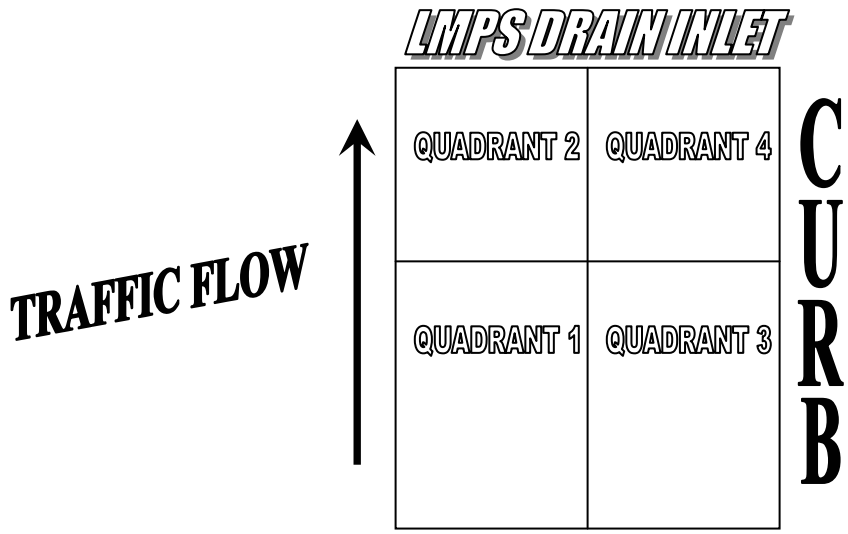
1. Confirm that the drain inlet is the correct one by locating its identification number. If no identification number can be found or if the number is different, contact the project coordinator (Ian Forrest (714) 648-2881) to confirm the location.
2. Clear debris from the top of the grate and in between the bars only as necessary to make measurements. Try to remove all matter including dried mud, tar, cement, and stones. Be careful to minimize the amount of soil and debris that is allowed to fall into the inlet.
3. Identify the 12 measurement stations marked in yellow on the grate. If the station points have worn off they must be replaced with the proper paint (see equipment list) at the designated distances from the pavement edge (origin), as identified within the "Inlet Deposition Monitoring – Initial Setup" forms located in Attachment 4.
4. Complete the "Inlet Deposition Monitoring Field Measurement and Observation" form (Attachment 5) which includes:
   - Date,
   - Field crew,
   - Inlet number,
   - Site Number,
   - Inlet description (Single Grate, Double Grate, etc.),
   - Description of inlet composition (described in Section 3.3.1),
   - Check list of pictures taken (e.g., inlet number with surrounding area and inlet number with contents),
   - Notes describing the physical properties of the inlet contents (e.g., vegetation type, litter types, and observations), and
   - Inlet deposition measurements (for each station as described in section 3.3.2).

4.3.1 Inlet Composition Estimates

Estimate the inlet composition of the accumulated solids by following the procedures below:

1. Divide the inlet bottom into four quadrants such that each area equals 25% of the total bottom area. Quadrant 1 should be located upstream of the traffic flow and next to the highway. Quadrant 2 should be downstream of traffic flow and next to Quadrant 1. Quadrant 3 should be behind Quadrant 1 and next to the curb. Quadrant 4 should be behind Quadrant 2 and next to the curb. See Figure 1 for a schematic of the proper quadrant delineation.

Figure 1 – Schematic of Quadrant Delineation



2. Estimate the percentage of concrete bottom, sediment, vegetation, and litter within each quadrant such that the sum of the four quadrants equals 100%. Moisture content should also be categorized in each quadrant as either dry, moist, or saturated.

4.3.2 Inlet Deposition Measurements

Uncompacted Depths

Starting at measuring Station 1 on the grate, insert the bottom of the measuring rod through the grate; always place the rod behind (toward the curb) the grate bar that is marked with the station number.

Use the spirit level to adjust the rod so it is vertical and slowly lower it down until it just touches the top of the accumulated solids or inlet bottom.

With the measuring rod plumb, just touching the accumulated solids or inlet bottom, take a depth reading, using the measuring tape mounted on the rod, from the top of the grate directly above the station number.

Record the depth to top of the accumulated solids on the line provided for “Uncompacted” depths at Station 1.

Compacted Depths

With the measuring rod plumb and just above the accumulated solids (as described above), allow the rod to press down on the solids. DO NOT push on the rod or add additional weight when performing the compacted measurement.

Using the measuring tape mounted on the rod, take a depth reading from the top if the grate to the top of compacted solids. Record the value on the line provided for "Compacted" depths for each station number.

Repeat the process of measuring and recording uncompacted and compacted depths at each of the 12 stations.

4.4 REQUIRED EQUIPMENT

The equipment list for inlet deposition monitoring is provided in Attachment 3.

4.5 QUALITY ASSURANCE

- Confirm the identity of each drain inlet that is visited.
- Assemble the measuring rod in a constant manner to ensure its actual length remains true to the gradations.
- Identify each monitoring station on the grate.
- Hold the measuring rod as vertical (plumb) as possible when measuring depths at each station.
- Lay a straight edge or ruler across the bars on the grate to gain a closer approximation of the depth of solids.
- Document the date, field crew, measurements, and observations in the proper location and form.
- Record the measurement from the measuring rod to the nearest hundredth of a foot (0.01 feet)
- Be sure that all photos contain the inlet identification number for reference.
- Reapply paint to the inlet identification number, measuring stations, and "Do Not Clean" sign and symbol as necessary. Do not allow the paint to completely wear off.

*Site 1 (105 Freeway) - Outfalls #60, #59, #58**

5 Freeway North or 57 Freeway North
91 Freeway West
605 Freeway North
105 Freeway West

Exit Long Beach Boulevard
Right on Long Beach Boulevard
Right at the first street (Mulford Ave.)
Right at first stop sign (look for church)
Proceed on Fernwood Ave. (east)
Park across the street from the perimeter fenced
monitoring equipment (nearest cross street is Muriel Dr.)
Enter Caltrans gate

*Water quality monitoring outfall

*Site 1 (105 Freeway) - Outfalls #50, #51, #52**

(Same as above)

Proceed on Fernwood Ave (east)
Park across street on Fernwood Ave (nearest cross street is Elm St.)
Walk across Fernwood Ave
Enter Caltrans gate

*Water quality monitoring outfall

Site 1 (105 Freeway) - Outfalls #47, #46, #44*

(Same as above)

Proceed on Fernwood Ave (east)
Right on Atlantic Blvd.
Right on Josephine St. (KFC Restaurant on corner)
Right on Second St.

Outfall #46 is at end of cul-de-sac (Second St.) surrounded by perimeter fencing
Enter Caltrans gate
Walk 200 feet east to reach Outfall #47
Walk 400 feet west to reach Outfall #44

*Water quality monitoring outfall

Site 1 (105 Freeway) - Outfalls #42, #B111, #B110*

(Same as before)

Back on Second Street (south)
Right on Josephine St. (KFC Restaurant on corner), proceed west
Right on Thorsen (cul-de-sac)

Outfall #42 is located 100 feet west from the Caltrans gate
Walk 150 feet west of Outfall #42 to reach Outfall #B111
Walk 150 feet west of Outfall #B111 to reach Outfall #B110 (Outfall #B110 can also be accessed through Caltrans gate located at Muriel Dr. & Louise St.)

*Water quality monitoring outfall

Site 6 (60 Freeway) - Outfalls #20B and #20C

5 Freeway North
57 Freeway North
60 Freeway West

Exit Hacienda Blvd.
Left on Hacienda Blvd.
Right at Three Palms
Proceed straight at stop sign
Right at Kwis Ave
Park at cul-de-sac
Enter through Caltrans gate
Proceed west along crushed stone path for 150 feet to reach Outfall #20B
Proceed west beyond Outfall #20B for 250 feet to reach Outfall #20C

Site 6 (60 Freeway) - Outfalls #20H, #20G, 20F, 20E**

(same as before)
If proceeding from at Kwis Ave cul-de-sac, proceed
south on Kwis Ave
Right at Los Robles
Right on Turnbull Canyon Rd., proceed north
Open side gate of Los Altos High School Parking area
(located across street from St. John's church)
Park in parking lot (close gate after driving vehicle through gate)
Walk 150 feet to gate
Outfall #20H and Outfall #20G are 300 feet from each other
Proceed 250 feet east along Caltrans right-of-way fence
Outfall #20F is surrounded by perimeter fencing
Outfall #20E is 250 feet east of Outfall #20F

***** Water quality monitoring outfalls

Site 8 (60 Freeway) - Outfalls #23C and #B001**

These outfalls drain the 60 Fwy (west) lanes)

5 Freeway North
57 Freeway North
60 Freeway West

Exit Wilcox/Garfield Ave
Proceed straight along W. Pomona Way (one way street)
Pass Wilcox Ave intersection
Park along right side of road midway between Wilcox Ave and Garfield Ave
Enter Caltrans gate
Walk 100 feet east to reach Outfall #23C

For Access to Outfall #B001 (located on corner of W. Pomona Way/Garfield)
Proceed along W. Pomona Way (west) until before Garfield Ave
Park across the street from the perimeter fencing
Enter through the Caltrans gate to reach Outfall #B001

* Water quality monitoring outfalls

Site 8 (60 Freeway) - Outfalls #24B, #24D, #24E and #24F

Outfalls are along the right-of-way along the 60 Fwy (east)

From Outfall #B001
Proceed straight in west direction along W. Pomona Way
Turn left at Garfield Ave
Turn left on Via Campo
Park at the East West Bank on the right side along Via Campo
Walk across the street to Caltrans right-of-way gate
Proceed left (west) within the Caltrans right-of-way fence
Outfall #24B is located near the intersection of Via Campo/Garfield
Proceed east to reach Outfall #24D
Proceed further east to reach Outfall #24E
Exit Caltrans gate
Walk across the intersection to the northeast corner of Wilcox Ave. and Via Campo
Enter the Caltrans gate to reach Outfall #24F (located around the corner intersection)

INLET DEPOSITION MONITORING TENTATIVE SCHEDULE

Month	Tuesday (Scheduled Day)	Wednesday (Contingency Day)
June	1	2
June	29	30
July	27	28
August	24	25
September	7	8
September	21	22
October	5	6
October	19	20
November	2	3
November	16	17
November	30	
December		1
December	14	15
December	27 (Mon)	28 (Tues)
January	11	12
January	25	26
February	8	9
February	22	23
March	7	8
March	21	22

INLET DEPOSITION MONITORING EQUIPMENT CHECKLIST

FIELD/SPECIALTY BOX

____ pH/Conductivity Meter (1)
____ Temperature Meter (1)
____ Keys for Caltrans gates & enclosures (1 set)
____ Pens/Pencils (3)
_____ Sigma Sampler and Flow Meter Manuals (1)
____ Health & Safety Plan (1)
____ Encroachment Permit (1)
____ Pepper Spray (1)
____ Leather Gloves (2 pairs)
____ Latex Gloves (8 pairs; some medium & large)
____ Paper Towels (1 roll)
____ Ziploc Bags (1 box)
____ Solvex (green) Gloves (2 pairs)
____ Duct Tape (1 roll)
____ First Aid Kit (1)
____ Flashlight w/ extra batteries (2)
____ Hard-hat Headlamps w/good batteries (2)
_____ Extra Straps (REI straps) (2)
_____ Disposal Camera (1)
_____ Trash Bags for waste pick-up (2)
_____ Masks (2)
_____ Goggles (1)
_____ Fire Extinguisher (1)

SAFETY/TRAFFIC EQUIPMENT

_____ Cellular Telephone (1)
_____ Hard Hat for each Crew Member
_____ Traffic Safety Vests
_____ Safety Boots (with Steel Toes)
____ 6 Traffic Cones (24")
_____ "Shoulder Work Ahead" Sign

INLET DEPOSITION MONITORING EQUIPMENT

_____ Standard Operating Procedures
_____ Measuring Rod
_____ Inlet Deposition Monitoring Forms (28)
_____ Three Rolls of 24 Exposure Film
_____ Camera (or Three Disposable Cameras) With Flash

OTHER

_____ Markal Ball Paint Marker (for grate stations)
_____ White & Red Spray Paint (for remarking LMPS inlets)

Note: If any non-reusable items are used, replace the item at the end of the workday. The Field/ Specialty Box is also used for storm water sampling therefore items may be needed in a moments notice during the "Rain Season". If any items are missing, restock and if item is out of stock please let the coordinator know for purchasing.

Signature_____ Date _____ Time: _____

URSGWC – Caltrans Litter Management Pilot Study

Inlet Deposition Monitoring - Initial Set Up

Date: 5/13/1999 Field Crew: AY/HR/TL/NJ

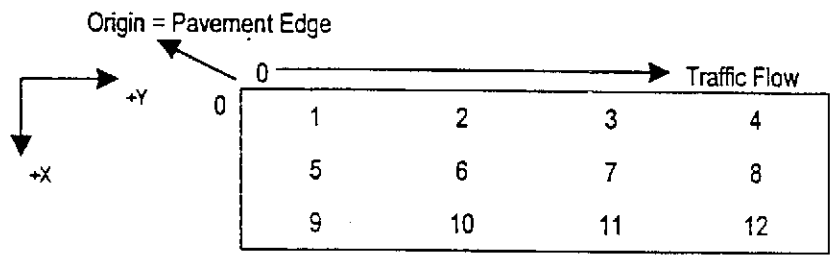
Site Number: 1 (East + West) Inlet Number: All Double Grates for Site 1E+1W

Inlet Description (circle one):

Single Grate (Double Grate) Single Grate Structural BMP Double Grate Structural BMP

Overhang Inlet?: Yes ☑ No ☐

Distance of Stations from Pavement:



In all cases place the station number on the grate bar closest to the below coordinates.

Station 1	Station 2	Station 3	Station 4
X 11 in	X 11 in	X 11 in	X 11 in
Y 4.5 in	Y 13 in	Y 21.5 in	Y 30 in

Station 5	Station 6	Station 7	Station 8
X 24.5 in	X 24.5 in	X 24.5 in	X 24.5 in
Y 4.5 in	Y 13 in	Y 21.5 in	Y 30 in

Station 9	Station 10	Station 11	Station 12
X 38 in	X 38 in	X 38 in	X 38 in
Y 4.5 in	Y 13 in	Y 21.5 in	Y 30 in

Painted? (check when completed) Do Not Clean ☑ Caltrans ID# ☑ Station Points ☑ Not Symbol ☑ URSGWC ID# ☑

URSGWC – Caltrans Litter Management Pilot Study

Inlet Deposition Monitoring Initial Set Up

Date: 5/12/1999 Field Crew: AY/HR/TL/NJ

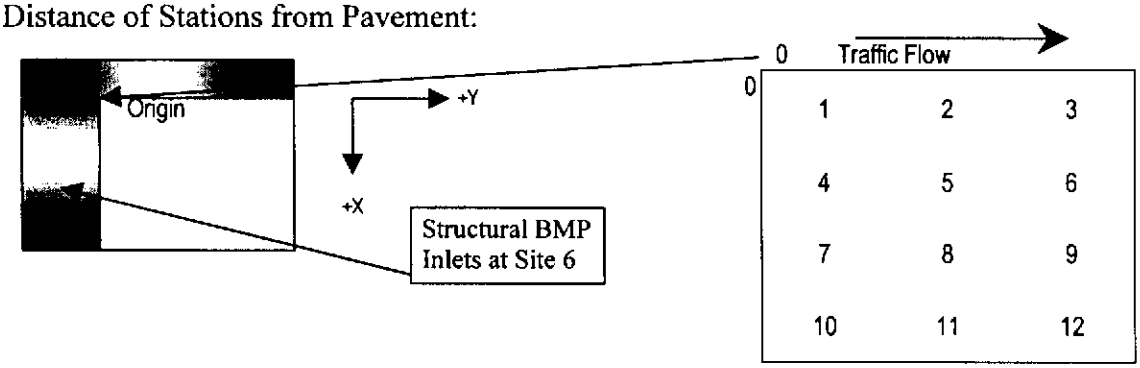
Site Number: 6 Inlet Number: All Double Grates w/ BMP

Inlet Description (circle one):

Single Grate | Double Grate | Single Grate Structural BMP | Double Grate Structural BMP

Overhang Inlet?: Yes ☐ No ☑

Distance of Stations from Pavement:



In all cases place the station number on the grate bar closest to the below coordinates.

Station 1	Station 2	Station 3
X 2 in	X 2 in	X 2 in
Y 1 in	Y 9 in	Y 22 in
Station 4	**Station 5**	**Station 6**
X 11 in	X 11 in	X 11 in
Y 1 in	Y 9 in	Y 22 in
Station 7	**Station 8**	**Station 9**
X 21.5 in	X 21.5 in	X 21.5 in
Y 1 in	Y 9 in	Y 22 in
Station 10	**Station 11**	**Station 12**
X 31 in	X 31 in	X 31 in
Y 1 in	Y 9 in	Y 22 in

Painted? (check when completed) Do Not Clean ☑ Caltrans ID# ☑ Station Points ☑ Not Symbol ☑ URSGWC ID# ☑

URSGWC – Caltrans Litter Management Pilot Study

Inlet Deposition Monitoring - Initial Set Up

Date: 5/12/1999 Field Crew: AV/ HR/TL/NJ

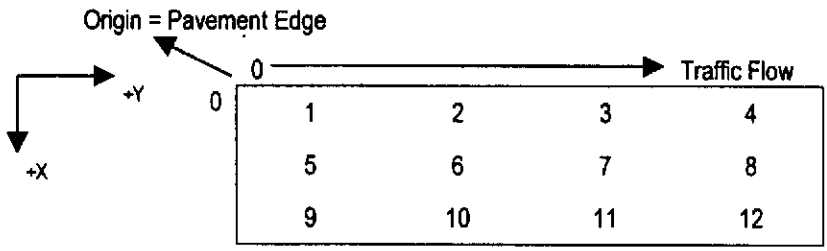
Site Number: 6 Inlet Number: All Double Grates

Inlet Description (circle one):

Single Grate (Double Grate) Single Grate Structural BMP Double Grate Structural BMP

Overhang Inlet?: Yes ☐ No ☑

Distance of Stations from Pavement:



In all cases place the station number on the grate bar closest to the below coordinates.

Station 1	Station 2	Station 3	Station 4
X 9 in	X 9 in	X 9 in	X 9 in
Y 4.5 in	Y 13.5 in	Y 22.5 in	Y 31.5 in

Station 5	Station 6	Station 7	Station 8
X 25 in	X 25 in	X 25 in	X 25 in
Y 4.5 in	Y 13.5 in	Y 22.5 in	Y 31.5 in

Station 9	Station 10	Station 11	Station 12
X 39 in	X 39 in	X 39 in	X 39 in
Y 4.5 in	Y 13.5 in	Y 22.5 in	Y 31.5 in

Painted? (check when completed) Do Not Clean ☑ Caltrans ID# ☑ Station Points ☑ Not Symbol ☑ URSGWC ID# ☑

URSGWC – Caltrans Litter Management Pilot Study

Inlet Deposition Monitoring - Initial Set Up

Date: 5/12/1999 Field Crew: AY/HR/TL/NJ

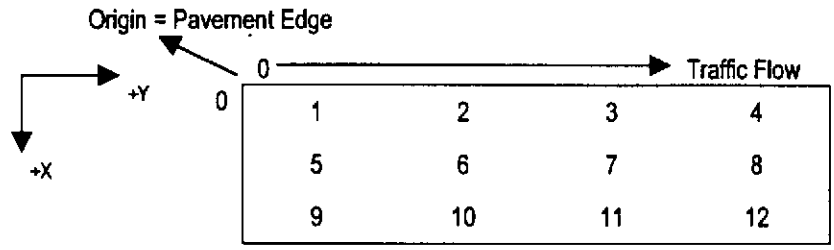
Site Number: 8 Inlet Number: All Single Grates w/ BMP

Inlet Description (circle one):

Single Grate Double Grate Single Grate Structural BMP Double Grate Structural BMP

Overhang Inlet?: Yes ☑ No ☐

Distance of Stations from Pavement:



In all cases place the station number on the grate bar closest to the below coordinates.

Station 1	Station 2	Station 3	Station 4
X 5.5 in	X 5.5 in	X 5.5 in	X 5.5 in
Y 4.5 in	Y 13.25 in	Y 22 in	Y 30.75 in

Station 5	Station 6	Station 7	Station 8
X 13 in	X 13 in	X 13 in	X 13 in
Y 4.5 in	Y 13.25 in	Y 22 in	Y 30.75 in

Station 9	Station 10	Station 11	Station 12
X 21 in	X 21 in	X 21 in	X 21 in
Y 4.5 in	Y 13.25 in	Y 22 in	Y 30.75 in

Painted? (check when completed) Do Not Clean ☑ Caltrans ID# ☑ Station Points ☑ Not Symbol ☑ URSGWC ID# ☑

URSGWC – Caltrans Litter Management Pilot Study

Inlet Deposition Monitoring - Initial Set Up

Date: 5/12/1999 Field Crew: AY/HR/TL/NJ

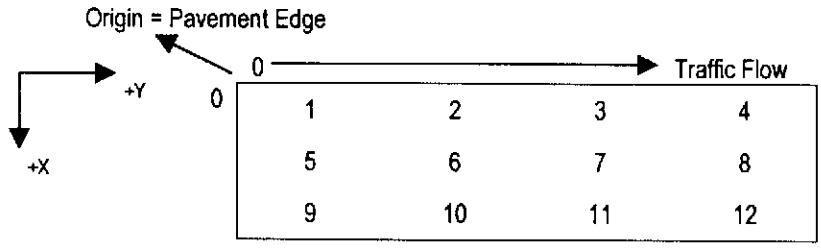
Site Number: 8 Inlet Number: All Single Grates

Inlet Description (circle one):

(Single Grate) Double Grate Single Grate Structural BMP Double Grate Structural BMP

Overhang Inlet?: Yes ☑ No ☐

Distance of Stations from Pavement:



In all cases place the station number on the grate bar closest to the below coordinates.

Station 1	Station 2	Station 3	Station 4
X 5 in	X 5 in	X 5 in	X 5 in
Y 3.75 in	Y 12.5 in	Y 21.25 in	Y 30 in

Station 5	Station 6	Station 7	Station 8
X 13 in	X 13 in	X 13 in	X 13 in
Y 3.75 in	Y 12.5 in	Y 21.25 in	Y 30 in

Station 9	Station 10	Station 11	Station 12
X 21 in	X 21 in	X 21 in	X 21 in
Y 3.75 in	Y 12.5 in	Y 21.25 in	Y 30 in

Painted? (check when completed) Do Not Clean ☑ Caltrans ID# ☑ Station Points ☑ Not Symbol ☑ URSGWC ID# ☑

URSGWC – Caltrans Litter Management Pilot Study

Inlet Deposition Monitoring - Initial Set Up

Date: 12/14/99 Field Crew: D Vukic, L. Forest

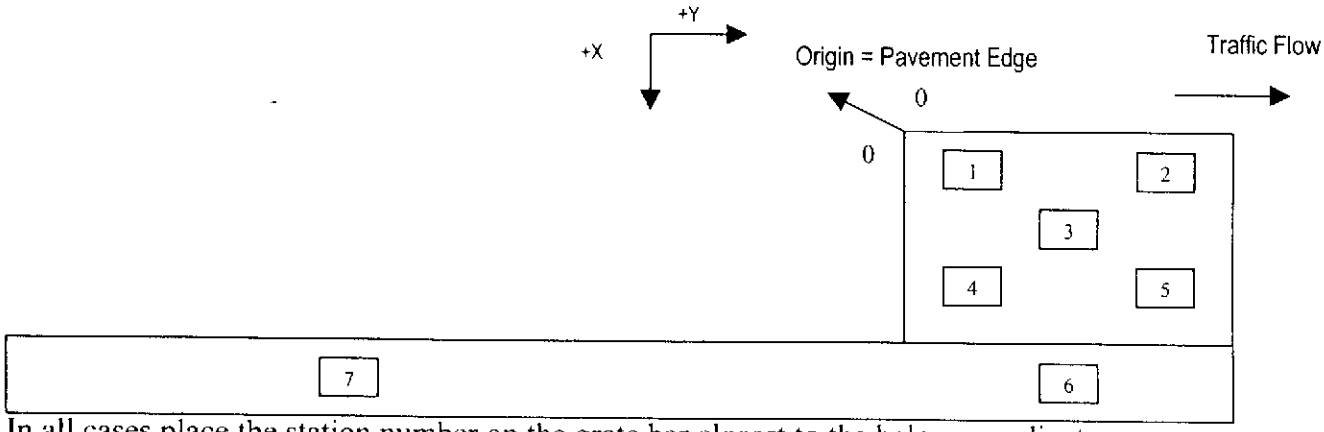
Site Number: C009/B001 Inlet Number: C009/B001

Inlet Description (circle one):

Single Grate | Double Grate | Single Grate Structural BMP – Flap Gate | Double Grate Structural BMP

Overhang Inlet?: Yes ☐ No ☐

Distance of Stations from Pavement:



In all cases place the station number on the grate bar closest to the below coordinates.

Station 1	Station 2	Station 3	Station 4
X 4" in	X 4" in	X 12" in	X 20.25" in
Y 12" in	Y 28" in	Y 20" in	Y 12.5" in

Station 5	Station 6	Station 7
X 20" in	X 32" in	X 33" in
Y 27" in	Y 20" in	Y .74" in

Painted? (check when completed) Do Not Clean ☐ Caltrans ID# ☐ Station Points ☐

Not Symbol ☐ URSGWC ID# ☐

URSGWC – Caltrans Litter Management Pilot Study

Inlet Deposition Monitoring - Initial Set Up

Date: 12/14/99 Field Crew: D. Vukovic, I. Forrest

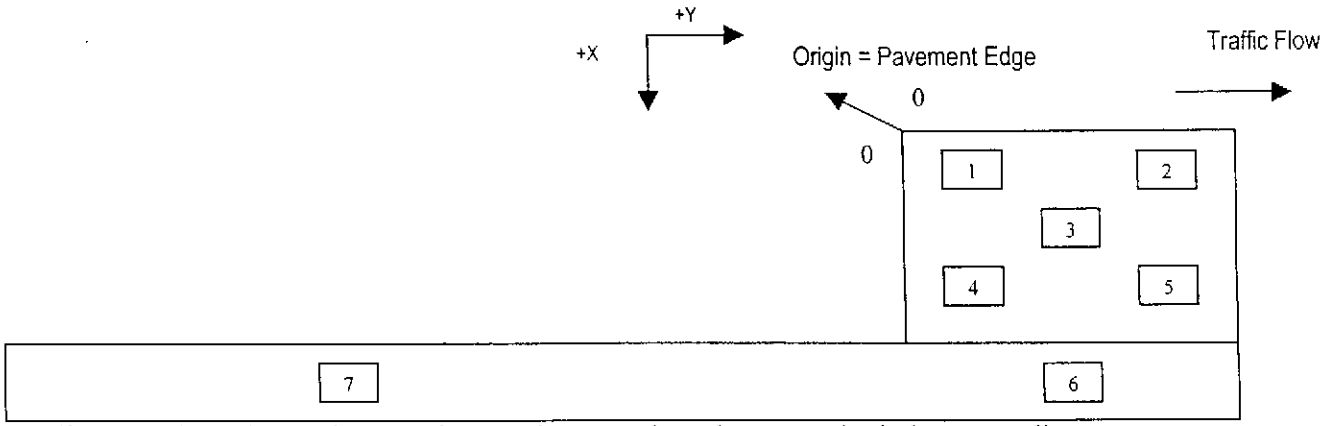
Site Number: C001 - 24B Inlet Number: C001 - 24B

Inlet Description (circle one):

Single Grate | Double Grate | Single Grate Structural BMP – Flap Gate | Double Grate Structural BMP

Overhang Inlet?: Yes ☐ No ☐

Distance of Stations from Pavement:



In all cases place the station number on the grate bar closest to the below coordinates.

Station 1	Station 2	Station 3	Station 4
X 4" in	X 4 in	X 12 in	X 20.25 in
Y 12 in	Y 27.5 in	Y 20 in	Y 13 in

Station 5	Station 6	Station 7
X 20.5 in	X 32.5 in	X 32.5 in
Y 27.25 in	Y 21.5 in	Y 34.5 in

Painted? (check when completed) Do Not Clean ☐ Caltrans ID# ☐ Station Points ☐ Not Symbol ☐ URSGWC ID# ☐

URSGWC – Caltrans Litter Management Pilot Study

Inlet Deposition Monitoring - Initial Set Up

Date: 12/14/99 Field Crew: D. Vukov / Forrest

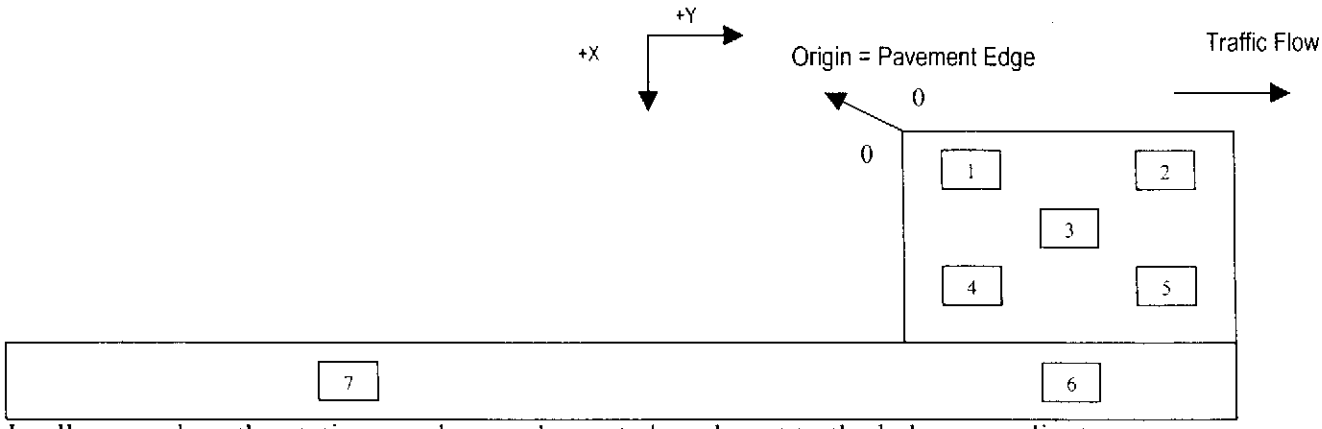
Site Number: C007 - 24F Inlet Number: C007 - 24F

Inlet Description (circle one):

Single Grate | Double Grate | Single Grate Structural BMP – Flap Gate | Double Grate Structural BMP

Overhang Inlet?: Yes ☐ No ☐

Distance of Stations from Pavement:



In all cases place the station number on the grate bar closest to the below coordinates.

Station 1	Station 2	Station 3	Station 4
X 4 in	X 4 in	X 12.25 in	X 20.25 in
Y 13 in	Y 27.5 in	Y 20.25 in	Y 13 in

Station 5	Station 6	Station 7
X 20.25 in	X 32 in	X 32 in
Y 27.25 in	Y 21.5 in	Y -123 in

Painted? (check when completed) Do Not Clean ☐ Caltrans ID# ☐ Station Points ☐ Not Symbol ☐ URSGWC ID# ☐

URSGWC- Caltrans Litter Management Pilot Study
Inlet Deposition Monitoring
Field Measurements & Observations

Field Crew: _____ **Date:** _____

Total Miles Driven: _____ **Site Number:** _____

Problems/Peripheral Conditions that could possibly affect study: _____

_____ (cont. on back if necessary)

Moisture is either:

Dry (D);
Moist (M); or
Saturated (S).

>>> Traffic Flow >>>

Quadrant 1 (Q 1)	Quadrant 2 (Q 2)
Quadrant 3 (Q 3)	Quadrant 4 (Q 4)

Inlet Description

Single Grate	SG
Sinlge Grate Structural BMP	SG/BMP
Double Grate	DG
Double Grate Structural BMP	DG/BMP

Inlet Number: **Inlet Description (circle one)** SG SG/BMP DG DG/BMP

Description of Inlet Contents (i.e., leaves and newspaper) Downstream Road:

	Q 1	Q 2	Q 3	Q 4
Concrete Bottom	%	%	%	%
Sediment	%	%	%	%
Vegetation	%	%	%	%
Litter	%	%	%	%
Moisture				

Inlet Deposition Measurements per station in feet.

	1	2	3	4
Uncompacted				
Compacted				
	5	6	7	8
Uncompacted				
Compacted				
	9	10	11	12
Uncompacted				
Compacted				

Pictures Taken (check when completed)

Inlet Number w/ Surrounding Area Inlet w/ Contents

Inlet Number: **Inlet Description (circle one)** SG SG/BMP DG DG/BMP

Description of Inlet Contents (i.e., leaves and newspaper) Downstream Road:

	Q 1	Q 2	Q 3	Q 4
Concrete Bottom	%	%	%	%
Sediment	%	%	%	%
Vegetation	%	%	%	%
Litter	%	%	%	%
Moisture				

Inlet Deposition Measurements per station in feet.

	1	2	3	4
Uncompacted				
Compacted				
	5	6	7	8
Uncompacted				
Compacted				
	9	10	11	12
Uncompacted				
Compacted				

Pictures Taken (check when completed)

Inlet Number w/ Surrounding Area Inlet w/ Contents

Inlet Number: **Inlet Description (circle one)** SG SG/BMP DG DG/BMP

Description of Inlet Contents (i.e., leaves and newspaper) Downstream Road:

	Q 1	Q 2	Q 3	Q 4
Concrete Bottom	%	%	%	%
Sediment	%	%	%	%
Vegetation	%	%	%	%
Litter	%	%	%	%
Moisture				

Inlet Deposition Measurements per station in feet.

	1	2	3	4
Uncompacted				
Compacted				
	5	6	7	8
Uncompacted				
Compacted				
	9	10	11	12
Uncompacted				
Compacted				

Pictures Taken (check when completed)

Inlet Number w/ Surrounding Area Inlet w/ Contents

Inlet Number: **Inlet Description (circle one)** SG SG/BMP DG DG/BMP

Description of Inlet Contents
(i.e., leaves and newspaper) Downstream Road:

	Q 1	Q 2	Q 3	Q 4
Concrete Bottom	%	%	%	%
Sediment	%	%	%	%
Vegetation	%	%	%	%
Litter	%	%	%	%
Moisture				

Pictures Taken (check when completed)

Inlet Number w/ Surrounding Area Inlet w/ Contents

Inlet Deposition Measurements per station in feet.

	1	2	3	4
Uncompacted				
Compacted				
	5	6	7	8
Uncompacted				
Compacted				
	9	10	11	12
Uncompacted				
Compacted				

Inlet Number: **Inlet Description (circle one)** SG SG/BMP DG DG/BMP

Description of Inlet Contents
(i.e., leaves and newspaper) Downstream Road:

	Q 1	Q 2	Q 3	Q 4
Concrete Bottom	%	%	%	%
Sediment	%	%	%	%
Vegetation	%	%	%	%
Litter	%	%	%	%
Moisture				

Pictures Taken (check when completed)

Inlet Number w/ Surrounding Area Inlet w/ Contents

Inlet Deposition Measurements per station in feet.

	1	2	3	4
Uncompacted				
Compacted				
	5	6	7	8
Uncompacted				
Compacted				
	9	10	11	12
Uncompacted				
Compacted				

Inlet Number: **Inlet Description (circle one)** SG SG/BMP DG DG/BMP

Description of Inlet Contents
(i.e., leaves and newspaper) Downstream Road:

	Q 1	Q 2	Q 3	Q 4
Concrete Bottom	%	%	%	%
Sediment	%	%	%	%
Vegetation	%	%	%	%
Litter	%	%	%	%
Moisture				

Pictures Taken (check when completed)

Inlet Number w/ Surrounding Area Inlet w/ Contents

Inlet Deposition Measurements per station in feet.

	1	2	3	4
Uncompacted				
Compacted				
	5	6	7	8
Uncompacted				
Compacted				
	9	10	11	12
Uncompacted				
Compacted				

Notes

URSGWC- Caltrans Litter Management Pilot Study
Inlet Deposition Monitoring
Field Measurements & Observations

Field Crew: _____ **Date:** _____

Total Miles Driven: _____ **Site Number:** **8**

Problems/Peripheral Conditions that could possibly affect study: _____

_____ (cont. on back if necessary)

Flap Gate BMP

Moisture is either:

Dry (D);
Moist (M); or
Saturated (S).

>>> Traffic Flow >>>

1		2
	3	
4		5
7	6	

Inlet Description

Single Grate	SG
Sinlge Grate Structural BMP	SG/BMP
Double Grate	DG
Double Grate Structural BMP	DG/BMP

Inlet Number: **Inlet Description (circle one)** SG SG/BMP DG DG/BMP

Description of Inlet Contents
(i.e., leaves and newspaper) Downstream Road:

	Q 1	Q 2	Q 3	Q 4
Concrete Bottom	%	%	%	%
Sediment	%	%	%	%
Vegetation	%	%	%	%
Litter	%	%	%	%
Moisture				

Pictures Taken (check when completed)

Inlet Number w/ Surrounding Area Inlet w/ Contents

Inlet Deposition Measurements per station in feet.

	1	2	3	4
Uncompacted				
Compacted				

	5	6	7	8
Uncompacted				
Compacted				

	9	10	11	12
Uncompacted				
Compacted				

Description of Inlet Contents
(i.e., leaves and newspaper) Downstream Road:

	Q 1	Q 2	Q 3	Q 4
Concrete Bottom	%	%	%	%
Sediment	%	%	%	%
Vegetation	%	%	%	%
Litter	%	%	%	%
Moisture				

Pictures Taken (check when completed)

Inlet Number w/ Surrounding Area Inlet w/ Contents

Inlet Deposition Measurements per station in feet.

	1	2	3	4
Uncompacted				
Compacted				

	5	6	7
Uncompacted			
Compacted			

Description of Inlet Contents
(i.e., leaves and newspaper) Downstream Road:

	Q 1	Q 2	Q 3	Q 4
Concrete Bottom	%	%	%	%
Sediment	%	%	%	%
Vegetation	%	%	%	%
Litter	%	%	%	%
Moisture				

Pictures Taken (check when completed)

Inlet Number w/ Surrounding Area Inlet w/ Contents

Inlet Deposition Measurements per station in feet.

	1	2	3	4
Uncompacted				
Compacted				

	5	6	7
Uncompacted			
Compacted			

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Description of Inlet Contents
(i.e., leaves and newspaper) Downstream Road:

	Q 1	Q 2	Q 3	Q 4
Concrete Bottom	%	%	%	%
Sediment	%	%	%	%
Vegetation	%	%	%	%
Litter	%	%	%	%
Moisture				

Pictures Taken (check when completed)

Inlet Number w/ Surrounding Area Inlet w/ Contents

Inlet Deposition Measurements per station in feet.

	1	2	3	4
Uncompacted				
Compacted				

	5	6	7	8
Uncompacted				
Compacted				

	9	10	11	12
Uncompacted				
Compacted				

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Description of Inlet Contents
(i.e., leaves and newspaper) Downstream Road:

	Q 1	Q 2	Q 3	Q 4
Concrete Bottom	%	%	%	%
Sediment	%	%	%	%
Vegetation	%	%	%	%
Litter	%	%	%	%
Moisture				

Pictures Taken (check when completed)

Inlet Number w/ Surrounding Area Inlet w/ Contents

Inlet Deposition Measurements per station in feet.

	1	2	3	4
Uncompacted				
Compacted				

	5	6	7	8
Uncompacted				
Compacted				

	9	10	11	12
Uncompacted				
Compacted				

Description of Inlet Contents
(i.e., leaves and newspaper) Downstream Road:

	Q 1	Q 2	Q 3	Q 4
Concrete Bottom	%	%	%	%
Sediment	%	%	%	%
Vegetation	%	%	%	%
Litter	%	%	%	%
Moisture				

Pictures Taken (check when completed)

Inlet Number w/ Surrounding Area Inlet w/ Contents

Inlet Deposition Measurements per station in feet.

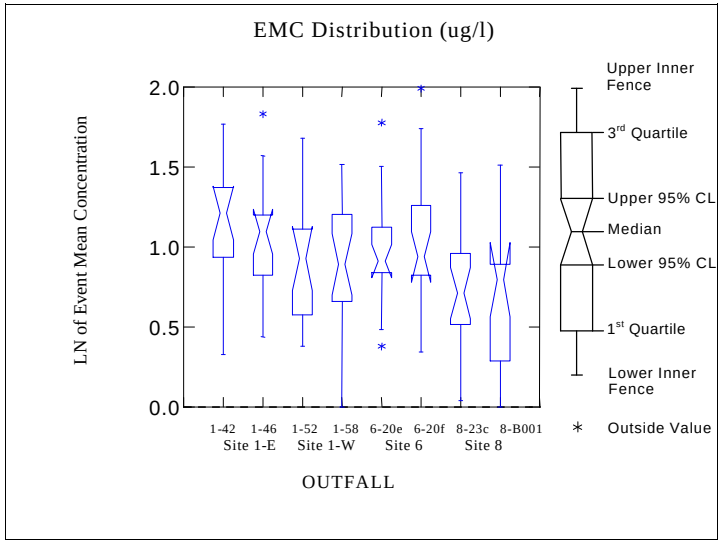
	1	2	3	4
Uncompacted				
Compacted				

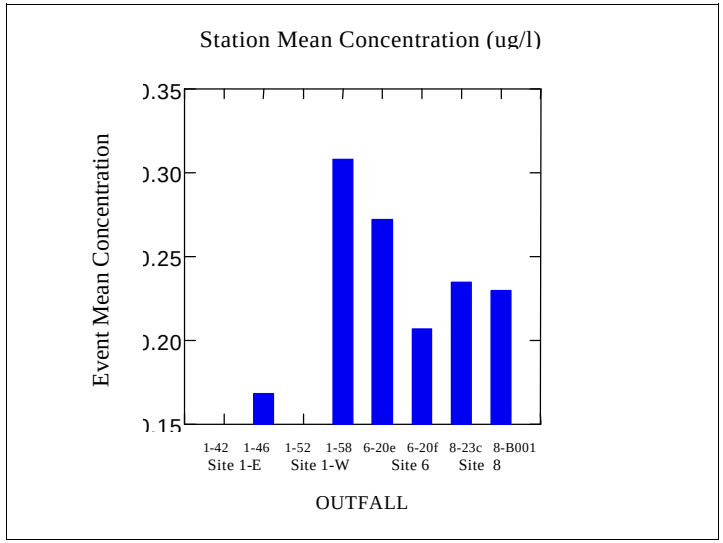
	5	6	7
Uncompacted			
Compacted			

Notes

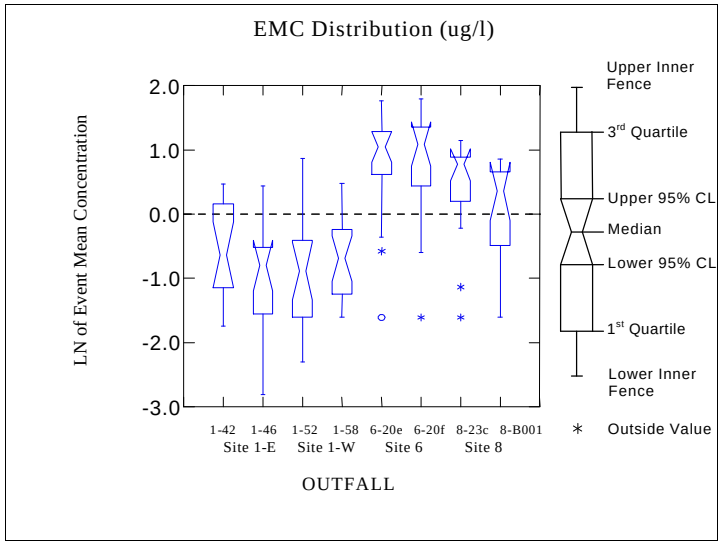
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Cadmium, Dissolved





Cadmium, Total



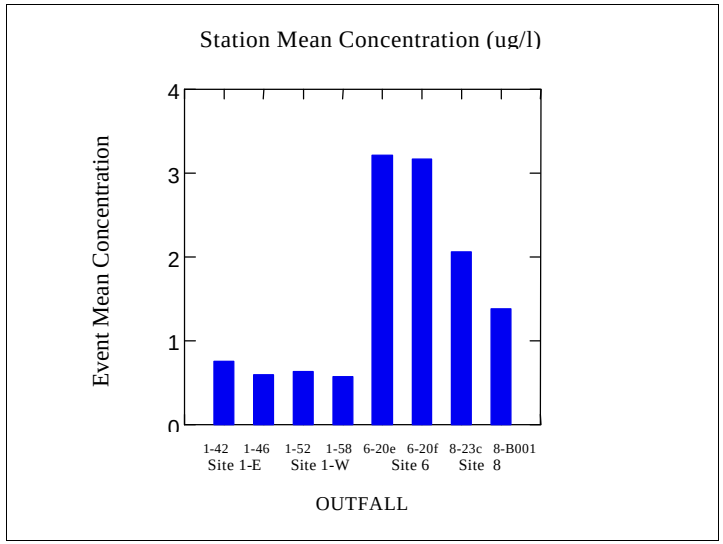
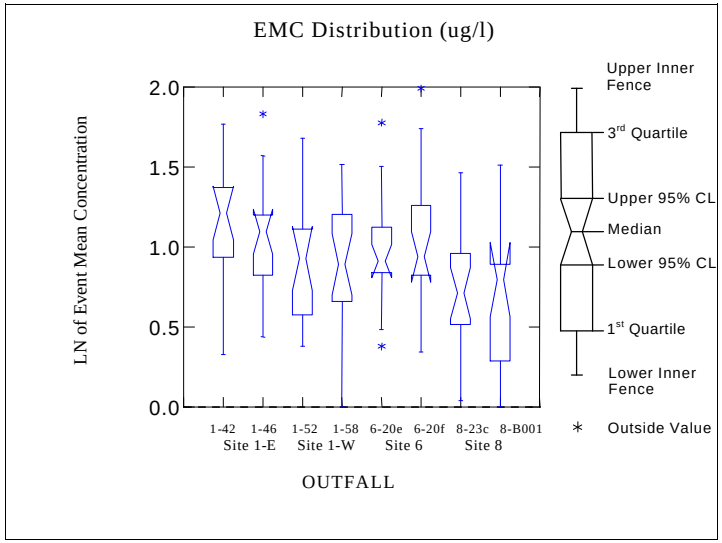
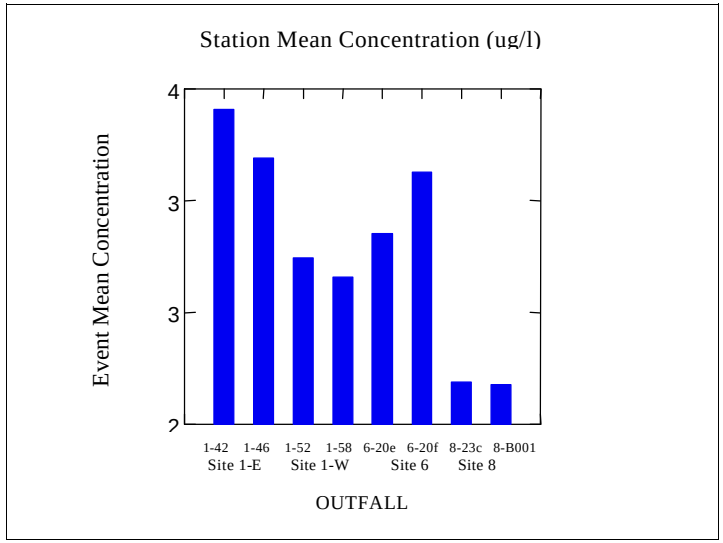


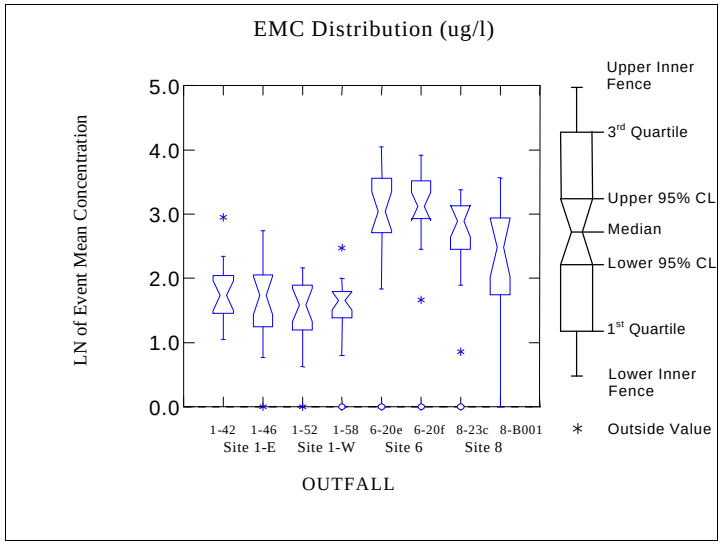
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Chromium, Dissolved





Chromium, Total



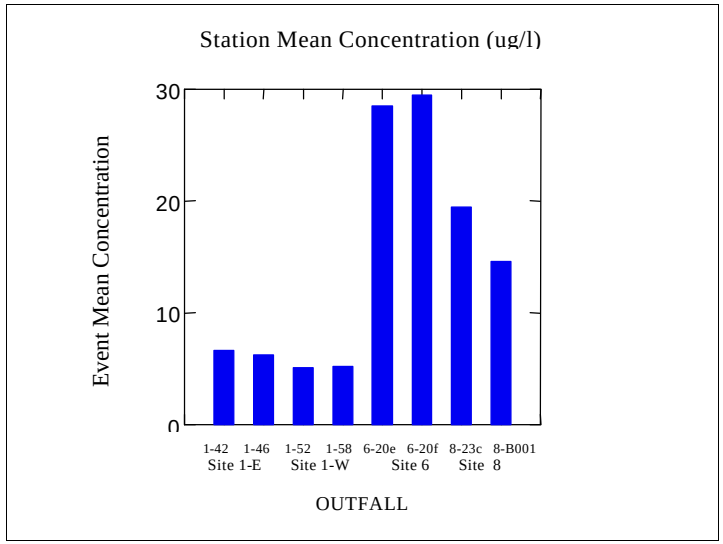
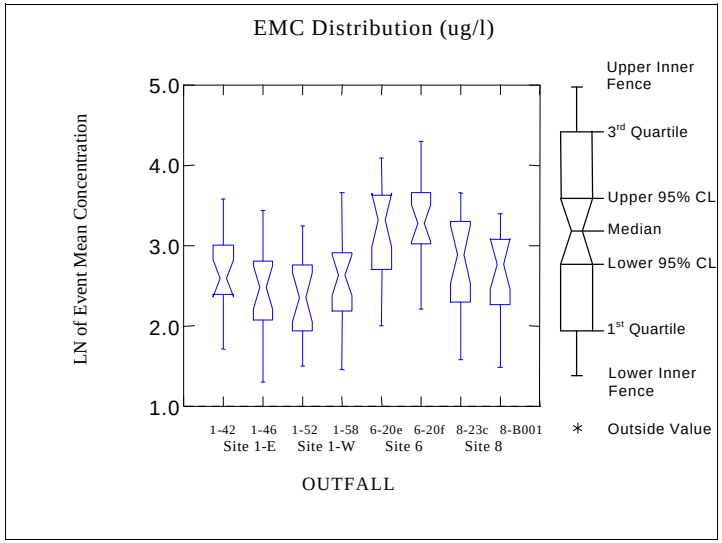
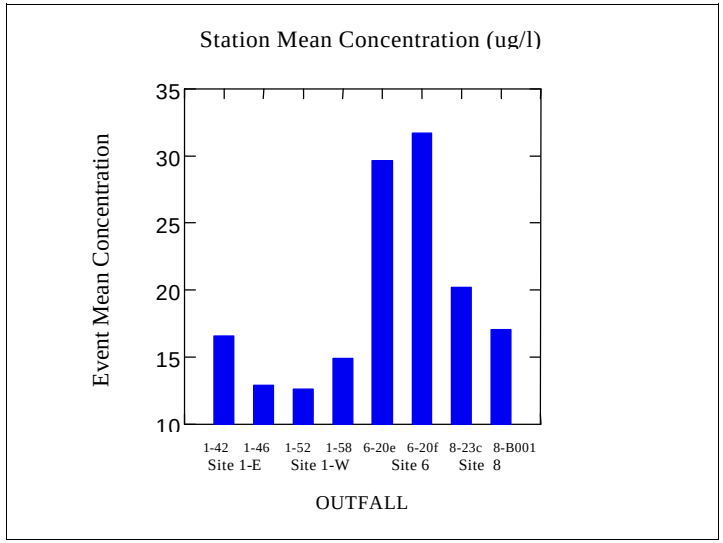


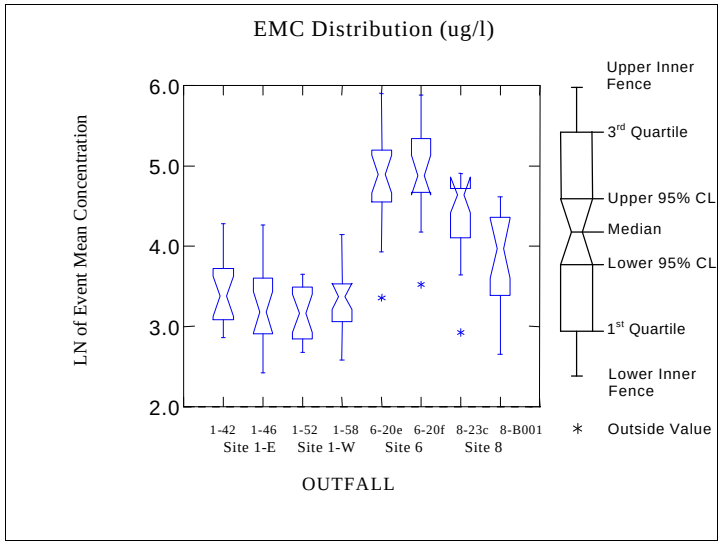
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Copper, Dissolved





Copper, Total



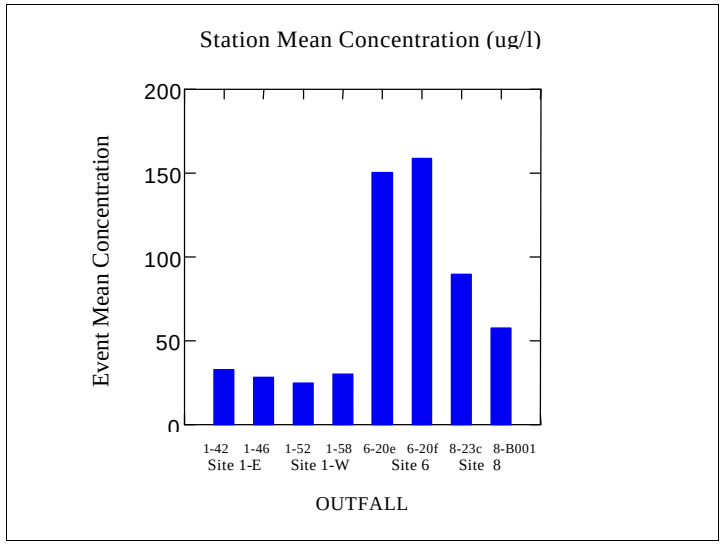
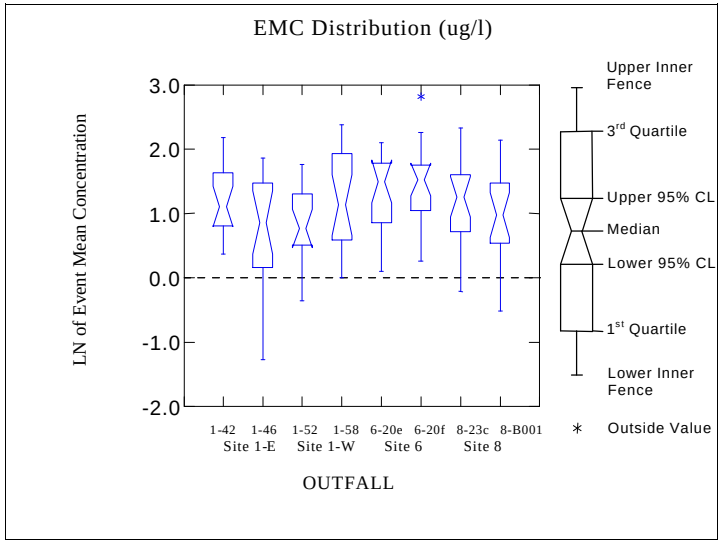
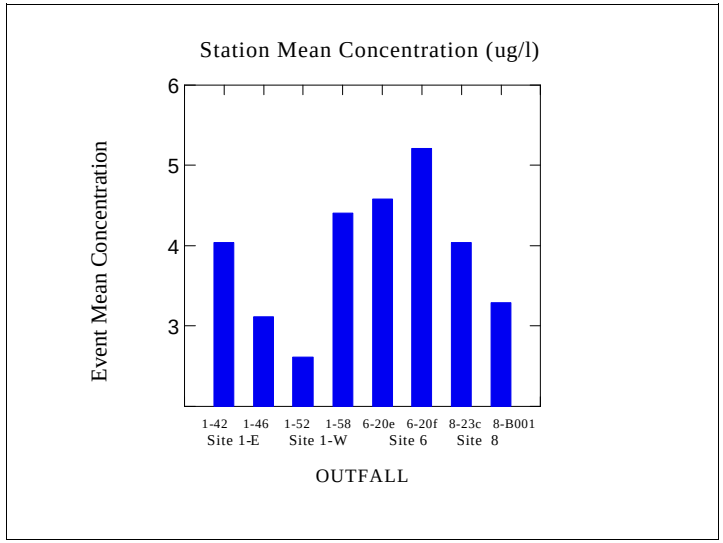


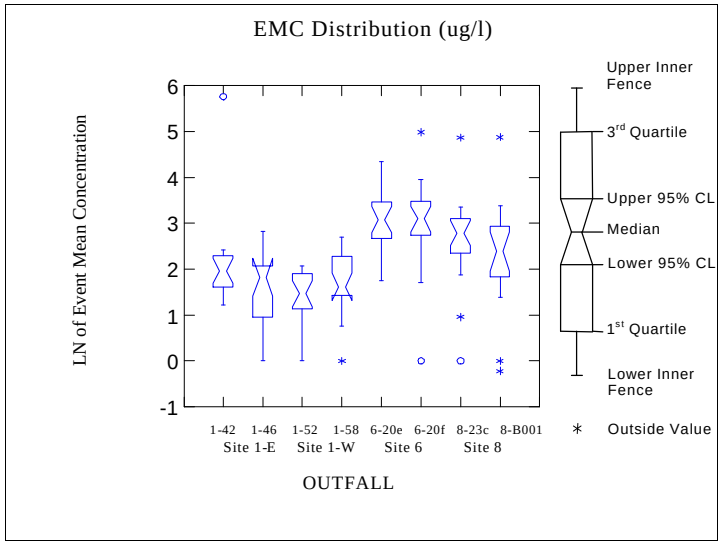
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Nickel, Dissolved





Nickel, Total



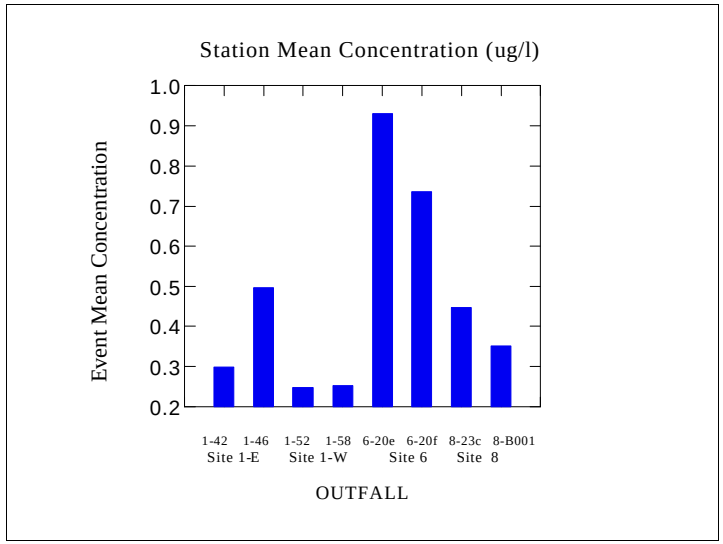
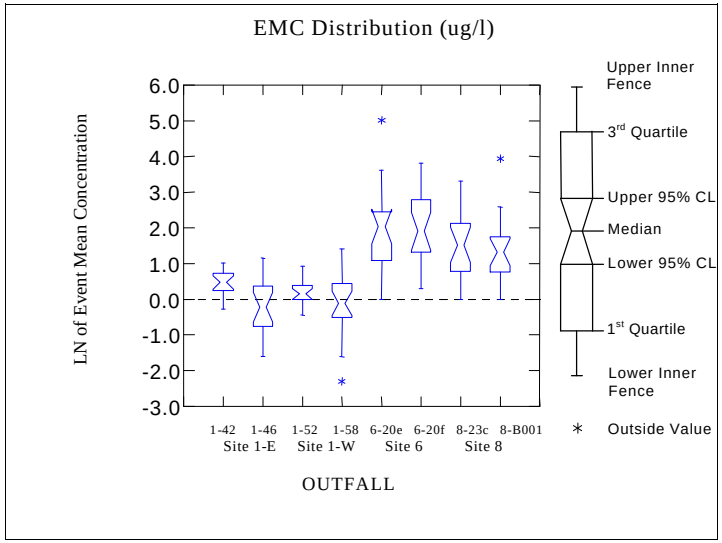
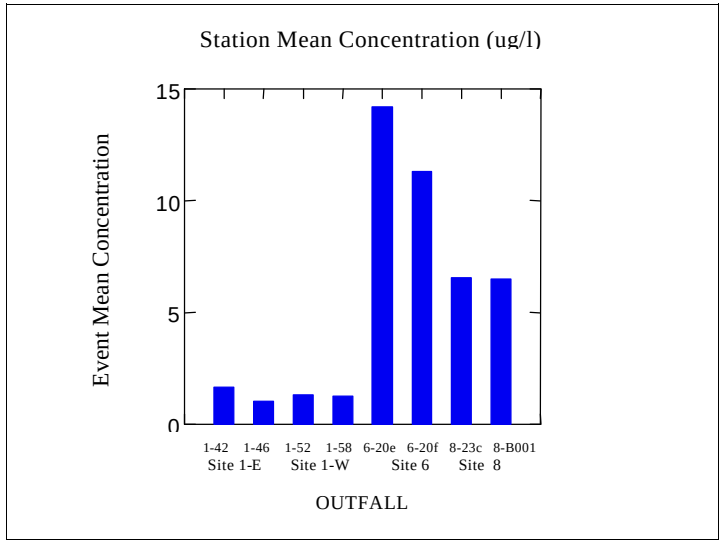


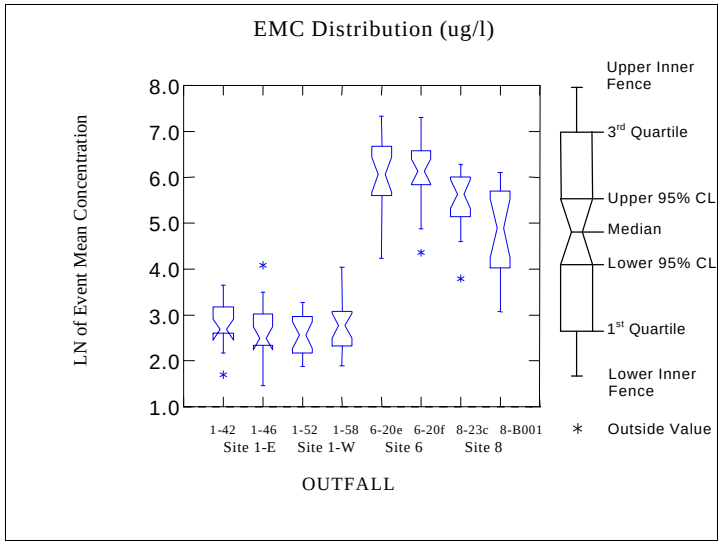
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Lead, Dissolved





Lead, Total



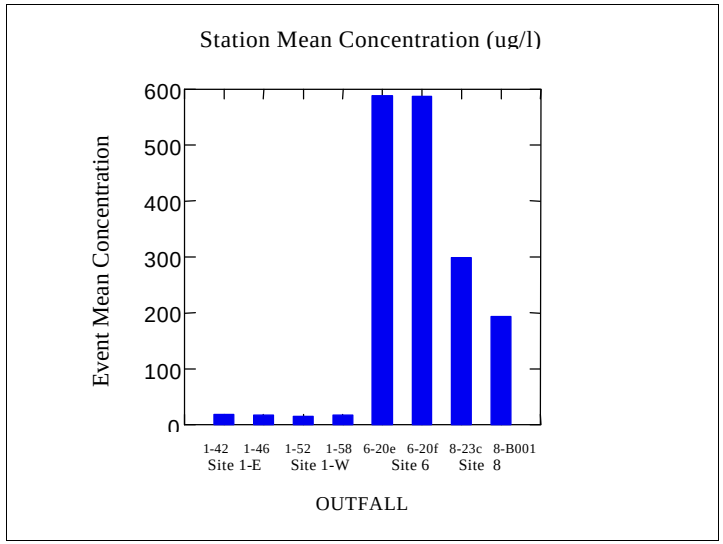
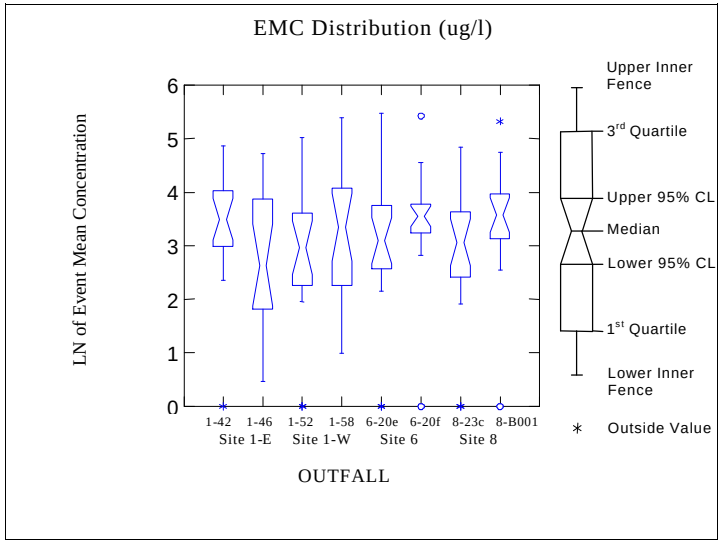
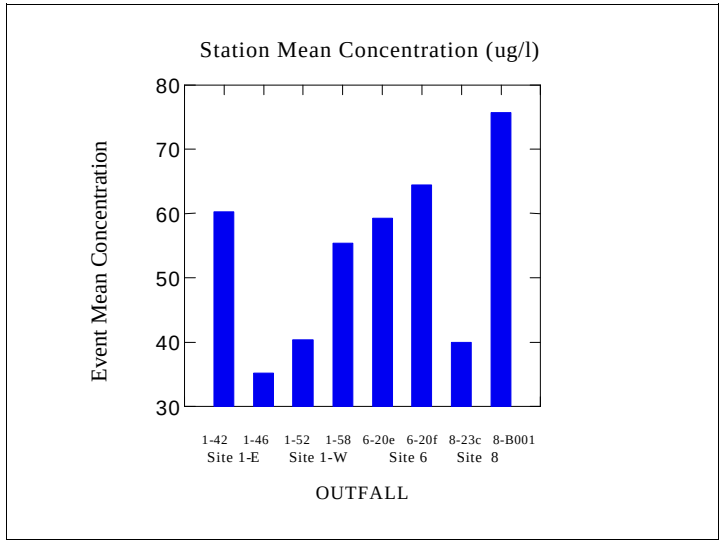


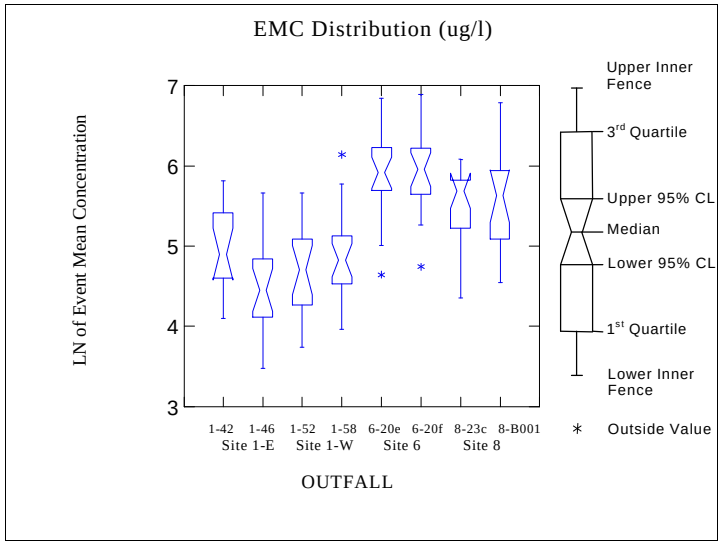
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Zinc, Dissolved





Zinc, Total



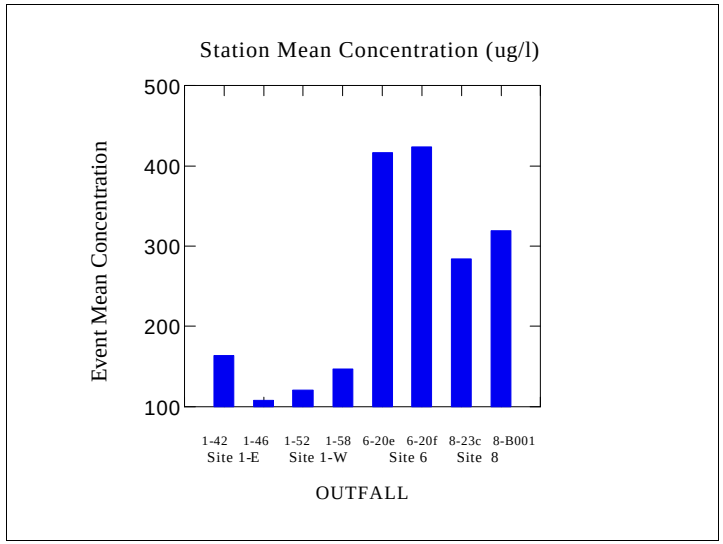
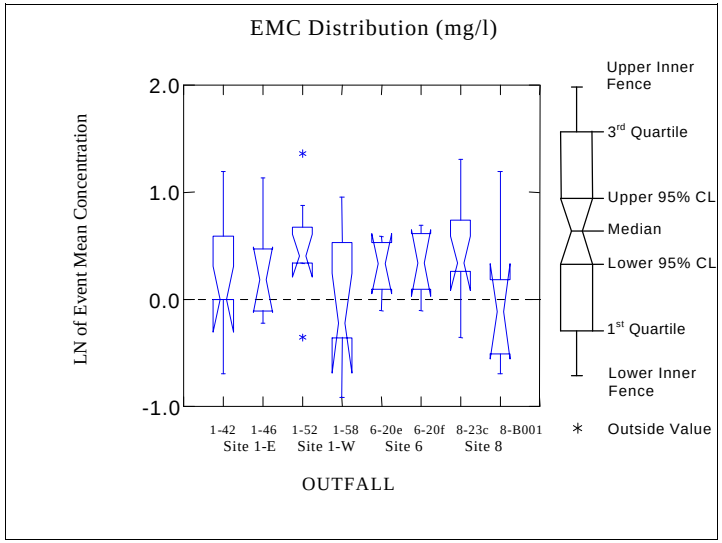
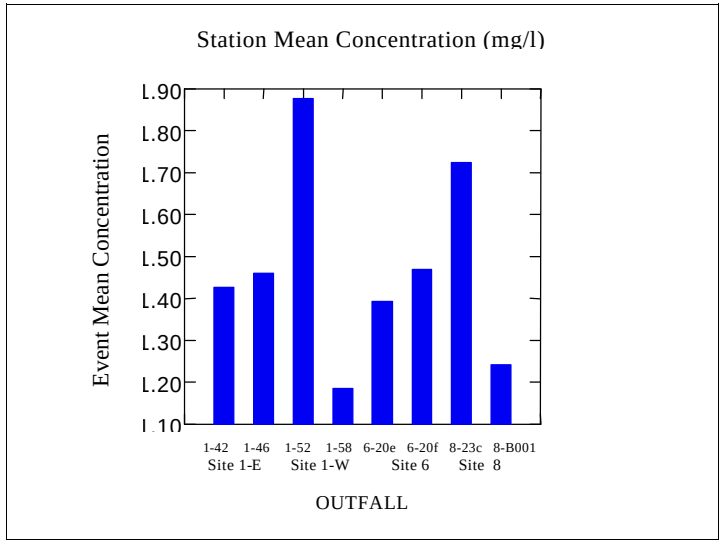


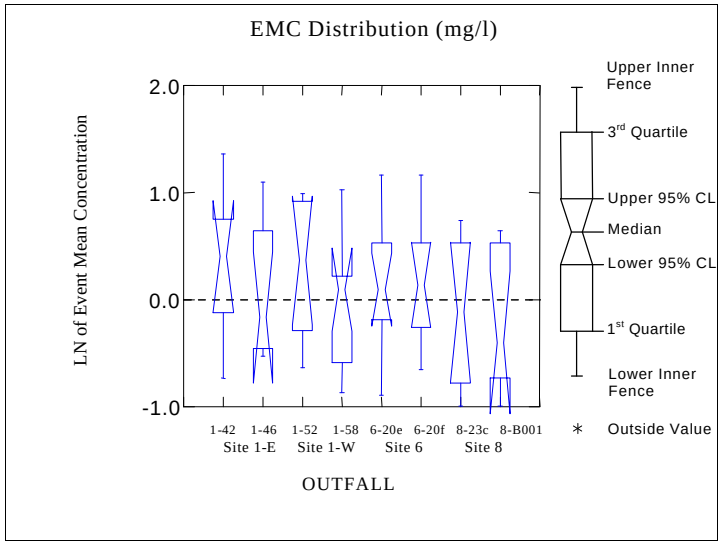
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Nitrate Nitrogen 1998





Nitrate Nitrogen 1999



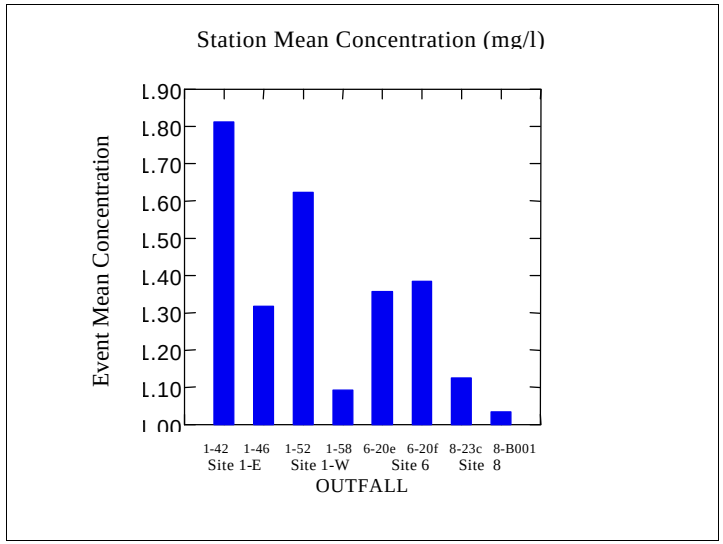
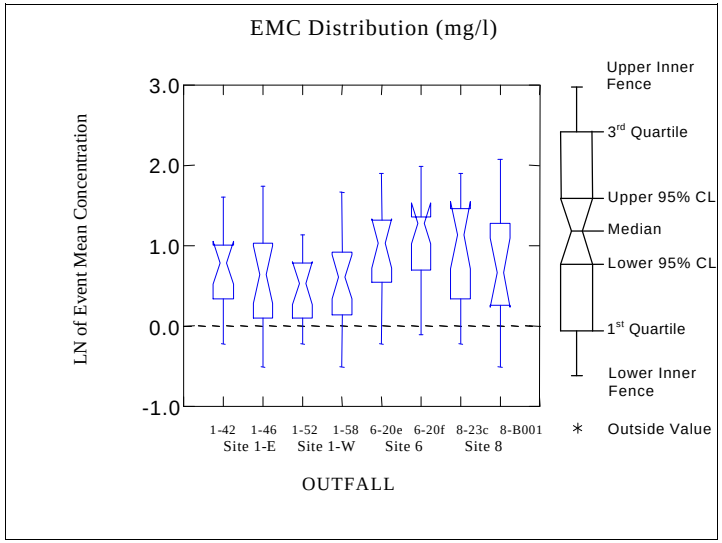
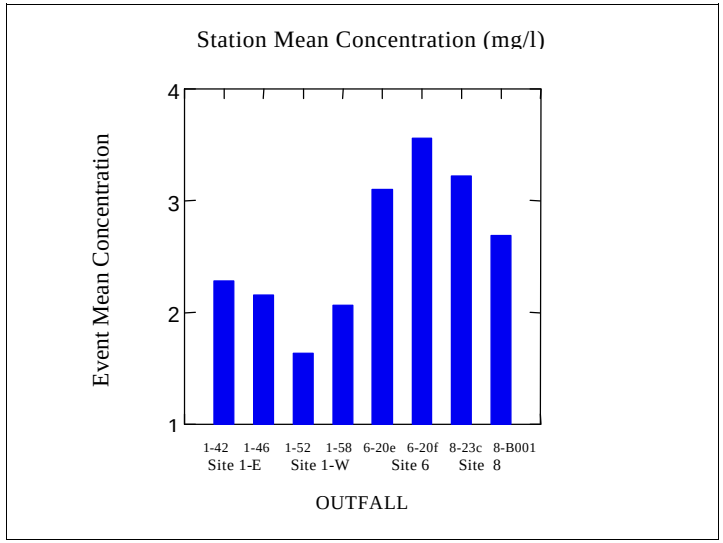


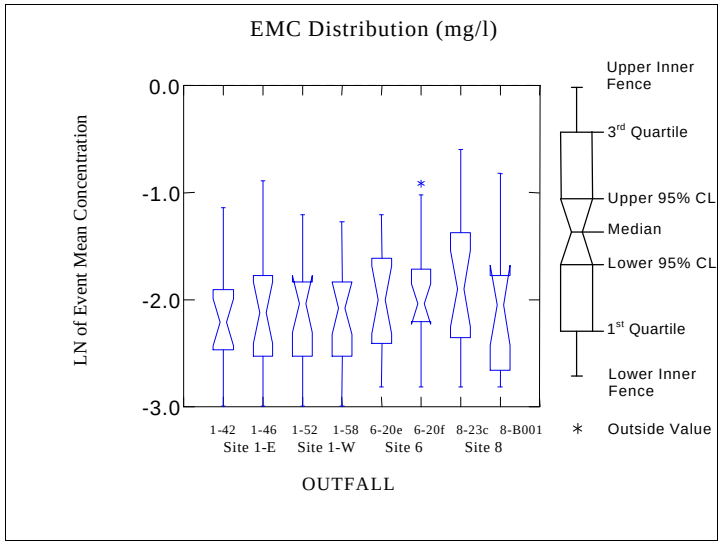
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Total Kjedhal Nitrogen





Ortho-Phosphorus



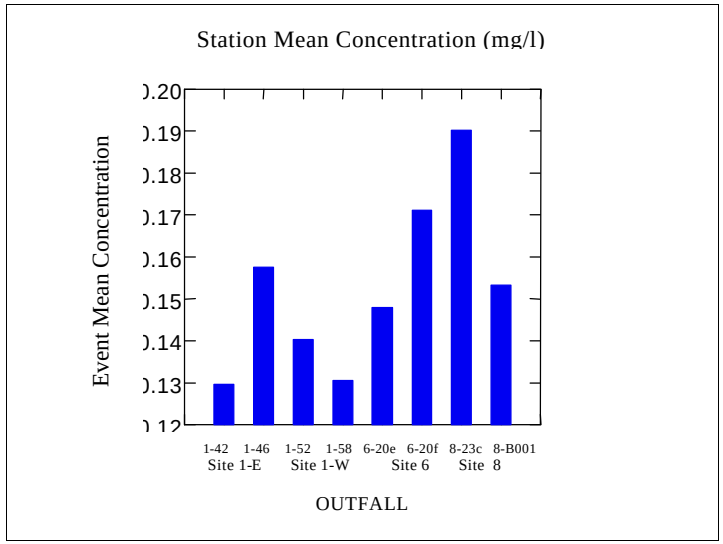
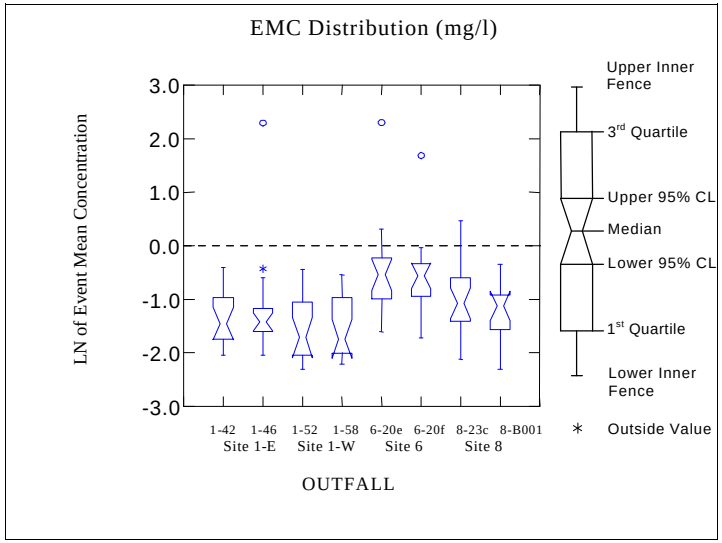
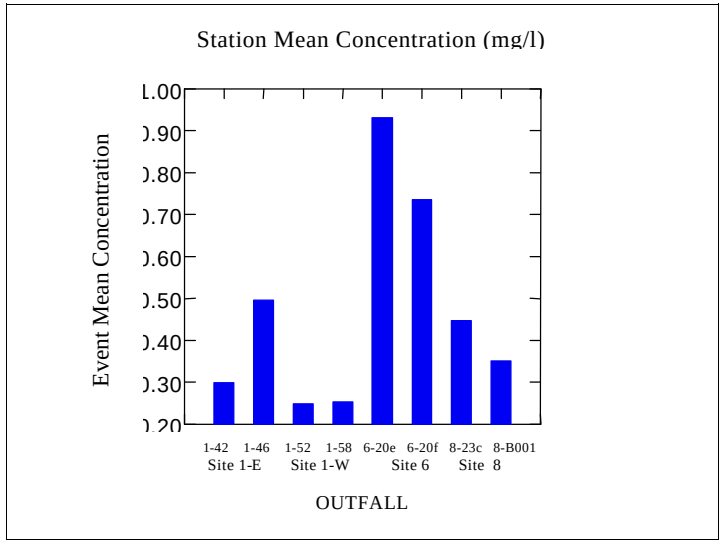


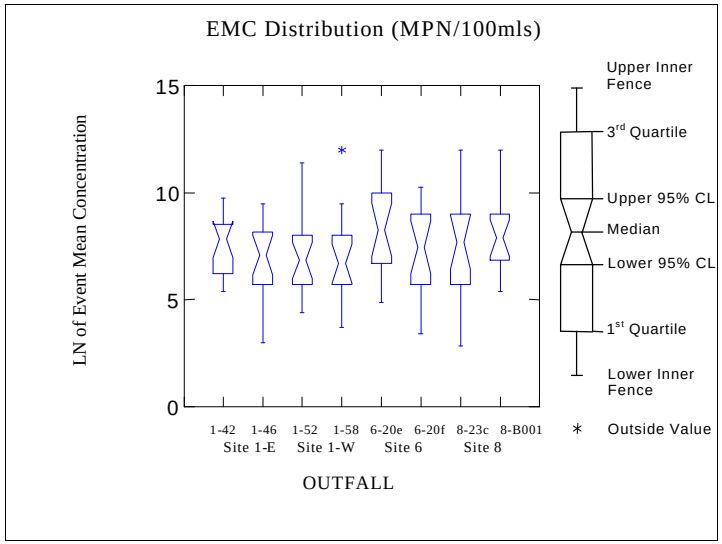
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Total Phosphorus





Coliforms, Total



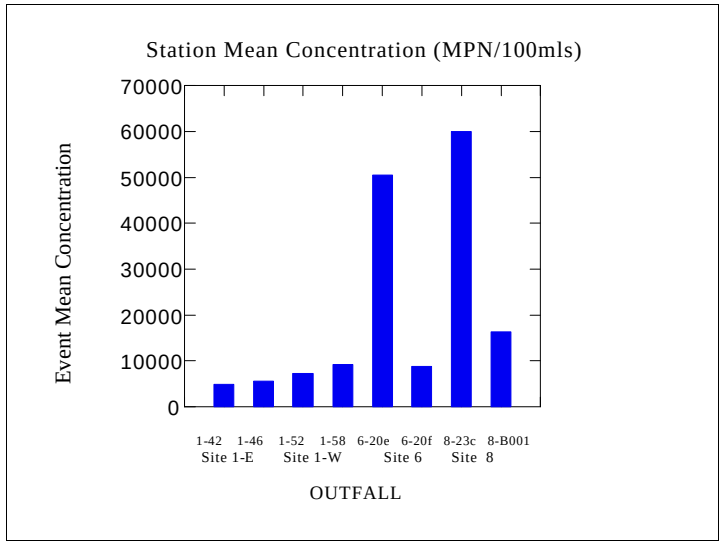
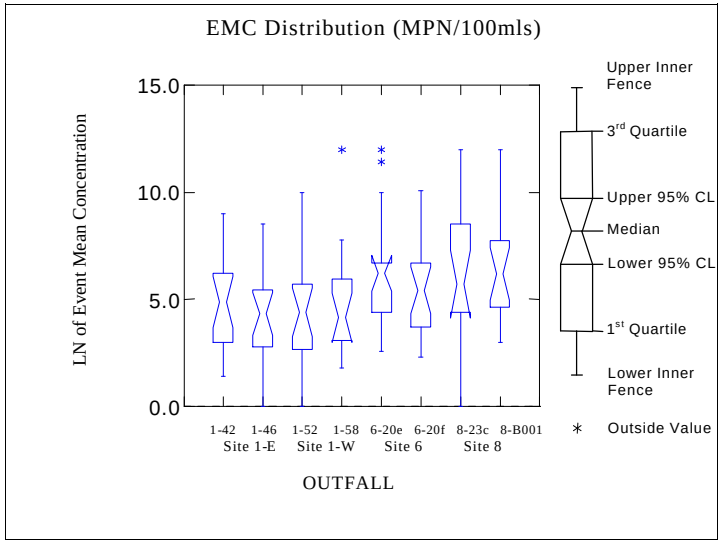
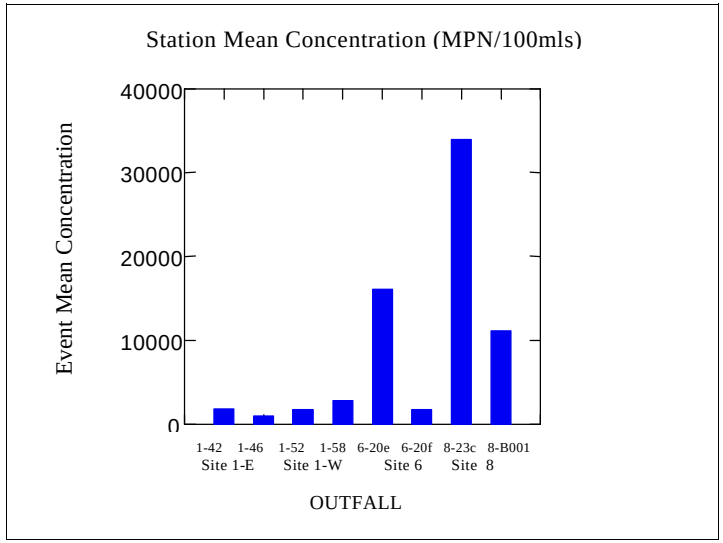


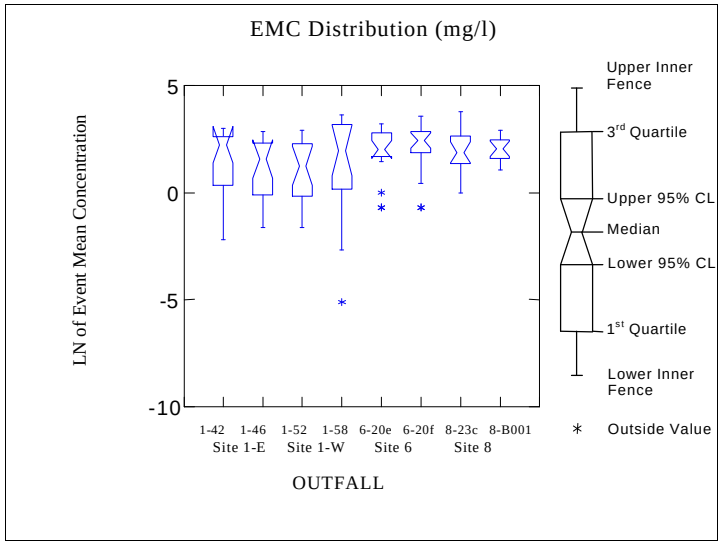
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Coliforms, Fecal





TPH (Diesel)



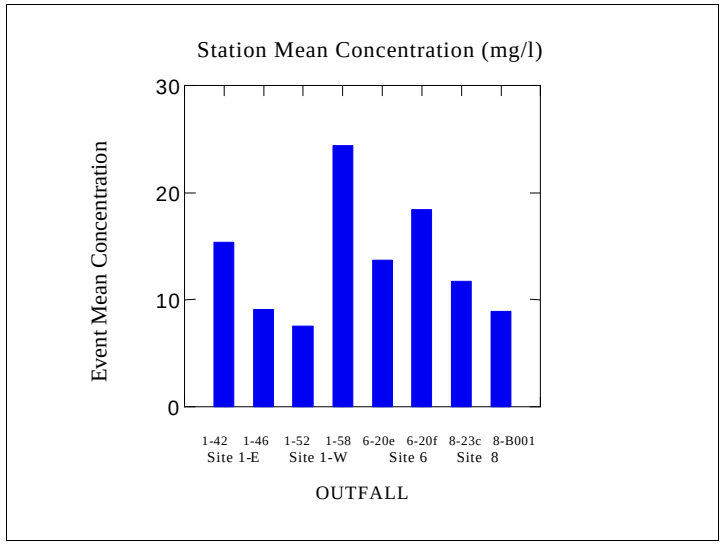
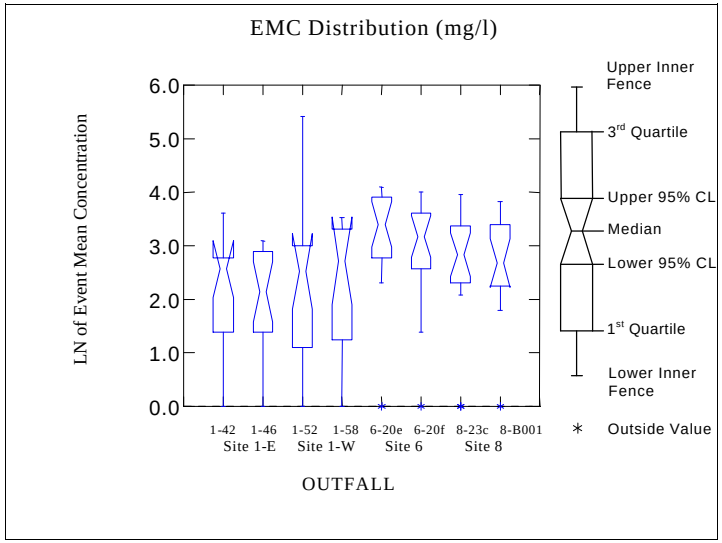
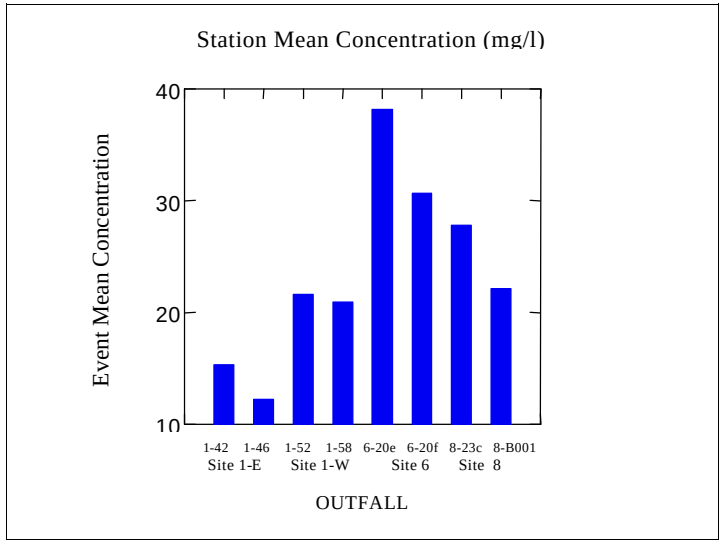


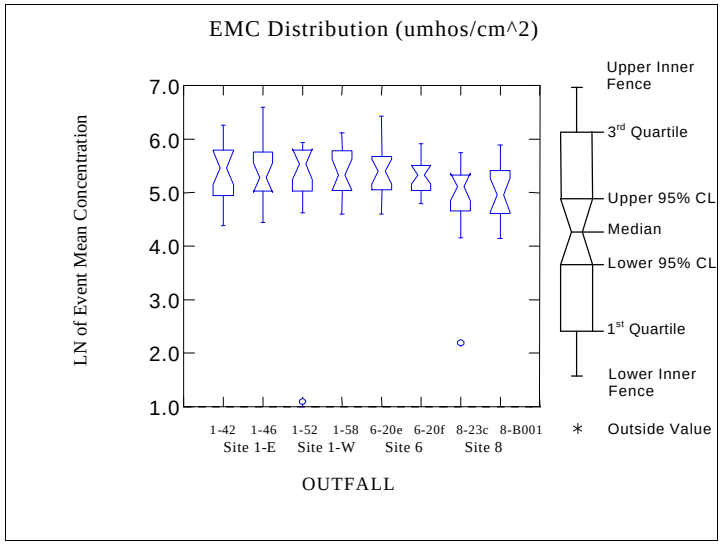
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Oil & Grease





Conductivity



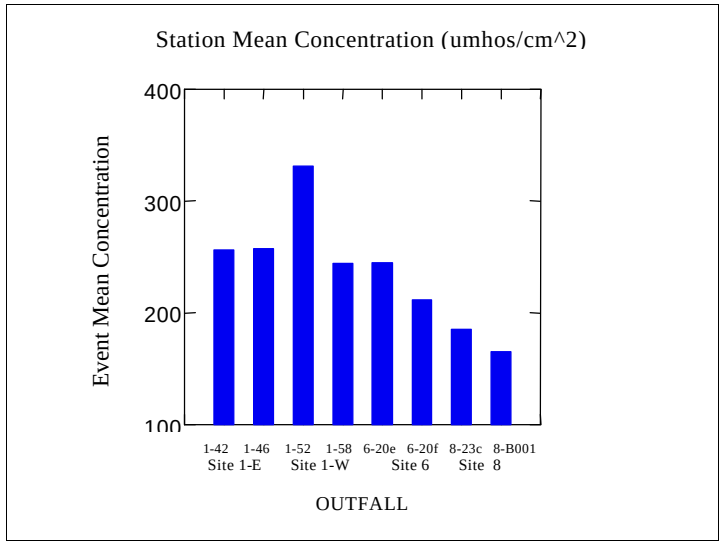
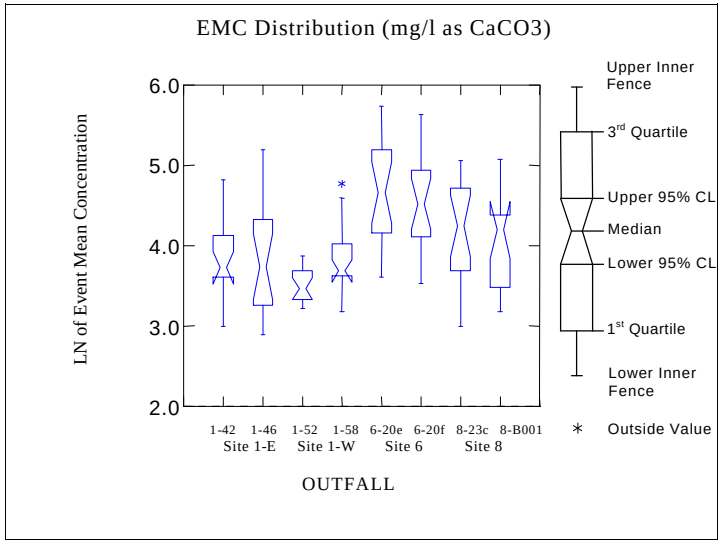
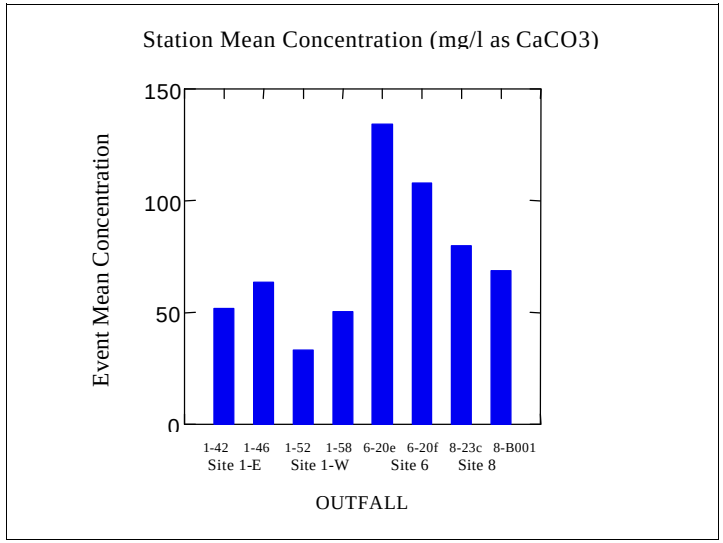


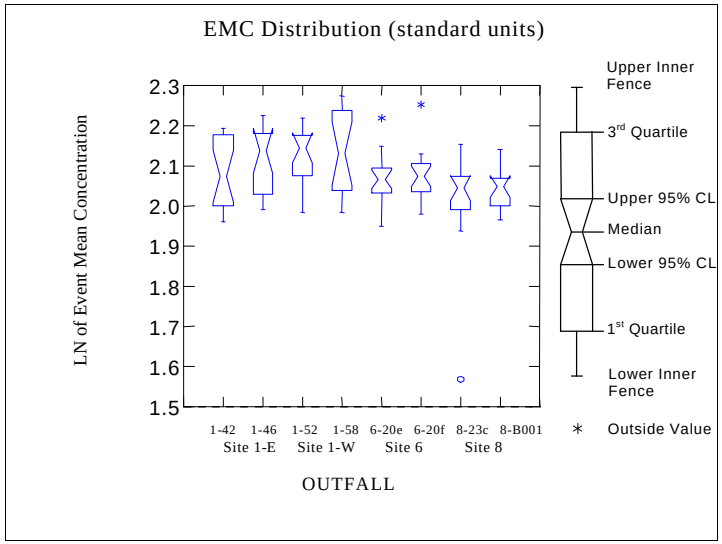
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Hardness as CaCO3





pH



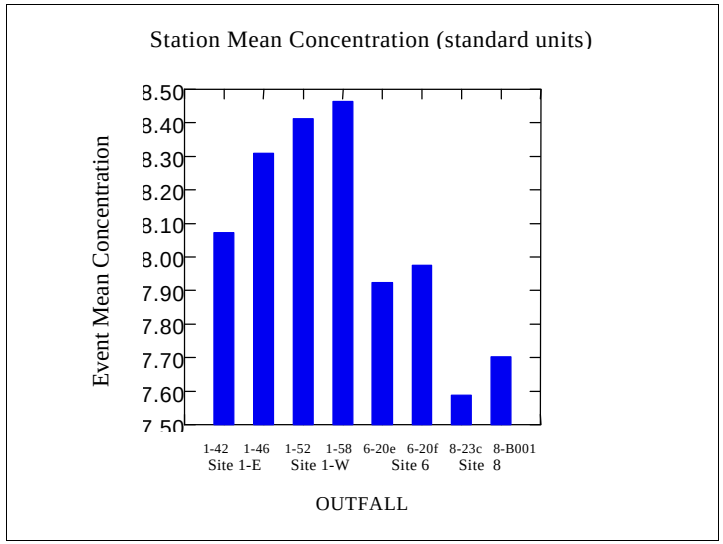
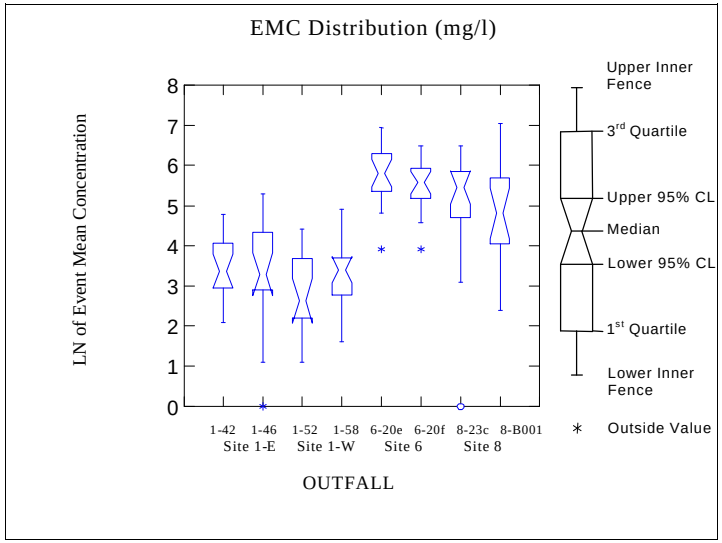
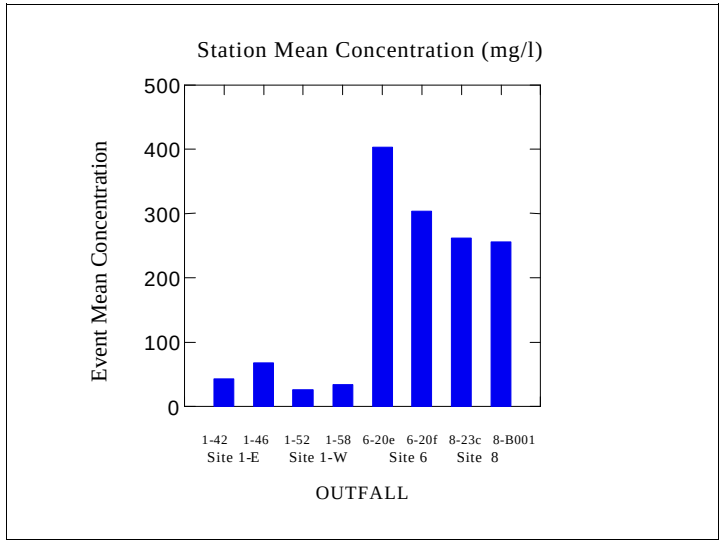


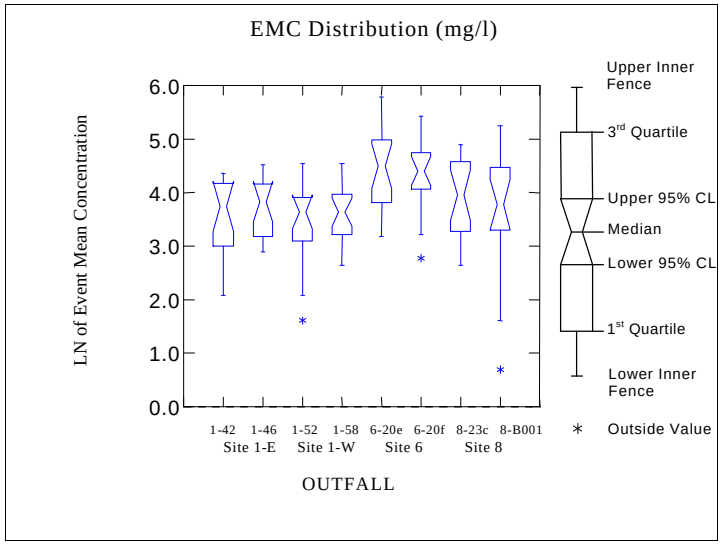
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Total Suspended Solids





Total Volatile Solids



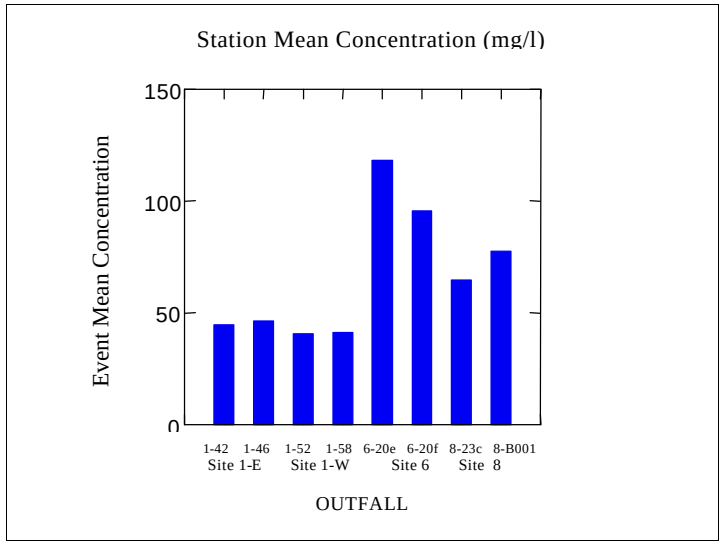
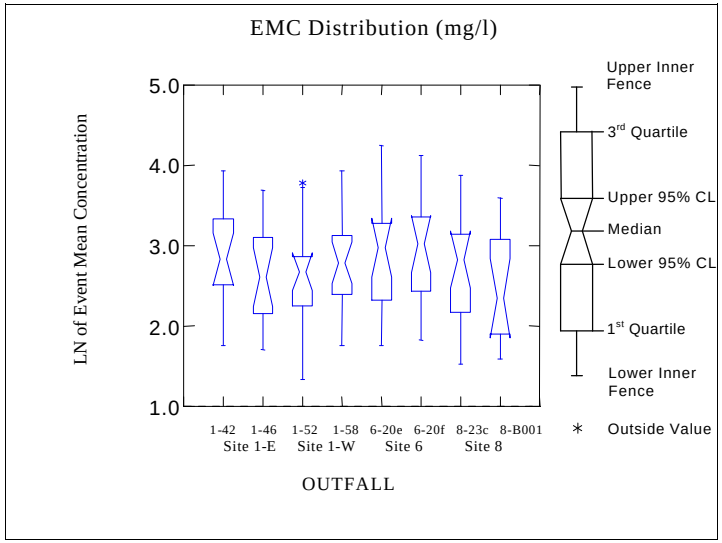
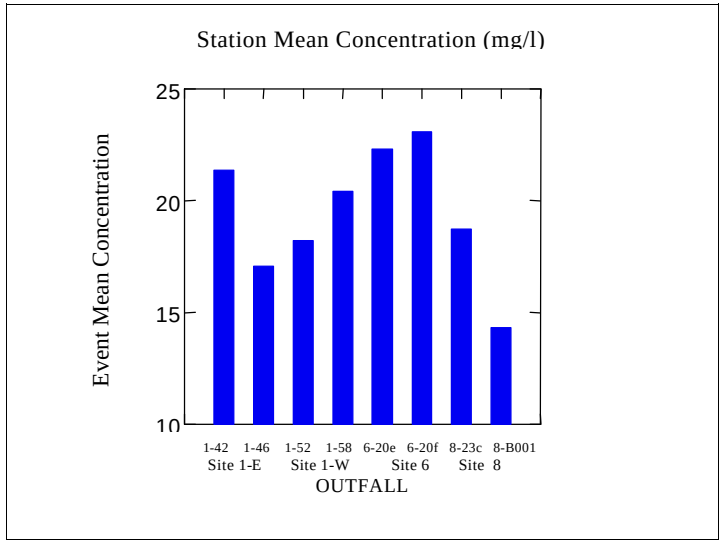


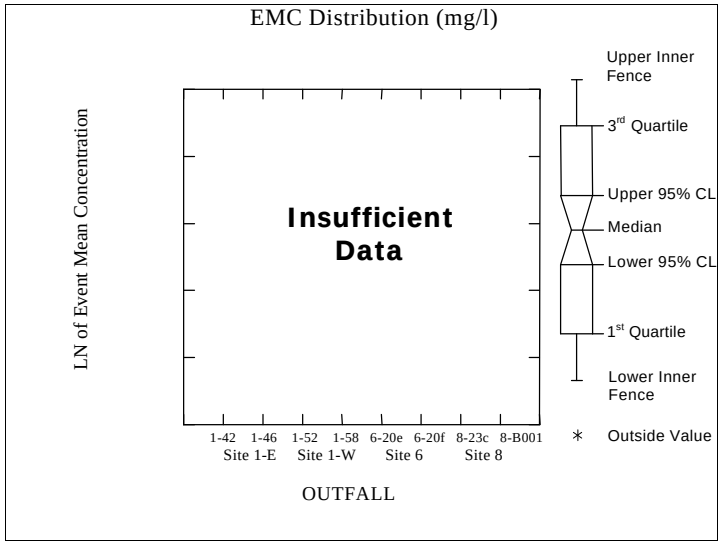
Figure G-1. SUMMARY STATISTICS FOR WATER QUALITY CONSTITUENTS

Total Organic Carbon





TPH (Gasoline)



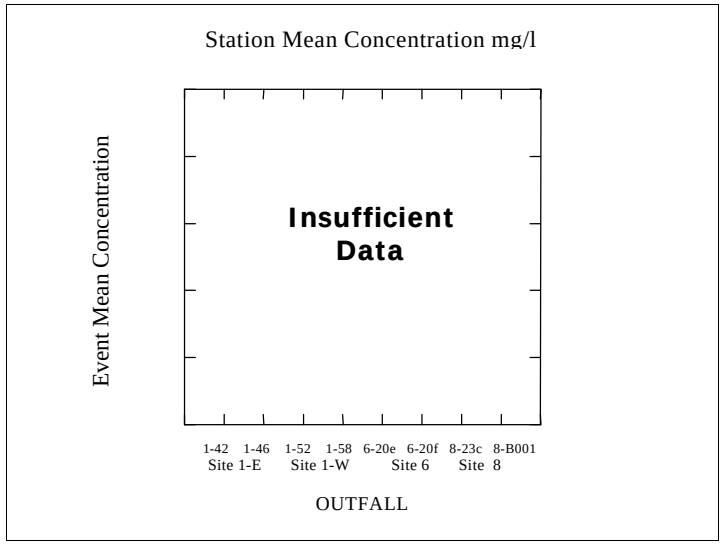


Table G-1. CHEMICAL WATER QUALITY DATA

Cadmium, Dissolved ug/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	ND	ND	ND	ND	ND	ND	ND	ND
	1998-03	12/01/98	ND	0.581	0.489	2.29	*****	*****	0.785	0.571
	1998-05	01/25/99	0.310	0.370	ND	ND	0.278	0.534	0.360	ND
	1998-06	02/09/99	ND	ND	ND	ND	1.54	0.466	0.286	*****
	1998-09	03/15/99	ND	ND	*****	ND	ND	ND	ND	ND
	1998-10	03/20/99	ND	ND	*****	0.216	ND	ND	ND	ND
	1998-11	03/25/99	ND	ND	ND	ND	0.954	ND	0.208	*****
	1998-12	04/06/99	ND	ND	ND	ND	ND	ND	ND	ND
	1998-13	04/11/99	ND	ND	ND	ND	ND	ND	ND	ND
	COV		*****	*****	*****	*****	4.15	*****	0.760	*****
	Mean		*****	*****	*****	*****	0.580	*****	0.391	*****
	Median		*****	*****	*****	*****	0.136	*****	0.311	*****
1999	1999-05	01/25/00	ND	0.309	ND	0.466	0.332	0.392	ND	ND
	1999-06	01/30/00	ND	ND	ND	0.212	ND	ND	ND	*****
	1999-08	02/10/00	0.205	ND	ND	0.364	ND	0.254	ND	0.388
	1999-09	02/12/00	*****	*****	ND	ND	ND	ND	ND	ND
	1999-10	02/13/00	ND	*****	ND	ND	0.265	0.286	ND	0.418
	1999-11	02/16/00	ND	ND	ND	ND	ND	0.244	ND	ND
	1999-12	02/20/00	*****	ND	ND	ND	ND	ND	ND	ND
	1999-13	02/23/00	*****	ND	ND	ND	ND	0.209	ND	ND
	1999-14	02/27/00	ND	ND	ND	ND	ND	0.264	*****	ND
	1999-15	03/04/00	ND	ND	ND	ND	ND	ND	ND	ND
	1999-16	03/08/00	ND	ND	ND	ND	ND	ND	ND	ND
	COV		*****	*****	*****	1.20	*****	0.730	*****	*****
	Mean		*****	*****	*****	0.171	*****	0.280	*****	*****
	Median		*****	*****	*****	0.109	*****	0.227	*****	*****
Combined	COV		*****	1.17	*****	11.39	5.01	0.737	1.36	0.698
	Mean		*****	0.168	*****	0.308	0.272	0.207	0.235	0.230
	Median		*****	0.109	*****	0.027	0.053	0.166	0.139	0.188

Cadmium, Total ug/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	1.51	1.36	2.39	0.661	2.45	2.96	2.72	0.612
	1998-03	12/01/98	0.664	0.494	0.956	0.719	*****	*****	2.76	2.16
	1998-05	01/25/99	1.60	0.420	1.84	0.400	3.08	2.09	2.38	2.35
	1998-06	02/09/99	1.09	0.520	0.663	0.821	3.47	3.08	2.39	*****
	1998-09	03/15/99	1.37	ND	*****	0.849	4.03	4.19	2.22	2.13
	1998-10	03/20/99	ND	0.692	*****	0.337	5.70	0.555	1.60	1.72
	1998-11	03/25/99	0.354	0.449	0.432	0.499	5.82	6.03	2.16	*****
	1998-12	04/06/99	0.403	0.569	0.391	0.302	3.31	3.00	1.41	1.17
	1998-13	04/11/99	0.241	ND	ND	ND	0.696	0.758	0.804	0.306
	COV		1.01	0.570	1.09	0.536	0.75	0.987	0.414	0.903
	Mean		0.888	0.560	1.05	0.544	3.85	3.13	2.09	1.65
	Median		0.624	0.486	0.714	0.480	3.08	2.23	1.93	1.22
1999	1999-05	01/25/00	0.596	0.643	0.566	0.801	4.48	5.28	2.46	1.65
	1999-06	01/30/00	0.285	1.42	0.24	0.502	2.71	2.13	2.87	*****
	1999-08	02/10/00	1.20	1.55	0.58	1.62	3.75	4.06	3.16	1.95
	1999-09	02/12/00	*****	*****	0.36	0.663	1.85	*****	1.05	0.804
	1999-10	02/13/00	*****	*****	1.09	0.770	3.12	3.83	2.10	1.91
	1999-11	02/16/00	1.13	0.593	0.355	0.865	2.85	3.89	2.23	1.33
	1999-12	02/20/00	*****	ND	ND	ND	ND	ND	ND	ND
	1999-13	02/23/00	*****	0.283	ND	0.399	2.31	3.04	1.76	1.06
	1999-14	02/27/00	0.473	ND	ND	0.276	1.86	1.55	*****	0.472
	1999-15	03/04/00	0.455	ND	0.556	0.201	0.562	0.548	0.321	0.292
	1999-16	03/08/00	ND	0.200	ND	0.204	1.63	2.39	0.914	1.53
	COV		0.740	1.60	0.932	0.807	1.14	1.38	1.20	0.97
	Mean		0.644	0.631	0.405	0.607	2.71	3.33	1.99	1.23
	Median		0.517	0.335	0.297	0.472	1.79	1.96	1.27	0.885
Combined	COV		0.867	1.072	1.145	0.669	1.019	1.154	0.870	0.929
	Mean		0.761	0.592	0.634	0.572	3.21	3.17	2.06	1.38
	Median		0.575	0.404	0.417	0.476	2.25	2.08	1.55	1.01

Note: Statistics are based on a log-normal distribution.

***** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

Chromium, Dissolved ug/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	1.39	2.17	3.04	ND	1.46	1.41	1.04	ND
	1998-03	12/01/98	5.87	6.24	5.37	2.47	*****	*****	3.14	2.29
	1998-05	01/25/99	3.56	3.88	3.47	4.04	4.50	7.33	4.32	4.54
	1998-06	02/09/99	2.82	2.95	2.24	2.44	2.49	2.18	1.86	*****
	1998-09	03/15/99	2.36	3.04	*****	1.27	2.51	3.10	2.06	2.28
	1998-10	03/20/99	4.77	4.81	*****	4.24	5.92	5.69	3.14	2.85
	1998-11	03/25/99	3.85	2.49	2.43	4.00	3.96	4.15	3.31	*****
	1998-12	04/06/99	4.82	4.73	4.16	4.00	4.30	4.12	2.74	2.99
	1998-13	04/11/99	2.56	2.77	2.13	2.07	2.94	3.61	2.18	2.05
	COV		0.469	0.362	0.354	0.575	0.465	0.559	0.438	0.487
	Mean		3.62	3.70	3.28	2.93	3.57	4.05	2.69	2.63
	Median		3.28	3.48	3.10	2.54	3.24	3.54	2.46	2.37
1999	1999-05	01/25/00	3.33	3.32	2.93	1.81	2.61	2.32	1.89	3.56
	1999-06	01/30/00	4.19	2.87	4.39	2.44	2.48	2.48	2.49	*****
	1999-08	02/10/00	3.36	3.31	2.50	2.48	1.78	2.31	1.83	1.55
	1999-09	02/12/00	*****	*****	1.75	1.65	2.32	2.73	1.35	1.33
	1999-10	02/13/00	2.55	*****	2.56	2.79	2.31	2.25	2.04	2.31
	1999-11	02/16/00	3.94	3.32	2.71	2.70	3.10	3.44	2.40	2.22
	1999-12	02/20/00	*****	2.21	1.75	2.28	1.91	1.96	1.63	1.07
	1999-13	02/23/00	*****	2.09	1.78	2.44	2.48	2.56	1.72	1.30
	1999-14	02/27/00	3.88	3.30	2.97	4.56	3.05	3.40	*****	1.92
	1999-15	03/04/00	1.95	1.55	1.68	1.69	1.62	2.08	1.05	1.03
	1999-16	03/08/00	2.30	2.28	1.46	2.40	2.42	2.38	1.17	2.44
	COV		0.286	0.280	0.342	0.288	0.207	0.181	0.293	0.419
	Mean		3.21	2.71	2.41	2.48	2.38	2.54	1.77	1.89
	Median		3.08	2.61	2.28	2.38	2.33	2.50	1.70	1.74
Combined	COV		0.380	0.349	0.373	0.421	0.369	0.409	0.411	0.465
	Mean		3.41	3.19	2.74	2.66	2.85	3.13	2.19	2.18
	Median		3.19	3.01	2.57	2.45	2.68	2.89	2.02	1.97

Chromium, Total ug/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	5.40	8.22	8.72	4.60	20.9	23.0	12.1	4.14
	1998-03	12/01/98	9.34	8.44	7.75	6.38	*****	*****	22.4	18.9
	1998-05	01/25/99	5.51	6.62	4.79	5.55	29.9	20.2	23.3	35.2
	1998-06	02/09/99	8.30	5.61	7.94	5.79	28.4	22.3	18.0	*****
	1998-09	03/15/99	19.1	7.81	*****	7.37	37.9	39.0	27.2	29.0
	1998-10	03/20/99	3.43	4.34	*****	4.51	57.2	48.1	18.8	19.4
	1998-11	03/25/99	5.77	6.85	5.88	6.24	46.0	50.2	22.6	*****
	1998-12	04/06/99	6.72	9.42	5.91	6.17	35.7	26.9	16.6	14.7
	1998-13	04/11/99	4.54	4.84	4.99	5.90	11.3	12.7	8.23	6.47
	COV		0.53	0.270	0.241	0.157	0.536	0.501	0.387	0.914
	Mean		7.55	6.94	6.60	5.84	34.4	30.8	19.1	19.9
	Median		6.68	6.70	6.41	5.77	30.3	27.6	17.8	14.7
1999	1999-05	01/25/00	6.53	7.69	6.64	5.19	35.7	38.9	23.3	19.0
	1999-06	01/30/00	7.19	4.40	4.96	2.79	22.4	19.4	29.4	*****
	1999-08	02/10/00	10.4	15.4	7.32	11.9	34.2	33.7	29.1	16.8
	1999-09	02/12/00	*****	*****	4.11	5.20	16.3	*****	11.1	4.80
	1999-10	02/13/00	*****	*****	3.50	3.79	19.3	24.9	15.0	9.37
	1999-11	02/16/00	4.41	5.72	4.67	5.33	17.2	29.8	19.0	11.9
	1999-12	02/20/00	*****	ND	ND	ND	ND	ND	ND	ND
	1999-13	02/23/00	*****	3.09	2.38	3.93	17.6	19.8	12.3	9.39
	1999-14	02/27/00	4.14	3.47	3.30	4.12	14.0	11.6	*****	5.72
	1999-15	03/04/00	3.48	2.15	1.86	2.23	6.26	5.27	2.35	2.10
	1999-16	03/08/00	2.85	2.74	2.08	4.08	13.1	18.7	6.66	12.5
	COV		0.478	0.920	0.651	0.678	1.28	1.54	1.57	1.19
	Mean		5.64	5.24	3.93	4.64	22.1	26.8	19.0	10.7
	Median		5.09	3.86	3.29	3.84	13.6	14.6	10.2	6.89
Combined	COV		0.512	0.704	0.636	0.536	1.11	1.15	1.07	1.18
	Mean		6.66	6.22	5.06	5.23	28.5	29.5	19.5	14.6
	Median		5.93	5.08	4.27	4.61	19.1	19.3	13.3	9.41

Note: Statistics are based on a log-normal distribution.

***** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

Copper, Dissolved ug/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	20.2	14.7	21.1	18.2	27.6	32.7	18.6	9.62
	1998-03	12/01/98	27.6	16.6	25.7	24.7	*****	*****	30.9	29.9
	1998-05	01/25/99	19.2	13.3	13.0	14.7	46.3	45.0	27.6	28.6
	1998-06	02/09/99	9.39	9.01	10.2	9.31	43.8	26.5	18.0	*****
	1998-09	03/15/99	13.3	13.0	*****	14.3	28.2	40.7	17.9	18.4
	1998-10	03/20/99	22.3	16.7	*****	19.6	57.2	73.9	33.0	28.1
	1998-11	03/25/99	11.0	10.2	10.2	15.3	59.9	53.8	27.0	*****
	1998-12	04/06/99	13.4	16.1	12.1	12.8	29.7	25.7	15.0	19.5
	1998-13	04/11/99	8.27	8.73	9.52	9.66	20.3	23.3	10.6	15.0
	COV		0.43	0.26	0.40	0.33	0.41	0.42	0.39	0.43
	Mean		16.2	13.2	14.6	15.5	39.6	40.5	22.3	21.7
	Median		14.9	12.8	13.6	14.7	36.7	37.3	20.8	19.9
1999	1999-05	01/25/00	35.9	31.1	25.7	39.1	51.8	54.2	34.9	26.5
	1999-06	01/30/00	29.5	20.6	21.2	25.9	32.3	37.3	38.8	*****
	1999-08	02/10/00	18.3	18.3	15.8	18.5	26.1	30.7	24.9	21.8
	1999-09	02/12/00	*****	*****	6.93	8.54	14.5	18.5	7.08	5.9
	1999-10	02/13/00	15.8	*****	11.8	14.7	32.5	31.9	22.9	21.1
	1999-11	02/16/00	11.0	11.0	10.9	13.5	22.6	24.5	14.8	12.0
	1999-12	02/20/00	*****	6.24	6.60	7.35	9.7	9.9	8.54	7.05
	1999-13	02/23/00	*****	5.31	5.26	7.47	13.3	17.8	9.39	7.19
	1999-14	02/27/00	11.1	7.98	9.27	11.4	15.4	22.8	*****	10.3
	1999-15	03/04/00	5.54	3.69	4.50	4.30	7.42	9.10	4.88	4.42
	1999-16	03/08/00	7.33	6.78	5.43	6.73	11.2	13.6	8.82	16.0
	COV		0.719	0.805	0.638	0.722	0.653	0.599	0.822	0.680
	Mean		17.3	12.6	11.3	14.5	21.8	25.0	18.1	13.6
	Median		14.0	9.83	9.6	11.7	18.3	21.5	14.0	11.2
Combined	COV		0.556	0.574	0.574	0.565	0.681	0.606	0.661	0.662
	Mean		16.6	12.9	12.6	14.9	29.7	31.7	20.2	17.0
	Median		14.5	11.2	10.9	13.0	24.5	27.1	16.9	14.2

Copper, Total ug/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	34.9	40.1	37.0	34.9	152	139	61.4	20.2
	1998-03	12/01/98	38.5	24.4	33.0	41.4	*****	*****	107	77.5
	1998-05	01/25/99	20.6	21.0	17.4	20.6	172	124	103	97.2
	1998-06	02/09/99	29.0	18.3	31.7	29.2	134	125	135	*****
	1998-09	03/15/99	72.4	36.5	*****	33.4	177	211	111	101
	1998-10	03/20/99	23.2	19.9	*****	29.1	366	359	103	85.5
	1998-11	03/25/99	29.5	23.8	36.3	30.8	292	331	125	*****
	1998-12	04/06/99	30.2	43.5	23.7	27.0	184	150	80.2	65.0
	1998-13	04/11/99	19.8	20.3	23.7	26.9	73	81.7	46.8	37.9
	COV		0.409	0.341	0.285	0.197	0.520	0.548	0.358	0.646
	Mean		33.1	27.6	29.2	30.4	197	193	98.1	72.9
	Median		30.6	26.2	28.1	29.9	175	169	92.4	61.3
1999	1999-05	01/25/00	49.3	46.9	38.4	51.4	211	237	113	84.7
	1999-06	01/30/00	44.4	27.7	24.7	29.2	141	124	129	*****
	1999-08	02/10/00	47.6	71.0	32.8	63.0	188	208	126	66.7
	1999-09	02/12/00	*****	*****	28.6	38.3	100	*****	59.7	23.7
	1999-10	02/13/00	*****	*****	21.1	24.3	122	149	83.8	44.5
	1999-11	02/16/00	24.8	30.7	19.7	30.8	123	166	106	53.0
	1999-12	02/20/00	*****	15.1	17.2	16.9	50.7	65.4	40.9	28.1
	1999-13	02/23/00	*****	17.0	14.6	21.1	99.1	113	65.0	44.6
	1999-14	02/27/00	25.4	13.0	15.9	21.6	90.0	75.6	*****	29.6
	1999-15	03/04/00	17.5	11.3	15.0	13.2	28.7	33.8	18.6	14.2
	1999-16	03/08/00	19.5	24.2	15.0	17.4	82.0	107	38.1	78.0
	COV		0.460	0.672	0.351	0.511	0.617	0.638	0.699	0.620
	Mean		33.1	28.8	22.2	29.9	116	133	81.8	48.1
	Median		30.1	23.9	20.9	26.6	99.0	112	67.0	40.9
Combined	COV		0.416	0.508	0.354	0.390	0.654	0.629	0.568	0.654
	Mean		32.9	28.1	24.9	30.1	150	159	89.7	57.7
	Median		30.4	25.0	23.4	28.0	126	134	78.0	48.3

Note: Statistics are based on a log-normal distribution.

***** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

Conductivity **umhos/cm**

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-03	12/01/98	326	240	271	157	282	272	198	252
	1998-05	01/25/99	327	735	181	104	303	340	166	163
	1998-06	02/09/99	461	474	196	225	291	251	302	198
	1998-09	03/15/99	80	169	153	103	208	246	106	123
	1998-10	03/20/99	177	171	308	189	616	190	207	264
	1998-11	03/25/99	140	140	162	393	322	138	176	260
	1998-12	04/06/99	214	219	268	151	211	212	112	110
	1998-13	04/11/99	305	171	325	99	226	225	315	195
	COV		0.614	0.634	0.305	0.501	0.360	0.271	0.416	0.347
	Mean		263	289	234	178	307	236	200	198
	Median		224	244	224	160	289	227	185	187
1999	1999-05	01/25/00	345	417	339	321	215	205	218	*****
	1999-08	02/10/00	129	356	330	290	230	209	268	363
	1999-09	02/12/00	233	294	351	*****	155	154	9	109
	1999-10	02/13/00	523	318	378	*****	392	371	*****	*****
	1999-11	02/16/00	239	285	237	399	202	193	162	165
	1999-12	02/20/00	250	175	122	327	250	241	167	103
	1999-13	02/23/00	144	102	102	164	99	124	76	76
	1999-14	02/27/00	132	85	3	320	156	181	89	84
	1999-15	03/04/00	400	123	343	455	110	121	64	63
	1999-16	03/08/00	123	152	153	158	123	126	117	98
	COV		0.553	0.614	2.737	0.399	0.442	0.361	1.333	0.595
	Mean		255	237	445	309	194	193	161	131
	Median		223	202	153	287	178	182	96	113
Combined	COV		0.56	0.61	1.53	0.55	0.48	0.34	1.00	0.55
	Mean		256	258	331	244	245	212	185	166
	Median		223	220	181	214	221	201	131	145

Note: Statistics are based on a log-normal distribution.

**** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

Coliforms, Fecal **MPN/100mL**

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-03	12/01/98	2300	2700	22000	160000	90000	24000	160000	160000
	1998-05	01/25/99	30	30	30	23	500	130	300	800
	1998-06	02/09/99	8000	200	1100	2400	22000	5000	17000	9000
	1998-09	03/15/99	23	23	80	300	500	170	300	170
	1998-10	03/20/99	130	80	80	50	160000	800	170	2300
	1998-11	03/25/99	8000	5000	800	500	800	500	5000	11000
	1998-12	04/06/99	230	70	230	80	80	30	300	300
	1998-13	04/11/99	500	230	230	700	500	230	230	2300
	COV		14.43	6.99	8.39	48.17	53.63	9.75	25.11	11.37
	Mean		6427	1402	2909	23935	142879	5301	35059	31557
	Median		444	198	344	497	2664	541	1395	2765
1999	1999-05	01/25/00	20	80	70	80	ND	ND	5000	*****
	1999-08	02/10/00	ND	20	ND	ND	230	220	5000	130
	1999-09	02/12/00	ND	500	300	*****	1300	ND	ND	80
	1999-10	02/13/00	110	170	80	*****	130	1100	*****	*****
	1999-11	02/16/00	130	ND	ND	40	300	500	ND	800
	1999-12	02/20/00	220	ND	ND	ND	80	40	40	20
	1999-13	02/23/00	1300	800	20	40	800	1300	130	170
	1999-14	02/27/00	20	ND	ND	ND	40	110	80	70
	1999-15	03/04/00	ND	ND	ND	20	ND	ND	ND	20
	1999-16	03/08/00	500	ND	500	110	800	500	1300	1100
	COV		5.4	14.1	10.7	1.3	3.5	4.2	91.1	2.9
	Mean		334	359	208	45	546	604	9055	364
	Median		60	25	19	27	151	141	99	120
Combined	COV		12.5	15.8	24.9	24.0	29.8	6.9	98.5	19.4
	Mean		1833	1000	1735	2775	16152	1795	33941	11173
	Median		147	63	70	115	541	256	345	577

Hardness as CaCO3 **mg/l**

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	46	42	28	48	58	50	42	30
	1998-03	12/01/98	124	120	40	118	*****	*****	136	152
	1998-05	01/25/99	32	180	30	38	180	92	140	160
	1998-06	02/09/99	68	178	40	40	68	68	52	*****
	1998-09	03/15/99	36	34	*****	50	200	198	152	80
	1998-10	03/20/99	50	70	*****	62	310	*****	66	80
	1998-11	03/25/99	30	26	32	32	272	280	*****	*****
	1998-12	04/06/99	40	44	44	42	220	140	80	66
	1998-13	04/11/99	20	20	30	24	64	54	36	30
	COV		0.56	0.97	0.18	0.47	0.79	0.74	0.62	0.76
	Mean		50	83	35	50	181	130	90	90
	Median		43	59	34	46	142	104	77	71
1999	1999-05	01/25/00	92	92	42	99	172	164	111	116
	1999-06	01/30/00	75	76	34	84	137	134	158	*****
	1999-08	02/10/00	38	70	28	48	169	140	112	70
	1999-09	02/12/00	*****	*****	25	30	94	77	31	24
	1999-10	02/13/00	56	*****	25	38	107	110	74	69
	1999-11	02/16/00	42	29	28	40	105	103	80	44
	1999-12	02/20/00	*****	24	27	31	46	39	36	24
	1999-13	02/23/00	*****	20	32	38	64	61	42	37
	1999-14	02/27/00	*****	*****	*****	70	*****	*****	*****	*****
	1999-15	03/04/00	41	18	32	37	37	34	20	35
	1999-16	03/08/00	38	33	48	40	69	70	40	67
	COV		0.37	0.72	0.22	0.42	0.56	0.58	0.75	0.58
	Mean		55	46	32	50	102	96	73	55
	Median		51	38	31	47	89	83	58	48
Combined	COV		0.48	0.88	0.20	0.43	0.70	0.64	0.69	0.68
	Mean		52	64	33	50	134	108	80	69
	Median		47	48	33	46	110	91	66	57

Note: Statistics are based on a log-normal distribution.

**** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

Nickel, Dissolved ug/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	5.12	3.72	3.73	5.44	4.47	4.62	3.33	1.71
	1998-03	12/01/98	8.87	5.85	5.84	9.63	*****	*****	10.30	8.50
	1998-05	01/25/99	3.03	4.82	2.88	4.63	5.96	5.78	4.19	4.38
	1998-06	02/09/99	2.20	1.78	1.87	1.75	5.03	4.88	3.61	*****
	1998-09	03/15/99	2.80	4.35	*****	3.96	6.12	9.58	2.97	3.07
	1998-10	03/20/99	8.20	2.58	*****	7.84	7.66	16.80	5.10	3.91
	1998-11	03/25/99	3.08	1.47	1.66	7.30	8.19	7.12	5.14	*****
	1998-12	04/06/99	2.69	2.50	2.86	2.01	4.13	3.09	3.47	3.16
	1998-13	04/11/99	2.90	2.23	2.40	2.63	5.98	5.74	2.91	2.45
	COV		0.545	0.499	0.445	0.673	0.244	0.548	0.411	0.536
	Mean		4.33	3.30	3.06	5.19	5.96	7.24	4.54	3.92
	Median		3.80	2.95	2.80	4.31	5.79	6.35	4.20	3.46
1999	1999-05	01/25/00	8.14	6.44	4.26	10.8	7.74	8.37	5.55	5.10
	1999-06	01/30/00	5.57	4.39	3.72	7.68	4.40	4.79	4.88	*****
	1999-08	02/10/00	4.80	4.86	3.72	6.53	4.82	4.94	4.90	5.54
	1999-09	02/12/00	*****	*****	ND	1.88	1.83	2.66	1.07	1.20
	1999-10	02/13/00	3.55	*****	1.93	3.09	5.14	4.58	3.90	4.51
	1999-11	02/16/00	2.24	2.05	1.83	3.15	3.53	3.85	2.34	2.27
	1999-12	02/20/00	*****	1.13	1.29	1.53	1.57	1.48	1.80	1.47
	1999-13	02/23/00	*****	0.72	ND	1.29	1.80	2.17	1.11	ND
	1999-14	02/27/00	2.16	1.17	1.72	2.50	3.05	4.21	*****	1.87
	1999-15	03/04/00	1.46	ND	ND	ND	1.11	1.30	0.81	ND
	1999-16	03/08/00	1.54	ND	3.60	1.48	1.43	1.76	1.43	1.85
	COV		0.698	1.503	0.696	0.925	0.699	0.643	0.900	0.797
	Mean		3.77	2.70	2.31	3.77	3.38	3.73	3.50	2.86
	Median		3.09	1.50	1.90	2.77	2.77	3.13	2.59	2.23
Combined	COV		0.608	1.090	0.629	0.840	0.684	0.725	0.730	0.720
	Mean		4.04	3.11	2.61	4.41	4.58	5.21	4.04	3.29
	Median		3.45	2.10	2.21	3.38	3.78	4.22	3.26	2.67

Nickel, Total ug/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	9.89	10.0	6.72	7.87	21.7	23.7	12.6	4.02
	1998-03	12/01/98	10.6	6.62	6.67	12.1	*****	*****	25.4	21.0
	1998-05	01/25/99	6.70	5.88	7.14	4.66	28.7	18.2	21.2	29.4
	1998-06	02/09/99	6.92	3.94	7.43	4.52	26.0	20.6	16.1	*****
	1998-09	03/15/99	317	11.8	*****	11.6	77.0	146	130	131
	1998-10	03/20/99	7.29	4.16	*****	11.5	56.3	52.5	18.9	18.7
	1998-11	03/25/99	7.33	6.51	5.91	7.42	43.7	46.2	21.6	*****
	1998-12	04/06/99	6.28	7.95	5.51	5.17	32.2	23.7	16.2	12.5
	1998-13	04/11/99	4.77	6.99	4.34	4.88	13.6	14.5	10.4	6.84
	COV		2.04	0.372	0.188	0.436	0.595	0.878	0.838	1.58
	Mean		25.1	7.15	6.27	7.82	38.2	42.5	28.0	32.9
	Median		11.1	6.70	6.16	7.17	32.8	31.9	21.5	17.6
1999	1999-05	01/25/00	11.3	11.1	7.91	13.90	34.40	36.8	23.1	18.9
	1999-06	01/30/00	8.53	7.76	4.30	8.33	22.6	19.7	28.6	*****
	1999-08	02/10/00	9.93	16.90	7.45	14.9	31.2	32.5	26.8	16.0
	1999-09	02/12/00	*****	*****	3.92	4.71	14.7	*****	9.32	4.51
	1999-10	02/13/00	*****	*****	3.11	4.62	20.3	23.6	15.3	10.8
	1999-11	02/16/00	4.62	4.96	3.52	6.44	16.8	24.9	17.2	10.2
	1999-12	02/20/00	*****	ND	ND	ND	ND	ND	ND	ND
	1999-13	02/23/00	*****	2.59	1.93	3.29	14.2	16.2	10.5	8.10
	1999-14	02/27/00	5.15	2.04	3.04	3.82	13.9	12.3	*****	2.91
	1999-15	03/04/00	4.03	2.52	2.79	2.12	5.78	5.50	2.60	ND
	1999-16	03/08/00	3.40	2.56	3.21	3.86	11.3	15.4	6.53	12.8
	COV		0.50	1.13	0.62	0.92	1.27	1.46	1.63	1.09
	Mean		6.82	5.99	3.93	6.40	20.7	24.2	19.5	11.4
	Median		6.09	3.97	3.34	4.70	12.8	13.7	10.2	7.72
Combined	COV		1.37	0.83	0.59	0.75	0.67	1.34	1.32	1.41
	Mean		14.5	6.69	4.92	7.10	26.7	33.3	24.5	19.2
	Median		8.52	5.16	4.23	5.69	22.3	20.0	14.8	11.1

Note: Statistics are based on a log-normal distribution.

**** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

Nitrate Nitrogen mg/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	1.90	1.60	2.40	1.90	1.80	2.00	1.40	0.50
	1998-03	12/01/98	3.30	3.10	3.90	2.60	*****	*****	3.70	3.30
	1998-05	01/25/99	1.00	0.90	1.60	0.70	1.70	1.40	1.60	*****
	1998-06	02/09/99	1.00	1.20	1.40	0.80	1.10	1.20	1.40	*****
	1998-09	03/15/99	1.00	1.20	*****	0.70	1.50	1.70	1.30	1.20
	1998-10	03/20/99	1.80	2.00	*****	1.70	*****	*****	2.30	*****
	1998-11	03/25/99	1.00	0.90	1.40	0.80	*****	2.00	2.10	*****
	1998-12	04/06/99	1.20	1.40	1.50	0.90	1.30	1.00	0.80	0.80
	1998-13	04/11/99	0.50	0.80	0.70	0.40	0.90	0.90	0.70	0.60
	COV		0.58	0.45	0.57	0.65	0.27	0.33	0.55	0.75
	Mean		1.43	1.46	1.88	1.19	1.39	1.47	1.72	1.24
	Median		1.24	1.33	1.63	0.99	1.34	1.40	1.51	0.99
1999	1999-05	01/25/00	3.90	3.00	2.70	2.80	3.20	3.20	1.70	1.70
	1999-06	01/30/00	2.50	1.90	2.50	1.80	2.20	2.00	2.10	*****
	1999-08	02/10/00	1.20	*****	1.30	1.10	1.20	1.20	1.80	1.90
	1999-09	02/12/00	*****	*****	1.60	0.46	0.83	1.10	0.37	0.37
	1999-10	02/13/00	1.80	*****	2.50	1.10	1.80	1.50	1.50	1.80
	1999-11	02/16/00	1.50	1.90	2.30	1.30	1.60	1.70	1.30	1.20
	1999-12	02/20/00	*****	0.60	0.86	0.52	0.41	0.52	0.45	0.39
	1999-13	02/23/00	*****	0.67	0.75	0.59	0.83	0.95	0.58	0.48
	1999-14	02/27/00	*****	*****	*****	1.20	1.10	*****	*****	*****
	1999-15	03/04/00	0.48	0.59	0.66	0.42	0.83	0.77	0.46	0.52
	1999-16	03/08/00	0.65	0.72	0.53	0.60	0.70	0.76	0.61	0.67
	COV		0.84	0.70	0.69	0.67	0.64	0.57	0.76	0.77
	Mean		1.81	1.32	1.62	1.09	1.36	1.38	1.12	1.04
	Median		1.4	1.08	1.34	0.91	1.14	1.20	0.90	0.82

Oil & Grease mg/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-03	12/01/98	25.0	15.0	226	27.0	28.0	30.0	35.0	44.0
	1998-05	01/25/99	16.0	16.0	8.0	7.00	58.0	18.0	29.0	46.0
	1998-06	02/09/99	37.0	22.0	27.0	24.0	60.0	39.0	34.0	21.0
	1998-09	03/15/99	23.0	ND	ND	ND	53.0	55.0	13.0	17.0
	1998-10	03/20/99	13.0	12.0	20.0	34.0	19.0	4.00	52.0	31.0
	1998-11	03/25/99	20.0	19.0	15.0	34.0	24.0	16.0	49.0	29.0
	1998-12	04/06/99	15.0	13.0	18.0	19.0	56.0	6.00	24.0	36.0
	1998-13	04/11/99	16.0	20.0	20.0	28.0	41.0	49.0	23.0	15.0
	COV		0.351	1.33	2.87	1.83	0.48	1.24	0.47	0.44
	Mean		20.7	19.2	49.9	31.6	43.3	31.3	33.0	30.3
	Median		19.5	11.5	16.4	15.2	39.0	19.6	29.9	27.7
1999	1999-05	01/25/00	10.0	18.0	14.0	23.0	32.0	37.0	29.0	*****
	1999-08	02/10/00	15.0	21.0	15.0	34.0	50.0	27.0	17.0	11.0
	1999-09	02/12/00	3.00	5.00	3.00	*****	11.0	13.0	ND	14.0
	1999-10	02/13/00	3.00	6.00	25.0	*****	34.0	42.0	*****	*****
	1999-11	02/16/00	4.00	4.00	4.00	12.0	34.0	32.0	16.0	8.00
	1999-12	02/20/00	*****	3.00	3.00	3.00	16.0	18.0	8.00	6.00
	1999-13	02/23/00	6.00	6.00	3.00	4.00	13.0	21.0	10.0	10.0
	1999-14	02/27/00	10.0	6.00	11.00	4.00	24.0	37.0	12.0	11.0
	1999-15	03/04/00	*****	2.00	2.00	2.00	10.0	8.00	10.0	9.00
	1999-16	03/08/00	ND	ND	ND	ND	ND	ND	ND	ND
	COV		1.26	1.15	1.40	1.86	1.57	1.59	1.80	1.01
	Mean		6.58	7.60	8.80	11.7	29.5	31.8	15.5	10.2
	Median		4.10	5.00	5.12	5.55	15.9	16.9	7.51	7.21
Combined	COV		1.49	1.36	2.31	2.05	1.26	1.37	1.65	1.20
	Mean		15.3	12.2	21.6	20.9	38.1	30.7	27.8	22.1
	Median		8.54	7.25	8.60	9.17	23.7	18.1	14.4	14.1

Note: Statistics are based on a log-normal distribution.

***** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

Ortho-Phosphorus mg/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	0.17	0.29	0.25	0.20	0.30	0.26	0.29	0.15
	1998-03	12/01/98	0.05	0.08	0.30	0.23	*****	*****	0.41	0.44
	1998-05	01/25/99	0.10	0.11	0.14	0.14	0.13	0.17	0.18	*****
	1998-06	02/09/99	0.08	0.11	0.11	0.10	0.12	0.13	0.15	*****
	1998-09	03/15/99	0.13	0.12	*****	0.11	0.14	0.12	0.15	0.17
	1998-10	03/20/99	0.09	0.07	*****	0.14	*****	*****	0.17	*****
	1998-11	03/25/99	0.12	0.12	0.13	0.17	*****	0.36	0.22	*****
	1998-12	04/06/99	0.12	0.13	0.13	0.13	0.19	0.18	0.15	0.15
	1998-13	04/11/99	0.12	0.17	0.16	0.13	0.17	0.18	0.11	0.16
	COV		0.36	0.43	0.39	0.27	0.35	0.40	0.42	0.49
	Mean		0.11	0.13	0.18	0.15	0.18	0.20	0.20	0.22
	Median		0.10	0.12	0.16	0.15	0.17	0.19	0.19	0.19
1999	1999-05	01/25/00	0.32	0.41	0.26	0.22	0.23	0.17	0.30	0.27
	1999-06	01/30/00	0.25	0.34	0.22	0.28	0.21	0.40	0.55	*****
	1999-08	02/10/00	0.19	0.33	0.16	0.15	0.24	0.26	0.31	0.23
	1999-09	02/12/00	*****	*****	0.11	0.12	0.14	0.13	0.10	0.11
	1999-10	02/13/00	0.10	*****	0.06	0.08	0.06	0.06	0.09	0.07
	1999-11	02/16/00	0.10	0.13	0.08	0.09	0.09	0.11	0.12	0.10
	1999-12	02/20/00	*****	0.09	0.08	0.08	0.09	0.10	0.08	0.07
	1999-13	02/23/00	*****	0.07	0.05	0.05	0.06	0.07	0.09	0.06
	1999-14	02/27/00	*****	*****	*****	0.06	*****	*****	*****	*****
	1999-15	03/04/00	0.07	0.05	0.05	0.05	0.07	0.07	0.06	0.06
	1999-16	03/08/00	0.06	0.06	0.06	0.05	0.10	0.12	0.08	0.10
	COV		0.72	1.04	0.67	0.66	0.59	0.66	0.86	0.60
	Mean		0.16	0.20	0.11	0.11	0.13	0.15	0.18	0.12
	Median		0.13	0.14	0.09	0.09	0.11	0.12	0.13	0.10
Combined	COV		0.53	0.71	0.63	0.56	0.54	0.59	0.67	0.65
	Mean		0.13	0.16	0.14	0.13	0.15	0.17	0.19	0.15
	Median		0.11	0.13	0.12	0.11	0.13	0.15	0.16	0.13

Total Phosphorus mg/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	0.39	0.30	0.36	0.38	0.80	0.76	0.36	0.21
	1998-03	12/01/98	0.32	0.24	0.47	0.38	*****	*****	0.67	0.58
	1998-05	01/25/99	0.17	0.13	0.14	0.20	0.21	0.20	0.20	*****
	1998-06	02/09/99	0.37	0.17	0.24	0.13	0.80	0.57	0.49	*****
	1998-09	03/15/99	0.21	0.32	*****	0.12	0.69	0.61	0.60	0.56
	1998-10	03/20/99	0.32	0.13	*****	0.38	*****	*****	0.26	*****
	1998-11	03/25/99	0.19	0.24	0.22	0.27	1.37	0.97	0.24	*****
	1998-12	04/06/99	0.19	0.23	0.18	0.18	0.58	0.44	0.30	0.38
	1998-13	04/11/99	0.13	0.22	0.16	0.15	0.32	0.33	0.23	0.21
	COV		0.40	0.34	0.46	0.50	0.69	0.57	0.46	0.53
	Mean		0.26	0.22	0.26	0.25	0.71	0.57	0.38	0.40
	Median		0.24	0.21	0.23	0.22	0.59	0.50	0.34	0.35
1999	1999-05	01/25/00	0.56	0.65	0.35	0.48	0.86	0.89	0.79	0.33
	1999-06	01/30/00	0.50	0.55	0.33	0.47	0.76	0.69	1.60	*****
	1999-08	02/10/00	0.67	9.90	0.64	0.58	10.00	5.40	0.68	0.71
	1999-09	02/12/00	*****	*****	0.41	0.38	0.88	0.57	0.34	0.40
	1999-10	02/13/00	0.26	*****	0.13	0.15	0.56	0.48	0.41	0.27
	1999-11	02/16/00	0.18	0.20	0.10	0.17	0.51	0.72	0.50	0.32
	1999-12	02/20/00	*****	0.31	0.15	0.12	0.27	0.28	0.25	0.17
	1999-13	02/23/00	*****	0.25	0.11	0.12	0.42	0.40	0.30	0.24
	1999-14	02/27/00	*****	*****	*****	0.14	*****	*****	*****	*****
	1999-15	03/04/00	0.17	0.14	0.11	0.14	0.20	0.18	0.12	0.10
	1999-16	03/08/00	0.13	0.21	0.11	0.11	0.37	0.39	0.22	0.35
	COV		0.74	2.29	0.78	0.73	1.48	1.14	0.85	0.59
	Mean		0.37	1.12	0.25	0.26	1.16	0.89	0.53	0.33
	Median		0.29	0.45	0.19	0.21	0.65	0.59	0.41	0.28
Combined	COV		0.55	1.32	0.64	0.61	1.11	0.89	0.66	0.56
	Mean		0.30	0.50	0.25	0.25	0.93	0.73	0.45	0.35
	Median		0.26	0.30	0.21	0.22	0.62	0.55	0.37	0.31

Note: Statistics are based on a log-normal distribution.

**** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

Lead, Dissolved ug/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	ND	ND	ND	ND	2.58	1.55	ND	ND
	1998-03	12/01/98	2.08	1.71	2.50	1.71	*****	*****	4.62	3.73
	1998-05	01/25/99	2.77	3.18	2.33	2.12	37.4	45.6	27.6	51.3
	1998-06	02/09/99	ND	ND	1.46	ND	151	4.22	1.53	*****
	1998-09	03/15/99	ND	ND	*****	ND	2.84	4.40	2.10	2.14
	1998-10	03/20/99	2.10	ND	*****	ND	3.11	5.31	3.08	1.36
	1998-11	03/25/99	ND	ND	ND	1.55	5.28	2.10	1.92	*****
	1998-12	04/06/99	ND	ND	ND	ND	ND	1.35	1.28	1.60
	1998-13	04/11/99	2.43	1.45	ND	4.10	2.80	3.32	4.82	2.15
	COV		0.25	1.07	0.53	1.15	3.83	1.55	1.32	2.19
	Mean		1.93	1.14	1.48	1.51	24.12	7.36	4.81	7.10
	Median		1.87	0.78	1.31	0.99	6.09	4.00	2.91	2.94
1999	1999-05	01/25/00	1.80	1.03	1.43	1.53	7.78	5.45	2.29	9.42
	1999-06	01/30/00	1.11	1.68	ND	ND	1.81	1.86	2.84	*****
	1999-08	02/10/00	2.18	1.16	1.86	1.47	8.01	14.8	6.71	5.73
	1999-09	02/12/00	*****	*****	ND	ND	10.5	15.7	9.49	2.40
	1999-10	02/13/00	1.19	*****	1.25	1.11	19.6	17.0	13.1	7.99
	1999-11	02/16/00	1.40	1.62	1.58	1.72	7.68	16.6	8.27	5.71
	1999-12	02/20/00	*****	ND	ND	ND	7.49	6.75	8.70	2.72
	1999-13	02/23/00	*****	0.82	ND	ND	14.9	16.7	11.4	5.79
	1999-14	02/27/00	1.34	ND	ND	1.51	11.4	16.8	*****	4.34
	1999-15	03/04/00	ND	ND	ND	ND	6.20	6.79	4.11	2.12
	1999-16	03/08/00	ND	ND	1.48	ND	11.6	15.3	6.97	13.3
	COV		0.35	0.58	0.26	0.96	0.68	0.82	0.64	0.67
	Mean		1.35	0.936	1.22	1.10	10.2	13.2	7.67	6.10
	Median		1.27	0.810	1.18	0.791	8.48	10.2	6.46	5.08
Combined	COV		0.36	0.80	0.37	1.02	1.64	1.30	1.09	1.25
	Mean		1.66	1.02	1.31	1.25	14.2	11.3	6.56	6.50
	Median		1.56	0.795	1.23	0.874	7.38	6.90	4.43	4.06

Lead, Total ug/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	23.4	32.9	23.0	23.7	401	445	174	44.2
	1998-03	12/01/98	24.6	10.6	22.7	30.7	*****	*****	413	344
	1998-05	01/25/99	12.8	15.7	7.16	13.8	822	504	462	448
	1998-06	02/09/99	24.9	10.8	26.6	17.5	476	420	213	*****
	1998-09	03/15/99	38.8	21.4	*****	23.4	881	894	401	396
	1998-10	03/20/99	5.47	7.70	*****	14.4	1530	1360	310	305
	1998-11	03/25/99	14.6	13.4	15.4	19.5	1260	1500	467	*****
	1998-12	04/06/99	17.8	28.5	19.1	21.2	878	609	272	227
	1998-13	04/11/99	12.9	10.4	13.9	13.0	213	244	127	120
	COV		0.610	0.529	0.468	0.29	0.725	0.687	0.490	0.990
	Mean		20.1	17.0	18.7	19.8	849	767	322	305
	Median		17.2	15.0	17.0	19.0	687	632	289	217
1999	1999-05	01/25/00	18.9	17.7	19.4	19.7	759	823	363	171
	1999-06	01/30/00	14.6	6.44	6.89	7.20	481	438	533	*****
	1999-08	02/10/00	32.5	59.3	23.6	56.8	660	716	427	144
	1999-09	02/12/00	*****	*****	13.7	18.2	383	*****	167	41.1
	1999-10	02/13/00	*****	*****	10.1	11.5	430	474	281	104
	1999-11	02/16/00	14.3	20.6	11.2	22.3	424	540	358	127
	1999-12	02/20/00	*****	12.3	8.76	8.05	117	132	99.1	38.7
	1999-13	02/23/00	*****	11.9	9.67	12.3	291	343	193	133
	1999-14	02/27/00	14.0	4.29	6.55	9.12	250	219	*****	56.4
	1999-15	03/04/00	14.3	5.26	12.3	6.67	69.8	78.2	44.5	21.6
	1999-16	03/08/00	8.71	11.3	7.68	8.27	255	352	103	297
	COV		0.413	0.948	0.42	0.714	0.813	0.859	0.926	0.965
	Mean		16.9	16.5	11.8	16.0	400	442	277	121
	Median		15.6	12.0	10.9	13.1	310	335	203	87
Combined	COV		0.514	0.734	0.492	0.578	0.916	0.863	0.741	1.15
	Mean		18.5	16.7	14.4	17.8	588	587	299	193
	Median		16.5	13.4	12.9	15.4	434	445	240	127

Note: Statistics are based on a log-normal distribution.

***** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

pH **pH Units**

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-03	12/01/98	7.63	8.84	7.79	7.90	7.72	7.58	7.70	7.87
	1998-05	01/25/99	7.64	8.69	9.20	8.87	8.21	8.21	8.30	8.03
	1998-06	02/09/99	7.47	7.53	7.42	7.50	7.84	7.39	7.31	7.23
	1998-09	03/15/99	7.50	9.05	8.81	8.47	7.82	7.66	7.73	7.46
	1998-10	03/20/99	7.33	7.61	8.71	7.66	7.03	7.47	7.28	7.88
	1998-11	03/25/99	7.37	7.33	7.27	7.27	7.16	7.24	7.33	7.24
	1998-12	04/06/99	8.97	8.69	8.51	8.38	9.20	9.51	7.95	7.72
	1998-13	04/11/99	7.39	7.48	7.97	7.70	8.04	8.06	7.34	7.36
	COV		0.07	0.09	0.09	0.07	0.08	0.09	0.05	0.04
	Mean		7.66	8.16	8.21	7.97	7.88	7.89	7.62	7.60
	Median		7.65	8.12	8.18	7.95	7.85	7.86	7.61	7.59
1999	1999-05	01/25/00	8.96	7.85	9.04	7.69	8.11	8.22	7.86	*****
	1999-08	02/10/00	7.10	7.46	8.82	7.59	7.97	8.02	6.94	7.44
	1999-09	02/12/00	8.85	8.40	8.43	*****	7.41	7.76	4.80	7.57
	1999-10	02/13/00	8.29	8.55	8.28	*****	7.63	7.87	*****	*****
	1999-11	02/16/00	8.88	8.30	8.57	8.79	7.83	8.02	7.47	7.14
	1999-12	02/20/00	8.70	9.25	9.14	9.65	7.57	7.82	7.90	7.95
	1999-13	02/23/00	8.74	8.85	8.74	9.43	8.57	8.39	8.62	8.51
	1999-14	02/27/00	7.20	7.61	7.65	9.46	8.12	8.02	8.12	7.82
	1999-15	03/04/00	8.82	9.15	8.33	9.31	7.96	7.90	7.82	8.23
	1999-16	03/08/00	8.42	8.88	8.71	9.72	8.41	8.41	8.35	7.79
	COV		0.09	0.08	0.05	0.10	0.05	0.03	0.18	0.06
	Mean		8.40	8.43	8.57	8.96	7.96	8.04	7.57	7.81
	Median		8.37	8.41	8.56	8.92	7.95	8.04	7.45	7.80
Combined	COV		0.09	0.08	0.07	0.10	0.06	0.06	0.13	0.05
	Mean		8.07	8.31	8.41	8.46	7.92	7.98	7.59	7.70
	Median		8.04	8.28	8.39	8.42	7.91	7.96	7.52	7.69

Total Kjedhal Nitrogen **mg/l**

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	2.7	1.9	2.4	2.2	3.6	3.1	2.7	1.1
	1998-03	12/01/98	3.4	5.7	2.5	3.5	*****	*****	6.7	8.0
	1998-05	01/25/99	2.0	1.4	1.4	1.1	3.9	3.1	2.8	*****
	1998-06	02/09/99	2.2	1.7	1.7	1.5	2.8	3.6	3.4	*****
	1998-09	03/15/99	2.5	3.1	*****	2.1	6.7	6.2	4.3	3.6
	1998-10	03/20/99	3.6	2.5	*****	3.4	*****	*****	4.8	*****
	1998-11	03/25/99	1.1	2.0	1.7	1.7	*****	7.3	*****	*****
	1998-12	04/06/99	2.5	2.8	2.2	2.5	3.4	3.9	3.1	3.6
	1998-13	04/11/99	1.4	1.1	2.0	2.0	2.8	2.5	1.4	2.0
	COV		0.40	0.51	0.21	0.38	0.33	0.41	0.49	0.86
	Mean		2.4	2.5	2.0	2.2	3.9	4.3	3.7	3.9
	Median		2.2	2.2	1.9	2.1	3.7	4.0	3.3	3.0
1999	1999-05	01/25/00	5.0	3.6	3.1	5.3	5.6	6.0	4.5	5.6
	1999-06	01/30/00	2.8	2.2	2.3	3.4	3.6	3.6	6.2	*****
	1999-08	02/10/00	2.2	2.8	1.7	2.5	3.9	4.5	4.2	1.8
	1999-09	02/12/00	*****	*****	1.1	1.4	1.5	1.7	1.1	1.4
	1999-10	02/13/00	1.4	*****	0.8	2.0	2.8	3.9	3.1	3.1
	1999-11	02/16/00	1.4	1.7	0.8	1.7	2.5	3.6	3.1	2.2
	1999-12	02/20/00	*****	0.6	0.8	0.8	1.4	1.7	1.4	0.8
	1999-13	02/23/00	*****	1.1	1.1	1.2	2.0	1.7	1.4	1.3
	1999-14	02/27/00	*****	*****	*****	0.6	*****	*****	*****	*****
	1999-15	03/04/00	0.8	0.6	0.8	0.8	0.8	0.9	0.8	0.6
	1999-16	03/08/00	1.1	1.1	1.1	1.1	1.1	2.0	1.4	1.9
	COV		0.68	0.76	0.52	0.74	0.67	0.64	0.79	0.76
	Mean		2.1	1.8	1.4	1.9	2.6	3.0	2.8	2.1
	Median		1.8	1.4	1.2	1.5	2.1	2.6	2.2	1.7
Combined	COV		0.53	0.67	0.48	0.61	0.63	0.59	0.69	0.83
	Mean		2.3	2.2	1.6	2.1	3.1	3.6	3.2	2.7
	Median		2.0	1.8	1.5	1.8	2.6	3.1	2.7	2.1

Note: Statistics are based on a log-normal distribution.

**** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

Total Organic Carbon mg/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	26.2	22.3	31.3	25.4	31.6	35.0	19.7	10.2
	1998-03	12/01/98	43.0	35.4	43.8	51.0	*****	*****	48.2	36.4
	1998-05	01/25/99	12.5	11.4	10.5	14.9	24.6	22.4	20.6	*****
	1998-06	02/09/99	12.8	12.4	15.4	10.8	17.5	20.2	15.8	*****
	1998-09	03/15/99	17.0	15.5	*****	15.1	7.2	33.0	5.9	5.9
	1998-10	03/20/99	30.0	26.0	*****	31.0	*****	*****	24.0	*****
	1998-11	03/25/99	25.0	11.9	14.5	17.3	70.0	62.0	34.0	*****
	1998-12	04/06/99	15.3	17.5	17.4	16.8	24.8	21.5	16.9	16.1
	1998-13	04/11/99	7.5	7.4	8.5	9.8	10.6	11.4	5.8	5.9
	COV		0.58	0.51	0.63	0.56	0.86	0.57	0.81	0.89
	Mean		21.5	18.0	20.5	21.4	27.7	29.9	22.4	15.5
	Median		18.6	16.0	17.4	18.7	21.0	26.0	17.4	11.6
1999	1999-05	01/25/00	51.0	40.0	41.5	48.0	37.5	34.3	24.0	30.0
	1999-06	01/30/00	34.8	27.3	34.6	51.0	32.4	28.8	31.6	*****
	1999-08	02/10/00	18.0	18.5	17.5	16.7	23.3	20.5	20.9	21.7
	1999-09	02/12/00	*****	*****	11.0	13.1	14.6	14.7	8.5	8.3
	1999-10	02/13/00	17.0	*****	16.1	20.6	26.6	25.1	22.4	21.9
	1999-11	02/16/00	12.2	13.6	14.1	17.1	19.6	20.5	16.7	12.8
	1999-12	02/20/00	*****	8.6	9.5	11.1	9.1	10.4	10.2	7.5
	1999-13	02/23/00	*****	6.6	6.7	9.5	10.2	10.8	7.9	6.7
	1999-14	02/27/00	*****	*****	*****	15.8	*****	*****	*****	*****
	1999-15	03/04/00	5.8	5.5	3.8	5.8	5.8	6.2	4.6	4.9
	1999-16	03/08/00	6.7	6.5	8.9	8.8	6.3	9.8	9.0	10.7
	COV		0.94	0.85	0.82	0.75	0.76	0.60	0.68	0.68
	Mean		21.9	16.2	16.8	19.8	19.3	18.5	16.1	14.1
	Median		15.9	12.4	13.0	15.9	15.4	15.9	13.3	11.7
Combined	COV		0.72	0.67	0.74	0.65	0.79	0.64	0.74	0.72
	Mean		21.4	17.1	18.2	20.4	22.3	23.1	18.7	14.3
	Median		17.4	14.2	14.6	17.1	17.5	19.5	15.1	11.6

Coliforms, Total MPN/100mL

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-03	12/01/98	3000	11000	90000	160000	90000	24000	160000	160000
	1998-05	01/25/99	500	1100	500	800	13000	3000	13000	8000
	1998-06	02/09/99	8000	6000	13000	5000	22000	28000	160000	28000
	1998-09	03/15/99	40	300	300	2400	3000	3000	1300	220
	1998-10	03/20/99	1400	500	220	800	160000	1100	300	2300
	1998-11	03/25/99	13000	13000	2300	1700	1700	1700	5000	30000
	1998-12	04/06/99	300	300	300	230	300	30	800	500
	1998-13	04/11/99	5000	1300	3000	13000	160000	8000	1300	8000
	COV		2.31	3.21	9.78	7.70	14.13	10.30	17.14	11.24
	Mean		6601	5555	17003	23138	189084	27800	91903	69916
	Median		2617	1651	1729	2982	13349	2687	5354	6197
1999	1999-05	01/25/00	2800	2300	340	3000	1300	230	2200	*****
	1999-08	02/10/00	17000	11000	23000	3000	30000	220	5000	2300
	1999-09	02/12/00	5000	500	1700	*****	2300	500	ND	1700
	1999-10	02/13/00	300	1700	80	*****	130	13000	*****	*****
	1999-11	02/16/00	3000	ND	1700	300	11000	8000	ND	2200
	1999-12	02/20/00	220	80	80	40	800	130	9000	3500
	1999-13	02/23/00	1300	2300	2200	500	8000	3000	2300	3000
	1999-14	02/27/00	270	230	500	300	500	500	270	220
	1999-15	03/04/00	500	40	300	40	230	300	40	300
	1999-16	03/08/00	2200	3500	3500	300	5000	1700	8000	3500
	COV		2.64	9.23	4.66	3.71	4.65	3.50	29.67	1.54
	Mean		3771	5108	3987	1320	8797	3180	17021	2689
	Median		1337	550	836	344	1851	875	573	1462
Combined	COV		2.50	6.20	6.20	9.03	11.28	6.03	36.58	5.34
	Mean		4844	5629	7251	9195	50438	8803	60029	16367
	Median		1801	897	1155	1012	4454	1440	1641	3010

Note: Statistics are based on a log-normal distribution.

**** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

TPH (Diesel) mg/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-03	12/01/98	14.2	15.6	13.4	22.3	ND	1.56	9.79	7.45
	1998-05	01/25/99	15.6	8.48	6.48	5.28	4.30	9.77	6.61	7.64
	1998-06	02/09/99	20.5	17.7	18.2	33.1	7.35	35.6	18.4	11.2
	1998-09	03/15/99	7.16	4.65	4.05	7.02	7.69	7.02	6.48	8.25
	1998-10	03/20/99	13.8	9.39	16.8	37.4	25.3	23.0	43.4	18.5
	1998-11	03/25/99	12.9	10.1	4.01	26.4	14.0	6.53	27.5	16.6
	1998-12	04/06/99	9.80	7.27	10.0	11.4	19.2	16.2	13.0	12.5
	1998-13	04/11/99	12.0	13.0	13.4	12.6	21.0	32.3	14.2	11.7
	COV		0.32	0.45	0.67	0.83	1.46	1.39	0.75	0.35
	Mean		13.4	10.9	11.2	20.6	15.5	19.6	17.8	11.8
	Median		12.7	10.0	9.3	15.8	8.8	11.5	14.2	11.1
1999	1999-05	01/25/00	ND	ND	ND	ND	ND	ND	ND	*****
	1999-08	02/10/00	17.0	13.0	4.90	37.0	5.90	13.0	4.70	12.0
	1999-09	02/12/00	0.570	ND	0.850	*****	ND	ND	ND	5.60
	1999-10	02/13/00	1.40	4.90	1.80	*****	5.40	9.60	*****	*****
	1999-11	02/16/00	2.30	1.90	2.20	2.80	18.0	26.0	2.50	2.90
	1999-12	02/20/00	ND	ND	ND	ND	16.0	17.0	3.90	4.30
	1999-13	02/23/00	3.50	2.80	3.00	3.00	5.90	7.30	3.30	4.20
	1999-14	02/27/00	10.0	3.90	2.50	7.40	15.0	14.0	7.80	6.00
	1999-15	03/04/00	ND	ND	ND	ND	5.70	4.60	4.60	3.90
	1999-16	03/08/00	9.10	ND	ND	ND	13.0	16.0	18.0	7.9
	COV		4.06	2.14	1.44	5.71	2.18	2.55	1.02	0.47
	Mean		6.81	3.31	1.93	6.30	12.5	17.4	5.41	5.89
	Median		1.63	1.40	1.10	1.70	5.22	6.33	3.78	5.33
Combined	COV		3.64	2.52	2.45	24.40	1.83	1.99	1.33	0.58
	Mean		15.3	9.09	7.52	24.4	13.7	18.4	11.7	8.92
	Median		4.06	3.35	2.85	3.44	6.57	8.25	7.05	7.70

TPH (Gasoline) mg/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-03	12/01/98	ND	ND	ND	ND	ND	ND	ND	ND
	1998-05	01/25/99	ND	ND	ND	ND	ND	ND	ND	ND
	1998-06	02/09/99	ND	ND	ND	ND	ND	ND	ND	ND
	1998-09	03/15/99	ND	ND	ND	ND	ND	ND	ND	ND
	1998-10	03/20/99	ND	ND	ND	ND	ND	ND	ND	ND
	1998-11	03/25/99	ND	ND	ND	ND	ND	ND	ND	ND
	1998-12	04/06/99	ND	ND	ND	ND	ND	ND	ND	ND
	1998-13	04/11/99	ND	ND	ND	ND	ND	ND	ND	ND
	COV		*****	*****	*****	*****	*****	*****	*****	*****
	Mean		*****	*****	*****	*****	*****	*****	*****	*****
	Median		*****	*****	*****	*****	*****	*****	*****	*****
1999	1999-05	01/25/00	ND	ND	ND	ND	ND	ND	ND	*****
	1999-08	02/10/00	ND	ND	ND	ND	ND	ND	ND	ND
	1999-09	02/12/00	ND	ND	ND	*****	ND	ND	ND	ND
	1999-10	02/13/00	ND	ND	ND	*****	ND	ND	*****	*****
	1999-11	02/16/00	ND	ND	ND	ND	ND	ND	ND	ND
	1999-12	02/20/00	ND	ND	ND	ND	ND	ND	ND	ND
	1999-13	02/23/00	ND	ND	ND	ND	ND	ND	ND	ND
	1999-14	02/27/00	ND	ND	ND	ND	ND	ND	ND	ND
	1999-15	03/04/00	ND	ND	ND	ND	ND	ND	ND	ND
	1999-16	03/08/00	ND	ND	ND	ND	ND	ND	ND	ND
	COV		*****	*****	*****	*****	*****	*****	*****	*****
	Mean		*****	*****	*****	*****	*****	*****	*****	*****
	Median		*****	*****	*****	*****	*****	*****	*****	*****
Combined	COV		*****	*****	*****	*****	*****	*****	*****	*****
	Mean		*****	*****	*****	*****	*****	*****	*****	*****
	Median		*****	*****	*****	*****	*****	*****	*****	*****

Note: Statistics are based on a log-normal distribution.

**** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

Total Suspended Solids mg/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	70	77	80	41	332	324	179	53
	1998-03	12/01/98	57	30	49	50	*****	*****	357	296
	1998-05	01/25/99	48	108	16	52	486	253	348	1150
	1998-06	02/09/99	120	56	83	34	402	255	233	*****
	1998-09	03/15/99	79	76	*****	56	700	657	425	386
	1998-10	03/20/99	10	24	*****	40	1040	*****	263	333
	1998-11	03/25/99	18	24	9	20	556	559	205	*****
	1998-12	04/06/99	38	199	40	32	662	422	298	253
	1998-13	04/11/99	8	15	9	18	145	130	78	57
	COV		1.2	1.0	1.2	0.4	0.6	0.6	0.5	1.5
	Mean		56	71	46	39	564	383	274	417
	Median		36	50	29	36	473	329	241	229
1999	1999-05	01/25/00	58	52	22	36	525	314	353	611
	1999-06	01/30/00	29	20	12	9	347	274	660	*****
	1999-08	02/10/00	70	174	52	135	605	477	395	203
	1999-09	02/12/00	*****	*****	17	30	246	177	89	43
	1999-10	02/13/00	19	*****	3	5	260	290	143	66
	1999-11	02/16/00	23	30	6	30	247	372	261	117
	1999-12	02/20/00	*****	22	22	16	122	126	75	42
	1999-13	02/23/00	*****	18	8	20	220	231	136	122
	1999-14	02/27/00	22	3	12	16	159	97	*****	94
	1999-15	03/04/00	23	ND	5	15	50	50	22	11
	1999-16	03/08/00	11	14	12	7	205	243	80	155
	COV		0.7	2.9	0.9	1.1	0.8	0.7	1.3	1.5
	Mean		32	51	16	28	285	254	246	160
	Median		27	16	12	19	225	205	149	90
Combined	COV		0.9	2.1	1.2	0.9	0.8	0.7	0.9	1.7
	Mean		43	68	26	34	403	304	262	256
	Median		31	29	17	25	308	247	190	132

Total Volatile Solids mg/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	76	70	94	50	144	132	54	22
	1998-03	12/01/98	44	40	42	38	*****	*****	90	82
	1998-05	01/25/99	50	64	50	66	180	116	102	190
	1998-06	02/09/99	40	54	52	32	90	74	96	*****
	1998-09	03/15/99	66	46	*****	48	210	106	100	96
	1998-10	03/20/99	66	68	*****	68	326	*****	130	134
	1998-11	03/25/99	8	22	28	14	267	228	26	*****
	1998-12	04/06/99	30	52	20	27	132	100	52	53
	1998-13	04/11/99	20	22	5	15	45	25	27	5
	COV		0.8	0.5	1.2	0.6	0.7	0.8	0.7	1.9
	Mean		48	50	49	41	183	119	78	116
	Median		37	45	31	35	150	95	66	53
1999	1999-05	01/25/00	78	92	62	66	130	144	58	92
	1999-06	01/30/00	64	34	52	30	118	82	134	*****
	1999-08	02/10/00	56	68	42	94	148	138	120	84
	1999-09	02/12/00	*****	*****	44	38	86	70	38	38
	1999-10	02/13/00	14	*****	22	24	40	82	24	34
	1999-11	02/16/00	20	24	12	24	72	96	46	28
	1999-12	02/20/00	*****	32	36	40	42	38	20	26
	1999-13	02/23/00	*****	24	32	24	32	48	38	34
	1999-14	02/27/00	*****	*****	*****	56	50	*****	*****	*****
	1999-15	03/04/00	16	18	8	26	24	16	14	2
	1999-16	03/08/00	32	46	38	38	46	58	20	50
	COV		0.8	0.6	0.7	0.5	0.7	0.7	0.9	1.6
	Mean		42	43	37	42	73	81	52	58
	Median		33	37	30	38	61	66	39	31
Combined	COV		0.8	0.5	0.9	0.5	0.9	0.8	0.8	1.7
	Mean		45	46	41	41	118	96	65	77
	Median		35	41	30	36	89	76	50	39

Note: Statistics are based on a log-normal distribution.

***** Insufficient data.

Table G-1. CHEMICAL WATER QUALITY DATA

Zinc, Dissolved ug/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	29.7	6.6	7.0	66.0	17.5	19.5	6.76	53.2
	1998-03	12/01/98	104	112	152	219	*****	*****	127	205
	1998-05	01/25/99	45.8	39.2	37.1	30.4	46.4	228	58.1	42.8
	1998-06	02/09/99	32.9	ND	50.0	ND	166	38.8	25.1	*****
	1998-09	03/15/99	21.2	31.6	*****	46.8	50.7	66.5	10.1	12.7
	1998-10	03/20/99	108	75.5	*****	55.3	20.6	94.5	22.2	33.2
	1998-11	03/25/99	129	13.7	11.8	55.9	110	28.2	78.4	*****
	1998-12	04/06/99	15.4	88.6	31.9	9.83	8.60	34.7	12.1	65.2
	1998-13	04/11/99	44.7	28.7	63.8	26.5	36.2	46.6	21.4	23.0
	COV		0.88	1.57	1.38	1.55	1.25	0.91	1.28	1.07
	Mean		61.3	52.8	57.2	64.8	61.7	69.5	42.4	63.8
	Median		46.1	28.4	33.5	35.2	38.5	51.5	26.1	43.5
1999	1999-05	01/25/00	ND	ND	ND	ND	ND	ND	ND	ND
	1999-06	01/30/00	94.3	48.2	30.3	150	30.0	71.8	50.5	*****
	1999-08	02/10/00	55.7	48.2	35.2	98.3	239	31.0	21.8	107
	1999-09	02/12/00	*****	*****	8.11	19.8	8.73	16.8	10.3	29.7
	1999-10	02/13/00	48.9	*****	11.3	23.1	39.4	40.7	66.4	115
	1999-11	02/16/00	23.6	14.2	18.7	61.6	20.1	30.7	16.1	35.6
	1999-12	02/20/00	*****	ND	ND	ND	ND	ND	ND	ND
	1999-13	02/23/00	*****	6.14	9.7	9.43	22.0	26.8	16.0	15.2
	1999-14	02/27/00	19.0	12.2	20.1	55.2	30.0	39.3	*****	46.2
	1999-15	03/04/00	10.6	5.08	18.7	7.68	9.89	34.7	19.0	37.2
	1999-16	03/08/00	20.0	10.4	54.4	24.1	17.5	24.4	28.0	24.8
	COV		2.46	1.66	2.18	2.02	3.33	2.70	2.70	4.00
	Mean		52.7	18.4	26.9	49.3	50.2	49.8	35.8	80.9
	Median		19.9	9.5	11.2	21.8	14.4	17.3	12.6	19.6
Combined	COV		1.66	1.90	2.12	1.78	2.53	2.13	2.00	2.59
	Mean		60.3	35.2	40.3	55.3	59.3	64.5	40.0	75.7
	Median		31.0	16.4	17.2	27.1	21.8	27.4	17.8	27.2

Zinc, Total ug/l

			1-42	1-46	1-52	1-58	6-20E	6-20F	8-23C	8-B001
1998	1998-02	11/28/98	275	193	156	168	468	454	188	94.5
	1998-03	12/01/98	187	112	182	173	*****	*****	325	382
	1998-05	01/25/99	124	74.2	74.1	100	339	283	309	418
	1998-06	02/09/99	167	54.4	288	91.7	394	290	286	*****
	1998-09	03/15/99	146	79.6	*****	129	439	496	295	369
	1998-10	03/20/99	94.6	58.5	*****	120	940	983	267	302
	1998-11	03/25/99	159	73.7	84.7	137	666	687	308	*****
	1998-12	04/06/99	92.5	126	129	169	637	382	352	277
	1998-13	04/11/99	60.2	187	133	94.5	189	233	132	107
	COV		0.47	0.50	0.48	0.26	0.52	0.51	0.32	0.68
	Mean		147	107	152	132	520	481	277	294
	Median		133	96.2	136	128	462	427	263	243
1999	1999-05	01/25/00	336	168	163	321	561	670	409	889
	1999-06	01/30/00	269	106	55.7	151	387	289	438	*****
	1999-08	02/10/00	269	287	186	465	550	559	436	420
	1999-09	02/12/00	*****	*****	162	163	242	*****	183	147
	1999-10	02/13/00	*****	*****	42.3	76.4	370	430	384	317
	1999-11	02/16/00	117	92.5	77.5	196	352	503	321	242
	1999-12	02/20/00	*****	61.3	71.3	52.8	150	193	155	634
	1999-13	02/23/00	*****	52.2	64.6	96.7	340	390	271	210
	1999-14	02/27/00	104	32.4	47.6	111	372	220	*****	162
	1999-15	03/04/00	86.4	119	94.6	56.3	104	115	78.2	102
	1999-16	03/08/00	118	62.4	136	90.4	260	346	173	267
	COV		0.60	0.74	0.57	0.78	0.55	0.58	0.62	0.75
	Mean		190	111	101	163	345	382	295	344
	Median		163	89.4	88.3	129	302	330	251	275
Combined	COV		0.52	0.60	0.58	0.56	0.57	0.56	0.47	0.70
	Mean		164	108	121	147	417	424	284	319
	Median		145	92.7	105	128	361	370	256	261

Note: Statistics are based on a log-normal distribution.

**** Insufficient data.

Caltrans Litter Management Pilot Study
Litter Characterization Protocol

A. Preparation

1. Put on Tyvek suit, apron, gloves, and safety glasses.

2. Check to see whether this set of sample bags will need to be duplicate for quality assurance/control purposes (every 5th bag for the first 3 storms events and every 10th bag thereafter).

3. Weigh the bag with contents on calibrated scale. Record weight on data sheet.

4. At the work table, pour out contents of litter bag in tub, and separate out litter material from leaves/organic debris. ***See note "b" below regarding possible contaminated or hazardous materials that you may encounter***.

5. Weigh leaves/organic debris on calibrated scale and record on data sheet. Discard leaves/organic debris into trash can.

6. Sift through litter and remove spike materials. Record the recovery of spike material on spike data sheet. Weigh spike materials (as a whole) on calibrated scale and recorded weight on data sheet. Dispose of spike materials as described under Section C - Disposal Procedures.

7. Place remaining litter in the # drying screen corresponding to the # litter bag. Litter should be placed on drying screen to achieve maximum drying (e.g., spread out as much as possible, avoid covering/overlapping of materials).

8. Leave materials to air-dry on drying screens for 24 hours. Record on data sheet the time that air-drying begins.

9. Record on data sheet how much time (in days) has passed between the previous storm for which litter collection took place and the storm for which you are now conducting litter analysis.

10. Photograph litter on drying screen. Be sure to include event and site/outfall identification information in the photograph.

B. Litter Characterization

11. Put on Tyvek suit, gloves, and safety glasses.

12. Take material off drying screen and segregate litter into the following categories:

    - Cardboard/Chipboard
    - Cigarette Butts
    - Cloth
    - Glass
    - Metal (foil and molded)
    - Other
    - Paper
    - Plastic-Film
    - Plastic-Moldable
    - Styrofoam
    - Wood Debris

13. If any materials appear to be accident- or spill-related (e.g., 5 or more pieces of related materials, broken glass, pellets, etc.,) consult the litter team's Accident Specialist for a determination if the materials are actually accident- or spill-related. If the Accident Specialist determines the materials to be accident- or spill-related, the Accident Specialist must fill in data on Accident/Spill form.

14. Further segregate the litter according to usage (e.g., smoking-related, food-related, or general unknown), as specified on the data sheet.

15. Weigh segregated materials on calibrated scale and record weight on data sheet ***(See note "b" below).***

16. Measure volume of segregated materials using appropriate volume measurement container and record volume on data sheet.

17. Count individual segregated items and record number on data sheet.

18. Conduct percent floatable analysis using "Percent of Floating Material Procedure."

19. Conduct oven-drying analysis using "Oven Drying Procedure."

C. Litter Disposal Procedures

20. Recyclable materials should be placed in recycle bin.

21. Non-recyclable materials should be placed in trash bin.

D. Clean-Up Procedures

22. Drying screens should be cleaned with water after each use. This should be accomplished at the geotechnical lab's large sink using a spray bottle.

23. Water from the tubs should be disposed into the sink of the geotechnical lab.

Health and Safety

- Do not smell or taste the contents of any container.

- All open wounds on the hand must be protected with protective gloves.

- If you get a cut or puncture wound from any litter materials, immediately disinfect and bandage using the first aid kit, etc. Serious infections can arise unless proper treatment is received. If necessary, seek emergency assistance at the nearest hospital, which is Western Medical Center located on Tustin Avenue between 4th St. and 17th St. in Tustin. Also, notify Ron Miller by pager @ 800-970-8131 or by phone @ ext. 503. If you have not had a tetanus shot within the past 10 years, you are advised to get one at the hospital immediately. For any wound, also contact Greany Medical at 1-800-455-6155 (they are associated with Western Medical Center).

- If you get any foreign objects or fluids in the eye, do not rub the eye. Flush eye with eye water rinse located in the litter lab. Liquid should be flushed for fifteen minutes and then consult a physician. If flushing fails to remove the object, apply a dry, protective dressing and consult a physician (Western Medical Center located on Tustin Ave. between 4th St. and 17th St. in Tustin). Also notify Ron Miller by pager @ 1800-970-8131 or by phone @ ext. 503.

NOTES

a. For the first set of characterization analyses, every 5th bag of litter should be weighed in duplicate (by one other team member to ensure accuracy of measurement). Through the duration of the study, 10% of the litter bags should be weighed in duplicate (both pre- and post-drying) for quality assurance/control purposes. The volumes of litter should also be measured in duplicate for 10% of the samples.
b. Any litter materials that appear to be contaminated or hazardous should be put aside. Then contact Ron Miller by pager @: 800-970-8131, or by phone @ ext. 503 for assessment. Material will likely be placed in a 55-gallon drum for disposal by a licensed hauler with Caltrans noted as the generator.

PERCENTAGE OF FLOATING MATERIAL PROCEDURE

OBJECTIVE
To estimate the proportion of litter that floats from the litter samples collected in highway runoff.

SUMMARY
This procedure involves submerging the collected litter into a drum of water, leaving the material for 30 seconds, and then retrieving the proportions that float and those that sink. An estimate of the volume that floats and that which sinks will be made; then the non-floatable material will be drained for 24 hours (on the existing drying screens) and weighed.

Samples to be used for analysis will be each type-classification summed over a whole storm event (i.e., all material from the event, grouped according the type, i.e., 11 samples for each event). The drum of water will need to be of sufficient size to allow all the material to become thoroughly wet.

Outputs from this analysis will be floatable and non-floatable volume estimates and a weight for the non-floatable material after 24 hours of air-drying for each category of material (11 type classifications).

PROCEDURE
1. At the end of litter sorting analysis, all litter should be placed into the labeled type-classification bins (the same bins from which the oven drying samples are taken).
2. These bins should be added together at the end of each analysis day until the complete storm event has been analyzed (including material from the oven-drying).
3. Take one type-classification bin and empty into a tub of water.
4. Stir thoroughly, ensuring everything gets submerged.
5. Leave for 30 seconds.
6. Scoop out floating material with sieve and place into volume measuring containers (select appropriate size container).
7. Estimate and record WET FLOATING VOLUME on data sheet.
8. Dispose of floating material.
9. Drain water and place remaining material into volume measuring container, estimate, and record WET NON-FLOATABLE VOLUME.
10. Place non-floatable material onto drying screens and leave for at least 24 hours.
11. Repeat for each type-classification.
12. After 24 hours, remove material and weigh and record each type-classification on data sheet.

OVEN DRYING PROCEDURE (sorted-weight: dry-weight ratio)

OBJECTIVE
To evaluate the comparative moisture content of different types of litter and litter from different storm events.

SUMMARY
This procedure involves oven-drying samples of litter and organic categories at the end of each analysis day to determine the moisture content of air-dried litter by litter type. The moisture contents care then be compared by litter type and between storms.

PROCEDURE
1. At the end of every day a representative samples for EACH CATEGORY INCLUDING ORGANIC MATERIAL – should be taken (i.e., for organic, cardboard, cig. butts, cloth etc.). Samples should be between 0.5 and 1 pound
2. Each sample to be placed into a clean drying container, labeled (with date and category) and weighed.
3. Record the label (date and category) and the weight of each sample (including tray).
4. Place into the drying oven (set at approximately 60 degrees Celsius) for at least 24 hours (potentially longer for very wet material).
5. When completely dry, remove from oven and weigh the sample, record along with label information.
6. Remove all material, weigh the drying container, and record values.
7. REPEAT AT THE END OF EACH ANALYSIS DAY.

OUTFALL LITTER BAG SUMMARY

SITE/OUTFALL #:_____
STORM EVENT #: _____

SUMMARY INFORMATION:

DUPLICATE ANALYSIS? YES ☐ NO ☐

Litter Analysis Team Member(s): _____

Date & Time collected bag (from bag label): _____

Date & Time started sort: _____

LITTER AIR DRYING:

Date & Time start drain litter (for min. 24 hrs): _____

Date & Time start measuring drained weight: _____

Is there any accident debris present? YES ☐ NO ☐

BAG TOTALS (litter & organic)

TOTAL WET WEIGHT	TOTAL WET VOLUME
(grams to 0.1)	(milliliters to 0.1)

ORGANIC MATERIAL

ORGANIC WEIGHT	ORGANIC VOLUME
(grams to 0.1)	(milliliters to 0.1)

Spike Color:		**Spike Color:**		**Spike Color:**		**Spike Color:**	
Wet Weight	**Count**	**Wet Weight**	**Count**	**Wet Weight**	**Count**	**Wet Weight**	**Count**
	Cigarette Butts: ____ Gum Wrappers: ____ Fabric Scraps: ____ Metal Cans: ____ Plastic Lids: ____ Poker Chips: ____ Popsicle Stick: ____ Styrofoam: ____ Tongue Depress.:____		Cigarette Butts: ____ Gum Wrappers: ____ Fabric Scraps: ____ Metal Cans: ____ Plastic Lids: ____ Poker Chips: ____ Popsicle Stick: ____ Styrofoam: ____ Tongue Depress.:____		Cigarette Butts: ____ Gum Wrappers: ____ Fabric Scraps: ____ Metal Cans: ____ Plastic Lids: ____ Poker Chips: ____ Popsicle Stick: ____ Styrofoam: ____ Tongue Depress.:____		Cigarette Butts: ____ Gum Wrappers: ____ Fabric Scraps: ____ Metal Cans: ____ Plastic Lids: ____ Poker Chips: ____ Popsicle Stick: ____ Styrofoam: ____ Tongue Depress.:____

LITTER CHARACTERIZATION -USING AIR DRIED LITTER

1. Minimum volume is 5mL.
2. Weights to 0.01 grams (small scales)
3. Fill in zeros if no material

	USAGE								
	General/Unknown			**Smoking Related**			**Food Related**		
Classification type	Count	Volume (mL)	Weight (g)	Count	Volume (mL)	Weight (g)	Count	Volume (mL)	Weight (g)
CARDBOARD/ CHIPBOARD									
CIG. BUTTS	-	-	-				-	-	-
CLOTH				-	-	-	-	-	-
GLASS				-	-	-			
METAL									
PAPER									
PLASTIC-FILM									
PLASTIC-MOLDABLE									
STYROFOAM				-	-	-			
WOOD				-	-	-			
OTHER*									

* "other" should be the sum of all non-characterized material together (i.e. do not show more than one "other" category) - but note composition of items found

"OTHER" COMPOSITION (briefly describe): _____

OVEN DRYING DATA RECORDING SHEET

Event #: _____

Date samples go into oven: _____

Date removed from oven: _____

Initials of person weighing: _____

BAGS NUMBERS SORTED DURING DAY:

CATEGORY	OVEN TRAY LABEL	CLEAN TRAY WEIGHT	WET WEIGHT WITH TRAY	DRY WEIGHT WITH TRAY
		(grams to 0.01)	(grams to 0.01)	(grams to 0.01)
ORGANIC MATERIAL				
CARDBOARD/ CHIPBOARD				
CIGARETTE BUTTS				
CLOTH				
GLASS				
METAL				
PAPER				
PLASTIC FILM				
PLASTIC MOLDABLE				
STYROFOAM				
WOOD DEBRIS				
ACCIDENT RELATED				
OTHER				

% FLOATABLE DATA RECORDING SHEET

Initials of person weighing: _____

Event #: _____

Date & time samples go into water: _____

Date & time samples placed onto racks: _____

Date & time weighing performed: _____

	BEFORE DRAINING		AFTER DRAINING		
CLASSIFICATION TYPE	**VOLUME FLOATABLE**	**VOLUME NON-FLOATABLE**	**NUMBER OF NON-FLOATABLE ITEMS**	**VOLUME OF NON-FLOATABLE (after draining)**	**NON-FLOATABLE AIR DRIED WEIGHT**
	(milliliters to 0.1)	(milliliters to 0.1)	(integer)	(integer)	(grams to 0.01)
CARDBOARD/ CHIPBOARD					
CIGARETTE BUTTS					
CLOTH					
GLASS					
METAL					
PAPER					
PLASTIC FILM					
PLASTIC MOLDABLE					
STYROFOAM					
WOOD DEBRIS					
ACCIDENT RELATED					
OTHER					

ONLY TO BE COMPLETED BY ACCIDENT/SPILL SPECIALIST

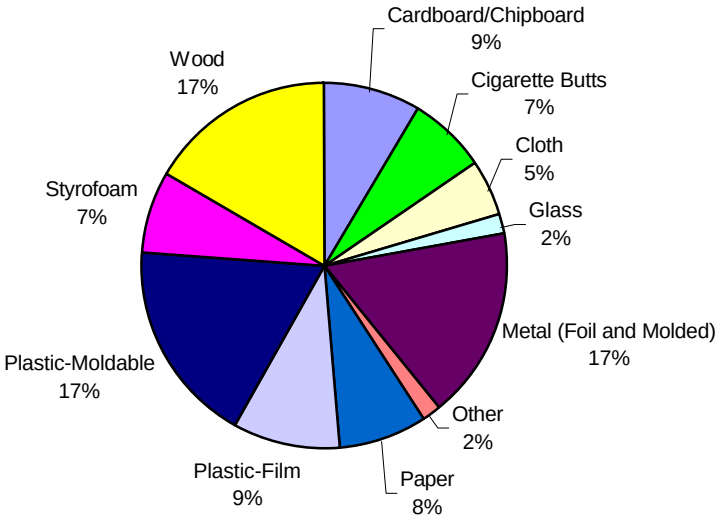
	USAGE: ACCIDENT/SPILL DEBRIS								
	General/Unknown			**Smoking Related**			**Food Related**		
MATERIAL	**Count**	**Volume (mL)**	**Weight (g)**	**Count**	**Volume (mL)**	**Weight (g)**	**Count**	**Volume (mL)**	**Weight (g)**
Glass									

	USAGE: ACCIDENT/SPILL DEBRIS								
	General/Unknown			**Smoking Related**			**Food Related**		
MATERIAL	**Count**	**Volume (mL)**	**Weight (g)**	**Count**	**Volume (mL)**	**Weight (g)**	**Count**	**Volume (mL)**	**Weight (g)**
Metal (foil and molded)									

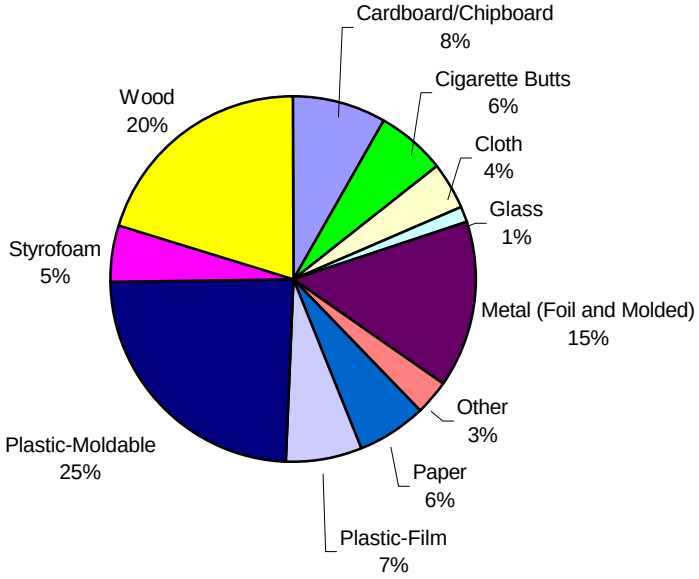
	USAGE: ACCIDENT/SPILL DEBRIS								
	General/Unknown			**Smoking Related**			**Food Related**		
MATERIAL	Count	Volume (mL)	Weight (g)	Count	Volume (mL)	Weight (g)	Count	Volume (mL)	Weight (g)
Plastic-Moldable									

	USAGE: ACCIDENT/SPILL DEBRIS								
	General/Unknown			**Smoking Related**			**Food Related**		
MATERIAL	Count	Volume (mL)	Weight (g)	Count	Volume (mL)	Weight (g)	Count	Volume (mL)	Weight (g)
Other:									

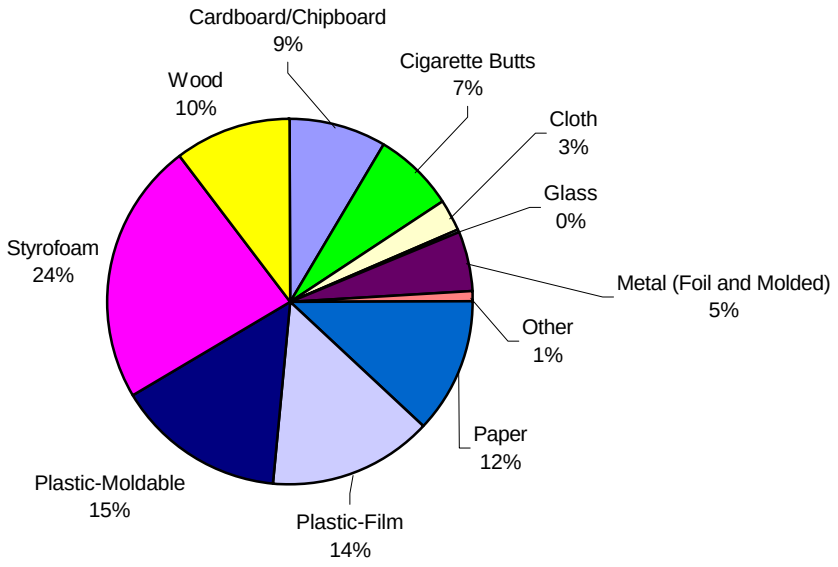
Litter Category Distribution by Air Dried Weight
All Events Combined
Control Outfalls Site 1E - Litter Pickup



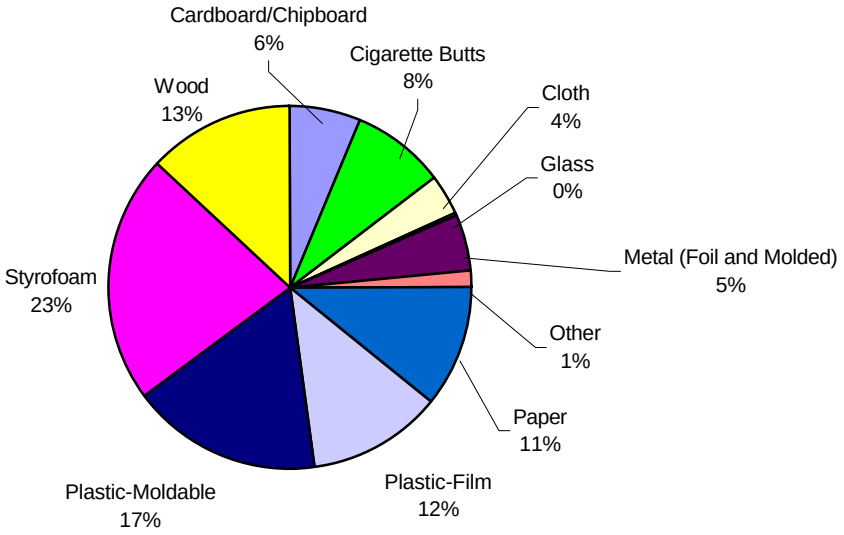
Litter Category Distribution by Air Dried Weight
All Events Combined
Treatment Outfalls Site 1E - Litter Pickup



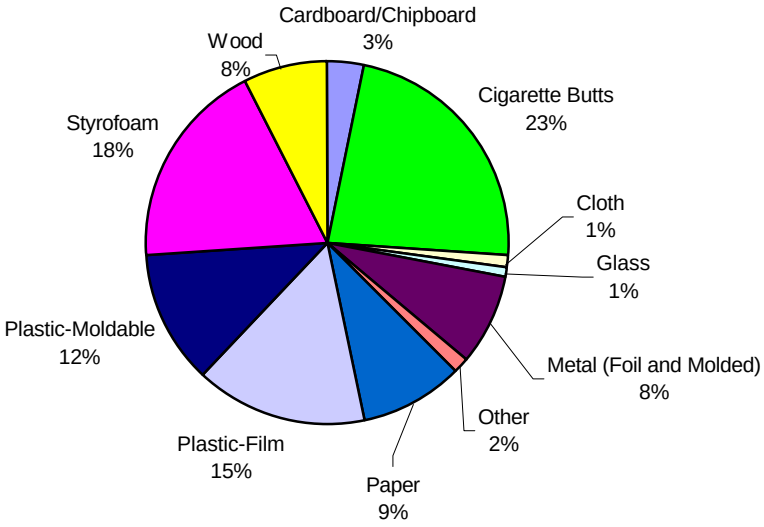
Litter Category Distribution by Volume
All Events Combined
Control Outfalls Site 1E - Litter Pickup



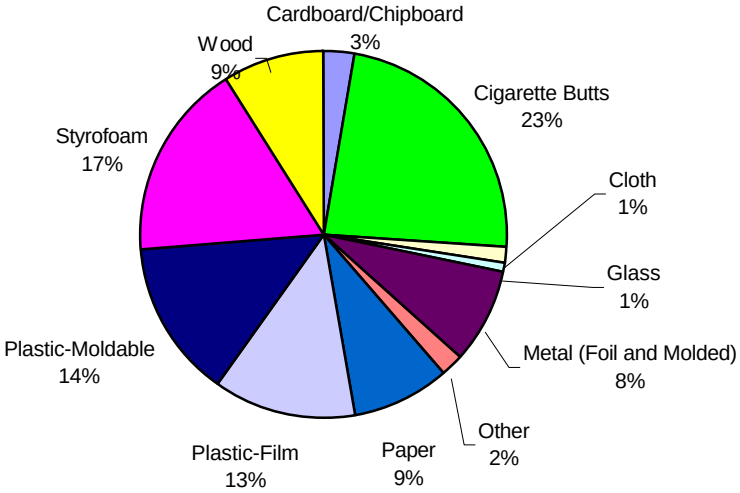
Litter Cateogry Distribution by Volume
All Events Combined
Treatment Outfalls Site 1E - Litter Pickup



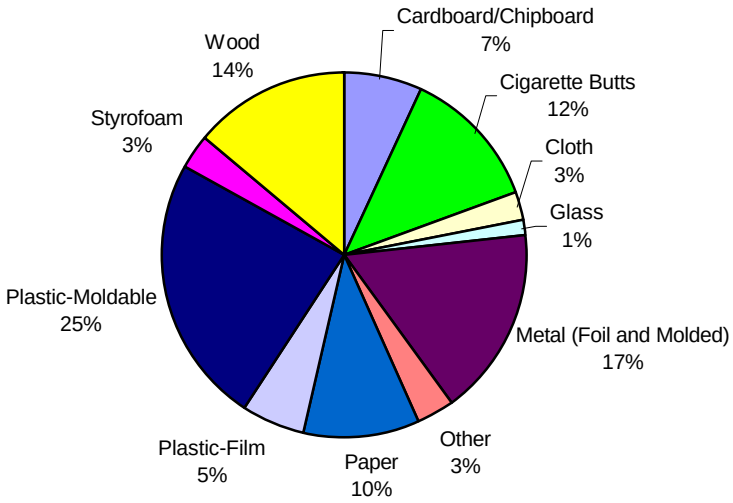
Litter Category Distribution by Count
All Events Combined
Control Outfalls Site 1E - Litter Pickup



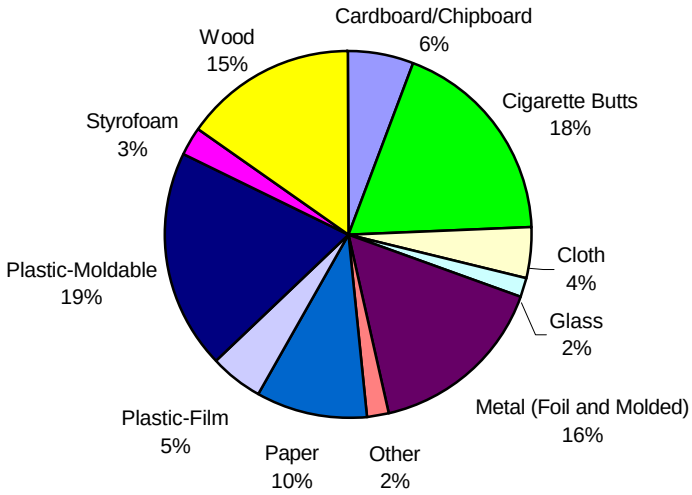
Litter Category Distribution by Count
All Events Combined
Treatment Outfalls Site 1E - Litter Pickup



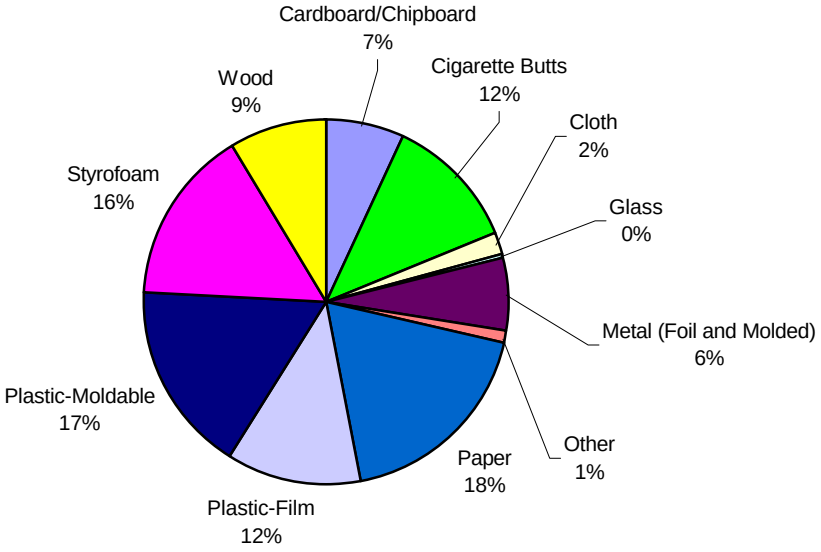
Litter Category Distribution by Air Dried Weight
All Events Combined
Control Outfalls Site 1W - Street Sweeping



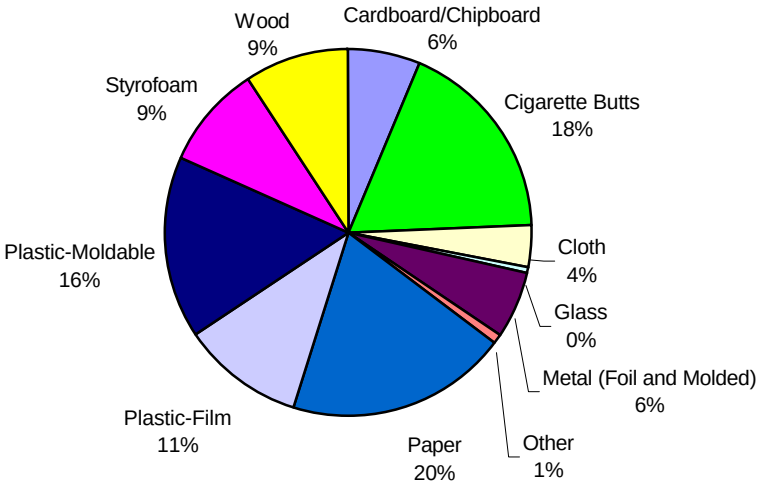
Litter Category Distribution by Air Dried Weight
All Events Combined
Treatment Outfalls Site 1W - Street Sweeping



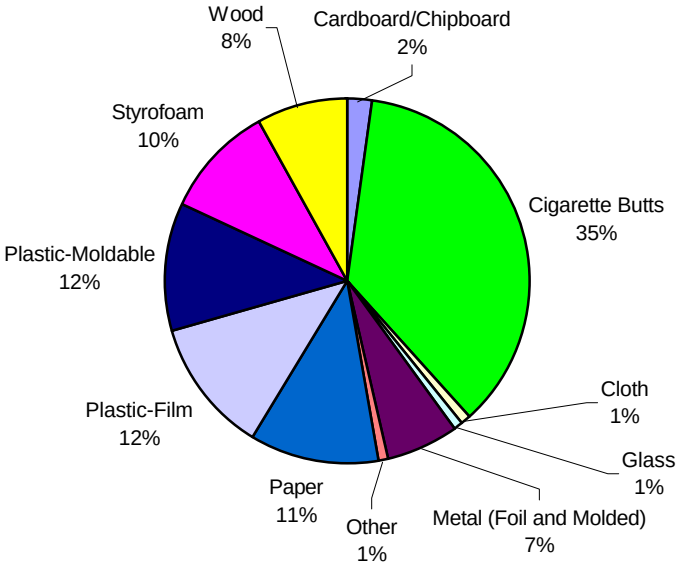
Litter Category Distribution by Volume
All Events Combined
Control Outfalls Site 1W - Street Sweeping



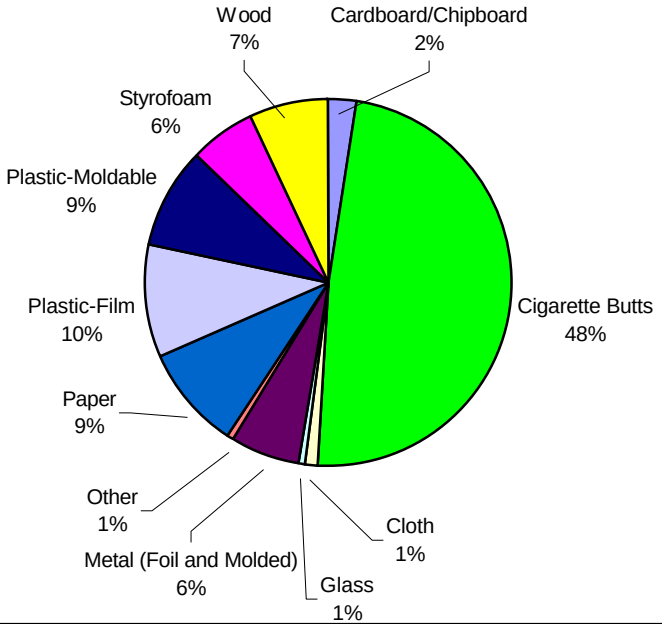
Litter Category Distribution by Volume
All Events Combined
Treatment Outfalls Site 1W - Street Sweeping



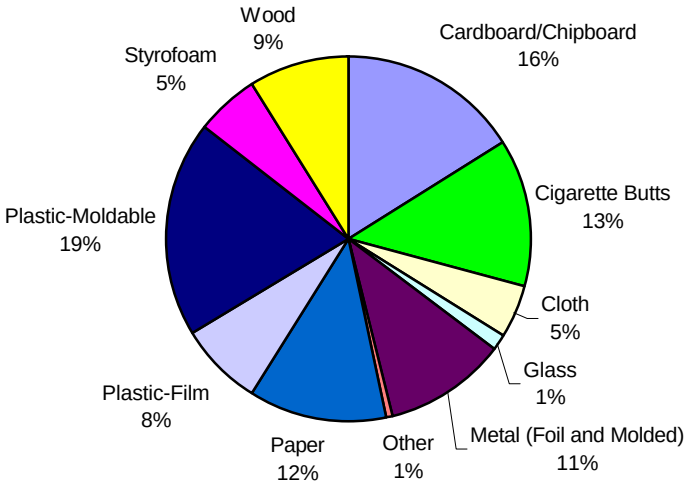
Litter Category Distribution by Count
All Events Combined
Control Outfalls Site 1W - Street Sweeping



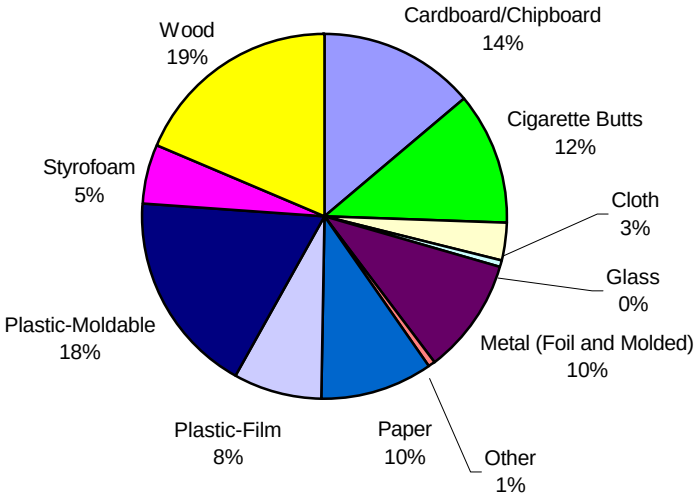
Litter Category Distribution by Count
All Events Combined
Treatment Outfalls Site 1W - Street Sweeping



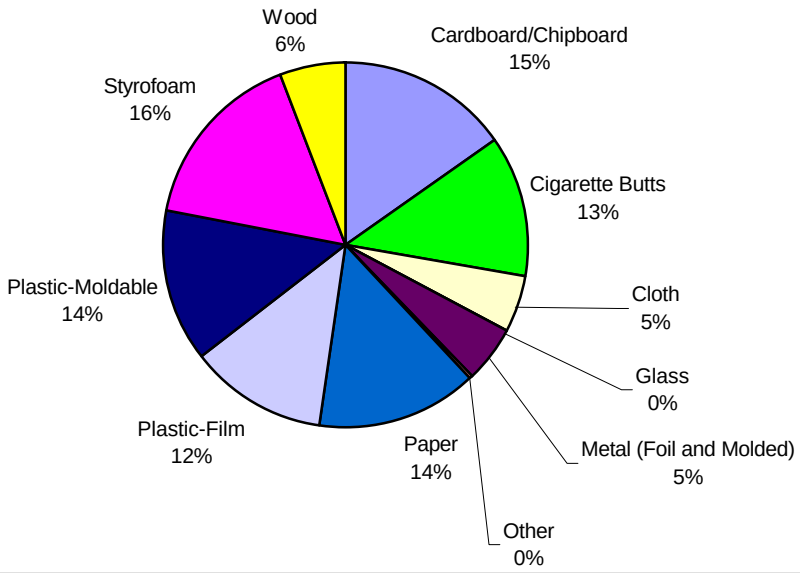
Litter Category Distribution by Air Dried Weight
All Events Combined
Control Outfalls Site 6 - Modified Inlet



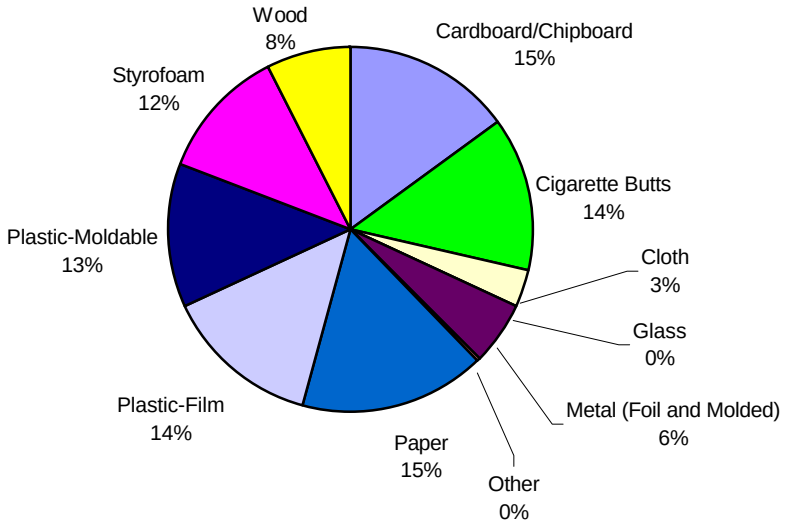
Litter Category Distribution by Air Dried Weight
All Events Combined
Treatment Outfalls Site 6 - Modified Inlet



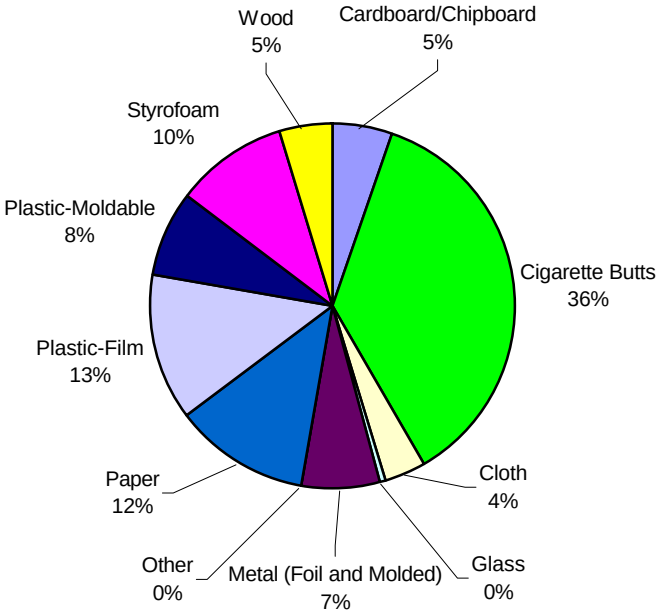
Litter Category Distribution by Volume
All Events Combined
Control Outfalls Site 6 - Modified Inlet



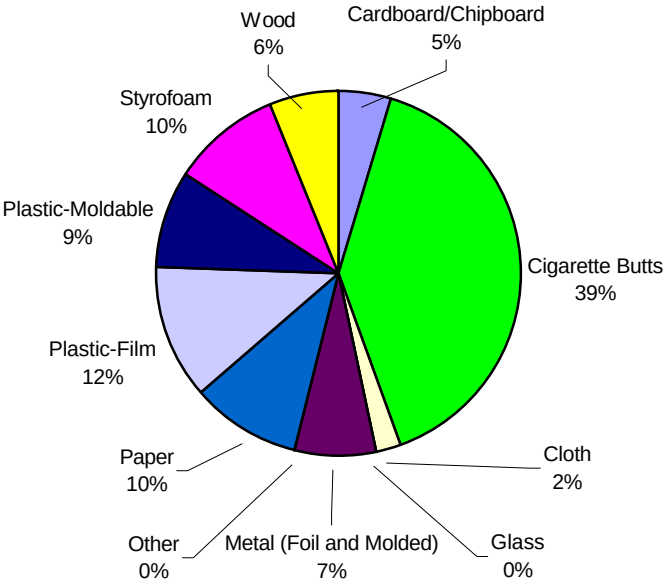
Litter Category Distribution by Volume
All Events Combined
Treatment Outfalls Site 6 - Modified Inlet



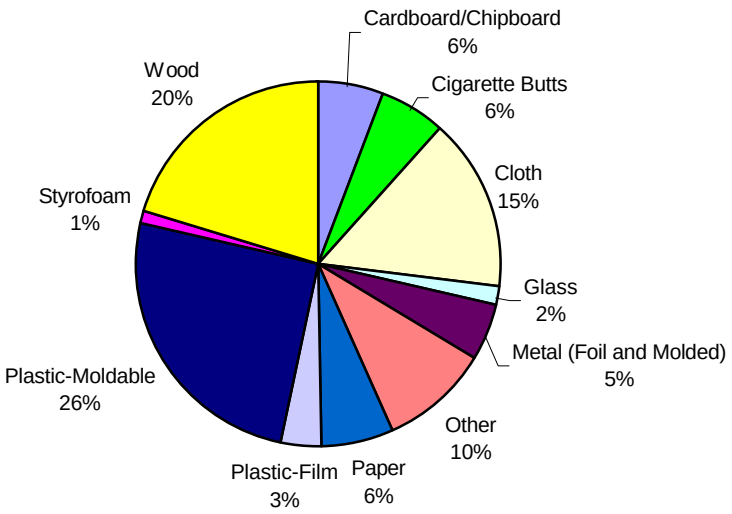
Litter Category Distribution by Count
All Events Combined
Control Outfalls Site 6 - Modified Inlet



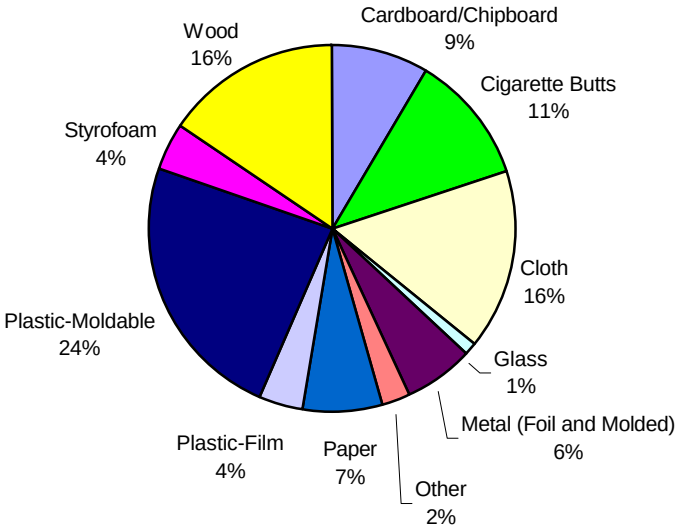
Litter Category Distribution by Count
All Events Combined
Treatment Outfalls Site 6 - Modified Inlet



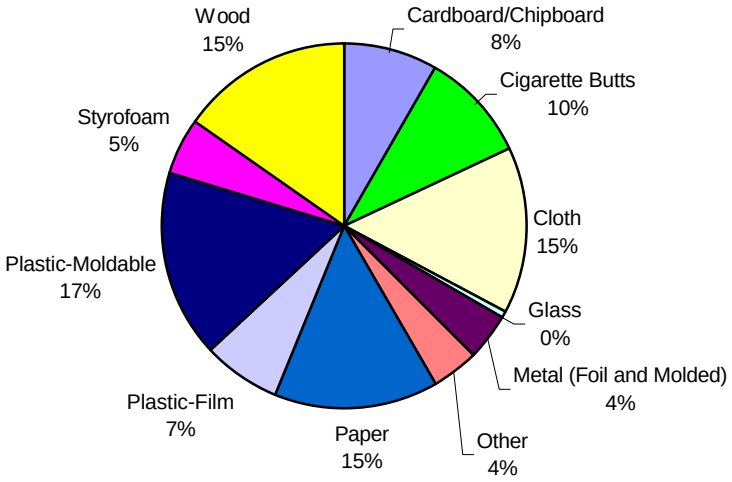
Litter Category Distribution by Air Dried Weight
All Events Combined
Control Outfalls Site 8 - Bicycle Grate (1998-1999)



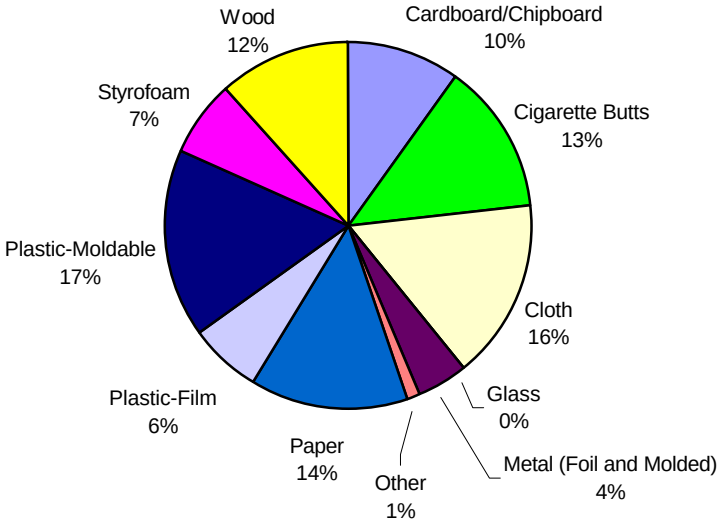
Litter Category Distribution by Air Dried Weight
All Events Combined
Treatment Outfalls Site 8 - Bicycle Grate (1998-1999)



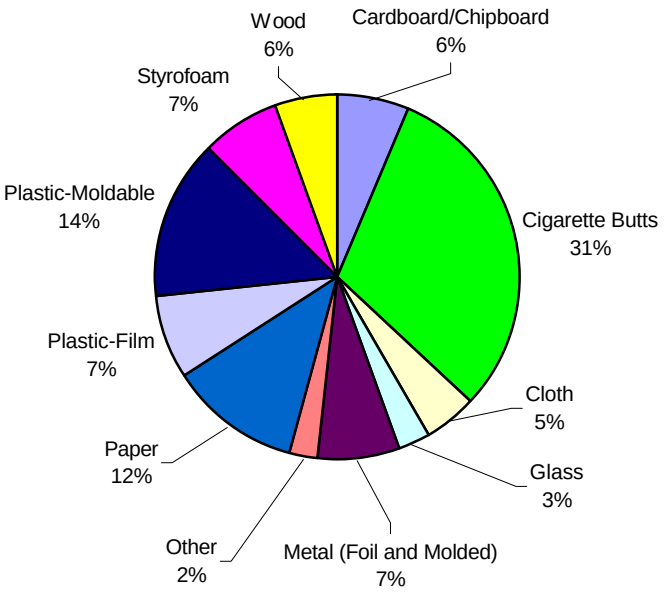
Litter Category Distribution by Volume
All Events Combined
Control Outfalls Site 8 - Bicycle Grate (1998-1999)



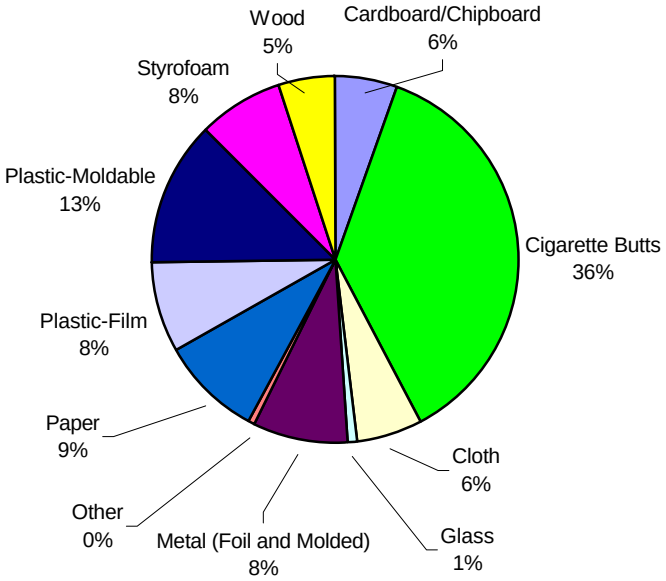
Litter Category Distribution by Volume
All Events Combined
Treatment Outfalls Site 8 - Bicycle Grate (1998-1999)



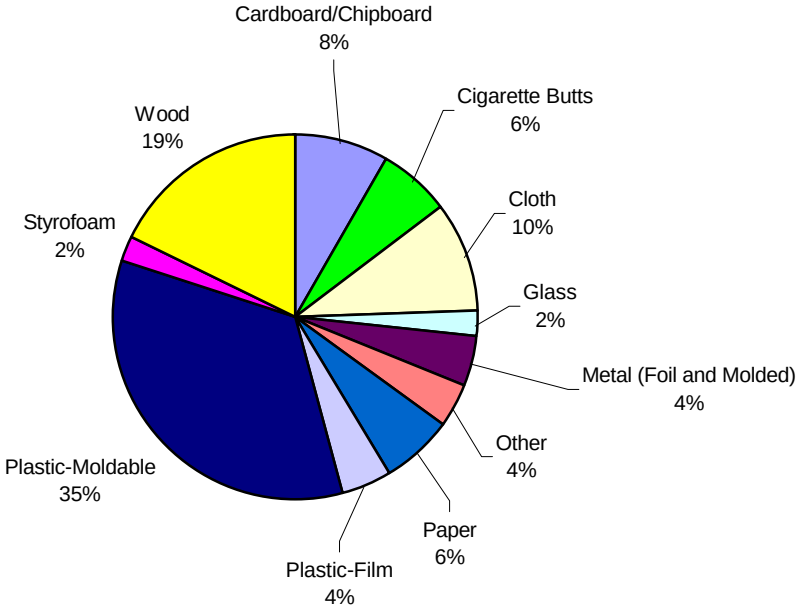
Litter Category Distribution by Count
All Events Combined
Control Outfalls Site 8 - Bicycle Grate (1998-1999)



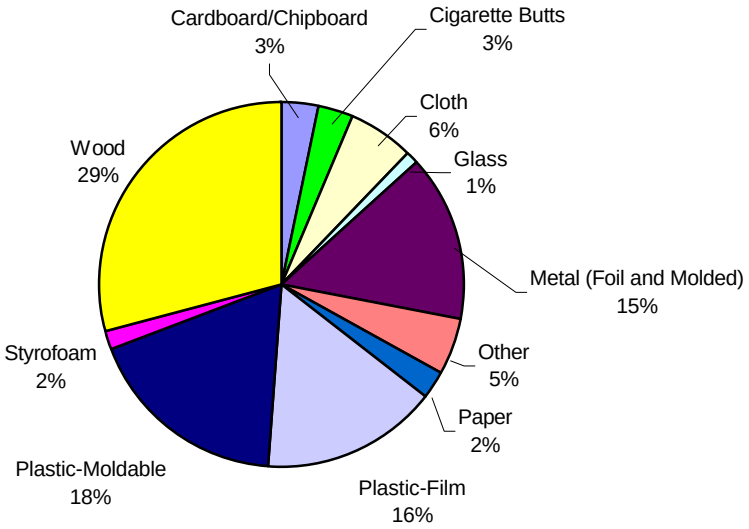
Litter Category Distribution by Count
All Events Combined
Treatment Outfalls Site 8 - Bicycle Grate (1998-1999)



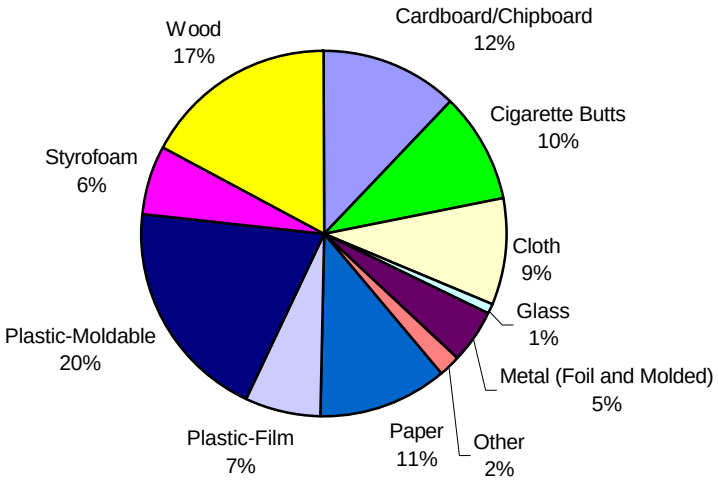
Litter Category Distribution by Air Dried Weight
All Events Combined
Control Outfalls Site 8 - LID (1999-2000)



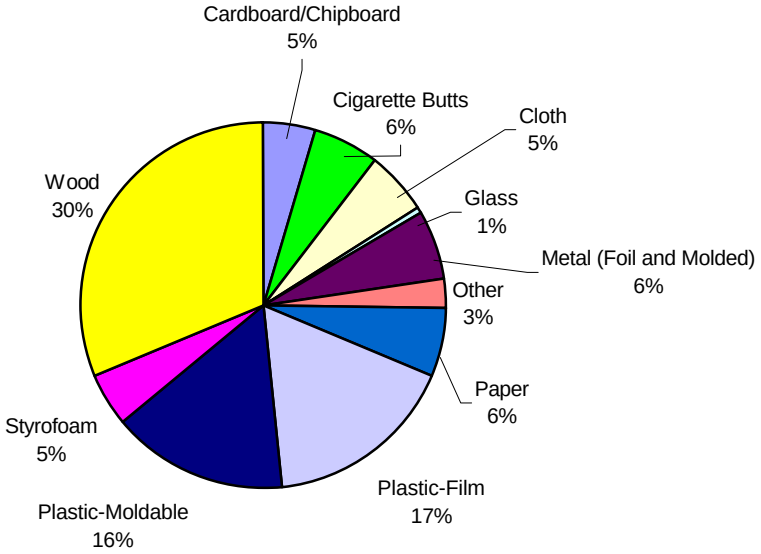
Litter Category Distribution by Air Dried Weight
All Events Combined
Treatment Outfalls Site 8 - LID (1999-2000)



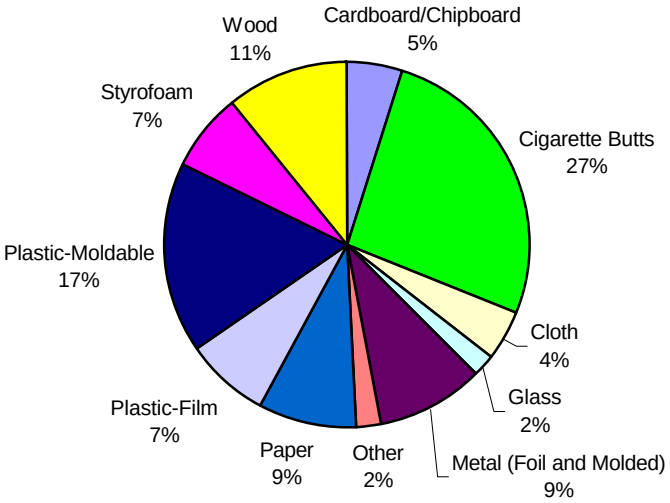
Litter Category Distribution by Volume
All Events Combined
Control Outfalls Site 8 - LID (1999-2000)



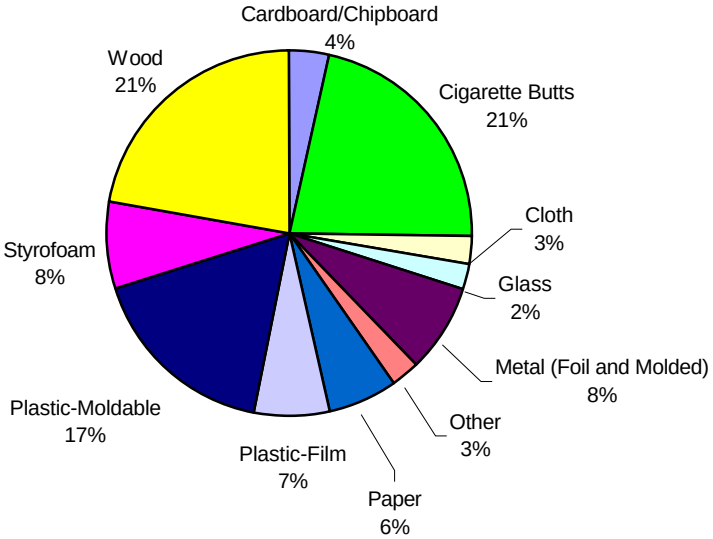
Litter Category Distribution by Volume
All Events Combined
Treatment Outfalls Site 8 - LID (1999-2000)

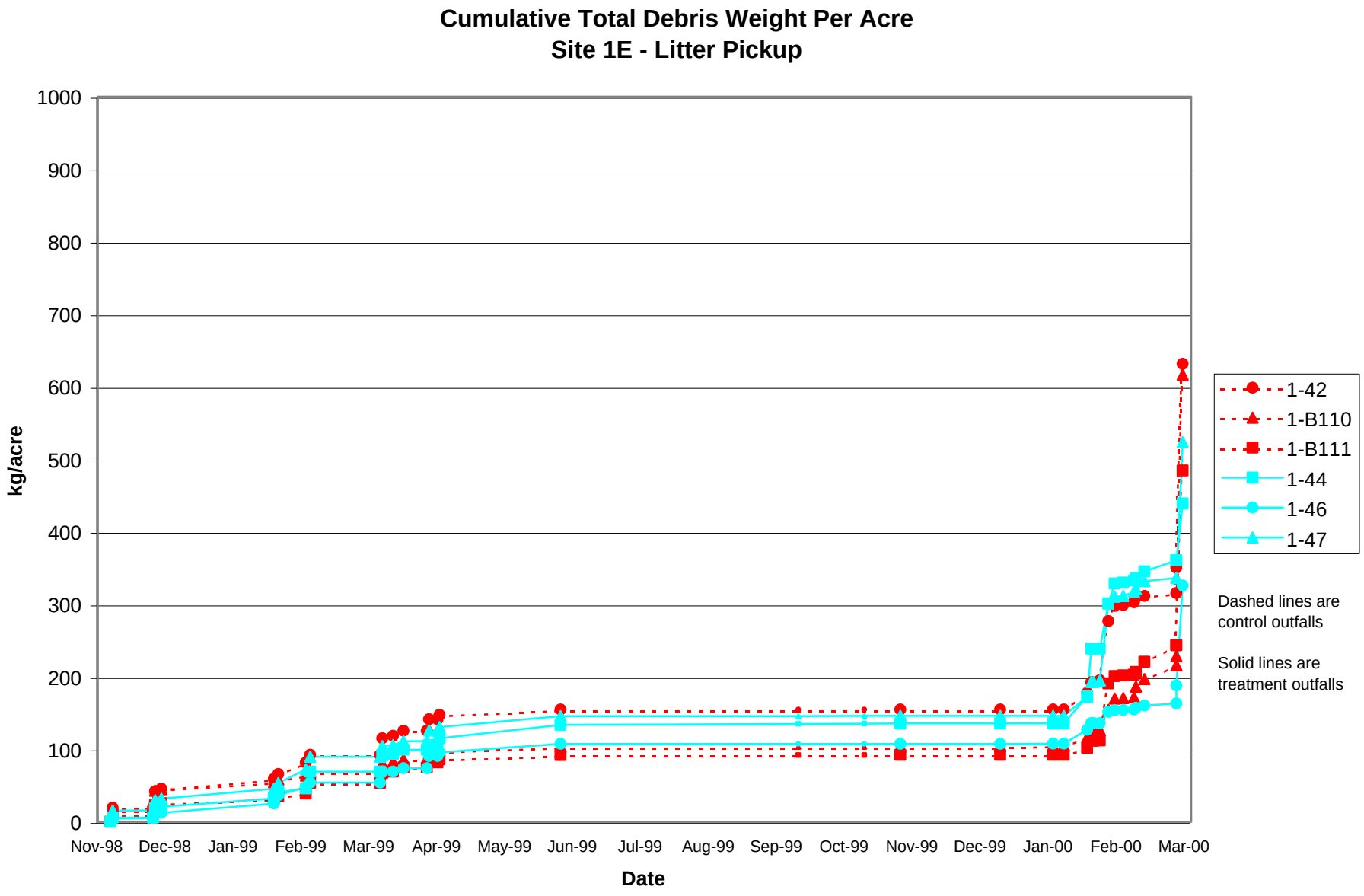


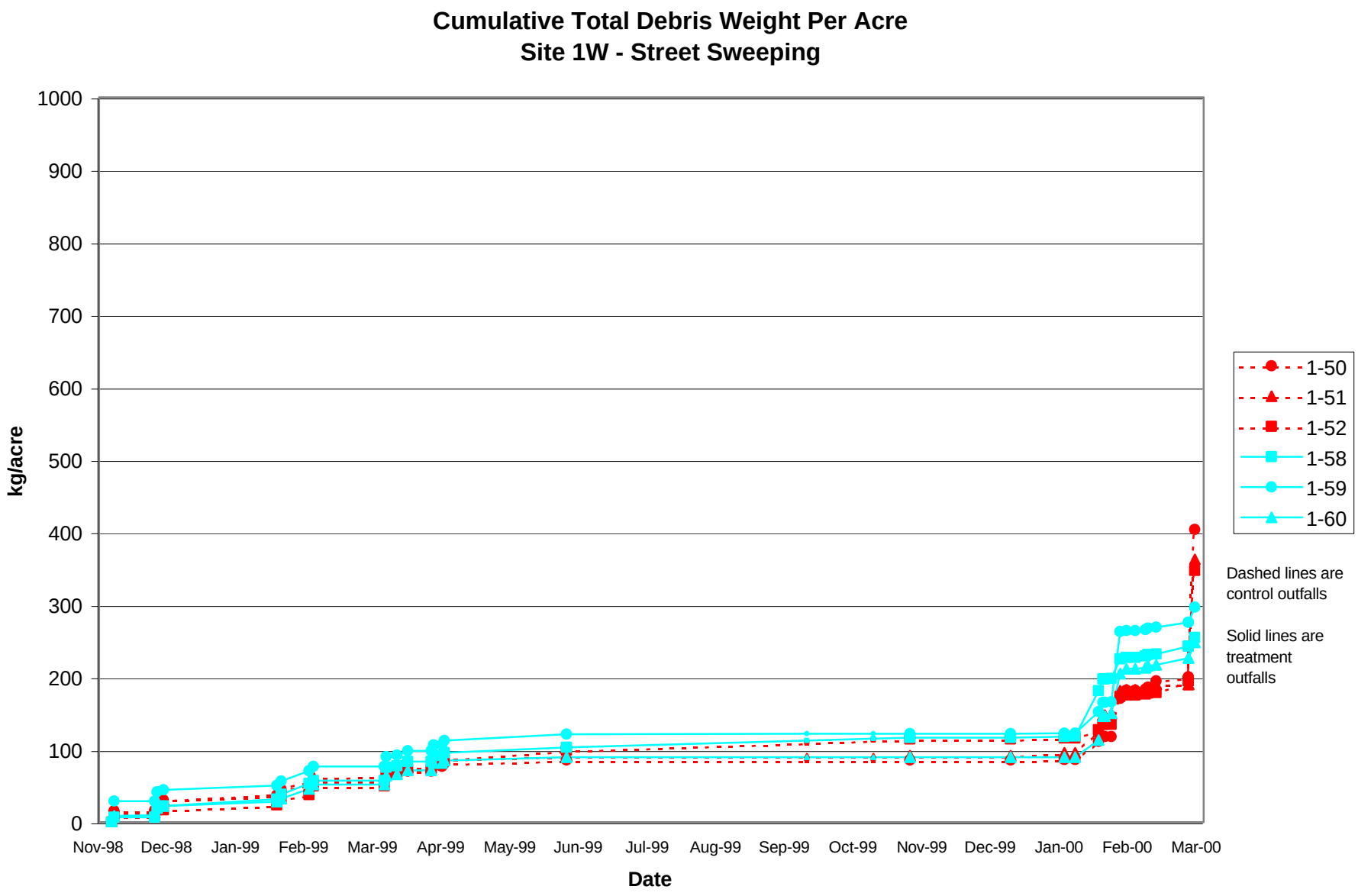
Litter Category Distribution by Count
All Events Combined
Control Outfalls Site 8 - LID (1999-2000)



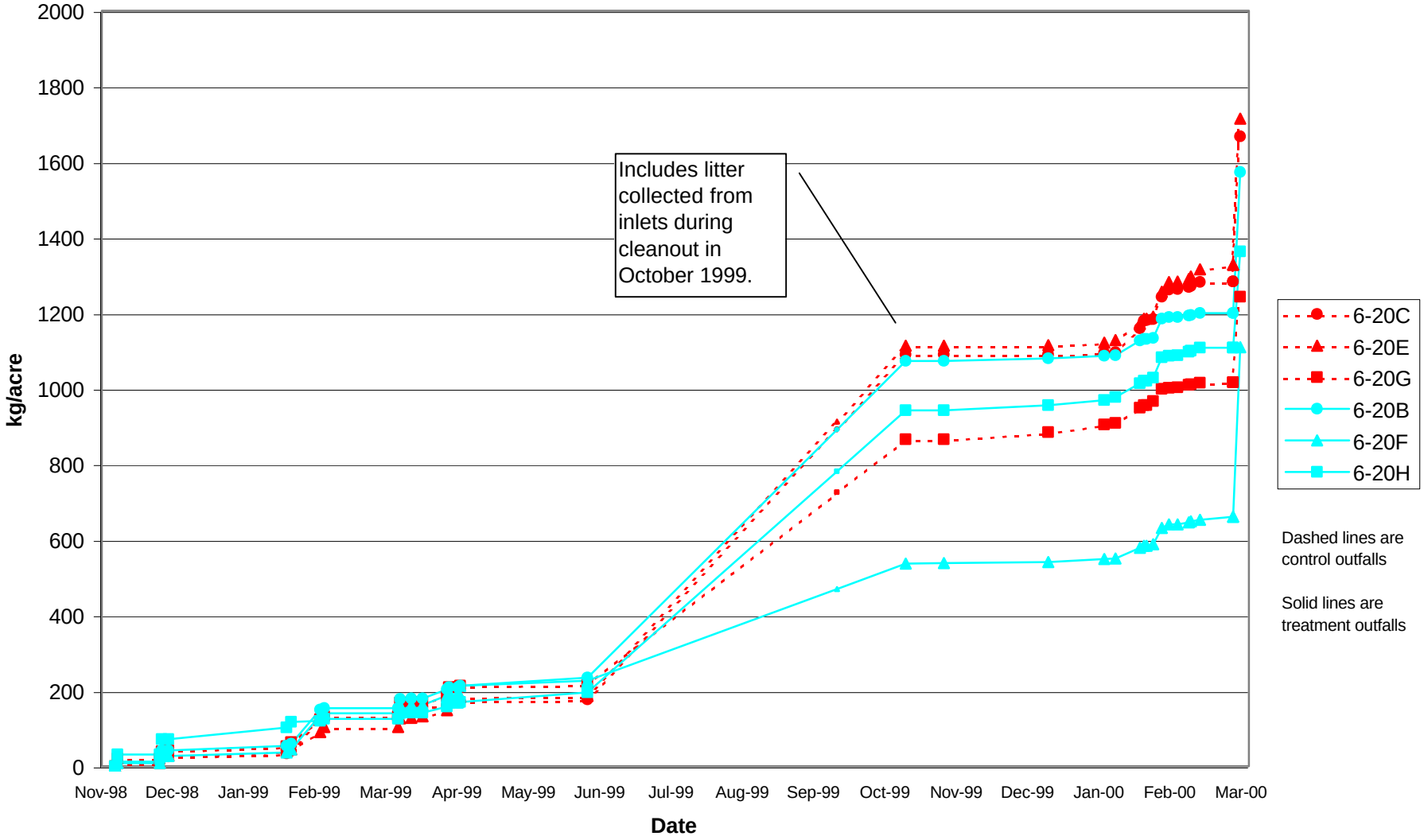
Litter Category Distribution by Count
All Events Combined
Treatment Outfalls Site 8 - LID (1999-2000)

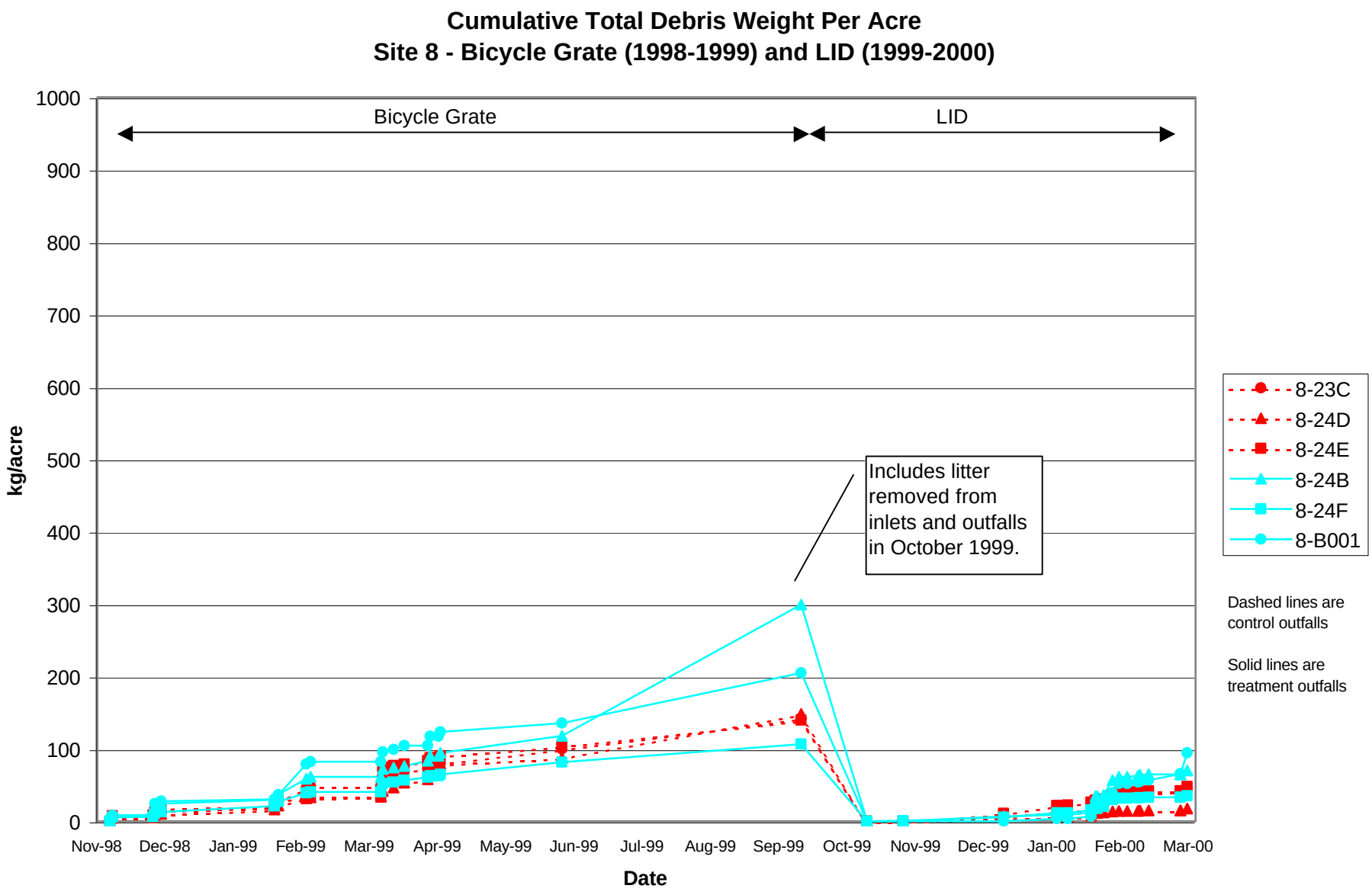


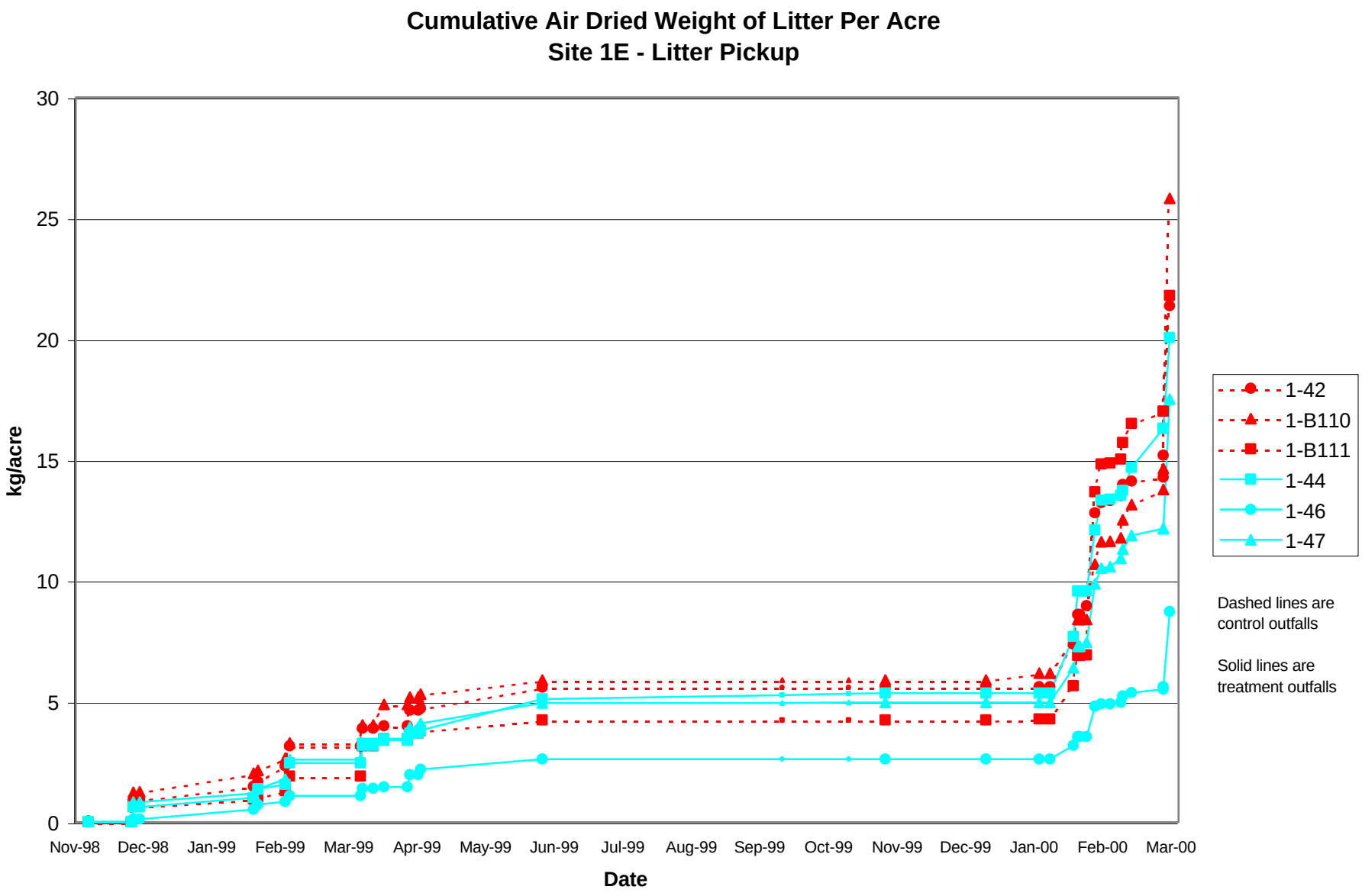

Cumulative Total Debris Weight Per Acre
Site 1E - Litter Pickup
kg/acre
1000
900
800
700
600
500
400
300
200
100
0
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
1-42
1-B110
1-B111
1-44
1-46
1-47
Dashed lines are control outfalls
Solid lines are treatment outfalls

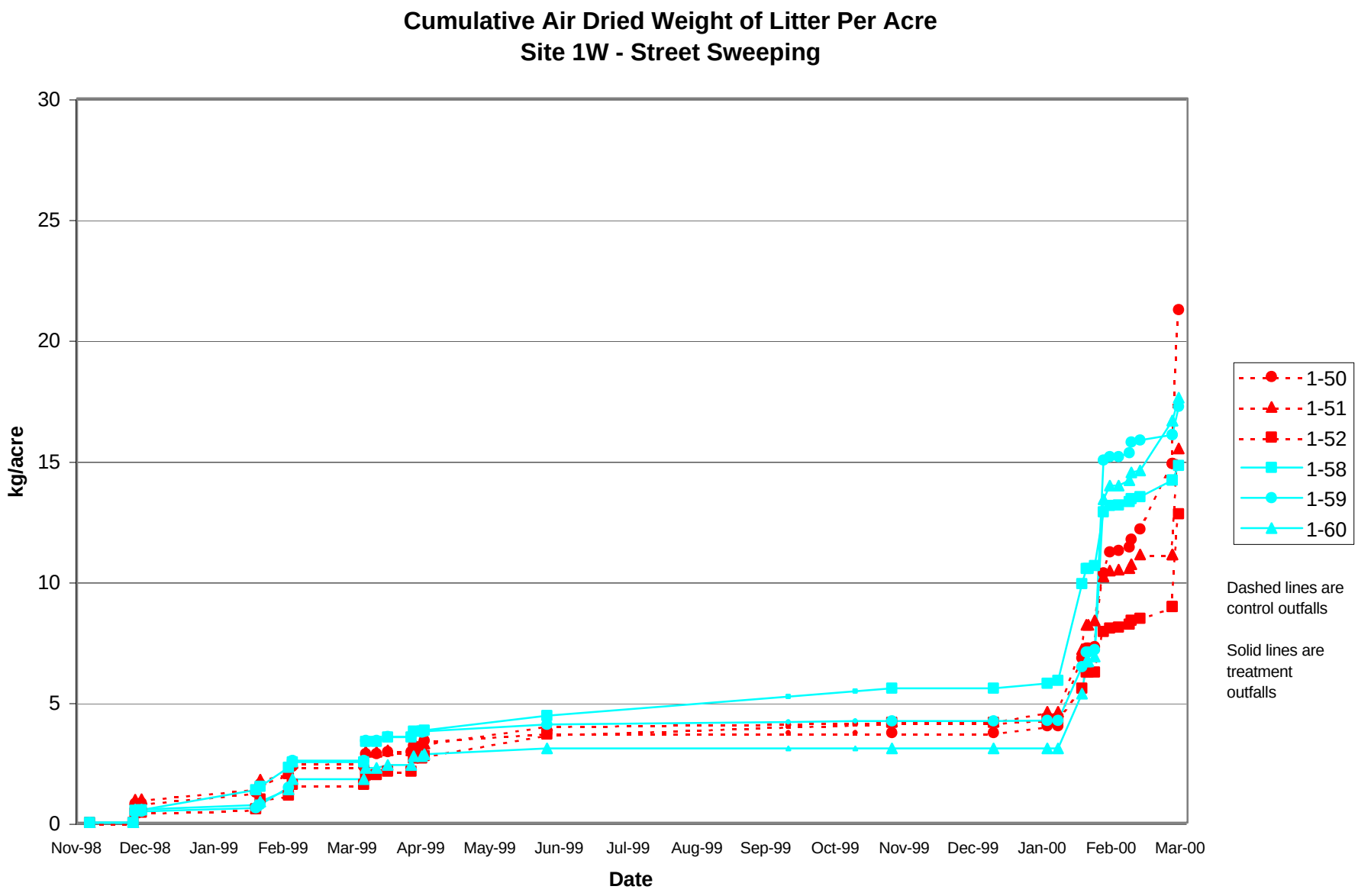

Cumulative Total Debris Weight Per Acre
Site 1W - Street Sweeping
kg/acre
1000
900
800
700
600
500
400
300
200
100
0
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
1-50
1-51
1-52
1-58
1-59
1-60
Dashed lines are control outfalls
Solid lines are treatment outfalls

Cumulative Total Debris Weight Per Acre
Site 6 - Modified Inlet

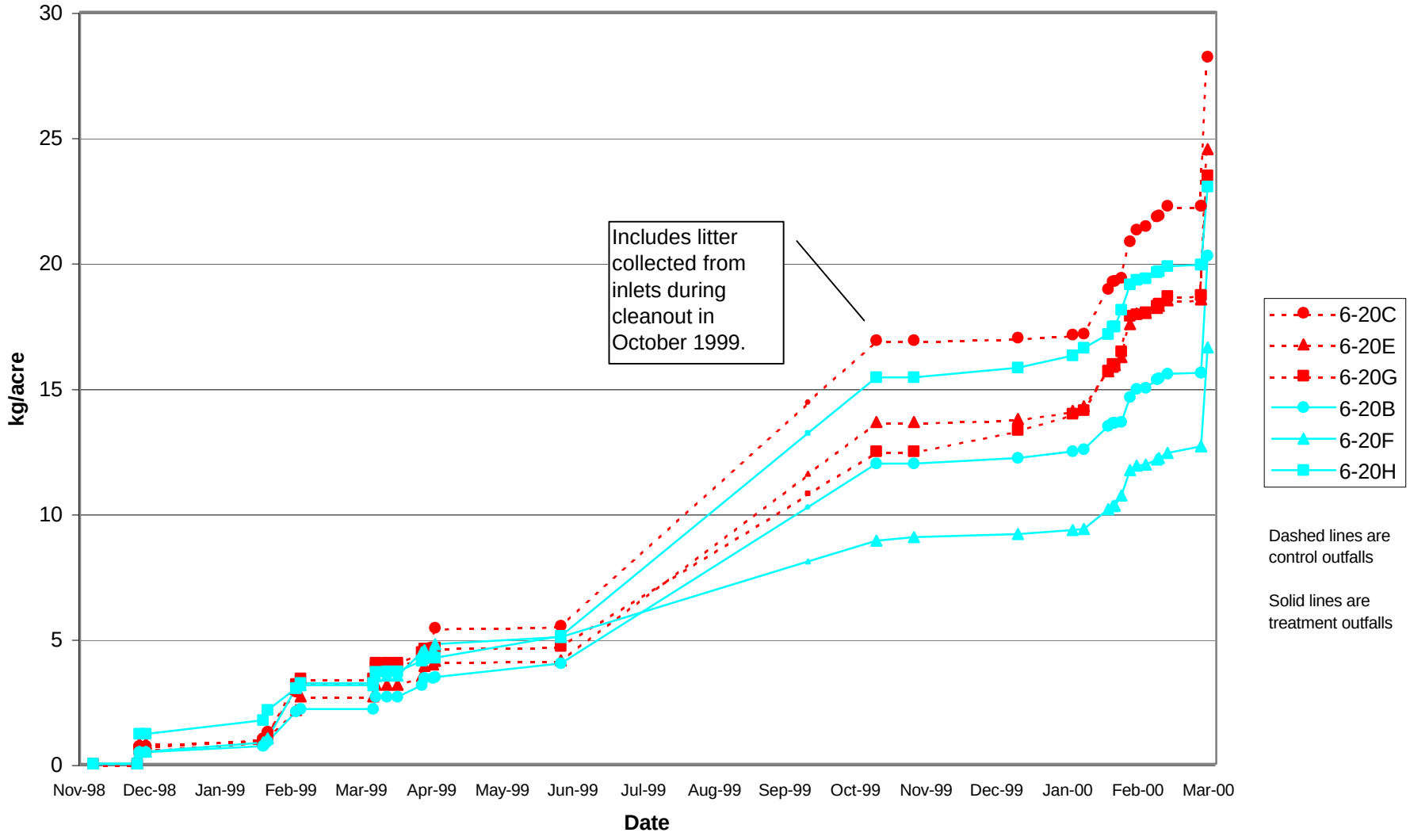


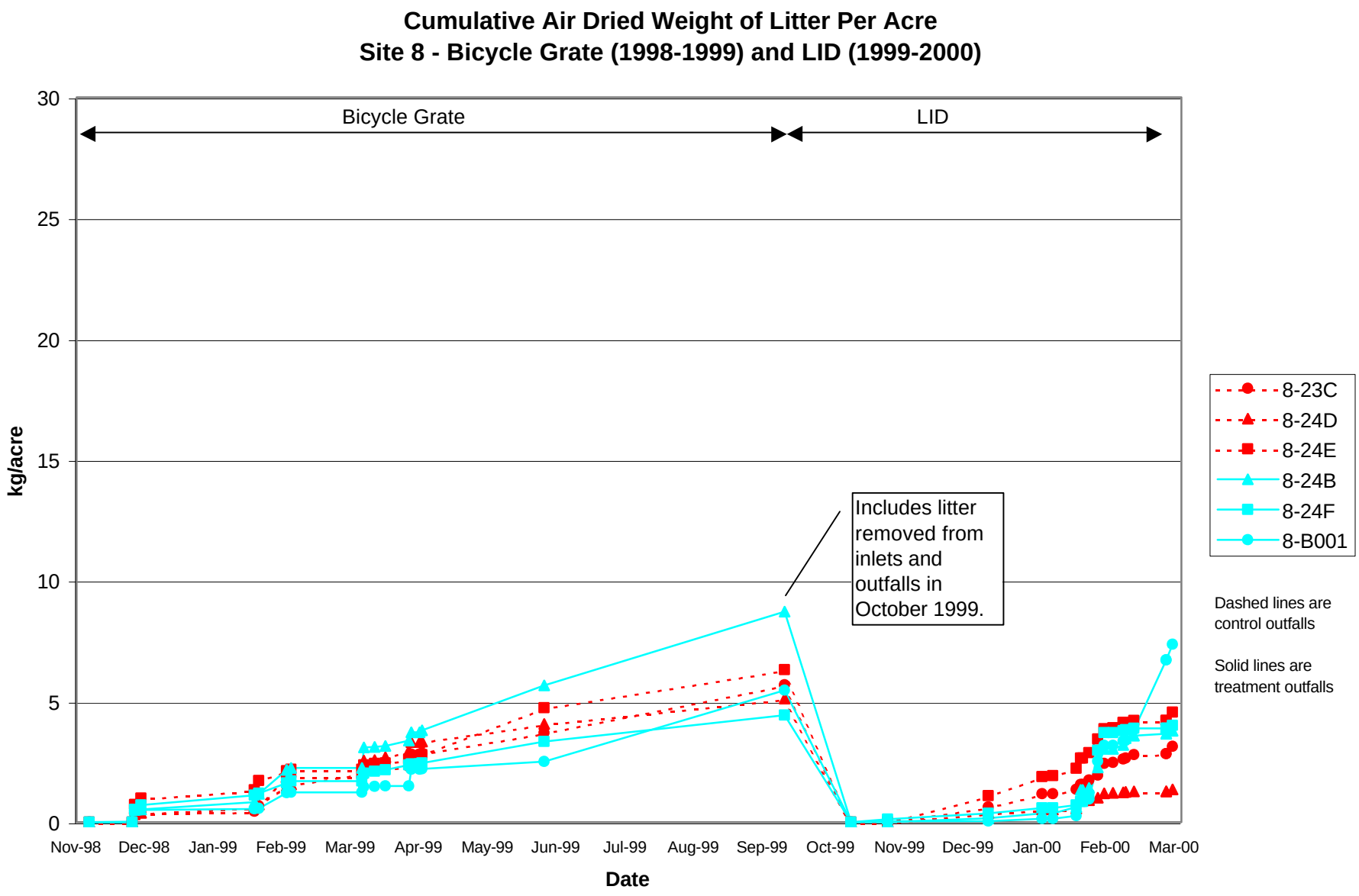

Cumulative Total Debris Weight Per Acre
Site 8 - Bicycle Grate (1998-1999) and LID (1999-2000)
Bicycle Grate
LID
kg/acre
1000
900
800
700
600
500
400
300
200
100
0
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
Includes litter removed from inlets and outfalls in October 1999.
8-23C
8-24D
8-24E
8-24B
8-24F
8-B001
Dashed lines are control outfalls
Solid lines are treatment outfalls

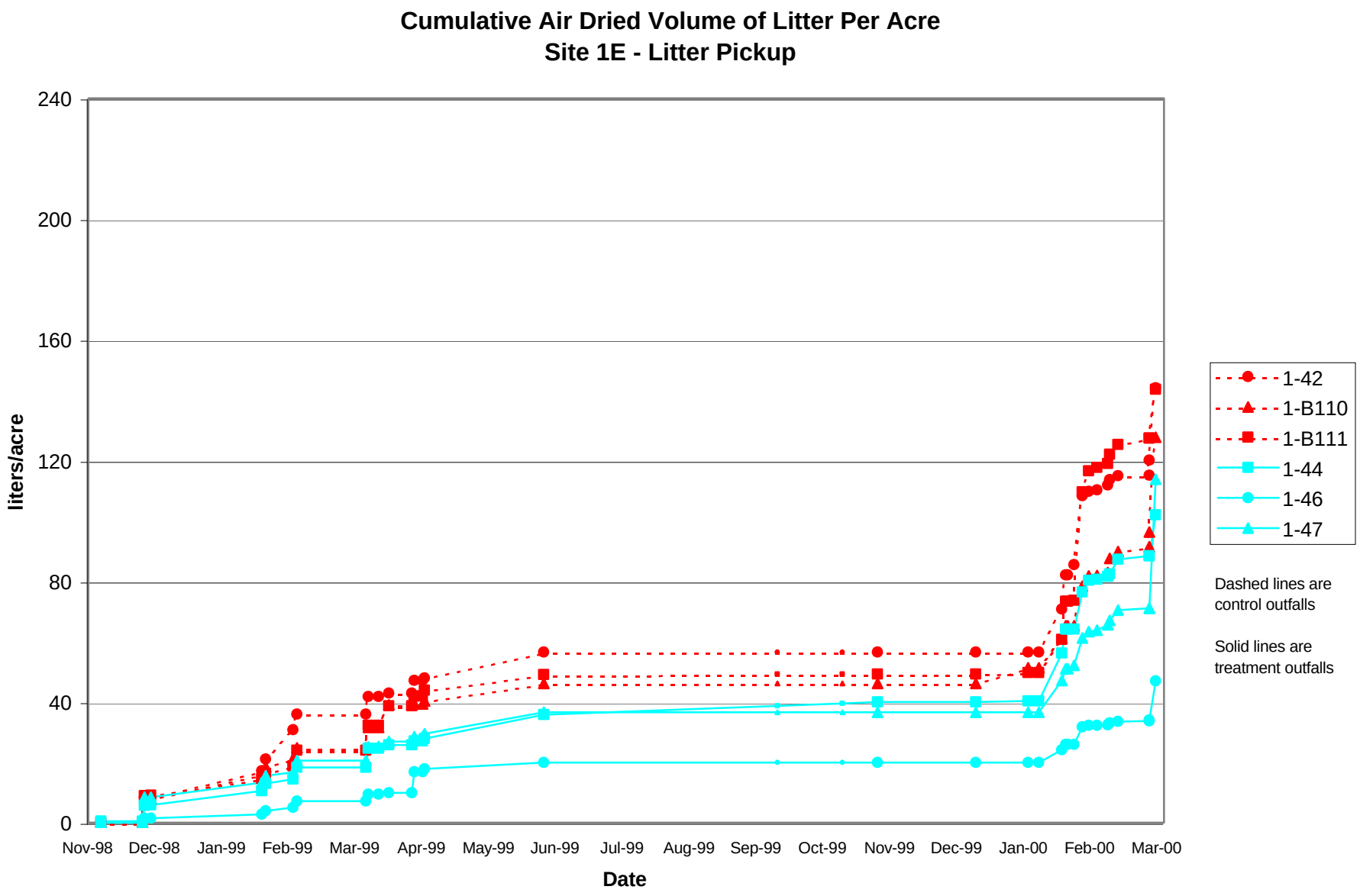

Cumulative Air Dried Weight of Litter Per Acre
Site 1E - Litter Pickup
kg/acre
30
25
20
15
10
5
0
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
1-42
1-B110
1-B111
1-44
1-46
1-47
Dashed lines are control outfalls
Solid lines are treatment outfalls

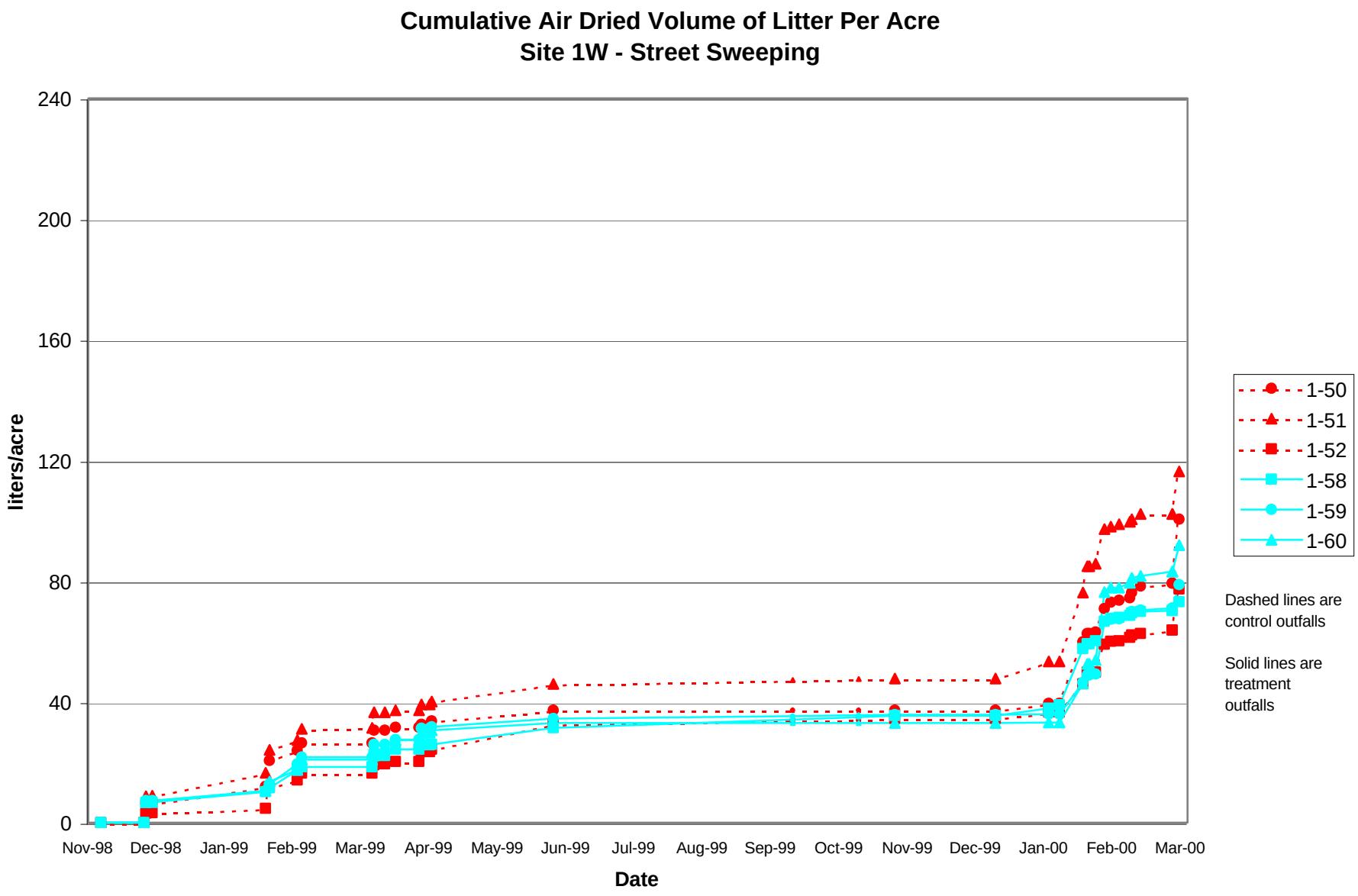

Cumulative Air Dried Weight of Litter Per Acre
Site 1W - Street Sweeping
kg/acre
30
25
20
15
10
5
0
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
1-50
1-51
1-52
1-58
1-59
1-60
Dashed lines are control outfalls
Solid lines are treatment outfalls

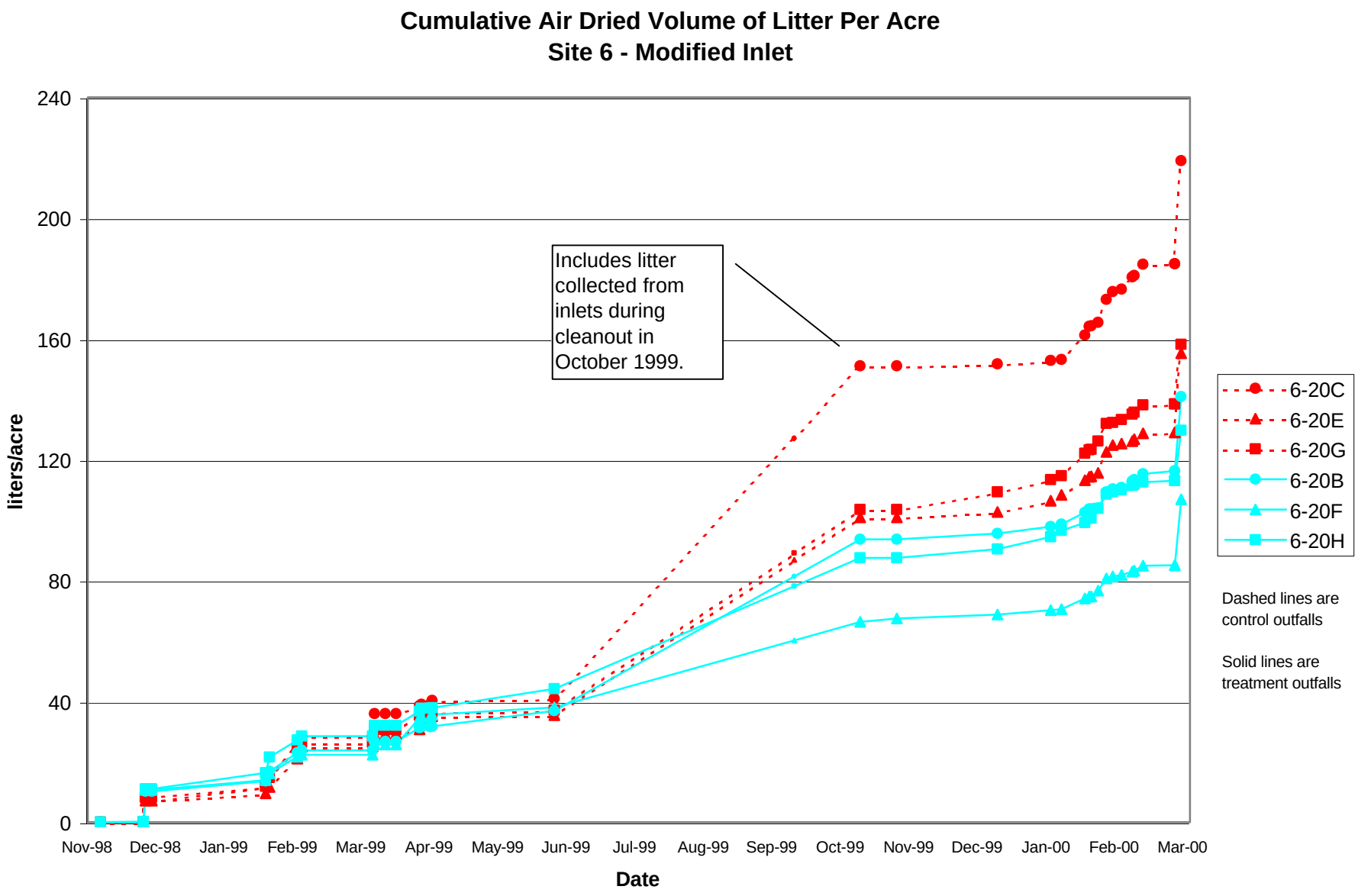
Cumulative Air Dried Weight of Litter Per Acre
Site 6 - Modified Inlet



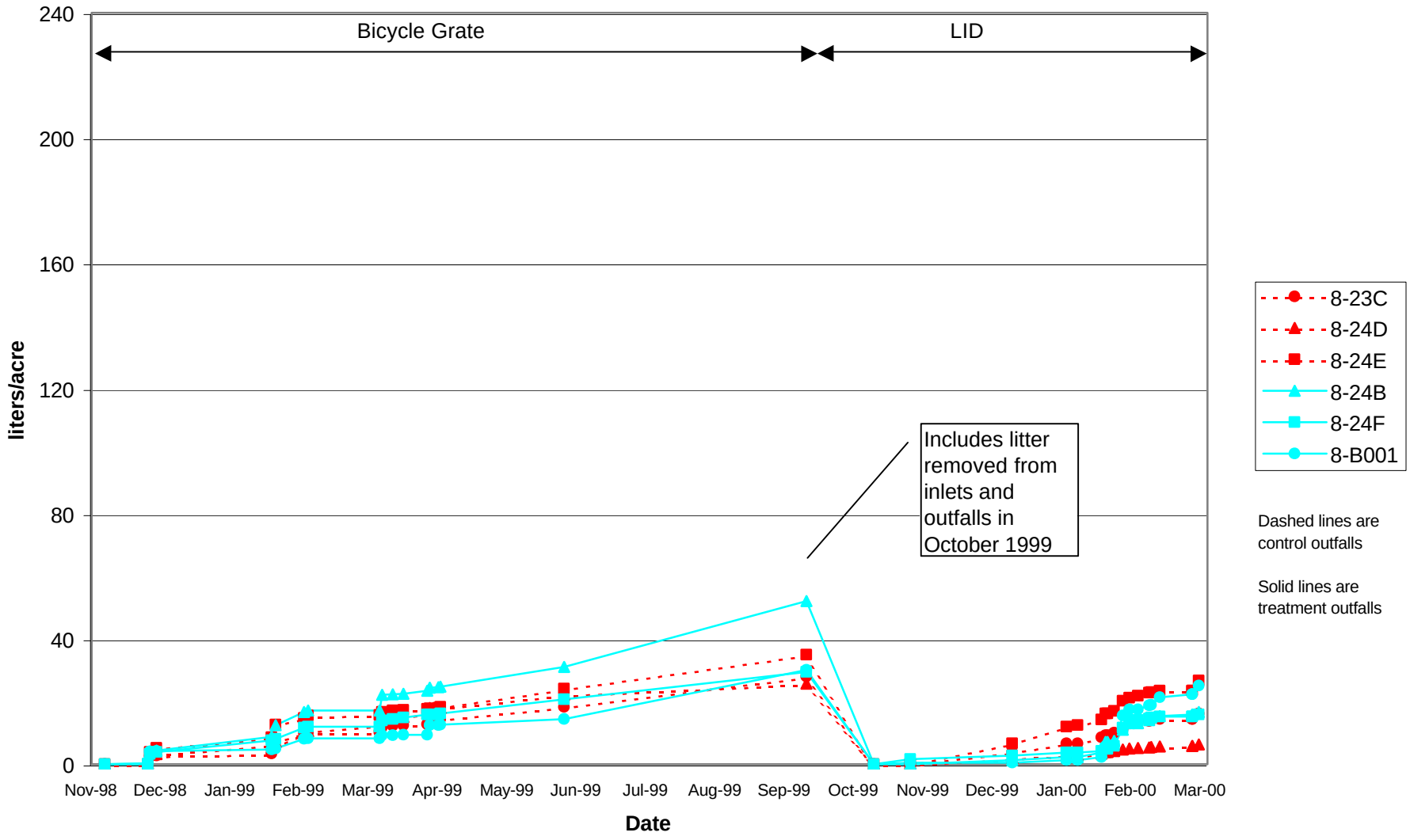

Cumulative Air Dried Weight of Litter Per Acre
Site 8 - Bicycle Grate (1998-1999) and LID (1999-2000)
Bicycle Grate
LID
kg/acre
30
25
20
15
10
5
0
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
Includes litter removed from inlets and outfalls in October 1999.
8-23C
8-24D
8-24E
8-24B
8-24F
8-B001
Dashed lines are control outfalls
Solid lines are treatment outfalls


Cumulative Air Dried Volume of Litter Per Acre
Site 1E - Litter Pickup
liters/acre
240
200
160
120
80
40
0
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
1-42
1-B110
1-B111
1-44
1-46
1-47
Dashed lines are control outfalls
Solid lines are treatment outfalls

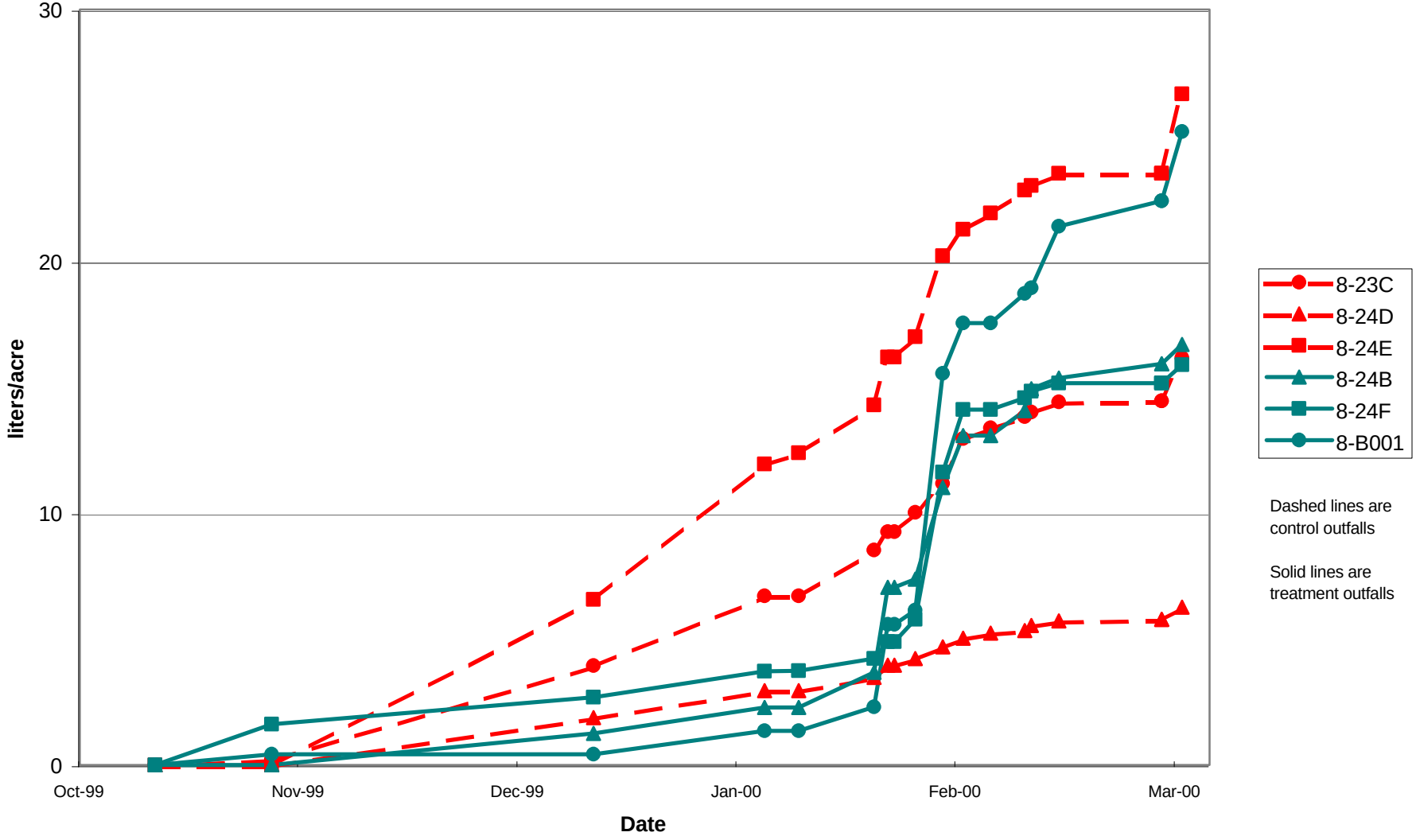

Cumulative Air Dried Volume of Litter Per Acre
Site 1W - Street Sweeping
liters/acre
240
200
160
120
80
40
0
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
1-50
1-51
1-52
1-58
1-59
1-60
Dashed lines are control outfalls
Solid lines are treatment outfalls

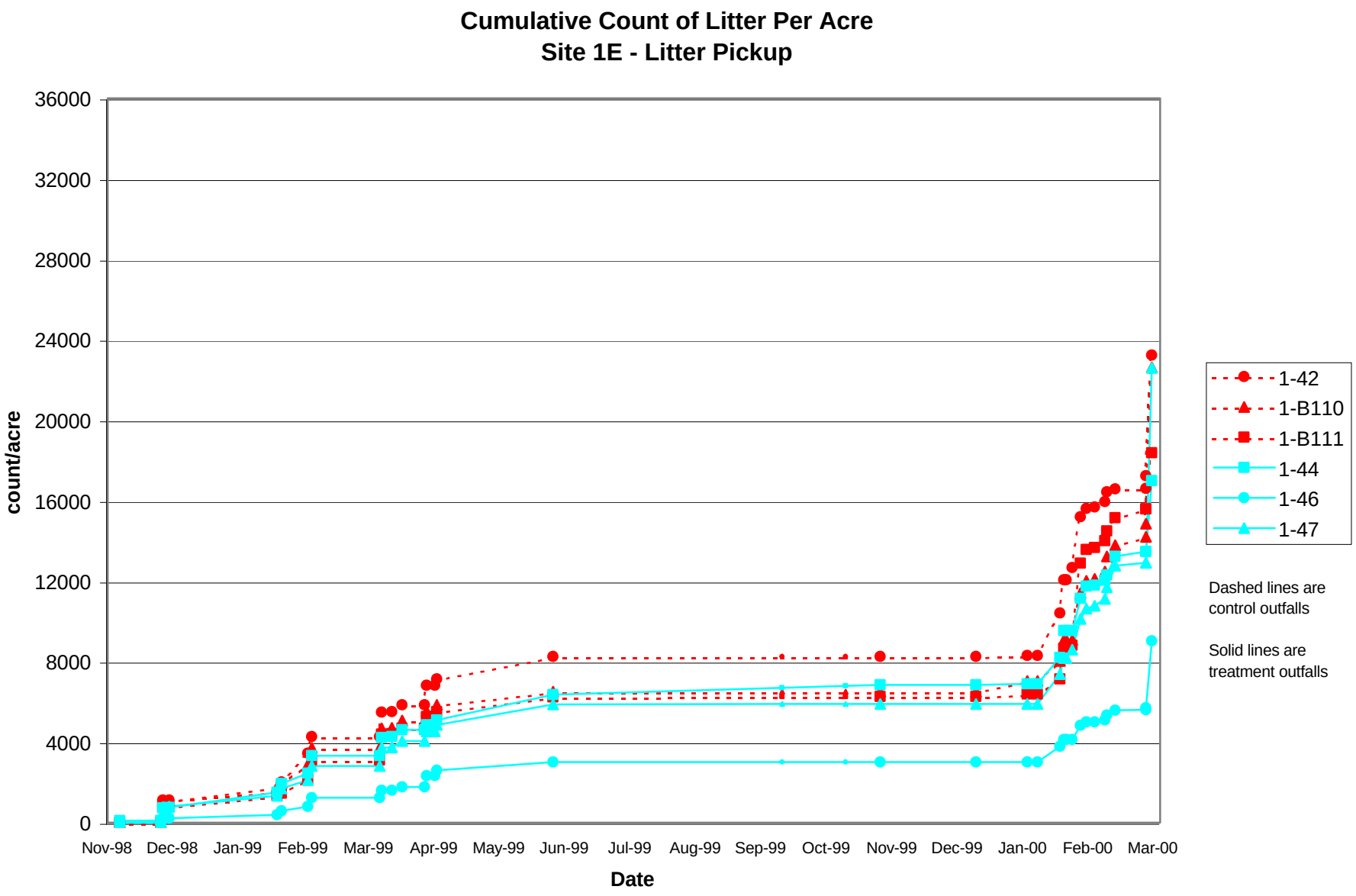

Cumulative Air Dried Volume of Litter Per Acre
Site 6 - Modified Inlet
liters/acre
240
200
160
120
80
40
0
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
Includes litter collected from inlets during cleanout in October 1999.
6-20C
6-20E
6-20G
6-20B
6-20F
6-20H
Dashed lines are control outfalls
Solid lines are treatment outfalls

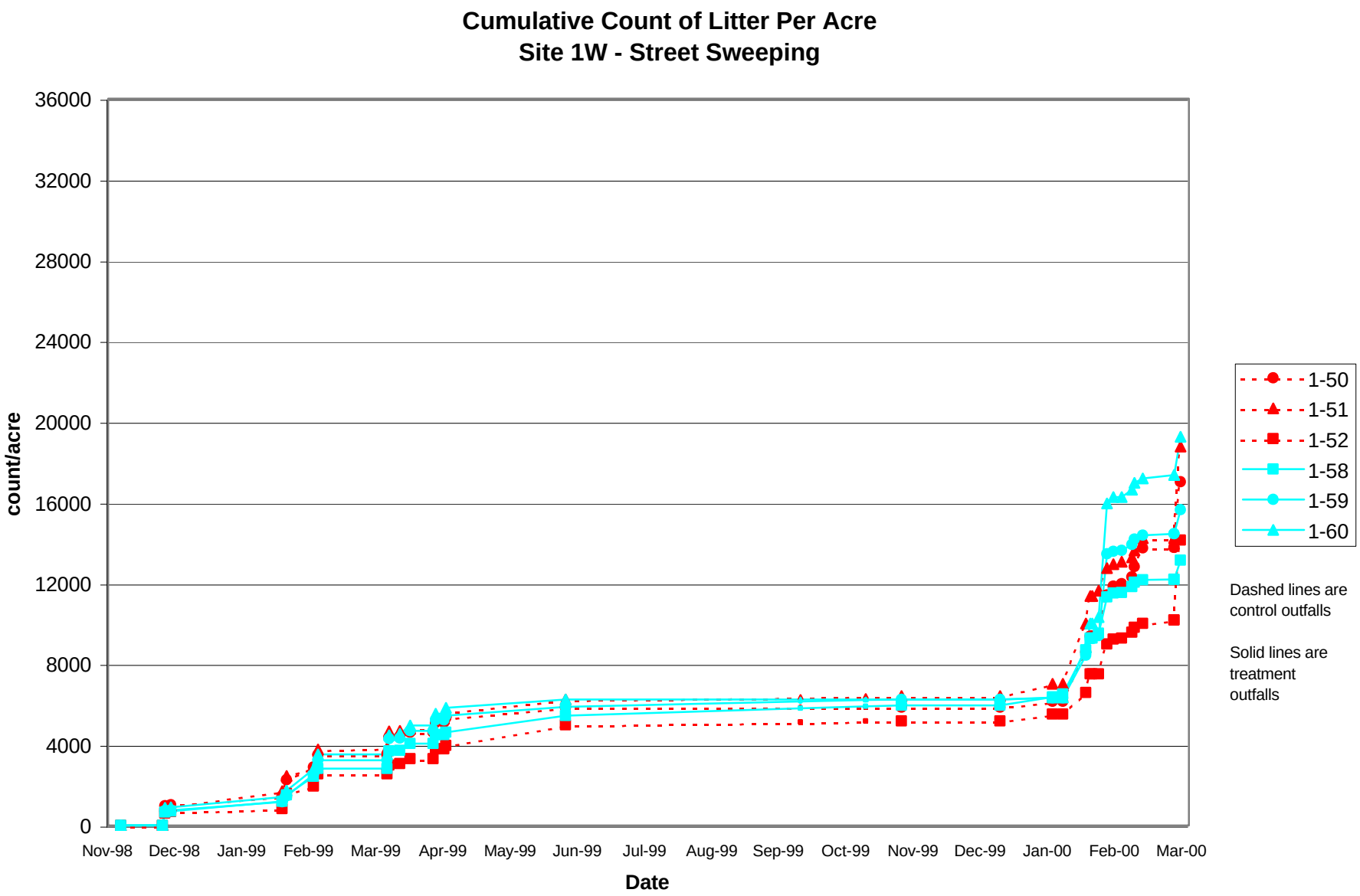
Cumulative Air Dried Volume of Litter Per Acre
Site 8 - Bicycle Grate (1998-1999) and LID (1999-2000)

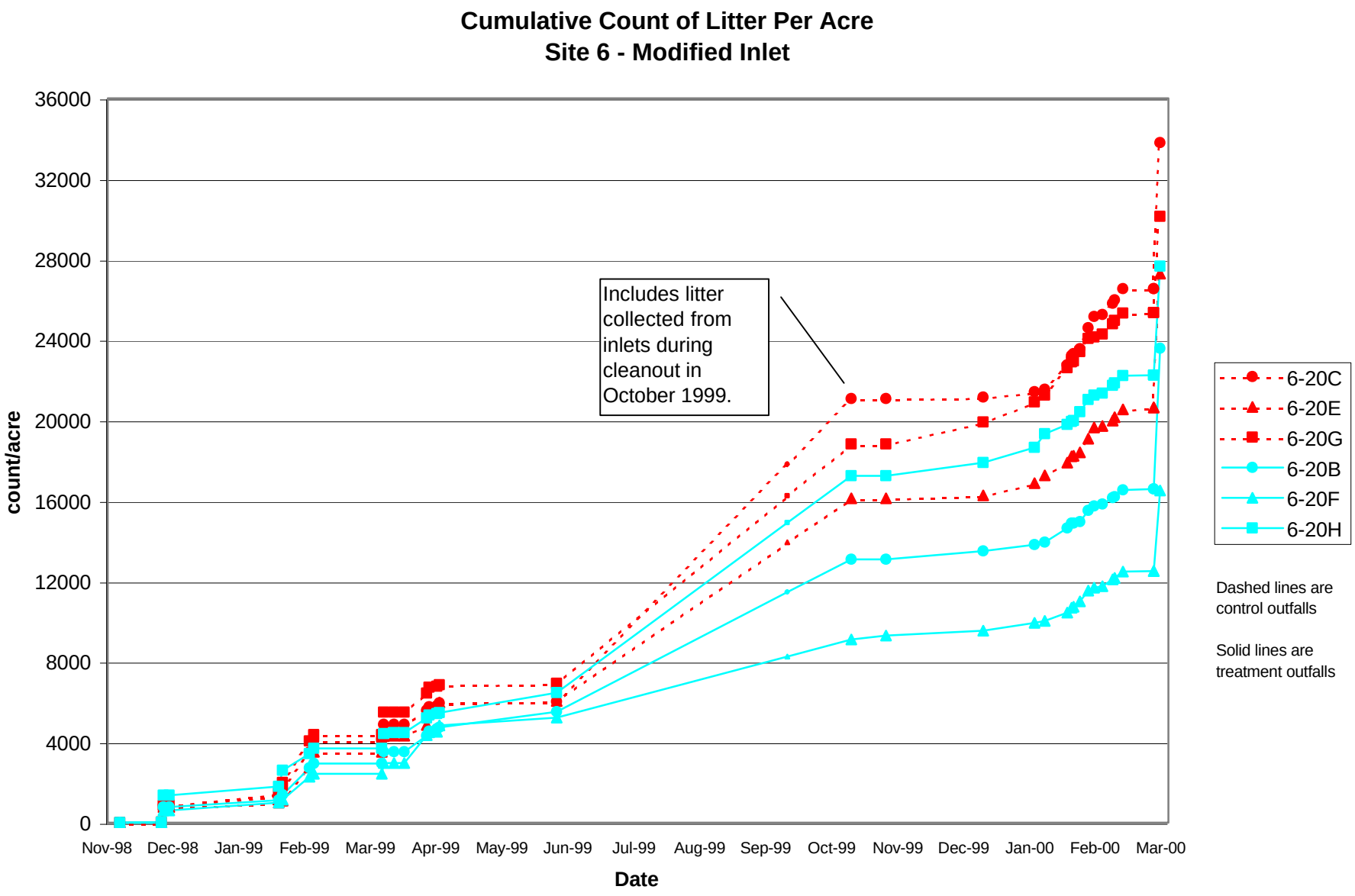


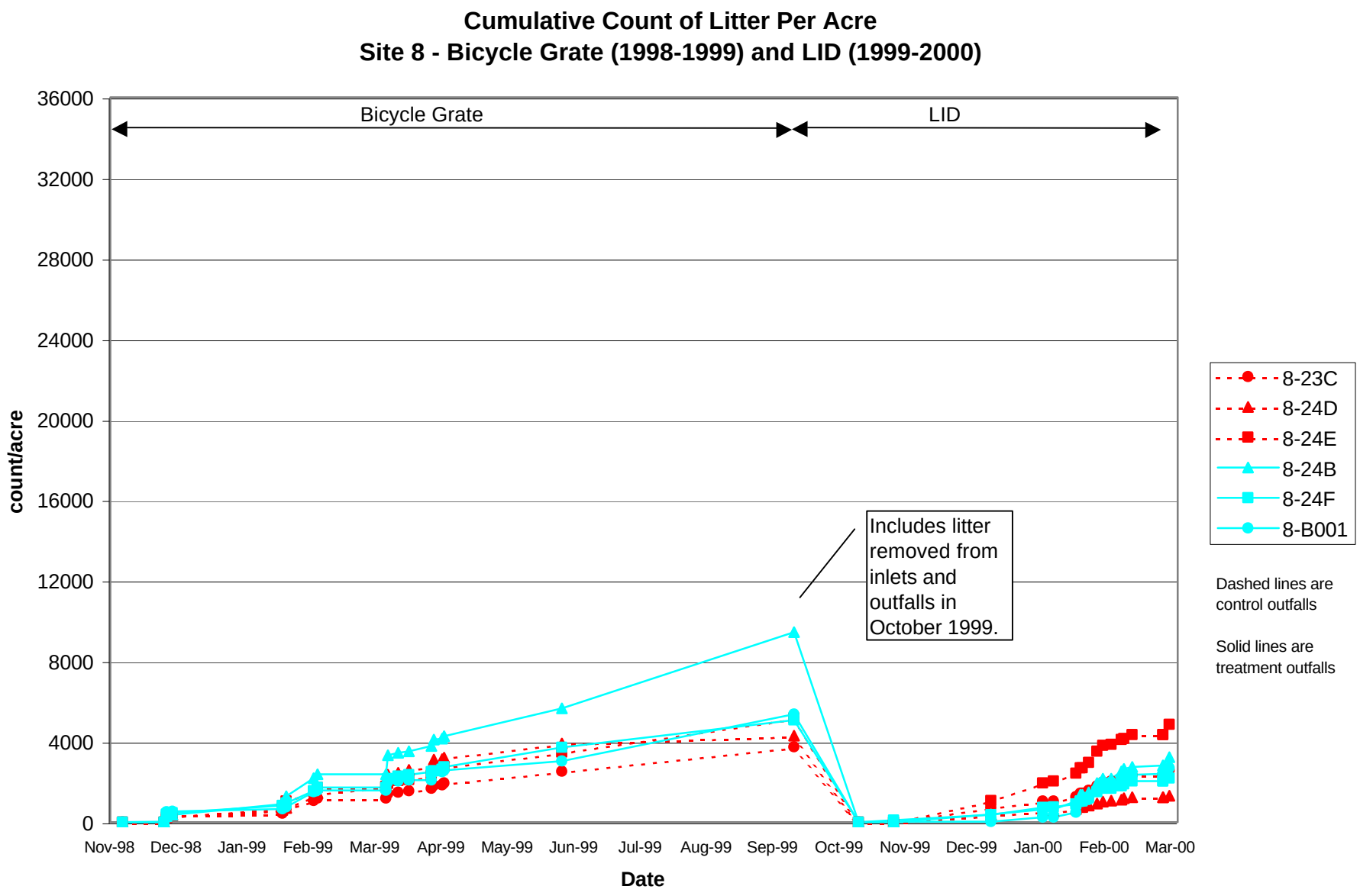
Cumulative Air Dried Volume of Litter Per Acre
Site 8 - LID (1999-2000)




Cumulative Count of Litter Per Acre
Site 1E - Litter Pickup
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
count/acre
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
1-42
1-B110
1-B111
1-44
1-46
1-47
Dashed lines are control outfalls
Solid lines are treatment outfalls


Cumulative Count of Litter Per Acre
Site 1W - Street Sweeping
count/acre
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
1-50
1-51
1-52
1-58
1-59
1-60
Dashed lines are control outfalls
Solid lines are treatment outfalls


Cumulative Count of Litter Per Acre
Site 6 - Modified Inlet
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
count/acre
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
Includes litter collected from inlets during cleanout in October 1999.
6-20C
6-20E
6-20G
6-20B
6-20F
6-20H
Dashed lines are control outfalls
Solid lines are treatment outfalls


Cumulative Count of Litter Per Acre
Site 8 - Bicycle Grate (1998-1999) and LID (1999-2000)
Bicycle Grate
LID
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
count/acre
Nov-98
Dec-98
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99
Jan-00
Feb-00
Mar-00
Date
Includes litter removed from inlets and outfalls in October 1999.
8-23C
8-24D
8-24E
8-24B
8-24F
8-B001
Dashed lines are control outfalls
Solid lines are treatment outfalls

Appendix K
Statistical Analysis of Litter BMP Effectiveness

K.1. Objective

This appendix describes the statistical methods used to evaluate the BMP effectiveness and presents the results of the analysis. Data analysis was performed using JMP version 3.2.6 statistical software.

K.2. Sampling Design

The following four BMPs were analyzed for the study period of 1998/1999:

- Manual litter pick-up (Site 1E),
- Street sweepers (Site 1W),
- Modified inlet grate (Site 6), and
- Bicycle grate (Site 8).

The bicycle grate at Site 8 was replaced with a curb inlet and Litter Inlet Deflector (LID) for the 1999/2000 study period.

Three pairs of control and treatment outfalls were monitored for litter for each BMP. There were a total of 16 litter collection storm events at the outfalls during 1998/1999. Litter was collected after 9 trigger storm events (a 70% probability of 0.2 inches of rain) and 6 times, after extended antecedent dry period, prior to the forecasted trigger storm events. During the 1999/2000 rainy season, there were 15 litter collections at the outfalls. Litter was collected after 13 storms and two times prior to forecasted trigger storms. During each litter collection event, litter was collected from each outfall and measured in count (number of items), volume (milliliters), and dry weight (grams).

K.3. Approach and Methodology – Data Normalized by Catchment Area

Several statistical methods can be used to evaluate the BMP effectiveness. When the statistical evaluation involves two data populations (control and treatment outfalls for this study), either a marginal (unpaired) analysis or a paired analysis can be utilized. For the marginal analysis, the marginal distributions of the two populations are characterized and the distributions of the treatment and control outfall data are tested to evaluate if the average values of the two distributions are the same. For the paired analysis, the difference in each pair of data is first calculated and tested to evaluate if the average difference is zero. These two approaches are explained in detail below.

Each of these two analyses (paired and unpaired) can be performed at the outfall level or the site level. At the outfall level, each data point at each outfall is considered to be an independent, random sample. At the site level, the 3 control outfalls are grouped together, and similarly, the 3 treatment outfalls are grouped together. The total litter collected in each event over all outfalls in each group is considered to be an independent, random sample. The site-level analysis filters

some of the "noise" in the data and may be more powerful in evaluating the significance of observed differences. This is especially true if data distributions are highly variable. Thus, if the site-level analysis transforms non-normally distributed outfall-level data into more robust, normally distributed data, the site-level analysis would be preferred to the outfall-level analysis.

For both marginal and paired analyses, the variability among the control outfalls and the variability among the treatment outfalls are assumed to be purely random. This assumption can be checked using a one-way Analysis of Variance (ANOVA) for control outfalls and separately for treatment outfalls. During the siting phase, the outfalls were selected to make sure that they would be expected to behave similarly and differences among them would be random. However, unanticipated field conditions may affect a particular outfall, making it behave differently from others. If such conditions are known, or suspected, to have occurred at a site, the statistical analysis may be used to confirm whether an outfall has been significantly affected by these conditions. An outfall that is confirmed to have been systematically affected by field conditions would be excluded from the analysis.

Each treatment outfall may be paired with exactly one control outfall that is considered to have very similar field conditions. This approach is termed "matched pairs". If there is no strong field evidence for matching a treatment outfall with only one control outfall, a treatment outfall may be matched with each of similar control outfalls. This approach is termed "cross pairing". ANOVA can again be used to evaluate the differences among various pairs of treatment and control outfalls. If these differences are statistically significant, the matched pairing would be more appropriate. If the differences are statistically not significant, the cross pairing would be more appropriate.

The paired analysis may be performed using either actual differences between control and treatment outfalls or percentage differences between the two outfalls, relative to the control outfall litter load. If the actual differences show a large amount of variability and do not pass the normality test, one can transform the data by calculating the percentage difference (i.e., difference between control and treatment divided by the control amount, expressed as a percentage). If the differences show an increasing relationship with the control amount, the percentage difference would be appropriate to consider. This is because, under these circumstances, using the percent difference may reduce the coefficient of variation of the data and is more likely to produce normally distributed data. Thus, if the actual differences are not normally distributed, but the percentage differences are, the use of the percentage differences would be more appropriate.

The steps involved in these methods of analysis (unpaired at outfall- and site-levels and paired at outfall- and site-levels) are described as follows:

(I) MARGINAL (UNPAIRED) ANALYSIS

1. Outfall-level analysis: for each BMP and measuring unit combination (e.g., litter from the street sweeping site measured in count), pool all data from control outfalls together and all

data from treatment outfalls together (i.e., 31 events × 3 control outfalls = 93 data points for control, and similarly, 93 data points for treatment).

2. Normalize the litter measurement with the corresponding catchment area (i.e., convert the litter data to count/acre, milliliter/acre, and gram/acre).
3. Perform exploratory data analysis (EDA) and check for anomalies in the data. Exploratory data analysis consists of calculating the summary statistics of the data, such as mean, median, minimum, maximum, standard deviation, variance, coefficient of variation, skewness, kurtosis, etc., (see Attachment 1 to this appendix) as well as examining the data using graphical representations, such as histogram, box and whisker plot, and normal probability plot. The purpose of performing EDA is to ensure that the data are behaved within expectations, and a continual distribution rather than a bi-modal or multi-modal distribution[1] is observed. By reviewing the data both numerically and graphically, the "structure" of the data can be evaluated and thereby appropriate approaches and limitations for using the data can be identified. Other data anomalies, such as extreme outliers or other obvious data recording/transcribing errors, can be readily identified if they exist.
4. Test the distributions of control and treatment data for normality using Shapiro-Wilk W Test at a 5% significance level. The frequency plot of a normally distributed variable has a bell-shaped curve (see Figure 1), with the highest point located at the mean (which is also equal to the median), and the population is distributed symmetrically about the mean.

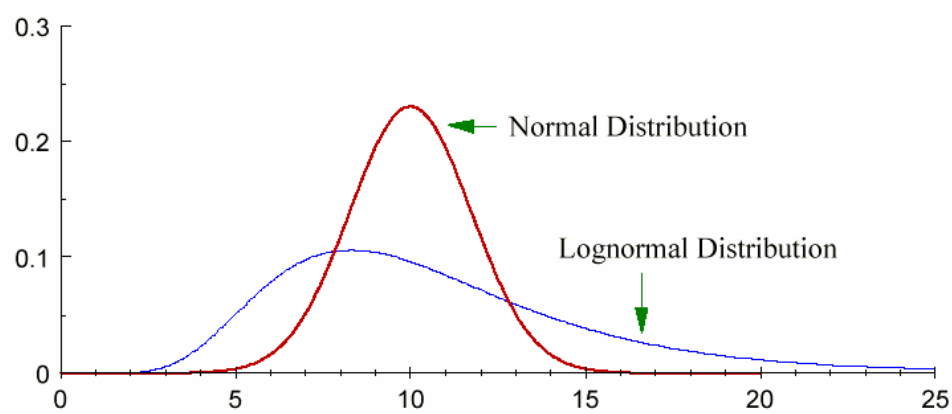


Figure 1. Frequency plot of normally and lognormally distributed variables

The assumption of normality is important, as it is the basis for the majority of statistical parametric tests. The Shapiro-Wilk W Test is recommended by U.S. EPA for testing data normality (USEPA, 1998). The test is similar to computing a correlation between the quantiles of the standard normal distribution and the ordered values of a data set. If the normal probability plot is approximately linear (i.e., the data follow a normal curve), the test

[1] A mode of a distribution is its peak. Distributions with more than one mode are usually problematic, and a different statistical analysis strategy may be required since conventional statistical procedures may not handle them well.

statistic will be relatively high. If the normal probability plot contains significant curves, the test statistic will be relatively low.

A 5% significance level is commonly used when applying the Shapiro-Wilk W Test, as described in DTSC Final Policy (DTSC, 1997), Gibbons (1994), and USEPA Guidance Document (USEPA, 1998). If the p-value (Prob < W) is less than 0.05, then it can be concluded that the data distribution is significantly different from a normal distribution; otherwise, it can be concluded that the data is normally distributed (or more precisely, the hypothesis that the data are normally distributed cannot be rejected).

5. Identify a null and alternative hypotheses and evaluate the data to test if the null hypothesis should be rejected. For the LMPS, the null hypothesis is that the litter collected in the treatment and control pairs is equal and the alternative hypothesis is that the litter in the control pairs is greater than the litter in the treatment pairs. These hypotheses are presented mathematically as:

   Null hypothesis, H_0: $\mu_{control} = \mu_{treatment}$

   Alternative hypothesis, H_A: $\mu_{control} > \mu_{treatment}$

   (a) If both control and treatment distributions are normal:

      (i) Use Levene Test at a 5% significance level to test if the variances are equal across groups. The variance is evaluated because the subsequent t-Test (in (ii) below) requires the assumption of equal variances across groups. If the variances are not equal across groups, a slightly modified version of conventional standard two-sample t-Test will be used. The Levene Test is recommended in the USEPA Guidance Document (USEPA, 1998), and the detail procedures of Levene Test can also be found in this document.

      (ii) Use two-sample (unpaired) t-Test to compare the mean litter amount at a 5% significance level, assuming equal variances or unequal variances based on the result of Levene Test. The two-sample t-Test is recommended by USEPA (USEPA, 1998) for comparing two populations when the data distributions are normal. For the LMPS this step answers the question "Is the mean normalized litter amount collected in control outfalls higher than that of treatment outfalls?".

      (iii) If the p-value of the respective t-Test is less than 0.05, the null hypothesis is rejected and the conclusion is that the average litter amount is higher at the control outfalls, i.e., there is statistically significant litter reduction using the BMP at the treatment outfalls.

   (b) If either the control or the treatment distribution is not normal:

      (i) Repeat (3) with log-transformed data. By transforming the data, the normality assumption that is not satisfied in the original data may be satisfied by the log-transformed data, particularly if the data distribution is positively skewed (see Figure 1). The following equation is used to for the log-transformation in order to accommodate data values that equal zero:

Original data is x and log-transformed data, y, is:

$$y = \ln(x+1)$$

(ii) If both the control and treatment distributions are lognormal, repeat (4) (a) with log-transformed data (i.e., y).

(iii) If either the control or the treatment distribution is not lognormal, use Wilcoxon Rank-Sum Test (a non-parametric test) to compare the litter amount at a 5% significance level using the raw data.[2] The Wilcoxon Rank-Sum Test is recommended by USEPA (1998) for populations of data that are neither normally nor lognormally distributed. It compares the distributions (shapes and locations) of two populations based on the relative rank of each data point when both populations are pooled together, and it does not assume a normal distribution for the data. If the p-value of Wilcoxon Rank-Sum Test is less than 0.05, the null hypothesis is rejected and it is concluded that the average litter amount is higher at the control outfalls; otherwise, the conclusion is that there are no significant differences in terms of average litter amount between control and treatment outfalls.

6. Site-level analysis: Sum the litter amount collected in all three control outfalls in each event, and similarly, sum the litter amount collected in all three treatment outfalls (i.e., 31 data points for control and 31 data points for treatment). Normalize the litter measurement with the corresponding total site catchment area. Repeat (3) to (5).
7. Repeat (1) to (6) for other BMP and measuring unit combinations.

(II) PAIRED ANALYSIS

1. Outfall-level analysis: Calculate the percentage differences of normalized litter amount for each BMP and measuring unit combination collected between each pair of control and treatment outfalls in each storm event. For example:

   BMP = manual litter pick-up (Site 1E)

   Measuring unit = count

   Storm event = 1

   Outfall pair = P1

$$\text{Percentage difference, } \%\,diff = \frac{\left(\begin{array}{l}\text{No. of items per acre collected at Outfall 1-47 (control outfall)}\\ \text{- No. of items per acre collected at Outfall B-110 (treatment outfall)}\end{array}\right)}{\text{No. of items per acre collected at Outfall 1-47 (control outfall)}} \times 100\%$$

The same calculations are done for the data from the other two outfall pairs for the litter collection events. If only a small amount of litter was collected in the control outfalls, the (absolute) value of *% diff* could become extremely large, thus resulting in an anomalous value relative to the rest of the data points. For this reason, if the litter amount collected in

[2] The Wilcoxon Rank-Sum Test results are the same for raw and log-transformed data.

the control outfalls was less than the following screening values, the respective event/data point was excluded from our analysis (for that measurement):

- count ≤ 5 items
- volume ≤ 30 ml
- dry weight ≤ 1 g

These screening values were based on the judgement that average sampling errors (the level of error that is expected due to the limits of the sample collection and measuring methodologies utilized) would be similar to the screening values. Thus, a measured value less than a screening value was considered to be within the range of the average sampling error.

Two approaches to pairing the outfalls were investigated – matched pairing and crossed pairing. In the first approach, each treatment outfall was matched with a specific control outfall based on similar field conditions. In the second approach, each treatment outfall was matched with each of the control outfalls. If the ANOVA of all pairs of control and treatment outfalls with the same traffic and water flow directions did not show systematic differences, each treatment outfall could be paired with each of the control outfalls in the same traffic and water flow directions. Cross-pairing increases the number of pairs and the resulting data used in the analysis, and would be preferred when it is valid.

2. Perform exploratory data analysis on *% diff*. Check for anomalies in the data. Check whether data differences among the control outfalls and among the treatment outfalls at each site are statistically significant. The appropriate method of statistical analysis is the one-way Analysis of Variance (ANOVA). During the project siting phase treatment and control outfalls that were as similar as possible were selected to maximize the likelihood that they would behave similarly and any differences among them would be purely random. However, unanticipated field conditions might affect a particular outfall, making it behave differently from others. If such conditions are known or suspected to have occurred at a site, the statistical analysis may be used to confirm whether an outfall has been significantly affected by these conditions.

3. Test the distribution of *% diff* for normality using Shapiro-Wilk W Test at a 5% significance level.

4. Hypothesis testing:

   Null hypothesis, H_0: $\mu_{\%\ diff} = 0$

   Alternative hypothesis, H_A: $\mu_{\%\ diff} > 0$

   (a) If the distribution of *% diff* is normal, use the one-sample one-sided t-Test at a 5% significance level to test the hypotheses. The one-sample t-Test compares the mean of *% diff* with 0. If the p-value of the t-Test is less than 0.05, the null hypothesis is rejected and it is concluded that the average *% diff* is greater than 0, i.e., there is statistically significant litter reduction using the BMP at the treatment outfalls. Otherwise, it is concluded that the average litter reduction due to the BMP does not appear to be statistically significant.

(b) If the distribution of *% diff* is not normal, the Wilcoxon Signed-Rank Test (a non-parametric test) is used instead of the t-Test at a 5% significance level. Similar to the Wilcoxon Rank-Sum Test, this statistical test does not require assumption of parametric distribution existed in the data, and it is based on the ranking of the data relative to the threshold for comparison (in this case, the threshold is zero). If the p-value of the Wilcoxon Signed-Rank Test is less than 0.05, the null hypothesis is rejected and it is concluded that the average *% diff* is greater than 0; otherwise, it is concluded that the average litter reduction due to the BMP does not appear to be statistically significant.

5. Site-level analysis: sum the litter amount collected in all three control outfalls in each event, and similarly, sum the litter amount collected in all three treatment outfalls. Normalize the litter measurement with the corresponding total site catchment area. Repeat the calculation of *% diff* using the site total (normalized) litter. Repeat (2) to (4) and apply the same small quantity screening criteria as described in (1).

6. Repeat (1) to (5) for other BMP and measuring unit combinations.

7. Alternatively, the paired analysis is repeated using the actual differences of normalized litter amount (instead of *% diff*) between each pair of control and treatment outfalls (for both outfall-level and site-level analyses). The actual differences are calculated as follows (using the same example as illustrated in (1)):

$$\text{Actual difference, } Act\ diff = \text{No. of items per acre collected at Outfall 1-47 (control outfall)} - \text{No. of items per acre collected at Outfall B-110 (treatment outfall)}$$

8. Cross pairing outfall-level analysis: for the outfall-level analysis described above, the one-to-one outfall pairing may not be "absolute," i.e., a treatment outfall may be comparable to two or three control outfalls, not just one. Further investigation of the site characteristics showed that most control and treatment outfalls followed the same pattern of traffic flow and water flow directions in each site, except at Site 8 (See Table 1). The exploratory data analysis described in (II) (2) indicated that the pairing comparison may be affected if either one of the directions is different between one pair and another. For example:

At Site 1E,

Treatment LP1 (1-47) can be compared to … → Control LP1 (1-B110)
→ Control LP2 (1-42)
→ Control LP3 (1-B111)

Site conditions are similar, including traffic-water flow directions, at treatment outfalls (E-W) and at control outfalls (E-E). Thus, besides the original pairing comparison between Treatment LP1 and Control LP1, there appeared to be no bias in comparing Treatment LP1 with Control LP2 and LP3.

However, at Site 8,

Treatment LP1 (8-B001) can be compared to → Control LP1 (8-23C)

Treatment LP2 (8-24B) can be compared to → Control LP2 (8-24D)
→ Control LP3 (8-24E)

The traffic direction is different between Control LP1 and Control LP2/LP3; therefore, Treatment LP1 can be compared with Control LP1 but not with Control LP2 or LP3. However, for Treatment LP2, besides the original paired "partner" Control LP2, Treatment LP2 can also be compared to Control LP3 because Control LP2 and LP3 had the same traffic and water flow directions.

Table 1. Traffic flow directions and water flow directions of all outfalls, and the associated "valid" comparison between control and treatment outfalls

Site Number	BMP	Outfall Type	Pair Design-ation	Outfall	Traffic Flow Direction	Water Flow Direction	Compare to Control Outfalls
1E	Litter Pickup	Control	LP1	1-B110	E	E	
			LP2	1-42	E	E	
			LP3	1-B111	E	E	
		Treatment	LP1	1-47	E	W	1-B110, 1-42, 1-B111
			LP2	1-46	E	W	1-B110, 1-42, 1-B111
			LP3	1-44	E	W	1-B110, 1-42, 1-B111
1W	Street Sweeping	Control	SP1	1-52	W	W	
			SP2	1-50	W	W	
			SP3	1-51	W	W	
		Treatment	SP1	1-58	W	E	1-52, 1-50, 1-51
			SP2	1-59	W	E	1-52, 1-50, 1-51
			SP3	1-60	W	E	1-52, 1-50, 1-51
6	Modified Inlet	Control	MP1	6-20G	E	E	
			MP2	6-20E	E	E	
			MP3	6-20C	E	E	
		Treatment	MP1	6-20H	E	E	6-20G, 6-20E, 6-20C
			MP2	6-20F	E	E	6-20G, 6-20E, 6-20C
			MP3	6-20B	E	E	6-20G, 6-20E, 6-20C
8	Bicycle Grate / LID	Control	BP1	8-23C	W	W	
			BP2	8-24D	E	W	
			BP3	8-24E	E	W	
		Treatment	BP1	8-B001	W	E	8-23C
			BP2	8-24B	E	E	8-24D, 8-24E
			BP3	8-24F	E	W	8-24D, 8-24E

Table 1 shows all possible cross pairing comparisons based on compatibility of traffic and water flow directions between control and treatment outfalls. As described in (1), if the ANOVA of all pairs of control and treatment outfalls with the same traffic and water flow directions do not show systematic differences, each treatment outfall could be paired with each of the control outfalls in the same traffic and water flow directions. Both variables, *% diff* and *Act diff*, are

used for this cross-pairing analysis at the outfall level[3] (Repeat steps 1 to 4, 6, and 7 above). One noticeable difference of this analysis is that the number of data points is much larger (i.e., for each litter collection event at Site 1E, there are nine pairs of comparison (nine *% diff*'s or *Act diff*'s) instead of three.

Approach and Methodology – Data Normalized by Flow Volume

Flow volume data (in litre) were collected for 22 storm events (out of 31 litter collection events) and for only one pair of control/treatment outfall at each site. Therefore, the statistical analysis procedures were reduced to the following two approaches:

(I) MARGINAL (UNPAIRED) ANALYSIS: Outfall-level analysis for raw data and log-transformed analysis. No site-level analysis.

(II) PAIRED ANALYSIS: Outfall-level analysis with matched pairs for *Act Diff* and *% Diff*. No site-level analysis and crossed pairs analysis (also, no one-way ANOVA on three controls and three treatments).

Otherwise, the same statistical procedures were used as described in the previous section.

Approach and Methodology – Analysis of Total System Litter Load

Litter load data were collected for two components of the storm drain system – the litter retained in the inlet during a given study period and the litter discharged to an outfall in each monitored storm event during the study period. Each inlet was cleaned at the start and end of the study period. These data provided an estimate of the litter load retained in the system during the study period. The total system annual litter load for each outfall was calculated as the sum of two components: (1) the litter load retained in the system and collected from inlet cleaning at an inlet during the study period and (2) the cumulative litter load collected in litter monitoring bags at an outfall in monitored events during the study period.

The differences in the total system litter load can be analyzed using the methods of paired analysis described above. Both actual and percentage differences can be analyzed. To provide an adequate number of data points, the cross-pairing of treatment and control outfalls is appropriate.

K.4. Results – Data Normalized by Catchment Area

Main Results

Table 2 summarizes the results of the statistical evaluation of BMP effectiveness. For each site and each litter measure, Table 2 presents the results of the paired analyses. For the paired

[3] Not at the site level, because all control outfalls and all treatment outfalls are combined together in the site-level analysis.

analysis, results are presented for three cases – matched pairs, crossed pairs, and site-level analysis. For each case, both actual and percentage differences are analyzed.

The data for Site 1E were analyzed with or without the treatment outfall 1-46, which was considered to be potentially suspect because of noticeably lower litter amount seen at this outfall (see Appendix J, pages 1, 5, and 9). However, the ANOVA results showed that the data at outfall 1-46 were statistically no different from the other two outfalls at this site.

Year 2 data for Site 8 (LID) were analyzed with and without the control outfall 8-24D, which was considered to be potentially affected by construction impacts (see Appendix J, pages 4, 8 and 12). In this case, the ANOVA results did confirm that this outfall behaved differently from the other control outfall (8-24E) in the same traffic direction.

For all other sites, there were no outfalls that were potentially suspect and ANOVA did not show the presence of statistically significant differences among either the three control outfalls or the three treatment outfalls. The analysis, therefore, used all outfalls at Sites 1W, 6, and 8 (bicycle grate).

Using the criteria discussed in Section L.3 “Approach and Methodology”, a preferred method of analysis was identified for each site and measure. Table 3 shows the preferred methods of analysis.

Note that for a paired sampling design (which was employed in the LMPS), the paired analysis should be preferred to the marginal analysis.

Table 2. Results (p-values) of Evaluation of BMP Effectiveness (data normalized by catchment area) (1)

Site	BMP	Measure	Paired Analysis					
			Matched Pairs		Crossed Pairs		Site Level	
			Actual Diff.	% Diff.	Actual Diff.	% Diff.	Actual Diff.	% Diff.
1E	Litter Pickup	Count	***0.000***	***0.001***	***0.000****	***0.000***	***0.003***	***0.040***
		Volume	***0.000***	***0.000***	***0.000****	***0.000***	***0.000***	***0.000***
		Weight	***0.012***	***0.016***	***0.000****	***0.002***	***0.046***	0.059
1W	Street Sweeping	Count	0.351	0.367	0.426*	0.530	0.463	0.370
		Volume	0.109	0.254	***0.032****	0.151	0.256	0.277
		Weight	0.643	0.817	0.656*	0.890	0.774	0.721
6	Modified Inlet	Count	***0.001***	***0.023***	***0.000****	***0.002***	***0.028***	***0.030***
		Volume	***0.022***	***0.047***	***0.000****	***0.002***	***0.045***	***0.013***
		Weight	***0.017***	0.161	***0.000****	***0.020***	0.064	0.051
8	Bicycle Grate	Count	0.918	0.890	0.991*	0.985	0.912	0.905
		Volume	0.273	0.315	0.546	0.351	0.626*	0.335
		Weight	0.297	0.173	0.321	0.429	0.133*	0.635
8 (2)	LID	Count	0.512	0.846	0.566	0.924	0.682	0.607
		Volume	0.746	0.943	0.816	0.965	0.604	0.830
		Weight	0.815	0.966	0.901	0.991	0.773	0.793
1E (w/o outfall 1-46)(3)	Litter Pickup	Count	0.179	0.319	***0.013***	0.056	0.125	0.329
		Volume	***0.018***	***0.027***	***0.000***	***0.001***	***0.011***	***0.009***
		Weight	0.578	0.546	0.481	0.685	0.526	0.555
8 (w/o outfall 8-24D)	LID	Count	***0.041***	0.119	***0.008****	***0.046***	***0.040***	0.137
		Volume	0.343	0.511	0.241	0.397	0.338*	0.607
		Weight	0.314	0.489	0.279*	0.379	0.446	0.527

* Preferred Method (See Table 3)
(1) Large, bold text indicates that the average litter amount in the control is greater than the treatment based on statistical testing (α=0.05)
(2) Preferred method is without Control 8-24D below.
(3) Preferred method is 1E above.

Table 3. Preferred Method of Statistical Analysis (data normalized by catchment area)

Site	BMP	Measure	Preferred Method of Analysis	Reasons
1E	Litter pickup	Count	Crossed pairs using actual difference	• all pairs behave similarly • site level does not transform data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Volume	Crossed pairs using actual difference	• all pairs behave similarly • site level does not transform data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Weight	Crossed pairs using actual difference	• all pairs behave similarly • site level does not transform data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
1W	Street Sweeping	Count	Crossed pairs using actual difference	• all pairs behave similarly • site level does not transform data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Volume	Crossed pairs using actual difference	• all pairs behave similarly • site level does not transform data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Weight	Crossed pairs using actual difference	• all pairs behave similarly • site level does not transform data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
6	Modified Inlet	Count	Crossed pairs using actual difference	• all pairs behave similarly • site level does not transform data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Volume	Crossed pairs using actual difference	• all pairs behave similarly • site level does not transform data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality

Table 3. Preferred Method of Statistical Analysis (data normalized by catchment area) (cont'd)

Site	BMP	Measure	Preferred Method of Analysis	Reasons
6	Modified Inlet	Weight	Crossed pairs using actual difference	• all pairs behave similarly • site level does not transform data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
8	Bicycle Grate	Count	Crossed pairs using actual difference	• all pairs behave similarly • site level does not transform data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Volume	Site level using actual difference	• all pairs behave similarly • site level transforms data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Weight	Site level using actual difference	• all pairs behave similarly • site level transforms data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
8 (w/o outfall 8-24D	LID	Count	Crossed pairs using actual difference	• all pairs behave similarly • site level does not transform data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Volume	Site level using actual difference	• all pairs behave similarly • site level transforms data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Weight	Crossed pairs using actual difference	• all pairs behave similarly • site level does not transform data to normally distributed • difference in litter load does not increase with control load and % difference transformation does not help pass normality

Details of Statistical Analysis

Details of the statistical analysis are provided in Attachment 1. Figure 1 to Figure 16 in Attachment 1 show the box plots of each BMP and measuring unit combination respectively across six individual outfalls, and Figure 16 to Figure 30 in Attachment 1 show the box plots of combining all three control outfalls and all three treatment outfalls. Each box plot is followed by the corresponding summary statistics and moments. The following diagram illustrates how to interpret these box plots:

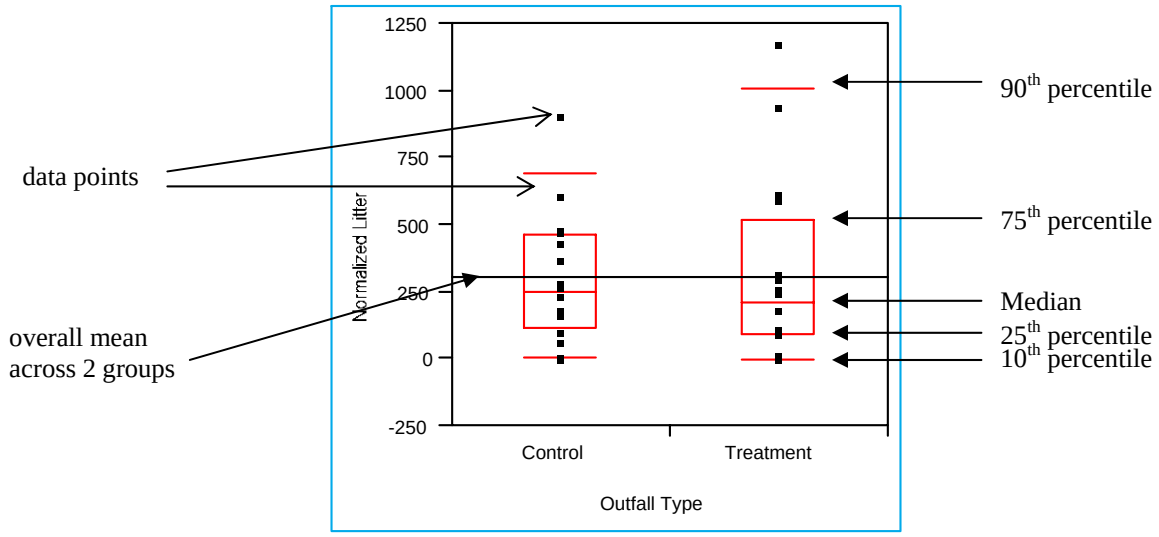


Figure 1. Key for Box and Whiskers Plots

The exploratory data analysis does not show any data anomalies. All statistical tests were carried out as described in the previous section. The test results are shown in tables in Attachment 2.

K.5. Conclusions - Data Normalized by Catchment Area

The main conclusions from the results shown in Tables 2 and 3 are as follows:

1. Litter pickup (Site 1E) appears to be effective at a 5% significance level for all parameters (count, volume, and weight). This conclusion is quite robust because it remains unchanged under most of the other methods of paired analysis. The ANOVA results did not show any significant differences among the three treatment outfalls; thus, the suspect treatment outfall, 1-46, is included in this analysis.

2. Street sweeping (Site 1W) does not appear to be effective at a 5% significance level for count or weight, but appears to be effective for volume. This conclusion is very robust for count and weight because it remains unchanged under all methods of paired analysis. The conclusion regarding volume is not robust because it changes if other methods of paired analysis are used. Additionally, the average volume reduction is only about 9% and does not appear to be practically significant.

3. Modified inlet (Site 6) appears to be effective at a 5% significance level for all parameters (count, volume, and weight). This conclusion is fairly robust because it remains unchanged under most methods of paired analysis.
4. Bicycle grate (Site 8) does not appear to be effective at a 5% significance level for any of the measures. This conclusion is very robust because it remains unchanged under all methods of paired analysis.
5. LID (Site 8) appears to be effective at a 5% significance level for reducing count, but not volume or weight. This conclusion is fairly robust because it remains unchanged under most methods of paired analysis. The ANOVA results show that the two control outfalls (8-24D and 8-24E) are significantly difference from each other; thus, outfall 8-24D may have been affected by the construction project and is excluded in this analysis.
6. The marginal analysis consistently fails to conclude that the observed differences are significant for any BMP and any measure. For a paired sampling design (which was used in the LMPS), this generally will be the case. This is because a paired analysis typically reduces the data variability caused by factors other than the application of a BMP. In a paired sampling design, other factors can be assumed to affect both control and treatment outfalls in a similar way. The marginal analysis fails to reduce the variability caused by other factors and generally results in a higher variance. The higher variance means that the power of detecting a specified difference would be less and that a larger number of data points would be necessary to show a statistically significant difference.

K.6. Results and Conclusions – Data Normalized by Flow Volume

Since only one pair of control/treatment outfalls has flow volume data for each site, and only storm events have flow volume data, the number of data points are much fewer than the normalized by catchment area analysis. Thus, the results and conclusions are considered less powerful for data normalized by flow volume. The statistical test results confirm that litter pickup (Site 1E) and modified inlet (Site 6) appear to be effective in litter reduction in all three measures (as seen in normalized by catchment area analysis). Also, bicycle grate (Site 8 in 1998/1999) and LID (Site 8 in 1999/2000) do not show significant litter reduction. Street sweeping (Site 1W) appears to be effective for count and volume, but not for weight.

The results of flow-normalized analysis are consistent with those of area-normalized analysis for all parameters except for two. The exceptions are count at Site 1W and count at Site 8 (LID). For count at Site 1W, the reduction is significant for the flow-normalized analysis, but not for the area-normalized analysis. For count at Site 8 (LID), the reduction is not significant for the flow-normalized analysis, but is significant for the area-normalized analysis. As noted above, the number of data points is substantially larger for the area-normalized analysis and hence the results of that analysis are considered more powerful.

K.7. Results and Conclusions – Analysis of Total System Load

Litter load data were collected for two components of the storm drain system – the litter retained in the inlet during a given study period and the litter discharged to an outfall in each monitored storm event during the study period. Each inlet was cleaned at the start and end of the study period. These data provided an estimate of the litter load retained in the system during the study period. The total system annual litter load for each outfall was calculated as the sum of two

components: (1) the litter load retained in the system and collected from inlet cleaning during the study period and (2) the cumulative litter load collected in litter monitoring bags at an outfall in monitored events during the study period. The differences in the total system litter load were analyzed statistically using the methods of paired analysis described above. A summary of results is shown in Table 6.

The main conclusions of the analysis of the total system loads were identical to those of the analysis of the outfall-discharged loads with the only exception of count at Site 8 (LID). Thus, litter pickup (Site 1E) and modified inlet (Site 6) appear to be effective in reducing both the total system load and the load discharged to an outfall in storm events. Street sweeping (site 1W) appears to reduce both total system litter volume and outfall-discharged litter volume, but not for litter count and weight. Bicycle grate (Site 8, 1998/1999) and LID (Site 8, 1999/2000) do not appear to be effective in reducing either the total system load or the load discharged to an outfall in a storm event. At Site 8 (LID), the count reduction is not significant at the level of the total system load, but is significant at the level of outfall-discharged load. The data at Site 8 (LID) show that the average litter count is lower for the treatment in the outfall-discharged load, but higher in the inlet retention load. The net effect is that the count reduction is not significant for the total system load.

Table 4. Results (p-values) of Evaluation of BMP Effectiveness (data normalized by flow volume) (1)

Site	BMP	Measure	Paired Analysis Matched Pairs Actual Diff.	% Diff.
1E	Litter Pickup	Count	*0.000*	*0.000**
		Volume	*0.000**	*0.001*
		Weight	*0.000**	*0.002*
1W	Street Sweeping	Count	*0.045**	*0.000*
		Volume	*0.027**	*0.001*
		Weight	*0.082**	*0.024*
6	Modified Inlet	Count	*0.030**	0.060
		Volume	*0.016**	*0.030*
		Weight	*0.002**	*0.022*
8	Bicycle Grate	Count	0.402*	0.500
		Volume	0.104*	0.213
		Weight	0.090*	0.057
8	LID	Count	0.840	0.895*
		Volume	0.449*	0.748
		Weight	0.449*	0.593

* Preferred Method (See Table 5)
(1) Large, Bold fond indicate that the average litter amount in the control is greater than the treatment based on statistical testing (α=0.05).

Table 5. Preferred Method of Statistical Analysis (data normalized by flow volume)

Site	BMP	Measure	Preferred Method of Analysis	Reasons
1E	Litter pickup	Count	Matched pairs using % difference	• difference in litter load increases with control load and % difference transformation helps pass normality
		Volume	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Weight	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality
1W	Street Sweeping	Count	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Volume	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Weight	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality
6	Modified Inlet	Count	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Volume	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Weight	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality
8	Bicycle Grate	Count	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Volume	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Weight	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality

Table 5. Preferred Method of Statistical Analysis (data normalized by flow volume) (cont'd)

Site	BMP	Measure	Preferred Method of Analysis	Reasons
8	LID	Count	Matched pairs using % difference	• difference in litter load increases with control load and % difference transformation helps pass normality
		Volume	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality
		Weight	Matched pairs using actual difference	• difference in litter load does not increase with control load and % difference transformation does not help pass normality

Table 6. Results (p-values) of Evaluation of BMP Effectiveness (data normalized by catchment area) Analysis of Total System Load (1)

Site	BMP	Measure	Total System Analysis (Crossed Pairs) Actual Diff.	% Diff.
1E	Litter Pickup	Count	*0.019**	*0.022*
		Volume	*0.002**	*0.002*
		Weight	*0.002**	*0.002*
1W	Street Sweeping	Count	0.297*	0.368
		Volume	*0.015**	*0.020*
		Weight	0.508*	0.711
6	Modified Inlet	Count	*0.000**	*0.000*
		Volume	*0.000*	*0.000**
		Weight	*0.000**	*0.000*
8	Bicycle Grate	Count	0.960*	0.962
		Volume	0.900*	0.900
		Weight	0.720*	0.731
8 (2)	LID	Count	0.376*	0.739
		Volume	0.500*	0.874
		Weight	0.913*	0.947
1E (w/o outfall 1-46)(3)	Litter Pickup	Count	0.176*	0.211
		Volume	*0.000**	*0.000*
		Weight	*0.005**	*0.003*
8 (w/o outfall 8-24D)	LID	Count	0.115*	0.127
		Volume	0.303*	0.418
		Weight	0.695*	0.725

* Preferred Method (See Table 5)

(1) Large, Bold fond indicate that the average litter amount in the control is greater than the treatment based on statistical testing (α=0.05).

(2) Preferred method is without Control 8-24D below.

(3) Preferred method is 1E above.

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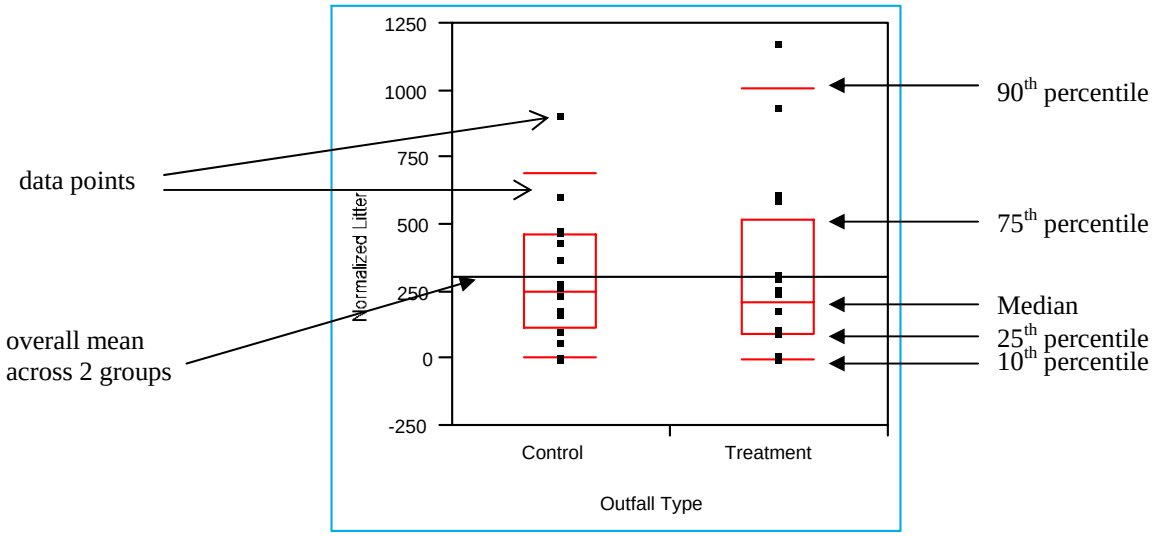
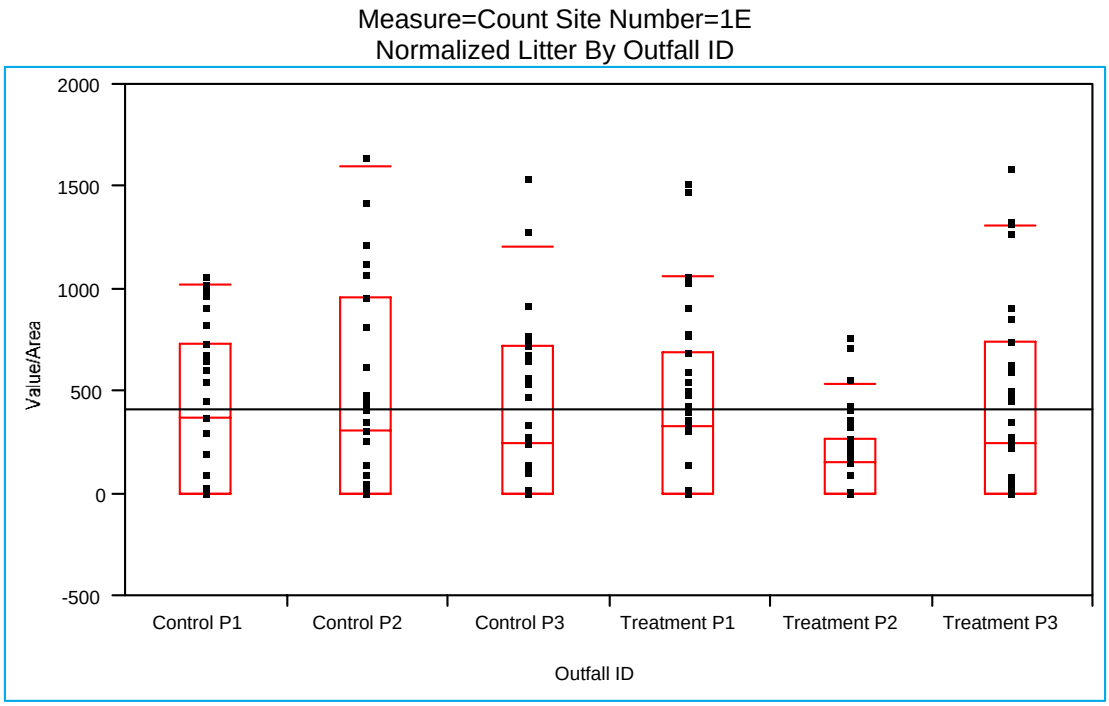
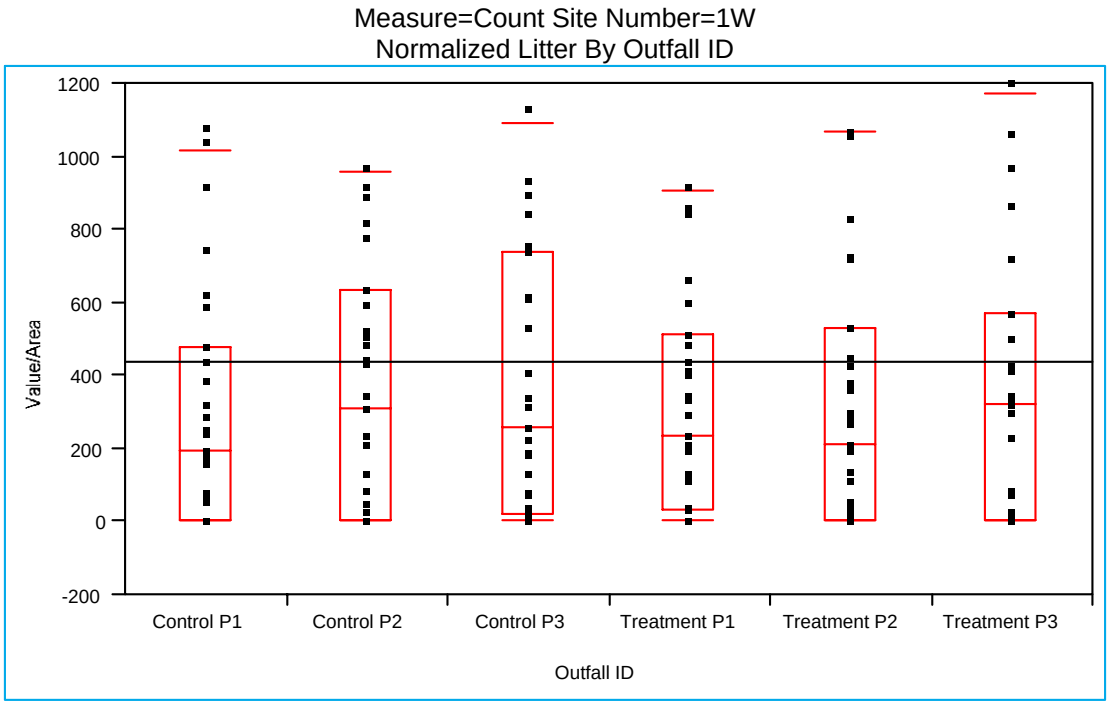


Key for Box and Whiskers Plots



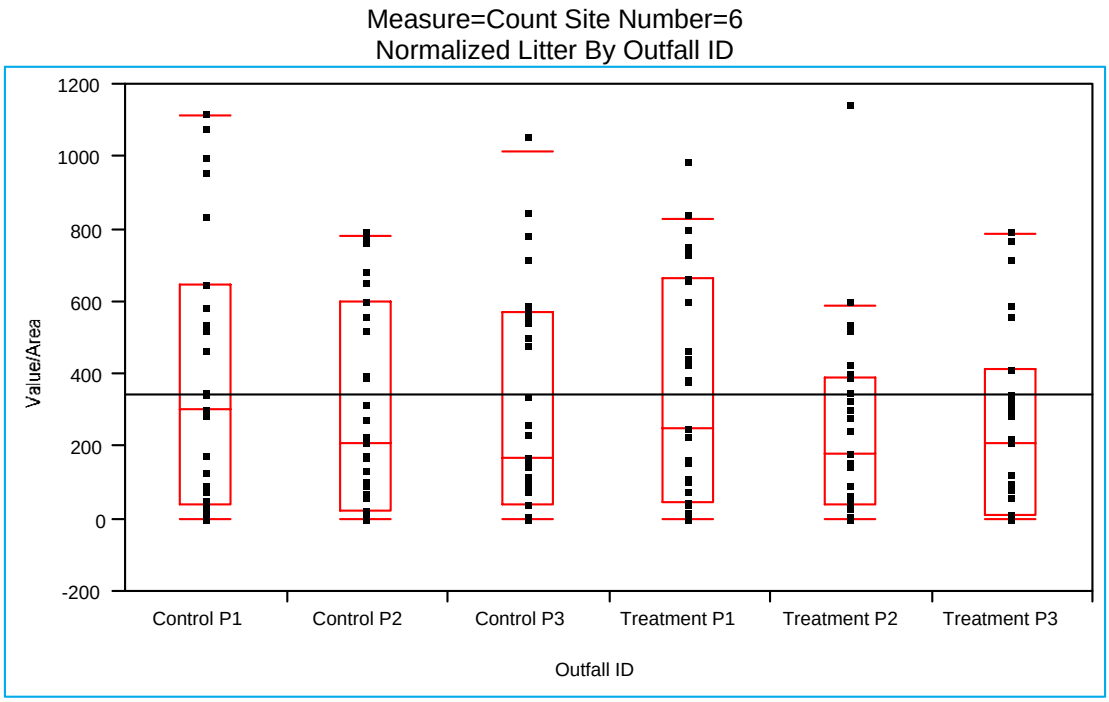
Moments	LP1 Control, Outfall 1-B110	LP2 Control, Outfall 1-42	LP3 Control, Outfall 1-B111	LP1 Treatment, Outfall 1-47	LP2 Treatment, Outfall 1-46	LP3 Treatment, Outfall 1-44
Mean	444.53	534.88	488.71	412.23	180.22	426.83
Std Dev	516.83	672.54	779.55	444.72	218.00	477.86
Std Error Mean	92.82	120.79	140.01	79.87	39.15	85.83
Upper 95% Mean	634.10	781.57	774.65	575.35	260.18	602.11
Lower 95% Mean	254.96	288.19	202.77	249.10	100.26	251.55
N	31	31	31	31	31	31
Sum	13,780.44	16,581.25	15,150.00	12,779.07	5,586.84	13,231.82
Variance	267,109.92	452,306.05	607,691.61	197,780.05	47,525.80	228,347.25
Skewness	1.72	1.45	3.45	1.02	1.27	1.01
Kurtosis	4.55	1.58	14.82	0.38	1.08	-0.03
CV	116.26	125.74	159.51	107.88	120.97	111.95
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	2,337.00	2,506.20	4,057.50	1,520.90	768.42	1,593.20

Figure 1. Box plots and summary statistics of individual outfalls (outfall-level) for manual litter pick-up (Site 1E) measured in count (normalized by catchment area, item/acre)



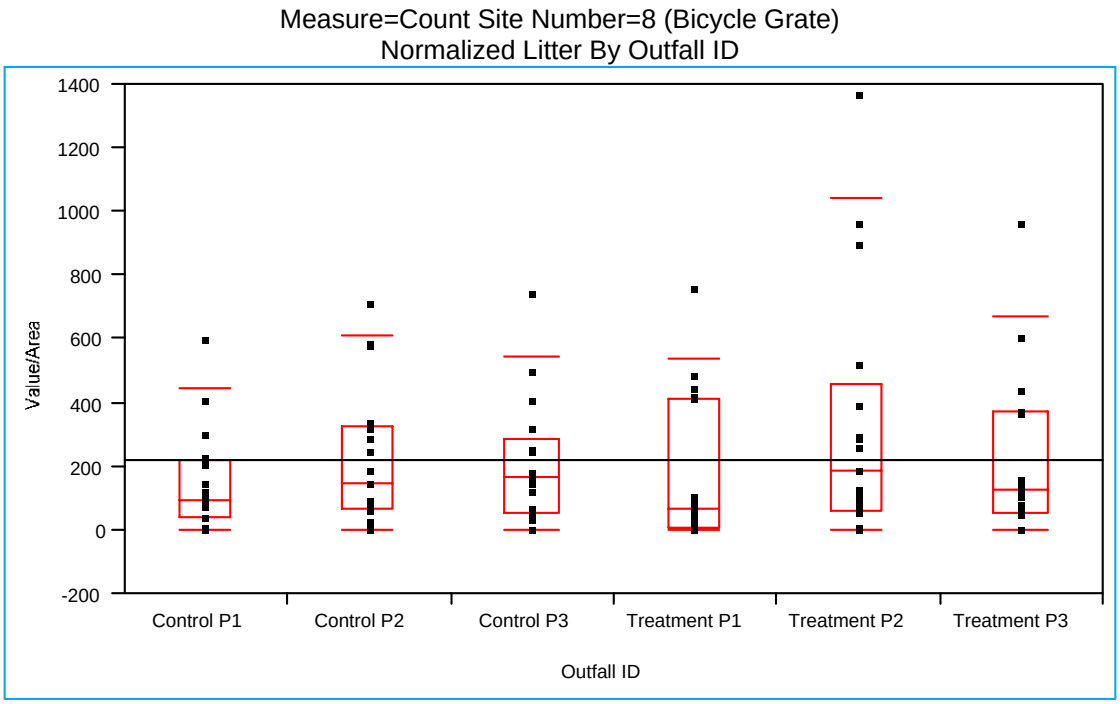
Moments	P1 Control, Outfall 1-52	P2 Control, Outfall 1-50	P3 Control, Outfall 1-51	P1 Treatment, Outfall 1-58	P2 Treatment, Outfall 1-59	P3 Treatment, Outfall 1-60
Mean	322.51	442.98	458.85	392.50	463.51	554.34
Std Dev	382.92	568.85	603.85	510.74	808.39	1072.65
Std Error Mean	68.78	102.17	108.45	91.73	145.19	192.65
Upper 95% Mean	462.96	651.64	680.34	579.84	760.02	947.78
Lower 95% Mean	182.05	234.33	237.36	205.16	166.99	160.89
N	31	31	31	31	31	31
Sum	9,997.67	13,732.50	14,224.39	12,167.57	14,368.75	17,184.38
Variance	146,630.75	323,593.09	364,635.23	260,854.50	653,489.84	1,150,574.00
Skewness	1.47	2.08	2.63	2.21	3.40	3.89
Kurtosis	1.74	5.03	9.45	5.45	13.47	17.24
CV	118.73	128.41	131.60	130.12	174.41	193.50
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	1,481.40	2,432.50	2,978.00	2,186.50	4,062.50	5,609.40

Figure 2. Box plots and summary statistics of individual outfalls (outfall-level) for street sweeping (Site 1W) measured in count (normalized by catchment area, item/acre)



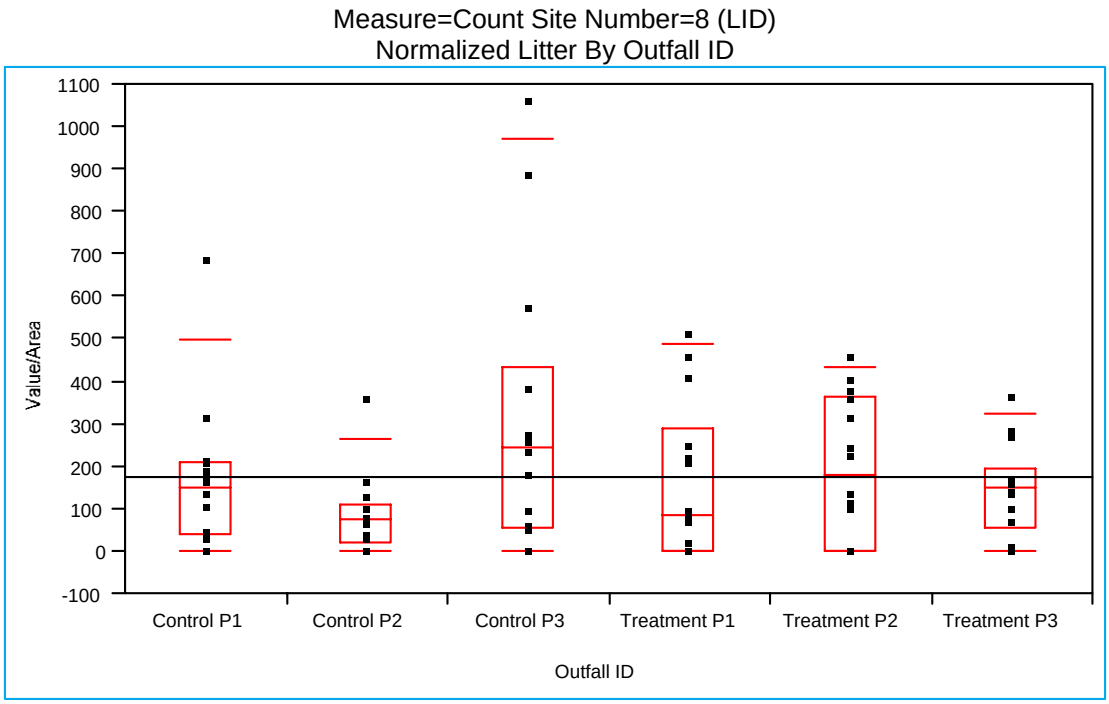
Moments	P1 Control, Outfall 6-20G	P2 Control, Outfall 6-20E	P3 Control, Outfall 6-20C	P1 Treatment, Outfall 6-20H	P2 Treatment, Outfall 6-20F	P3 Treatment, Outfall 6-20B
Mean	432.89	336.79	369.97	368.55	277.11	288.94
Std Dev	496.69	373.52	430.58	357.52	318.10	321.20
Std Error Mean	89.21	67.09	77.33	64.21	57.13	57.69
Upper 95% Mean	615.08	473.80	527.91	499.69	393.79	406.76
Lower 95% Mean	250.70	199.78	212.03	237.41	160.43	171.12
N	31	31	31	31	31	31
Sum	13,419.61	10,440.48	11,469.05	11,425.00	8,590.48	8,957.14
Variance	246,700.94	139,515.06	185,398.59	127,817.83	101,184.69	103,169.52
Skewness	1.53	1.65	1.62	0.82	2.05	1.48
Kurtosis	2.50	3.80	2.94	-0.01	4.94	2.23
CV	114.74	110.91	116.38	97.01	114.79	111.17
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	2,062.70	1,664.30	1,809.50	1,332.80	1,373.80	1,326.20

Figure 3. Box plots and summary statistics of individual outfalls (outfall-level) for modified inlet grate (Site 6) measured in count (normalized by catchment area, item/acre)



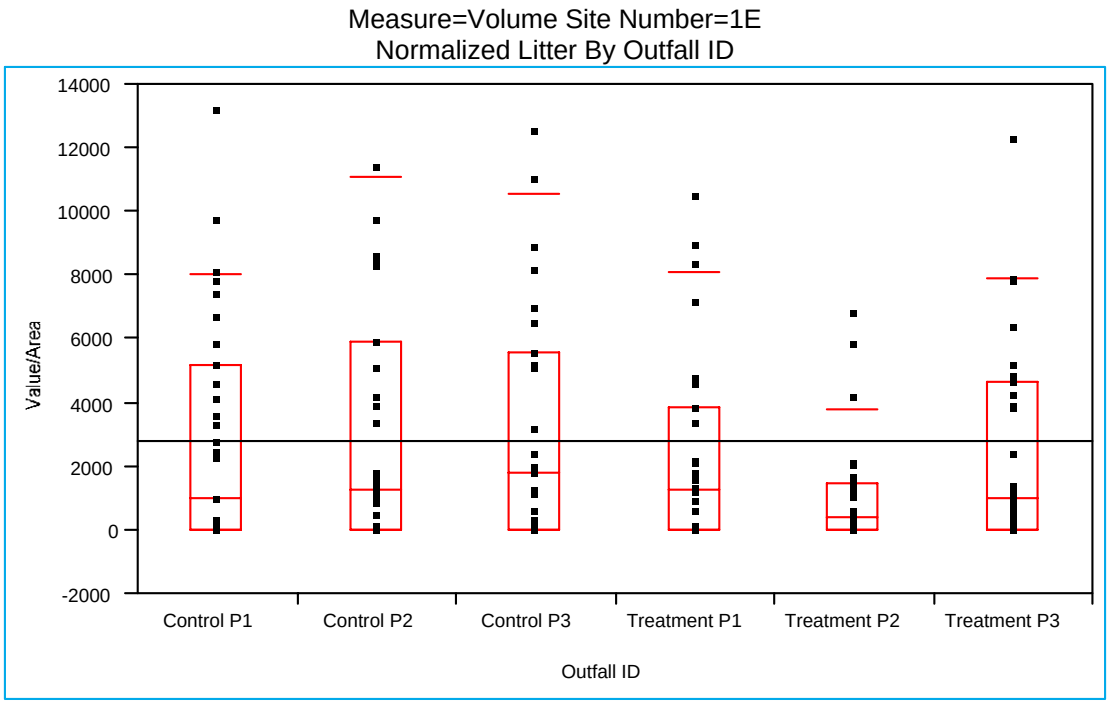
Moments	P1 Control, Outfall 8-23C	P2 Control, Outfall 8-24D	P3 Control, Outfall 8-24E	P1 Treatment, Outfall 8-B001	P2 Treatment, Outfall 8-24B	P3 Treatment, Outfall 8-24F
Mean	148.96	229.89	204.67	178.13	332.07	217.71
Std Dev	161.58	218.10	198.34	232.53	394.35	258.75
Std Error Mean	39.19	52.90	48.10	56.40	95.64	62.76
Upper 95% Mean	232.03	342.02	306.64	297.68	534.83	350.75
Lower 95% Mean	65.88	117.75	102.69	58.57	129.32	84.68
N	17	17	17	17	17	17
Sum	2,532.26	3,908.06	3,479.31	3,028.13	5,645.24	3,701.10
Variance	26,106.58	47,568.00	39,337.38	54,072.27	155,508.16	66,949.93
Skewness	1.71	1.08	1.47	1.34	1.59	1.81
Kurtosis	2.94	0.21	2.26	0.81	1.90	3.35
CV	108.47	94.87	96.91	130.55	118.75	118.85
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	603.23	712.90	744.83	762.50	1,369.00	963.74

Figure 4. Box plots and summary statistics of individual outfalls (outfall-level) for bicycle grate (Site 8) measured in count (normalized by catchment area, item/acre)



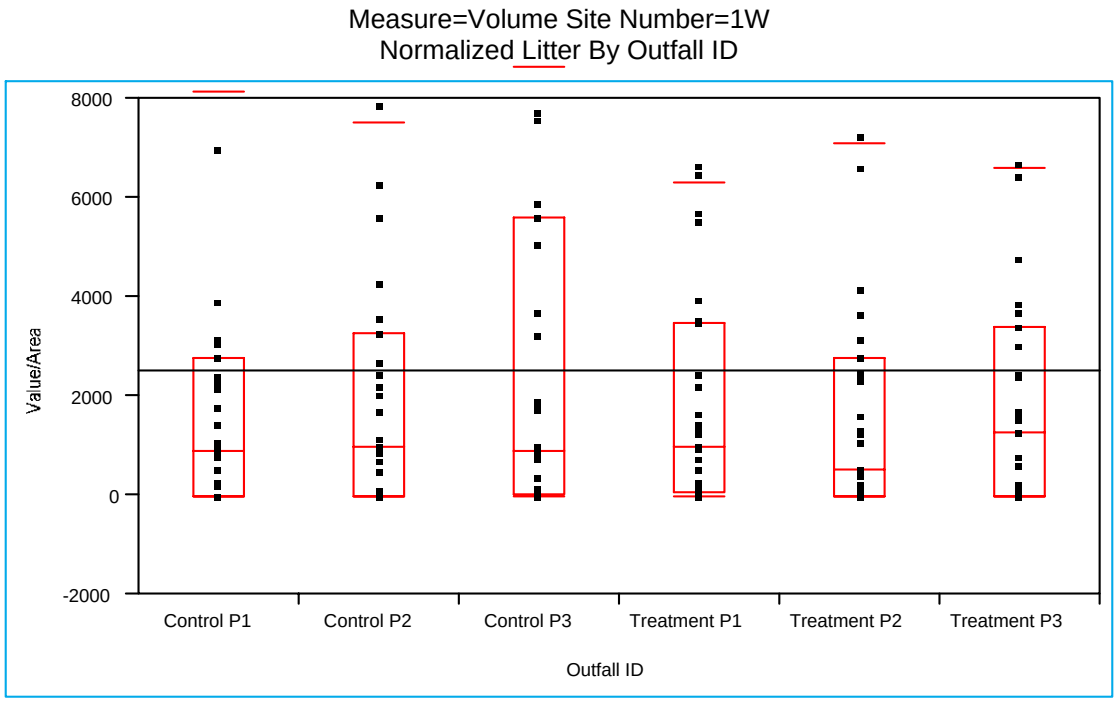
Moments	P1 Control, Outfall 8-23C	P2 Control, Outfall 8-24D	P3 Control, Outfall 8-24E	P1 Treatment, Outfall 8-B001	P2 Treatment, Outfall 8-24B	P3 Treatment, Outfall 8-24F
Mean	166.47	88.02	309.36	167.46	195.92	145.84
Std Dev	177.22	93.58	324.74	182.72	167.79	108.05
Std Error Mean	47.36	25.01	86.79	48.83	44.84	28.88
Upper 95% Mean	268.80	142.05	496.86	272.96	292.80	208.23
Lower 95% Mean	64.15	33.98	121.86	61.96	99.04	83.45
N	14	14	14	14	14	14
Sum	2,330.65	1,232.26	4,331.03	2,344.44	2,742.86	2,041.76
Variance	31,405.66	8,757.99	105,459.03	33,384.89	28,152.30	11,674.63
Skewness	2.10	2.08	1.40	0.88	0.17	0.43
Kurtosis	5.74	5.65	1.29	-0.59	-1.51	-0.12
CV	106.45	106.32	104.97	109.11	85.64	74.09
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	688.71	362.90	1,062.10	516.67	461.90	363.74

Figure 5. Box plots and summary statistics of individual outfalls (outfall-level) for LID (Site 8) measured in count (normalized by catchment area, item/acre)



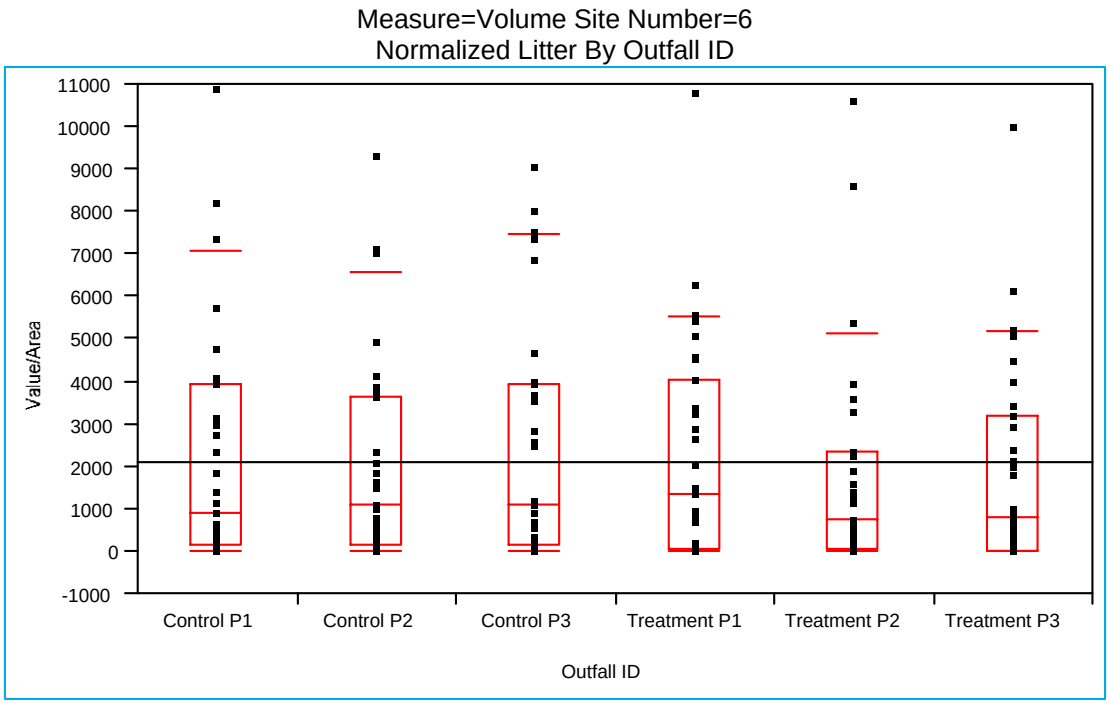
Moments	LP1 Control, Outfall 1-B110	LP2 Control, Outfall 1-42	LP3 Control, Outfall 1-B111	LP1 Treatment, Outfall 1-47	LP2 Treatment, Outfall 1-46	LP3 Treatment, Outfall 1-44
Mean	2,895.86	3706.16	4041.21	2269.90	1080.12	2812.39
Std Dev	3,556.30	5339.94	6909.27	2950.79	1709.95	3886.74
Std Error Mean	638.73	959.08	1240.94	529.98	307.12	698.08
Upper 95% Mean	4,200.31	5664.85	6575.53	3352.25	1707.33	4238.05
Lower 95% Mean	1,591.40	1747.47	1506.89	1187.55	452.91	1386.73
N	31	31	31	31	31	31
Sum	89,771.52	114,890.97	125,277.50	70,366.98	33,483.71	87,184.09
Variance	12,647,284.00	28,515,005.00	47,738,071.00	8,707,159.20	2,923,915.10	15,106,708.00
Skewness	1.22	1.98	3.54	1.51	2.24	1.87
Kurtosis	0.88	4.46	15.36	1.47	4.94	3.59
CV	122.81	144.08	170.97	130.00	158.31	138.20
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	13,217.00	22,859.00	35,925.00	10,477.00	6,834.20	15,795.00

Figure 6. Box plots and summary statistics of individual outfalls (outfall-level) for manual litter pick-up (Site 1E) measured in volume (normalized by catchment area, ml/acre)



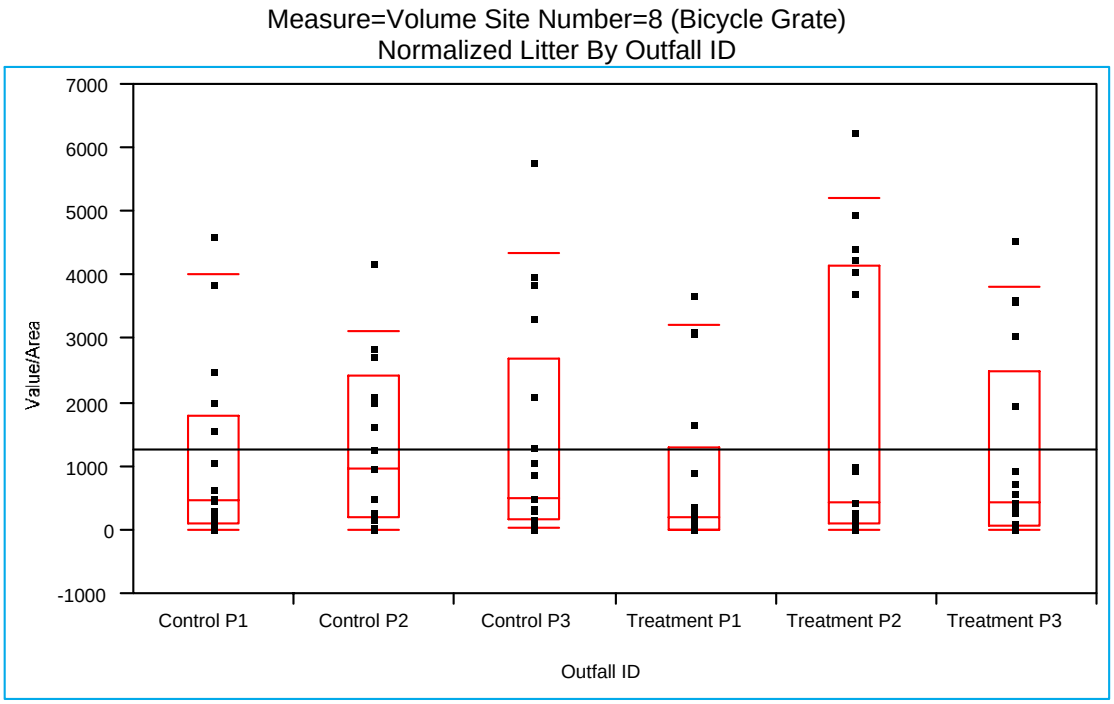
Moments	P1 Control, Outfall 1-52	P2 Control, Outfall 1-50	P3 Control, Outfall 1-51	P1 Treatment, Outfall 1-58	P2 Treatment, Outfall 1-59	P3 Treatment, Outfall 1-60
Mean	2,019.73	2527.22	3301.71	2255.49	2271.86	2637.00
Std Dev	2,783.27	4085.48	4879.55	3643.01	3758.51	4621.00
Std Error Mean	499.89	733.77	876.39	654.30	675.05	829.96
Upper 95% Mean	3,040.63	4025.77	5091.53	3591.75	3650.48	4331.98
Lower 95% Mean	998.83	1028.66	1511.89	919.24	893.23	942.01
N	31	31	31	31	31	31
Sum	62,611.63	78,343.75	102,352.98	69,920.27	70,427.53	81,746.88
Variance	7,746,585.50	16,691,129.00	23,810,020.00	13,271,499.00	14,126,387.00	21,353,672.00
Skewness	1.74	3.12	2.48	3.25	2.75	3.17
Kurtosis	2.11	12.02	7.79	13.12	8.68	11.55
CV	137.80	161.66	147.79	161.52	165.44	175.24
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	9,337.20	20,400.00	22,866.00	18,514.00	17,437.00	22,437.00

Figure 7. Box plots and summary statistics of individual outfalls (outfall-level) for street sweeping (Site 1W) measured in volume (normalized by catchment area, ml/acre)



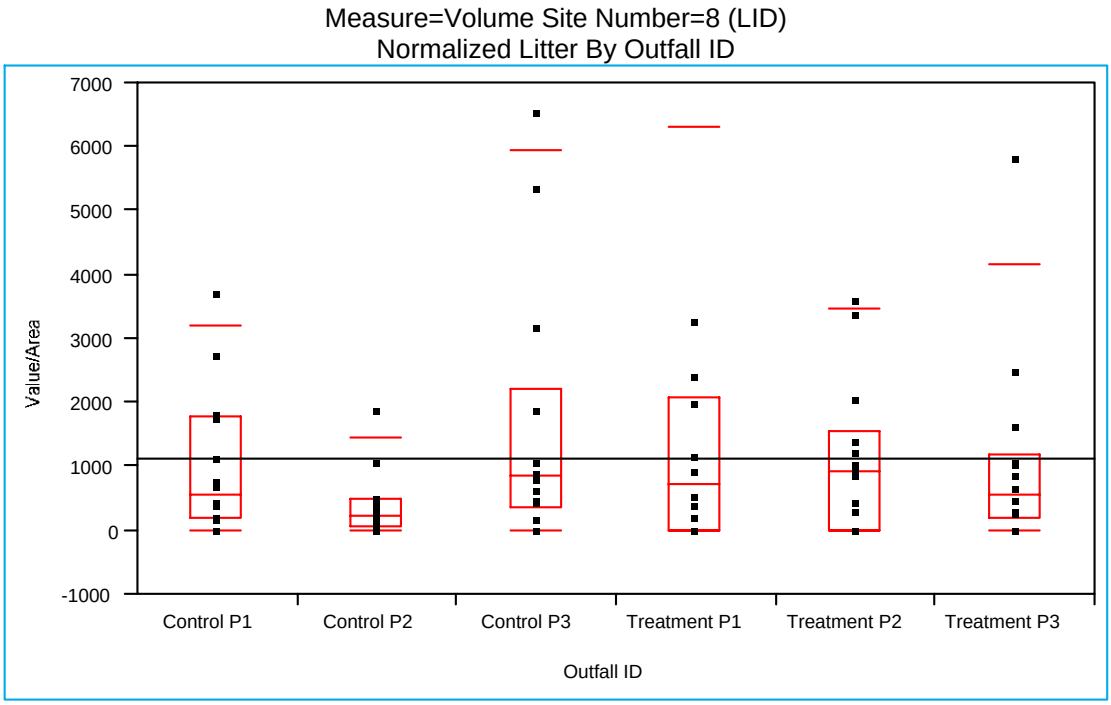
Moments	P1 Control, Outfall 6-20G	P2 Control, Outfall 6-20E	P3 Control, Outfall 6-20C	P1 Treatment, Outfall 6-20H	P2 Treatment, Outfall 6-20F	P3 Treatment, Outfall 6-20B
Mean	2,304.12	2035.29	2406.67	2235.97	1824.25	1885.42
Std Dev	2,838.55	2418.03	2804.41	2584.15	2516.68	2387.22
Std Error Mean	509.82	434.29	503.69	464.13	452.01	428.76
Upper 95% Mean	3,345.31	2922.23	3435.33	3183.83	2747.37	2761.05
Lower 95% Mean	1,262.94	1148.36	1378.01	1288.10	901.13	1009.79
N	31	31	31	31	31	31
Sum	71,427.84	63,094.05	74,606.71	69,315.00	56,551.69	58,448.10
Variance	8,057,365.20	5,846,890.30	7,864,700.70	6,677,819.30	6,333,679.30	5,698,804.80
Skewness	1.49	1.53	1.13	1.47	2.23	1.69
Kurtosis	1.77	1.94	0.07	2.55	5.24	3.22
CV	123.19	118.81	116.53	115.57	137.96	126.61
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	10,951.00	9,322.60	9,107.60	10,852.00	10,607.00	10,048.00

Figure 8. Box plots and summary statistics of individual outfalls (outfall-level) for modified inlet grate (Site 6) measured in volume (normalized by catchment area, ml/acre)



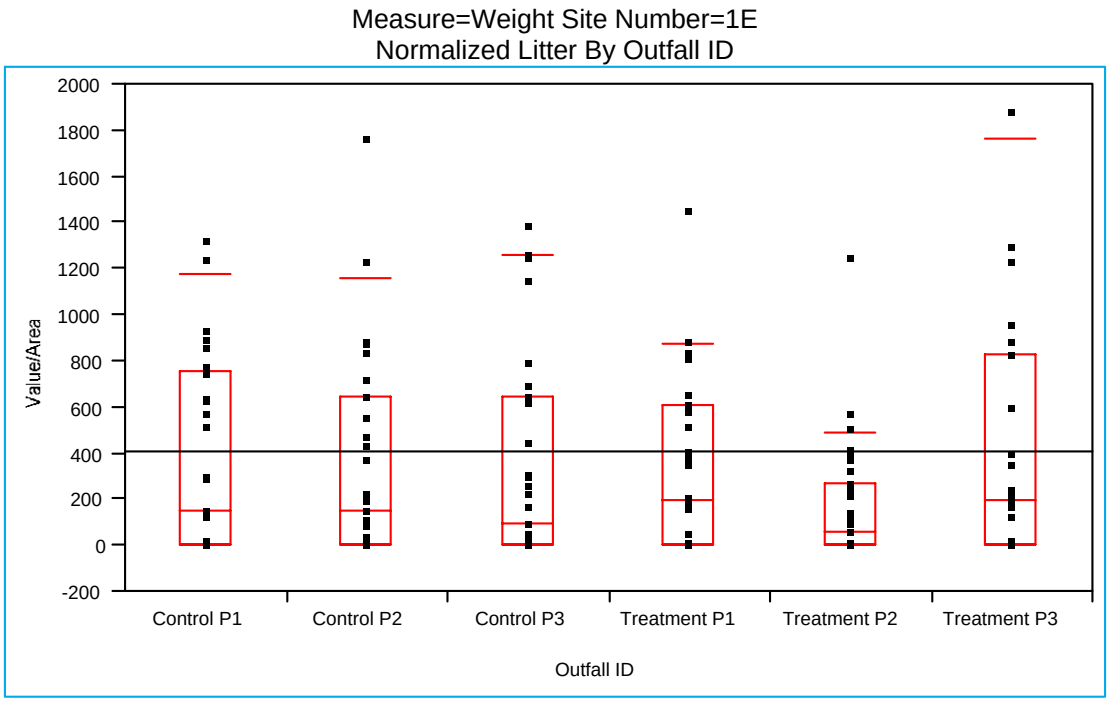
Moments	P1 Control, Outfall 8-23C	P2 Control, Outfall 8-24D	P3 Control, Outfall 8-24E	P1 Treatment, Outfall 8-B001	P2 Treatment, Outfall 8-24B	P3 Treatment, Outfall 8-24F
Mean	1,075.93	1307.78	1420.01	842.74	1827.33	1221.56
Std Dev	1,411.56	1294.90	1764.63	1253.20	2202.60	1522.63
Std Error Mean	342.35	314.06	427.99	303.95	534.21	369.29
Upper 95% Mean	1,801.68	1973.55	2327.30	1487.07	2959.80	2004.42
Lower 95% Mean	350.17	642.00	512.73	198.41	694.87	438.70
N	17	17	17	17	17	17
Sum	18,290.75	22,232.19	24,140.24	14,326.59	31,064.64	20,766.50
Variance	1,992,507.50	1,676,762.60	3,113,923.20	1,570,505.00	4,851,433.60	2,318,412.20
Skewness	1.59	0.78	1.36	1.54	0.82	1.21
Kurtosis	1.71	-0.41	0.84	0.88	-1.04	-0.03
CV	131.20	99.02	124.27	148.71	120.54	124.65
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	4,637.10	4,196.80	5,784.50	3,687.50	6,260.20	4,571.40

Figure 9. Box plots and summary statistics of individual outfalls (outfall-level) for bicycle grate (Site 8) measured in volume (normalized by catchment area, ml/acre)



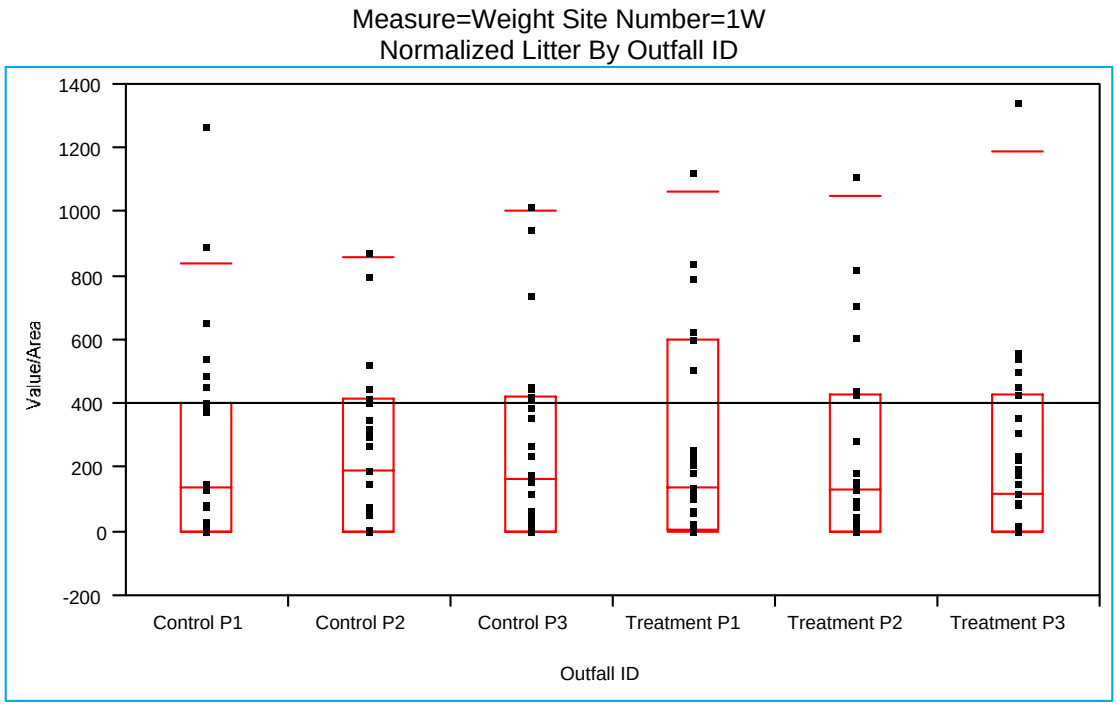
Moments	P1 Control, Outfall 8-23C	P2 Control, Outfall 8-24D	P3 Control, Outfall 8-24E	P1 Treatment, Outfall 8-B001	P2 Treatment, Outfall 8-24B	P3 Treatment, Outfall 8-24F
Mean	1,029.95	408.41	1677.96	1527.78	1097.87	1083.20
Std Dev	1,116.15	509.94	2029.62	2486.77	1196.88	1537.36
Std Error Mean	298.30	136.29	542.44	664.62	319.88	410.88
Upper 95% Mean	1,674.40	702.84	2849.82	2963.59	1788.93	1970.85
Lower 95% Mean	385.51	113.98	506.09	91.96	406.81	195.56
N	14	14	14	14	14	14
Sum	14,419.36	5,717.74	23,491.38	21,388.89	15,370.24	15,164.84
Variance	1,245,791.90	260,041.69	4,119,358.90	6,183,998.10	1,432,532.30	2,363,482.00
Skewness	1.40	2.20	1.63	2.79	1.21	2.63
Kurtosis	1.36	5.31	1.85	8.67	0.67	7.74
CV	108.37	124.86	120.96	162.77	109.02	141.93
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	3,725.80	1,887.10	6,560.30	9,416.70	3,631.00	5,857.10

Figure 10. Box plots and summary statistics of individual outfalls (outfall-level) for LID (Site 8) measured in volume (normalized by catchment area, ml/acre)



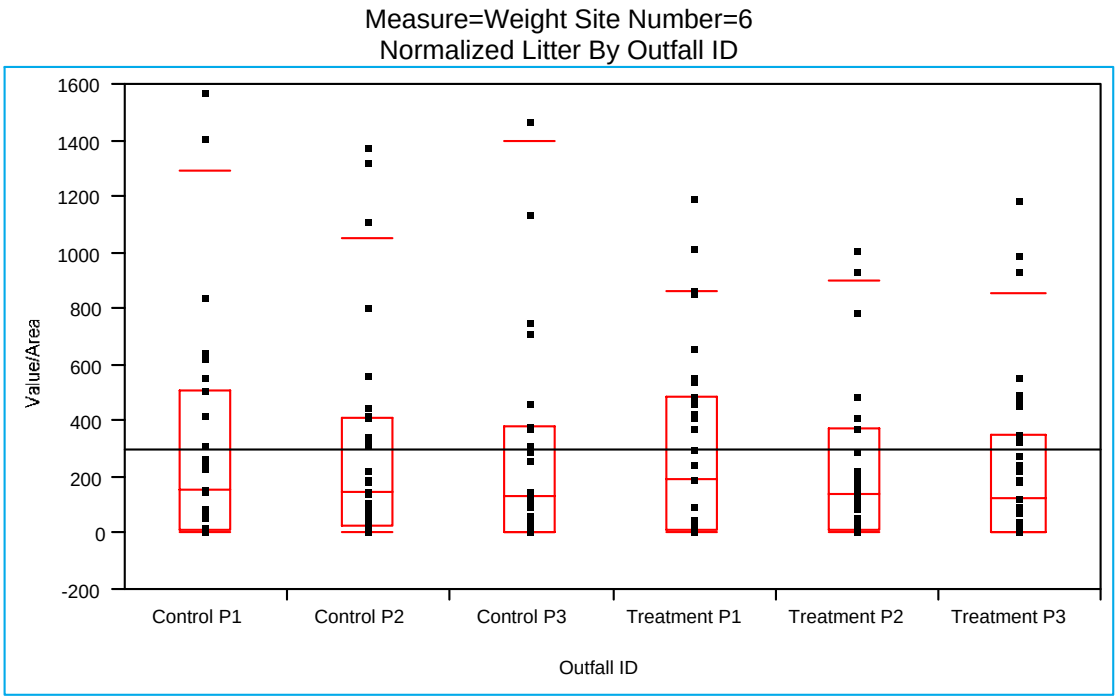
Moments	LP1 Control, Outfall 1-B110	LP2 Control, Outfall 1-42	LP3 Control, Outfall 1-B111	LP1 Treatment, Outfall 1-47	LP2 Treatment, Outfall 1-46	LP3 Treatment, Outfall 1-44
Mean	423.66	455.37	532.28	382.92	172.69	473.55
Std Dev	536.17	763.17	1230.64	528.57	263.02	706.04
Std Error Mean	96.30	137.07	221.03	94.93	47.24	126.81
Upper 95% Mean	620.32	735.30	983.68	576.80	269.17	732.53
Lower 95% Mean	226.99	175.44	80.88	189.04	76.22	214.58
N	31	31	31	31	31	31
Sum	13,133.35	14,116.38	16,500.63	11,870.58	5,353.45	14,680.16
Variance	287,473.67	582,427.82	1,514,470.90	279,382.91	69,177.75	498,491.19
Skewness	1.64	3.24	4.56	2.30	2.58	1.80
Kurtosis	3.44	12.91	23.09	6.81	8.73	2.55
CV	126.56	167.59	231.20	138.04	152.30	149.09
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	2,285.80	3,840.50	6,740.40	2,433.20	1,252.30	2,538.50

Figure 11. Box plots and summary statistics of individual outfalls (outfall-level) for manual litter pick-up (Site 1E) measured in dry weight (normalized by catchment area, g/acre)



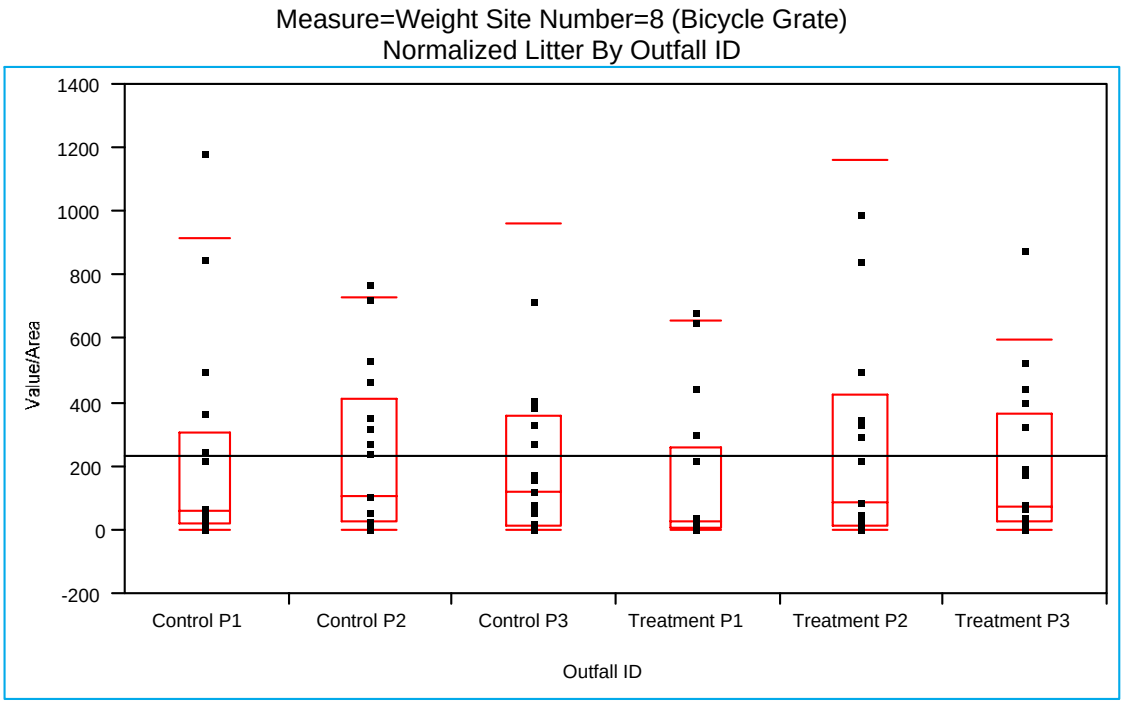
Moments	P1 Control, Outfall 1-52	P2 Control, Outfall 1-50	P3 Control, Outfall 1-51	P1 Treatment, Outfall 1-58	P2 Treatment, Outfall 1-59	P3 Treatment, Outfall 1-60
Mean	272.70	392.26	357.97	434.94	510.88	470.71
Std Dev	398.86	717.19	570.23	813.22	1435.79	1213.03
Std Error Mean	71.64	128.81	102.42	146.06	257.88	217.87
Upper 95% Mean	419.00	655.32	567.14	733.23	1037.53	915.65
Lower 95% Mean	126.40	129.19	148.81	136.65	-15.77	25.77
N	31	31	31	31	31	31
Sum	8,453.77	12,159.95	11,097.17	13,483.19	15,837.34	14,591.88
Variance	159,085.62	514,363.73	325,167.43	661,324.21	2,061,485.20	1,471,448.00
Skewness	2.20	3.11	2.68	3.36	4.79	4.50
Kurtosis	5.17	9.60	7.91	12.86	24.54	21.98
CV	146.26	182.84	159.30	186.97	281.04	257.71
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	1,691.20	3,051.70	2,574.00	4,005.90	7,848.20	6,514.10

Figure 12. Box plots and summary statistics of individual outfalls (outfall-level) for street sweeping (Site 1W) measured in dry weight (normalized by catchment area, g/acre)



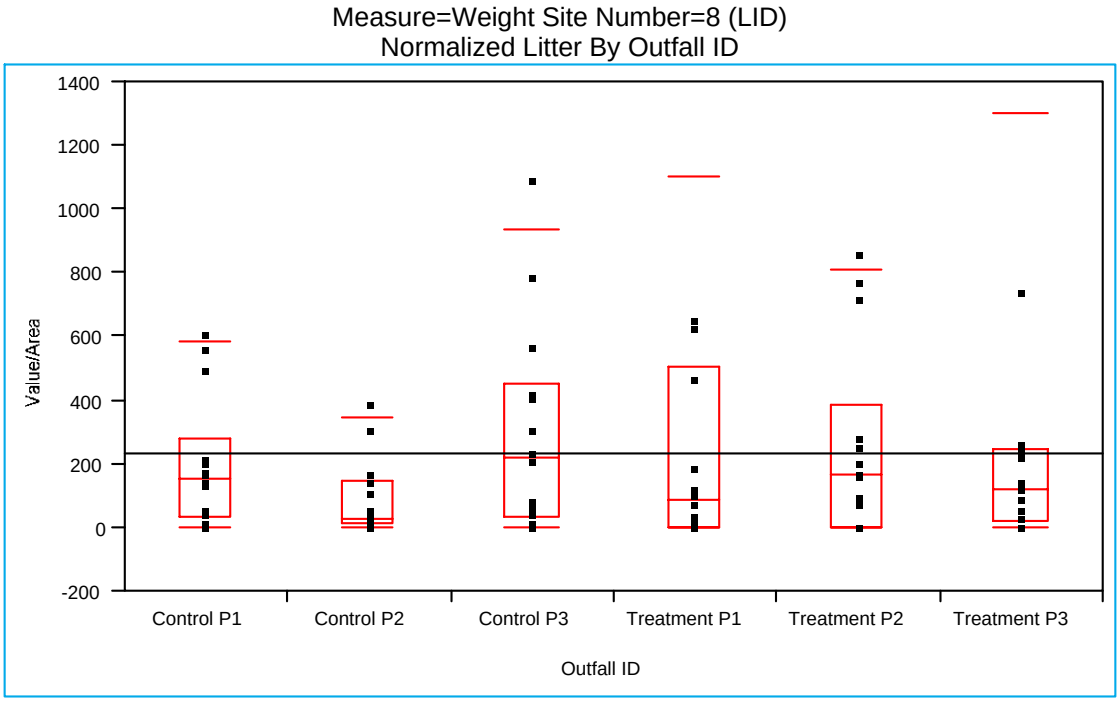
Moments	P1 Control, Outfall 6-20G	P2 Control, Outfall 6-20E	P3 Control, Outfall 6-20C	P1 Treatment, Outfall 6-20H	P2 Treatment, Outfall 6-20F	P3 Treatment, Outfall 6-20B
Mean	351.27	289.70	349.60	306.57	276.12	245.03
Std Dev	502.86	381.62	499.36	334.83	418.30	315.88
Std Error Mean	90.32	68.54	89.69	60.14	75.13	56.73
Upper 95% Mean	535.72	429.68	532.77	429.38	429.55	360.90
Lower 95% Mean	166.82	149.73	166.43	183.75	122.69	129.17
N	31	31	31	31	31	31
Sum	10,889.35	8,980.76	10,837.55	9,503.58	8,559.62	7,596.00
Variance	252,864.56	145,630.47	249,365.30	112,111.44	174,971.80	99,780.20
Skewness	2.11	1.85	1.83	1.10	2.82	1.67
Kurtosis	4.27	2.79	2.48	0.49	9.44	2.39
CV	143.15	131.73	142.84	109.22	151.49	128.91
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	2,042.70	1,380.00	1,779.00	1,193.70	2,008.10	1,190.10

Figure 13. Box plots and summary statistics of individual outfalls (outfall-level) for modified inlet grate (Site 6) measured in dry weight (normalized by catchment area, g/acre)



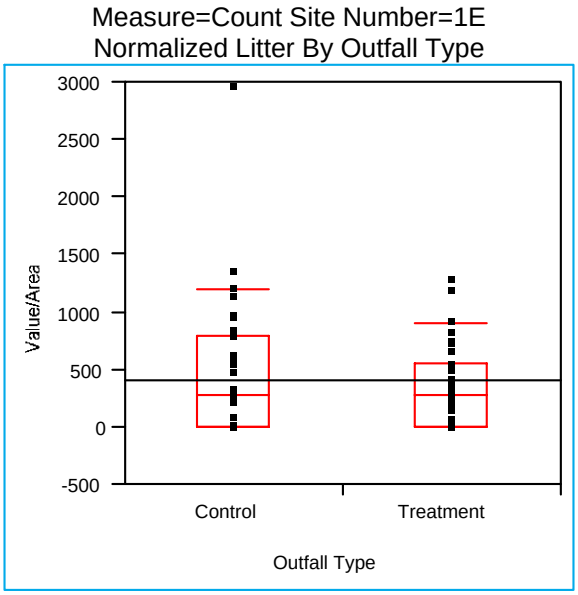
Moments	P1 Control, Outfall 8-23C	P2 Control, Outfall 8-24D	P3 Control, Outfall 8-24E	P1 Treatment, Outfall 8-B001	P2 Treatment, Outfall 8-24B	P3 Treatment, Outfall 8-24F
Mean	217.57	239.26	278.59	147.14	332.65	195.97
Std Dev	337.67	254.77	471.57	233.00	492.70	243.92
Std Error Mean	81.90	61.79	114.37	56.51	119.50	59.16
Upper 95% Mean	391.19	370.25	521.04	266.94	585.97	321.38
Lower 95% Mean	43.96	108.27	36.13	27.35	79.32	70.56
N	17	17	17	17	17	17
Sum	3,698.76	4,067.44	4,735.95	2,501.41	5,654.98	3,331.51
Variance	114,024.16	64,906.17	222,374.65	54,288.15	242,752.50	59,496.46
Skewness	2.04	0.98	3.08	1.62	2.18	1.64
Kurtosis	3.74	-0.14	10.62	1.36	5.10	2.58
CV	155.20	106.48	169.27	158.35	148.12	124.47
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	1,184.80	772.26	1,943.30	688.75	1,851.70	878.79

Figure 14. Box plots and summary statistics of individual outfalls (outfall-level) for bicycle grate (Site 8) measured in dry weight (normalized by catchment area, g/acre)



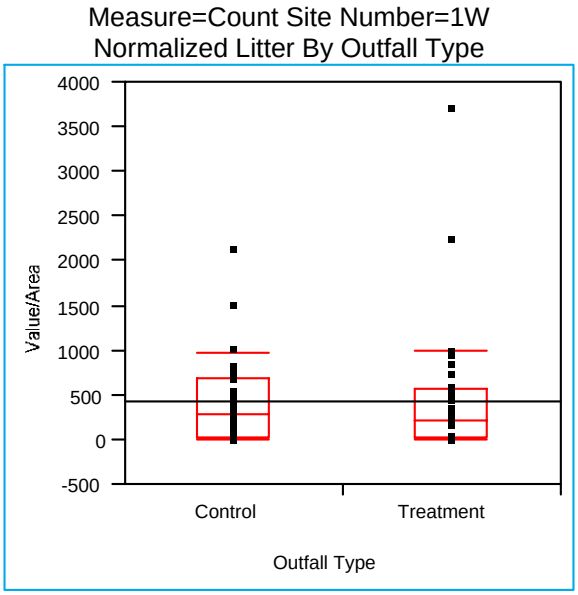
Moments	P1 Control, Outfall 8-23C	P2 Control, Outfall 8-24D	P3 Control, Outfall 8-24E	P1 Treatment, Outfall 8-B001	P2 Treatment, Outfall 8-24B	P3 Treatment, Outfall 8-24F
Mean	199.00	91.02	300.69	273.62	255.05	276.52
Std Dev	206.00	121.42	329.57	437.69	301.86	495.27
Std Error Mean	55.06	32.45	88.08	116.98	80.68	132.37
Upper 95% Mean	317.94	161.12	490.98	526.33	429.34	562.48
Lower 95% Mean	80.06	20.91	110.40	20.91	80.76	-9.44
N	14	14	14	14	14	14
Sum	2,786.05	1,274.26	4,209.71	3,830.67	3,570.69	3,871.30
Variance	42,435.93	14,742.65	108,617.56	191,568.63	91,119.53	245,293.71
Skewness	1.12	1.64	1.28	2.26	1.23	2.96
Kurtosis	0.05	1.90	1.22	5.58	0.11	9.31
CV	103.52	133.40	109.60	159.96	118.35	179.11
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	607.52	386.26	1,092.70	1,561.80	857.29	1,866.70

Figure 15. Box plots and summary statistics of individual outfalls (outfall-level) for LID (Site 8) measured in dry weight (normalized by catchment area, g/acre)



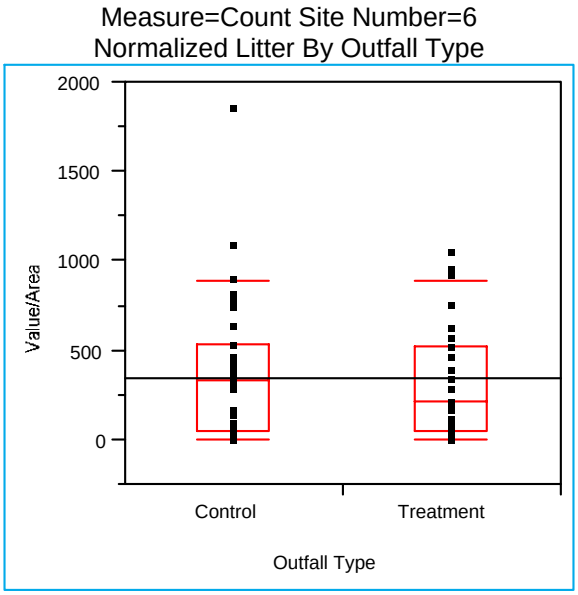
Moments	Control	Treatment
Mean	484.01	346.84
Std Dev	622.20	373.56
Std Error Mean	111.75	67.09
Upper 95% Mean	712.23	483.86
Lower 95% Mean	255.78	209.82
N	31	31
Sum	15,004.24	10,752.00
Variance	387,133.76	139,548.28
Skewness	2.32	1.05
Kurtosis	7.49	0.39
CV	128.55	107.70
Minimum	0.00	0.00
Maximum	2,966.10	1,300.80

Figure 16. Box plots and summary statistics of combined outfalls (site-level) for manual litter pick-up (Site 1E) measured in count (normalized by catchment area, item/acre)



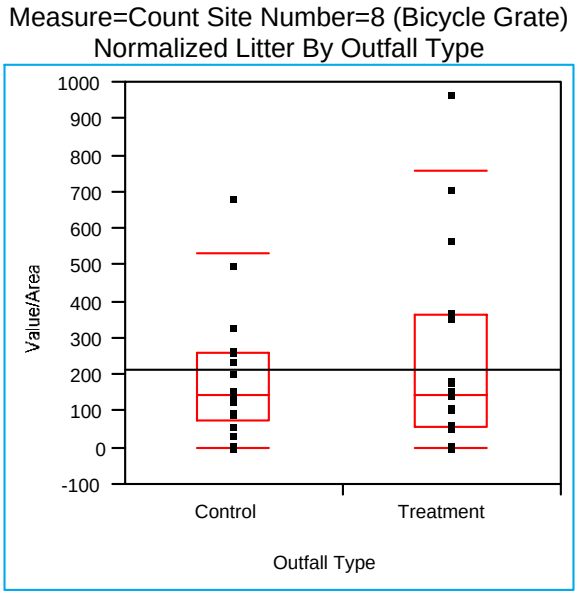
Moments	Control	Treatment
Mean	406.45	466.27
Std Dev	489.70	760.55
Std Error Mean	87.95	136.60
Upper 95% Mean	586.07	745.24
Lower 95% Mean	226.83	187.30
N	31	31
Sum	12,600.00	14,454.46
Variance	239,808.06	578,440.34
Skewness	1.93	3.20
Kurtosis	4.55	11.70
CV	120.48	163.11
Minimum	0.00	0.00
Maximum	2,143.50	3,722.80

Figure 17. Box plots and summary statistics of combined outfalls (site-level) for street sweeping (Site 1W) measured in count (normalized by catchment area, item/acre)



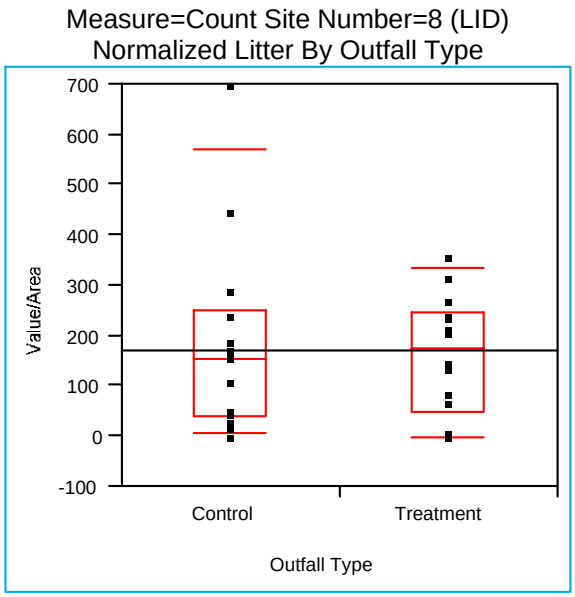
Moments	Control	Treatment
Mean	383.42	320.01
Std Dev	410.75	308.50
Std Error Mean	73.77	55.41
Upper 95% Mean	534.08	433.17
Lower 95% Mean	232.75	206.85
N	31	31
Sum	11,885.93	9,920.27
Variance	168,715.38	95,172.68
Skewness	1.75	0.94
Kurtosis	4.33	0.08
CV	107.13	96.40
Minimum	0.00	0.00
Maximum	1,860.00	1,062.80

Figure 18. Box plots and summary statistics of combined outfalls (site-level) for modified inlet grate (Site 6) measured in count (normalized by catchment area, item/acre)



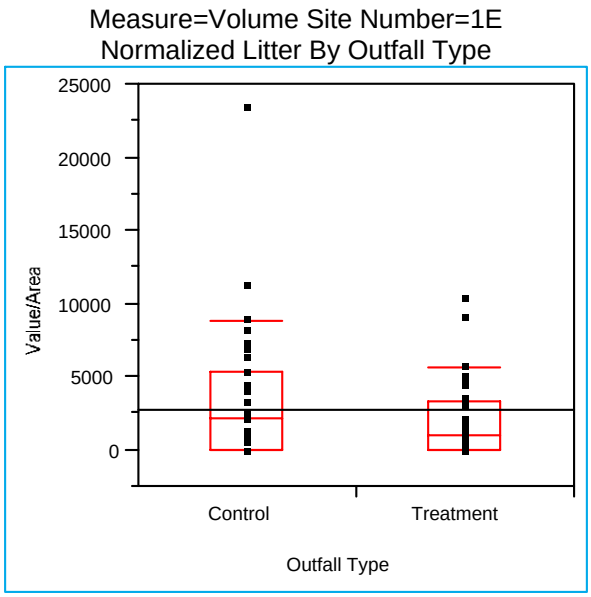
Moments	Control	Treatment
Mean	194.28	239.14
Std Dev	180.00	275.08
Std Error Mean	43.66	66.72
Upper 95% Mean	286.83	380.58
Lower 95% Mean	101.73	97.71
N	17	17
Sum	3,302.75	4,065.45
Variance	32,400.87	75,669.61
Skewness	1.53	1.59
Kurtosis	2.51	2.00
CV	92.65	115.03
Minimum	0.00	0.00
Maximum	685.71	967.27

Figure 19. Box plots and summary statistics of combined outfalls (site-level) for bicycle grate (Site 8) measured in count (normalized by catchment area, item/acre)



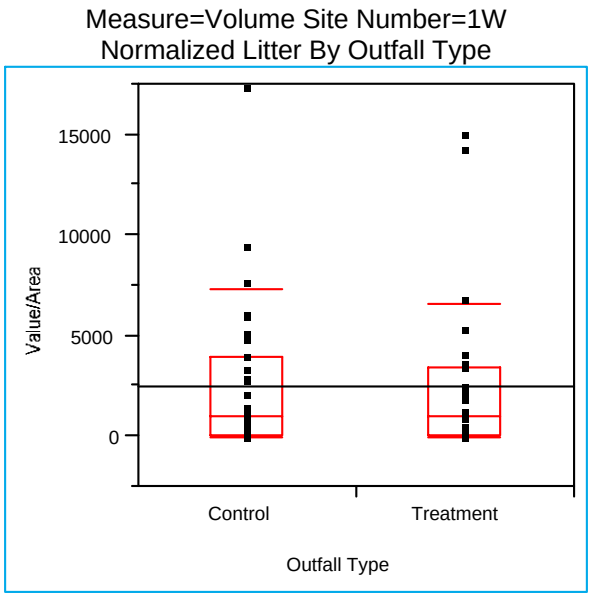
Moments	Control	Treatment
Mean	185.28	162.35
Std Dev	191.63	118.09
Std Error Mean	51.22	31.56
Upper 95% Mean	295.93	230.53
Lower 95% Mean	74.64	94.16
N	14	14
Sum	2,593.96	2,272.85
Variance	36,723.09	13,944.72
Skewness	1.69	-0.03
Kurtosis	3.11	-1.16
CV	103.43	72.74
Minimum	0.00	0.00
Maximum	696.70	356.95

Figure 20. Box plots and summary statistics of combined outfalls (site-level) for LID (Site 8) measured in count (normalized by catchment area, item/acre)



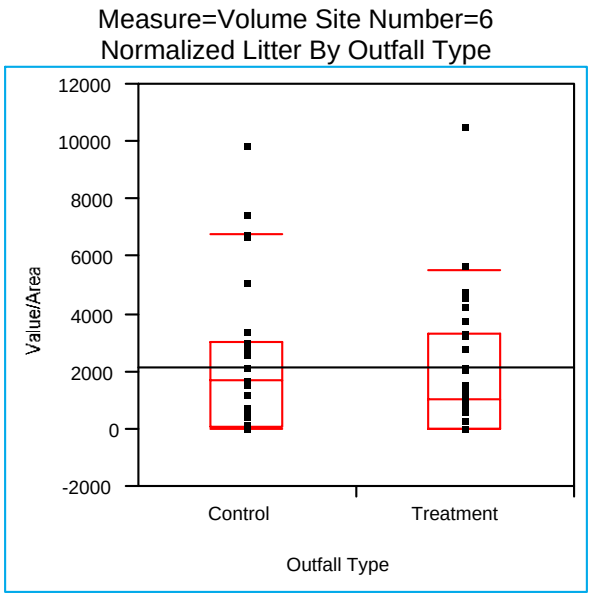
Moments	Control	Treatment
Mean	3,503.86	2,099.16
Std Dev	4,900.10	2,704.92
Std Error Mean	880.08	485.82
Upper 95% Mean	5,301.21	3,091.33
Lower 95% Mean	1,706.50	1,107.00
N	31	31
Sum	108,619.50	65,074.09
Variance	24,010,948.00	7,316,611.90
Skewness	2.54	1.70
Kurtosis	8.56	2.73
CV	139.85	128.86
Minimum	0.00	0.00
Maximum	23,530.00	10,444.00

Figure 21. Box plots and summary statistics of combined outfalls (site-level) for manual litter pick-up (Site 1E) measured in volume (normalized by catchment area, ml/acre)



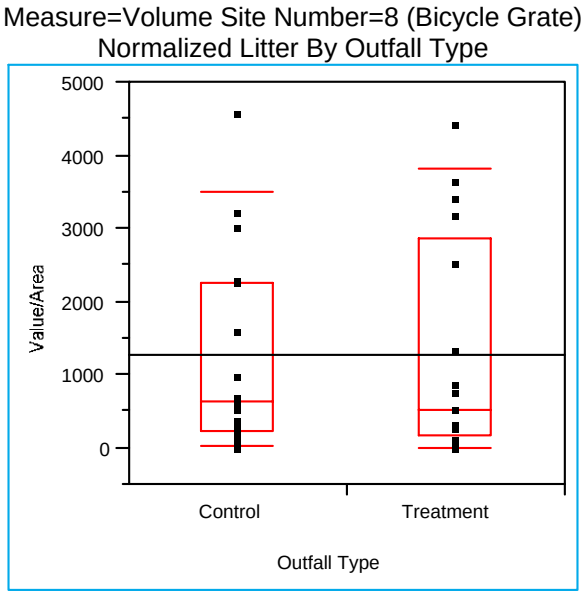
Moments	Control	Treatment
Mean	2,607.32	2,381.55
Std Dev	3,739.08	3,703.04
Std Error Mean	671.56	665.09
Upper 95% Mean	3,978.81	3,739.83
Lower 95% Mean	1,235.82	1,023.27
N	31	31
Sum	80,826.79	73,828.03
Variance	13,980,751.00	13,712,521.00
Skewness	2.44	2.56
Kurtosis	7.38	6.66
CV	143.41	155.49
Minimum	0.00	0.00
Maximum	17,379.00	15,010.00

Figure 22. Box plots and summary statistics of combined outfalls (site-level) for street sweeping (Site 1W) measured in volume (normalized by catchment area, ml/acre)



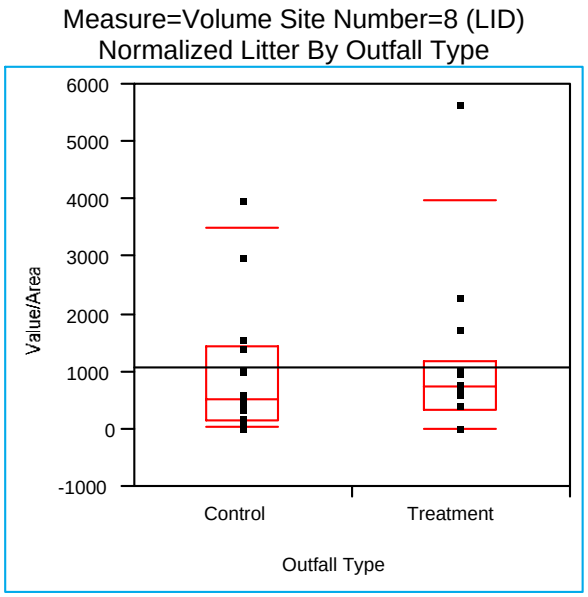
Moments	Control	Treatment
Mean	2,252.39	2,019.65
Std Dev	2,544.49	2,421.27
Std Error Mean	457.00	434.87
Upper 95% Mean	3,185.71	2,907.77
Lower 95% Mean	1,319.07	1,131.53
N	31	31
Sum	69,824.09	62,609.13
Variance	6,474,436.80	5,862,542.20
Skewness	1.47	1.75
Kurtosis	1.78	3.77
CV	112.97	119.89
Minimum	0.00	0.00
Maximum	9,870.90	10,554.00

Figure 23. Box plots and summary statistics of combined outfalls (site-level) for modified inlet grate (Site 6) measured in volume (normalized by catchment area, ml/acre)



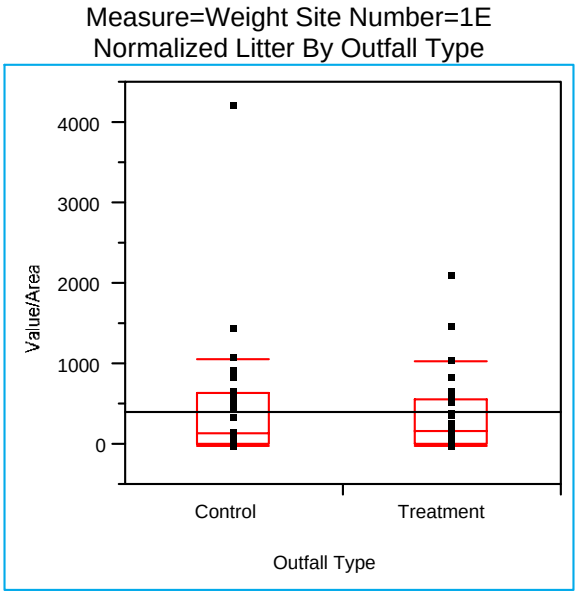
Moments	Control	Treatment
Mean	1,264.56	1,302.29
Std Dev	1,348.35	1,510.81
Std Error Mean	327.02	366.43
Upper 95% Mean	1,957.82	2,079.07
Lower 95% Mean	571.31	525.50
N	17	17
Sum	21,497.56	22,138.89
Variance	1,818,052.20	2,282,552.30
Skewness	1.24	1.02
Kurtosis	0.72	-0.53
CV	106.63	116.01
Minimum	0.00	0.00
Maximum	4,591.80	4,440.80

Figure 24. Box plots and summary statistics of combined outfalls (site-level) for bicycle grate (Site 8) measured in volume (normalized by catchment area, ml/acre)



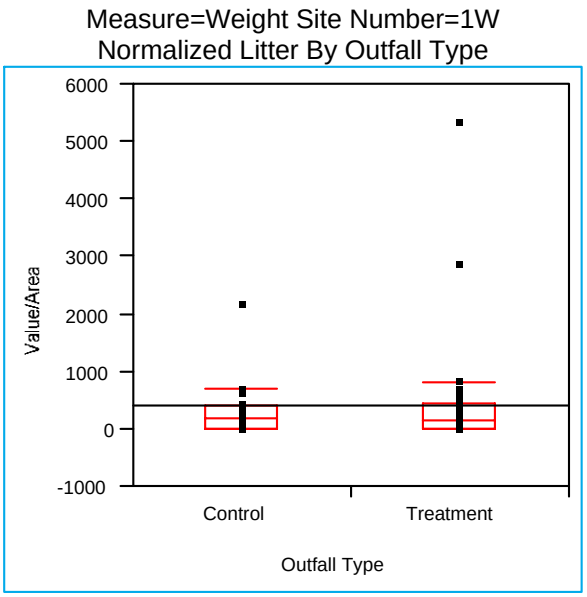
Moments	Control	Treatment
Mean	1,024.73	1,140.28
Std Dev	1,175.31	1,451.83
Std Error Mean	314.11	388.02
Upper 95% Mean	1,703.33	1,978.54
Lower 95% Mean	346.12	302.02
N	14	14
Sum	14,346.15	15,963.91
Variance	1,381,343.30	2,107,809.00
Skewness	1.69	2.62
Kurtosis	2.43	7.88
CV	114.70	127.32
Minimum	0.00	0.00
Maximum	4,002.70	5,662.30

Figure 25. Box plots and summary statistics of combined outfalls (site-level) for LID (Site 8) measured in volume (normalized by catchment area, ml/acre)



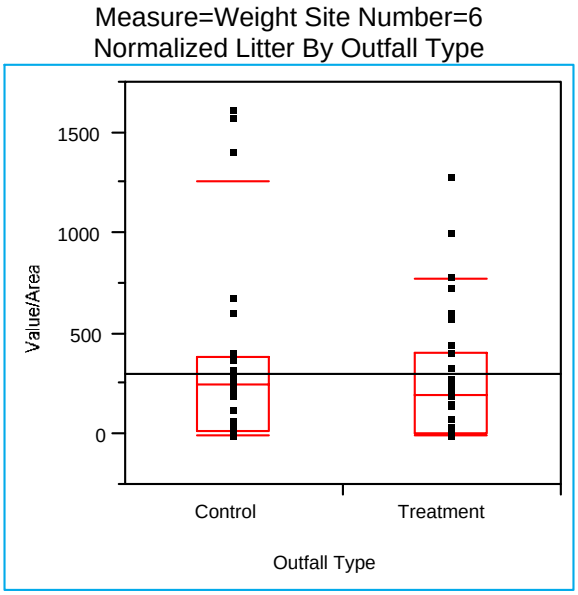
Moments	Control	Treatment
Mean	469.08	350.91
Std Dev	801.83	492.99
Std Error Mean	144.01	88.54
Upper 95% Mean	763.19	531.74
Lower 95% Mean	174.96	170.09
N	31	31
Sum	14,541.38	10,878.34
Variance	642,933.22	243,040.22
Skewness	3.65	2.09
Kurtosis	16.31	4.88
CV	170.94	140.49
Minimum	0.00	0.00
Maximum	4,217.40	2,111.30

Figure 26. Box plots and summary statistics of combined outfalls (site-level) for manual litter pick-up (Site 1E) measured in dry weight (normalized by catchment area, g/acre)



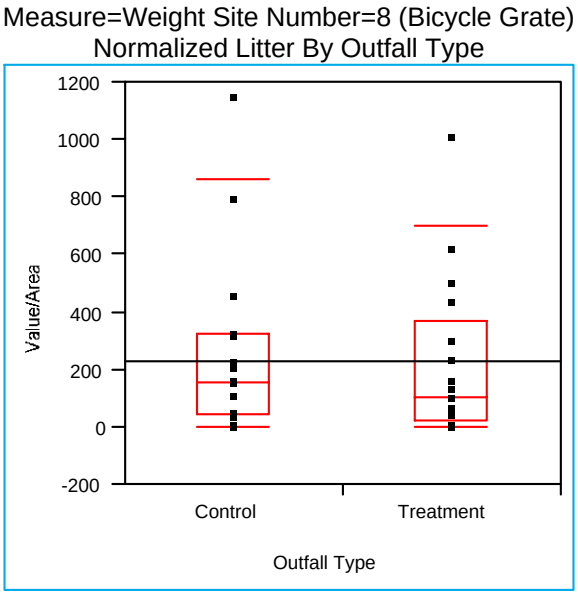
Moments	Control	Treatment
Mean	339.46	470.33
Std Dev	537.57	1,055.41
Std Error Mean	96.55	189.56
Upper 95% Mean	536.64	857.46
Lower 95% Mean	142.28	83.21
N	31	31
Sum	10,523.34	14,580.33
Variance	288,979.08	1,113,885.50
Skewness	2.80	3.95
Kurtosis	8.04	16.70
CV	158.36	224.40
Minimum	0.00	0.00
Maximum	2,194.30	5,368.90

Figure 27. Box plots and summary statistics of combined outfalls (site-level) for street sweeping (Site 1W) measured in dry weight (normalized by catchment area, g/acre)



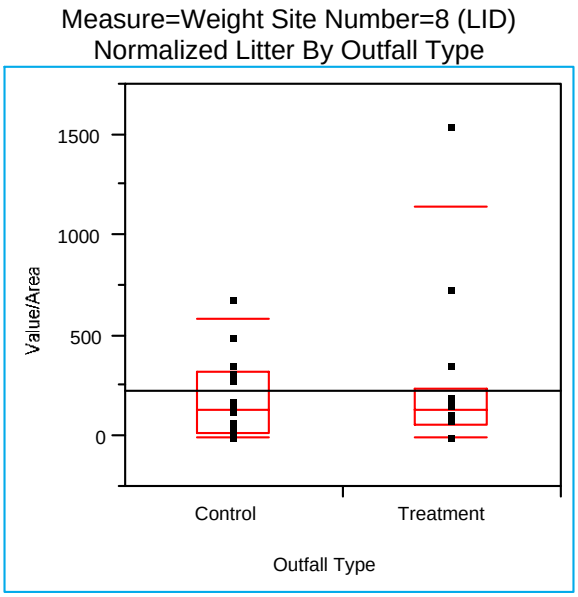
Moments	Control	Treatment
Mean	331.60	280.46
Std Dev	440.21	323.93
Std Error Mean	79.06	58.18
Upper 95% Mean	493.06	399.28
Lower 95% Mean	170.13	161.65
N	31	31
Sum	10,279.45	8,694.36
Variance	193,781.92	104,931.07
Skewness	2.08	1.52
Kurtosis	3.85	2.11
CV	132.75	115.50
Minimum	0.00	0.00
Maximum	1,619.60	1,281.50

Figure 28. Box plots and summary statistics of combined outfalls (site-level) for modified inlet grate (Site 6) measured in dry weight (normalized by catchment area, g/acre)



Moments	Control	Treatment
Mean	244.41	221.29
Std Dev	311.33	279.21
Std Error Mean	75.51	67.72
Upper 95% Mean	404.48	364.85
Lower 95% Mean	84.33	77.74
N	17	17
Sum	4,154.89	3,761.95
Variance	96,929.03	77,957.62
Skewness	2.02	1.74
Kurtosis	4.09	2.95
CV	127.38	126.17
Minimum	0.00	0.00
Maximum	1,155.30	1,013.60

Figure 29. Box plots and summary statistics of combined outfalls (site-level) for bicycle grate (Site 8) measured in dry weight (normalized by catchment area, g/acre)



Moments	Control	Treatment
Mean	194.62	270.20
Std Dev	206.83	413.85
Std Error Mean	55.28	110.61
Upper 95% Mean	314.05	509.15
Lower 95% Mean	75.20	31.25
N	14	14
Sum	2,724.74	3,782.84
Variance	42,780.24	171,271.16
Skewness	1.21	2.68
Kurtosis	1.00	7.62
CV	106.27	153.16
Minimum	0.00	0.00
Maximum	686.76	1,549.60

Figure 30. Box plots and summary statistics of combined outfalls (site-level) for LID (Site 8) measured in dry weight (normalized by catchment area, g/acre)

Statistical test results of the marginal analysis, raw data at outfall-level (normalized by catchment area)

Mean normalized litter for control and treatment datasets:

		Count (items/acre)		Volume (ml/acre)		Weight (g/acre)	
Site	**BMP**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1E	Manual litter pick-up	489	340	3548	2054	470	343
1W	Street sweepers	408	470	2616	2388	341	472
6	Modified inlet grate	380	312	2249	1982	330	276
8	Bicycle grate (98/99)	195	243	1268	1297	245	225
8	LID (99/00)	188	170	1039	1236	197	268
1E	Manual litter pick-up (w/o Outfall 1-46)	489	420	3548	2541	470	428
8	LID (99/00) (w/o Outfall 8-24D)	238	170	1354	1236	250	268

A p-value > 0.05 indicates that the data sets are normally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

		Count		Volume		Weight	
Site	**BMP**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1E	Manual litter pick-up	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1W	Street sweepers	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
6	Modified inlet grate	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	Bicycle grate (98/99)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	LID (99/00)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1E	Manual litter pick-up (w/o Outfall 1-46)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	LID (99/00) (w/o Outfall 8-24D)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis can be rejected, i.e., the average litter amount in control is greater than treatment.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	>0.05	>0.05	>0.05
1W	Street sweepers	>0.05	>0.05	>0.05
6	Modified inlet grate	>0.05	>0.05	>0.05
8	Bicycle grate (98/99)	>0.05	>0.05	>0.05
8	LID (99/00)	>0.05	>0.05	>0.05
1E	Manual litter pick-up (w/o Outfall 1-46)	>0.05	>0.05	>0.05
8	LID (99/00) (w/o Outfall 8-24D)	>0.05	>0.05	>0.05

*Based on the results of the normality test, data are not normally distributed in one or both datasets, and the Wilcoxon Rank-Sum Test (at 5% significance level) was used.

Statistical test results of the marginal analysis, raw data at site-level (normalized by catchment area)

Mean normalized litter for control and treatment datasets:

		Count (items/acre)		Volume (ml/acre)		Weight (g/acre)	
Site	**BMP**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1E	Manual litter pick-up	484	347	3504	2099	469	351
1W	Street sweepers	406	466	2607	2382	339	470
6	Modified inlet grate	383	320	2252	2020	332	280
8	Bicycle grate (98/99)	194	239	1265	1302	244	221
8	LID (99/00)	185	162	1025	1140	195	270
1E	Manual litter pick-up (w/o Outfall 1-46)	484	420	3504	2544	469	429
8	LID (99/00) (w/o Outfall 8-24D)	236	162	1343	1140	248	270

A p-value > 0.05 indicates that the data sets are normally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

		Count		Volume		Weight	
Site	**BMP**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1E	Manual litter pick-up	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1W	Street sweepers	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
6	Modified inlet grate	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	Bicycle grate (98/99)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	LID (99/00)	<0.05	>0.05	<0.05	<0.05	<0.05	<0.05
1E	Manual litter pick-up (w/o Outfall 1-46)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	LID (99/00) (w/o Outfall 8-24D)	<0.05	>0.05	<0.05	<0.05	<0.05	<0.05

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis can be rejected, i.e., the average litter amount in control is greater than treatment

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	>0.05	>0.05	>0.05
1W	Street sweepers	>0.05	>0.05	>0.05
6	Modified inlet grate	>0.05	>0.05	>0.05
8	Bicycle grate (98/99)	>0.05	>0.05	>0.05
8	LID (99/00)	>0.05	>0.05	>0.05
1E	Manual litter pick-up (w/o Outfall 1-46)	>0.05	>0.05	>0.05
8	LID (99/00) (w/o Outfall 8-24D)	>0.05	>0.05	>0.05

*Based on the results of the normality test, data are not normally distributed in one or both datasets, and the Wilcoxon Rank-Sum Test (at 5% significance level) was used.

Statistical test results of the marginal analysis, log-transformed data at outfall-level (normalized by catchment area)

Mean normalized log-transformed litter for control and treatment datasets:

		Count (items/acre)		Volume (ml/acre)		Weight (g/acre)	
Site	**BMP**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1E	Manual litter pick-up	4.30	3.95	5.54	5.02	3.94	3.66
1W	Street sweepers	4.31	4.31	5.51	5.43	3.93	3.91
6	Modified inlet grate	4.63	4.51	6.04	5.83	4.29	4.13
8	Bicycle grate (98/99)	4.48	4.25	5.91	5.42	4.23	3.88
8	LID (99/00)	4.17	3.93	5.48	5.24	4.04	3.93
1E	Manual litter pick-up (w/o Outfall 1-46)	4.30	4.29	5.54	5.44	3.94	3.97
8	LID (99/00) (w/o Outfall 8-24D)	4.48	3.93	5.90	5.24	4.41	3.93

A p-value > 0.05 indicates that the data sets are lognormally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

		Count		Volume		Weight	
Site	**BMP**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1E	Manual litter pick-up	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1W	Street sweepers	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
6	Modified inlet grate	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	Bicycle grate (98/99)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	LID (99/00)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1E	Manual litter pick-up (w/o Outfall 1-46)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	LID (99/00) (w/o Outfall 8-24D)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis can be rejected, i.e., the average litter amount in control is greater than treatment.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	>0.05	>0.05	>0.05
1W	Street sweepers	>0.05	>0.05	>0.05
6	Modified inlet grate	>0.05	>0.05	>0.05
8	Bicycle grate (98/99)	>0.05	>0.05	>0.05
8	LID (99/00)	>0.05	>0.05	>0.05
1E	Manual litter pick-up (w/o Outfall 1-46)	>0.05	>0.05	>0.05
8	LID (99/00) (w/o Outfall 8-24D)	>0.05	>0.05	>0.05

*Based on the results of the normality test, data are not lognormally distributed in one or both datasets, and the Wilcoxon Rank-Sum Test (at 5% significance level) was used.

Statistical test results of the marginal analysis, log-transformed data at site-level (normalized by catchment area)

Mean normalized log-transformed litter for control and treatment datasets:

		Count (items/acre)		Volume (ml/acre)		Weight (g/acre)	
Site	**BMP**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1E	Manual litter pick-up	4.46	4.31	5.81	5.54	4.13	3.95
1W	Street sweepers	4.51	4.53	5.82	5.81	4.12	4.16
6	Modified inlet grate	4.83	4.75	6.34	6.14	4.51	4.37
8	Bicycle grate (98/99)	4.62	4.48	6.24	5.84	4.50	4.24
8	LID (99/00)	4.50	4.25	5.99	5.69	4.33	4.28
1E	Manual litter pick-up (w/o Outfall 1-46)	4.46	4.47	5.81	5.70	4.13	4.11
8	LID (99/00) (w/o Outfall 8-24D)	4.71	4.25	6.24	5.69	4.57	4.28

A p-value > 0.05 indicates that the data sets are lognormally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

		Count		Volume		Weight	
Site	**BMP**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1E	Manual litter pick-up	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1W	Street sweepers	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
6	Modified inlet grate	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	Bicycle grate (98/99)	<0.05	<0.05	<0.05	<0.05	>0.05	>0.05
8	LID (99/00)	<0.05	<0.05	<0.05	<0.05	>0.05	<0.05
1E	Manual litter pick-up (w/o Outfall 1-46)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	LID (99/00) (w/o Outfall 8-24D)	<0.05	<0.05	<0.05	<0.05	>0.05	<0.05

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis can be rejected, i.e., the average litter amount in control is greater than treatment.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	>0.05	>0.05	>0.05
1W	Street sweepers	>0.05	>0.05	>0.05
6	Modified inlet grate	>0.05	>0.05	>0.05
8	Bicycle grate (98/99)	>0.05	>0.05	>0.05**
8	LID (99/00)	>0.05	>0.05	>0.05
1E	Manual litter pick-up (w/o Outfall 1-46)	>0.05	>0.05	>0.05
8	LID (99/00) (w/o Outfall 8-24D)	>0.05	>0.05	>0.05

*Based on the results of the normality test, data are not lognormally distributed in one or both datasets, and the Wilcoxon Rank-Sum Test (at 5% significance level) was used (except as noted).
**Data are lognormally distributed, one-sample t-test (at 5% significance level) was used.

Statistical test results of the paired analysis, using actual difference (*Act diff*) at outfall-level (normalized by catchment area)

Mean actual difference, *Act Diff*, between normalized litter of control and treatment:

Site	BMP	Count (items/acre)	Volume (ml/acre)	Weight (g/acre)
1E	Manual litter pick-up	150	1494	127
1W	Street sweepers	-62	228	-131
6	Modified inlet grate	68	267	54
8	Bicycle grate (98/99)	-48	-29	20
8	LID (99/00)	18	-198	-71
1E	Manual litter pick-up (w/o Outfall 1-46)	47	927	50
8	LID (99/00) (w/o Outfall 8-24D)	81	48	-25

A p-value > 0.05 indicates that the actual difference, *Act diff*, is normally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.000	0.000	0.000
1W	Street sweepers	0.000	0.000	0.000
6	Modified inlet grate	0.000	0.000	0.000
8	Bicycle grate (98/99)	0.000	0.003	0.000
8	LID (99/00)	0.000	0.000	0.000
1E	Manual litter pick-up (w/o Outfall 1-46)	0.000	0.000	0.000
8	LID (99/00) (w/o Outfall 8-24D)	0.001	0.002	0.000

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis (*Act diff* = 0) can be rejected, i.e., the average litter amount in control greater than treatment.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.000	0.000	0.012
1W	Street sweepers	0.351	0.109	0.643
6	Modified inlet grate	0.001	0.022	0.017
8	Bicycle grate (98/99)	0.918	0.273	0.297
8	LID (99/00)	0.512	0.746	0.815
1E	Manual litter pick-up (w/o Outfall 1-46)	0.179	0.018	0.578
8	LID (99/00) (w/o Outfall 8-24D)	0.041	0.343	0.314

*Based on the results of the normality test, data are not normally distributed, and the Wilcoxon Signed-Rank Test (at 5% significance level) was used.

Statistical test results of the paired analysis, using actual difference (*Act diff*) at site-level (normalized by catchment area)

Mean actual difference, *Act Diff*, between normalized litter of control and treatment:

Site	BMP	Count (items/acre)	Volume (ml/acre)	Weight (g/acre)
1E	Manual litter pick-up	137	1405	118
1W	Street sweepers	-60	226	-131
6	Modified inlet grate	63	233	51
8	Bicycle grate (98/99)	-45	-38	23
8	LID (99/00)	23	-116	-76
1E	Manual litter pick-up (w/o Outfall 1-46)	64	960	40
8	LID (99/00) (w/o Outfall 8-24D)	73	203	-22

A p-value > 0.05 indicates that the actual difference, *Act diff*, is normally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.000	0.000	0.000
1W	Street sweepers	0.000	0.000	0.000
6	Modified inlet grate	0.001	0.007	0.001
8	Bicycle grate (98/99)	0.021	0.091	0.069
8	LID (99/00)	0.000	0.085	0.000
1E	Manual litter pick-up (w/o Outfall 1-46)	0.000	0.000	0.000
8	LID (99/00) (w/o Outfall 8-24D)	0.000	0.064	0.002

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis (Act diff = 0) can be rejected, i.e., the average litter amount in control greater than treatment.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.003	0.000	0.046
1W	Street sweepers	0.463	0.256	0.774
6	Modified inlet grate	0.028	0.045	0.064
8	Bicycle grate (98/99)	0.912	0.626**	0.133**
8	LID (99/00)	0.682	0.604**	0.773
1E	Manual litter pick-up (w/o Outfall 1-46)	0.125	0.011	0.526
8	LID (99/00) (w/o Outfall 8-24D)	0.040	0.338**	0.446

Least significant value (LSV) of t-Test***

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	--	--	--
1W	Street sweepers	--	--	--
6	Modified inlet grate	--	--	--
8	Bicycle grate (98/99)	--	202	35
8	LID(99/00)	--	759	--
1E	Manual litter pick-up (w/o Outfall 1-46)	--	--	--
8	LID (99/00) (w/o Outfall 8-24D)	--	842	--

Statistical test results of the paired analysis, using percentage difference *(% diff)* at outfall-level (normalized by catchment area)

Mean percentage difference, *% diff*, between normalized litter of control and treatment:

Site	BMP	Count (%)	Volume (%)	Weight (%)
1E	Manual litter pick-up	-14	26	-74
1W	Street sweepers	-15	-1	-30
6	Modified inlet grate	-27	-24	-37
8	Bicycle grate (98/99)	-22	-9	-12
8	LID (99/00)	-39	-123	-138
1E	Manual litter pick-up (w/o Outfall 1-46)	-53	8	-134
8	LID (99/00) (w/o Outfall 8-24D)	13	-50	-32

A p-value > 0.05 indicates that the percentage difference, *% diff*, is normally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.000	0.000	0.000
1W	Street sweepers	0.000	0.000	0.000
6	Modified inlet grate	0.000	0.000	0.000
8	Bicycle grate (98/99)	0.000	0.000	0.000
8	LID (99/00)	0.000	0.000	0.000
1E	Manual litter pick-up (w/o Outfall 1-46)	0.000	0.000	0.000
8	LID (99/00) (w/o Outfall 8-24D)	0.004	0.000	0.000

Results of hypothesis testing (p-values)*:

A p-value <0.05 indicates that the null hypothesis (% diff = 0) can be rejected, i.e., the average litter amount in control is greater than treatment.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.001	0.000	0.012
1W	Street sweepers	0.351	0.109	0.643
6	Modified inlet grate	0.001	0.022	0.017
8	Bicycle grate (98/99)	0.918	0.273	0.297
8	LID (99/00)	0.512	0.746	0.815
1E	Manual litter pick-up (w/o Outfall 1-46)	0.179	0.018	0.578
8	LID (99/00) (w/o Outfall 8-24D)	0.041	0.343	0.314

*Based on the results of the normality test, data are not normally distributed, and the Wilcoxon Signed-Rank Test (at 5% significance level) was used.

Statistical test results of the paired analysis, using percentage difference (*% diff*) at site-level (normalized by catchment area)

Mean percentage difference, *% diff*, between normalized litter of control and treatment:

Site	BMP	Count (%)	Volume (%)	Weight (%)
1E	Manual litter pick-up	-91	36	-239
1W	Street sweepers	-7	7	-8
6	Modified inlet grate	-16	-8	-22
8	Bicycle grate (98/99)	-15	4	-4
8	LID (99/00)	-21	-121	-175
1E	Manual litter pick-up (w/o Outfall 1-46)	-159	23	-368
8	LID (99/00) (w/o Outfall 8-24D)	4	-62	-99

A p-value > 0.05 indicates the percentage difference, *% diff*, is normally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.000	0.593	0.000
1W	Street sweepers	0.016	0.330	0.294
6	Modified inlet grate	0.000	0.000	0.000
8	Bicycle grate (98/99)	0.183	0.341	0.104
8	LID (99/00)	0.001	0.000	0.000
1E	Manual litter pick-up (w/o Outfall 1-46)	0.000	0.217	0.000
8	LID (99/00) (w/o Outfall 8-24D)	0.022	0.000	0.000

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis (% diff = 0) can be rejected, i.e., the average litter amount in control greater than treatment.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.003	0.000**	0.046
1W	Street sweepers	0.463	0.256**	0.774**
6	Modified inlet grate	0.028	0.045	0.064
8	Bicycle grate (98/99)	0.912**	0.626**	0.133**
8	LID (99/00)	0.682	0.604	0.773
1E	Manual litter pick-up (w/o Outfall 1-46)	0.125	0.011**	0.526
8	LID (99/00) (w/o Outfall 8-24D)	0.040	0.338	0.446

Least significant value (LSV) of t-Test***

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	--	12	--
1W	Street sweepers	--	20	24
6	Modified inlet grate	--	--	--
8	Bicycle grate (98/99)	19	17	22
8	LID (99/00)	--	--	--
1E	Manual litter pick-up (w/o Outfall 1-46)	--	15	--
8	LID (99/00) (w/o Outfall 8-24D)	--	--	--

Statistical test results of the outfall-level paired analysis, using actual difference (*Act diff*), comparison between each treatment outfall and all three control outfalls (normalized by catchment area)

Mean actual difference, *Act Diff*, between normalized litter of control and treatment:

Site	BMP	Count (items/acre)	Volume (ml/acre)	Weight (g/acre)
1E	Manual litter pick-up	150	1494	127
1W	Street sweepers	-62	228	-131
6	Modified inlet grate	68	267	54
8	Bicycle grate (98/99)	-52	-82	10
8	LID (99/00)	22	-137	-71
1E	Manual litter pick-up (w/o Outfall 1-46)	70	1007	42
8	LID (99/00) (w/o Outfall 8-24D)	92	226	-2

A p-value > 0.05 indicates that the actual difference, *Act diff*, is normally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.000	0.000	0.000
1W	Street sweepers	0.000	0.000	0.000
6	Modified inlet grate	0.000	0.000	0.000
8	Bicycle grate (98/99)	0.000	0.000	0.000
8	LID (99/00)	0.000	0.000	0.000
1E	Manual litter pick-up (w/o Outfall 1-46)	0.000	0.000	0.000
8	LID(99/00) (w/o Outfall 8-24D)	0.000	0.000	0.000

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis (*Act diff* = 0) can be rejected, i.e., the average litter amount in control is greater than treatment.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.000	0.000	0.000
1W	Street sweepers	0.426	0.032	0.656
6	Modified inlet grate	0.000	0.000	0.000
8	Bicycle grate (98/99)	0.991	0.546	0.321
8	LID (99/00)	0.566	0.816	0.901
1E	Manual litter pick-up (w/o Outfall 1-46)	0.013	0.000	0.481
8	LID (99/00) (w/o Outfall 8-24D)	0.008	0.241	0.279

*Based on the results of the normality test, data are not normally distributed, and the Wilcoxon Signed-Rank Test (at 5% significance level) was used.

Statistical test results of the outfall-level paired analysis, using percentage difference (*% diff*), comparison between each treatment outfall and all three control outfalls (normalized by catchment area)

Mean percentage difference, *% diff* , between normalized litter of control and treatment:

Site	BMP	Count (%)	Volume (%)	Weight (%)
1E	Manual litter pick-up	4	15	-23
1W	Street sweepers	-16	0	-26
6	Modified inlet grate	-37	-33	-58
8	Bicycle grate (98/99)	-27	-17	-19
8	LID (99/00)	-34	-117	-167
1E	Manual litter pick-up (w/o Outfall 1-46)	-24	5	-58
8	LID (99/00) (w/o Outfall 8-24D)	16	-37	-65

A p-value > 0.05 indicates that the percentage difference, *% diff* , is normally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.000	0.000	0.000
1W	Street sweepers	0.000	0.000	0.000
6	Modified inlet grate	0.000	0.000	0.000
8	Bicycle grate (98/99)	0.000	0.000	0.000
8	LID (99/00)	0.000	0.000	0.000
1E	Manual litter pick-up (w/o Outfall 1-46)	0.000	0.000	0.000
8	LID (99/00) (w/o Outfall 8-24D)	0.001	0.000	0.000

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis (% diff = 0) can be rejected, i.e., the average litter amount in control is greater than treatment.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.000	0.000	0.000
1W	Street sweepers	0.530	0.151	0.890
6	Modified inlet grate	0.002	0.002	0.020
8	Bicycle grate (98/99)	0.985	0.351	0.429
8	LID (99/00)	0.924	0.965	0.991
1E	Manual litter pick-up (w/o Outfall 1-46)	0.056	0.001	0.685
8	LID(99/00) (w/o Outfall 8-24D)	0.046	0.397	0.379

*Based on the results of the normality test, data are not normally distributed, and the Wilcoxon Signed-Rank Test (at 5% significance level) was used.

Statistical test results of the marginal analysis, raw data at outfall-level (normalized by flow volume)

Mean normalized litter for control and treatment datasets:

		Count (items/L)		Volume (ml/L)		Weight (g/L)	
Site	**BMP**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1E	Manual litter pick-up	2.39E-02	1.13E-02	1.49E-01	7.16E-02	1.87E-02	8.54E-03
1W	Street sweepers	1.75E-02	1.29E-02	1.04E-01	8.29E-02	1.37E-02	1.42E-02
6	Modified inlet grate	1.58E-02	1.22E-02	1.14E-01	9.51E-02	1.31E-02	8.85E-03
8	Bicycle grate (98/99)	7.33E-03	6.91E-03	4.22E-02	2.58E-02	6.46E-03	4.52E-03
8	LID (99/00)	1.47E-02	6.16E-03	8.80E-02	3.64E-02	1.44E-02	5.87E-03

A p-value > 0.05 indicates that the data sets are normally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

		Count		Volume		Weight	
Site	**BMP**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1E	Manual litter pick-up	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1W	Street sweepers	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
6	Modified inlet grate	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	Bicycle grate (98/99)	>0.05	<0.05	>0.05	>0.05	>0.05	>0.05
8	LID (99/00)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis can be rejected, i.e., the average litter amount in control is greater than amount.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	<0.05	<0.05	>0.05
1W	Street sweepers	>0.05	>0.05	>0.05
6	Modified inlet grate	>0.05	>0.05	>0.05
8	Bicycle grate (98/99)	>0.05	>0.05**	>0.05**
8	LID (99/00)	>0.05	>0.05	>0.05

*Based on the results of the normality test, data are not normally distributed in one or both datasets, and the Wilcoxon Rank-Sum Test (at 5% significance level) was used (except as noted).
**Data are normally distributed, two-sample t-test (at 5% significance level) was used.

Statistical test results of the marginal analysis, log-transformed data at outfall-level (normalized by flow volume)

Mean normalized log-transformed litter for control and treatment datasets:

		Count (items/L)		Volume (ml/L)		Weight (g/L)	
Site	**BMP**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1E	Manual litter pick-up	2.32E-02	1.10E-02	1.25E-01	6.20E-02	1.82E-02	8.39E-03
1W	Street sweepers	1.72E-02	1.27E-02	9.10E-02	6.96E-02	1.34E-02	1.35E-02
6	Modified inlet grate	1.55E-02	1.19E-02	9.87E-02	7.94E-02	1.29E-02	8.75E-03
8	Bicycle grate (98/99)	7.30E-03	6.88E-03	4.09E-02	2.54E-02	6.43E-03	4.51E-03
8	LID (99/00)	1.40E-02	6.11E-03	7.25E-02	3.51E-02	1.39E-02	5.84E-03

A p-value > 0.05 indicates that the data sets are lognormally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

		Count		Volume		Weight	
Site	**BMP**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1E	Manual litter pick-up	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1W	Street sweepers	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
6	Modified inlet grate	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
8	Bicycle grate (98/99)	>0.05	<0.05	>0.05	>0.05	>0.05	>0.05
8	LID (99/00)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis can be rejected, i.e., the average litter amount in control is greater than treatment.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	<0.05	<0.05	>0.05
1W	Street sweepers	>0.05	>0.05	>0.05
6	Modified inlet grate	>0.05	>0.05	>0.05
8	Bicycle grate (98/99)	>0.05	>0.05**	>0.05**
8	LID (99/00)	>0.05	>0.05	>0.05

*Based on the results of the normality test, data are not lognormally distributed in one or both datasets, and the Wilcoxon Rank-Sum Test (at 5% significance level) was used (except as noted).
**Data are lognormally distributed, two-sample t-test (at 5% significance level) was used.

Statistical test results of the paired analysis, using actual difference (*Act diff*) at outfall-level (normalized by flow volume)

Mean actual difference, *Act Diff*, between normalized litter of control and treatment:

Site	BMP	Count (items/L)	Volume (ml/L)	Weight (g/L)
1E	Manual litter pick-up	1.20.E-02	7.43.E-02	9.77.E-03
1W	Street sweepers	4.57.E-03	2.12.E-02	-5.30.E-04
6	Modified inlet grate	3.49.E-03	2.29.E-02	4.75.E-03
8	Bicycle grate (98/99)	4.20.E-04	1.64.E-02	1.93.E-03
8	LID (99/00)	8.52.E-03	5.16.E-02	8.54.E-03

A p-value > 0.05 indicates that the actual difference, *Act diff*, is normally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.009	0.007	0.000
1W	Street sweepers	0.175	0.007	0.000
6	Modified inlet grate	0.001	0.000	0.004
8	Bicycle grate (98/99)	0.696	0.482	0.337
8	LID (99/00)	0.000	0.000	0.000

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis (*Act diff* = 0) can be rejected, i.e., the average litter amount in control is greater than treatment.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.000	0.000	0.000
1W	Street sweepers	0.045**	0.027	0.082
6	Modified inlet grate	0.030	0.016	0.002
8	Bicycle grate (98/99)	0.402**	0.104**	0.090**
8	LID (99/00)	0.840	0.449	0.449
	Least significant value (LSV) of t-Test* **			
Site	**BMP**	**Count**	**Volume**	**Weight**
1E	Manual litter pick-up	--	--	--
1W	Street sweepers	4.43E-03	--	--
6	Modified inlet grate	--	--	--
8	Bicycle grate (98/99)	3.04E-03	2.23E-02	2.45E-03
8	LID (99/00)	--	--	--

*Based on the results of the normality test, data are not normally distributed, and the Wilcoxon Signed-Rank Test (at 5% significance level) was used (except as noted).
**Data are normally distributed, one-sample t-test (at 5% significance level) was used.
***This is the minimum mean *Act diff* required before the t-Test can detect a significant difference.

Statistical test results of the paired analysis, using percentage difference *(% diff)* at outfall-level (normalized by flow volume)

Mean percentage difference, *% diff*, between normalized litter of control and treatment:

Site	BMP	Count (%)	Volume (%)	Weight (%)
1E	Manual litter pick-up	57	55	46
1W	Street sweepers	36	38	26
6	Modified inlet grate	20	24	20
8	Bicycle grate (98/99)	-17	10	26
8	LID (99/00)	-43	-169	-93

A p-value > 0.05 indicates that the percentage difference, *% diff*, is normally distributed based on the Shapiro-Wilk Normality Test at 5% significance level.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.260	0.000	0.000
1W	Street sweepers	0.028	0.099	0.041
6	Modified inlet grate	0.249	0.213	0.007
8	Bicycle grate (98/99)	0.048	0.005	0.896
8	LID (99/00)	0.676	0.009	0.004

Results of hypothesis testing (p-values)*:
A p-value <0.05 indicates that the null hypothesis (% diff = 0) can be rejected, i.e., the average litter amount in control is greater than treatment.

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	0.000**	0.001	0.002
1W	Street sweepers	0.000	0.001**	0.024
6	Modified inlet grate	0.060**	0.030**	0.022
8	Bicycle grate (98/99)	0.500	0.213	0.057**
8	LID (99/00)	0.895**	0.748	0.593

Least significant value (LSV) of t-Test***

Site	BMP	Count	Volume	Weight
1E	Manual litter pick-up	13	--	--
1W	Street sweepers	--	17	--
6	Modified inlet grate	21	21	--
8	Bicycle grate (98/99)	--	--	27
8	LID (99/00)	58	--	--

*Based on the results of the normality test, data are not normally distributed, and the Wilcoxon Signed-Rank Test (at 5% significance level) was used (except as noted).
**Data are normally distributed, one-sample t-test (at 5% significance level) was used.
***This is the minimum mean *% diff* required before the t-Test can detect a significant difference.

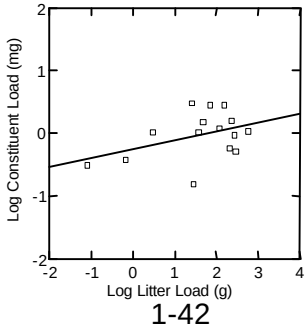
Water Quality Constituents Per Event Versus Litter Per Event

Cadmium, Dissolved

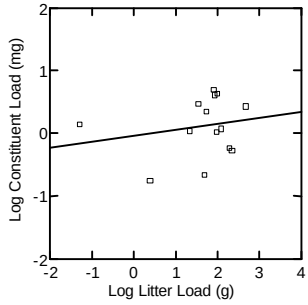
Units: mg

BMP: Litter Pick-Up

R^2 = 0.17



1-42

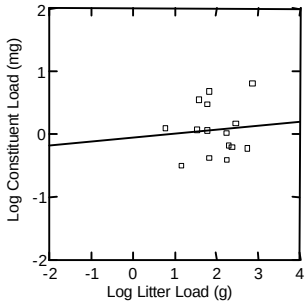


1-46

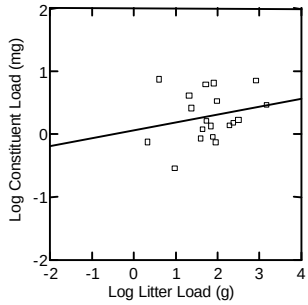
R^2 = 0.04

BMP: Street Sweeping

R^2 = 0.01



1-52

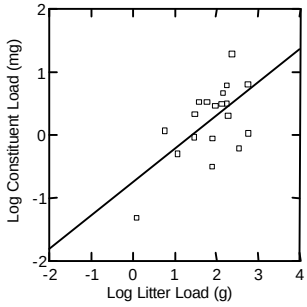


1-58

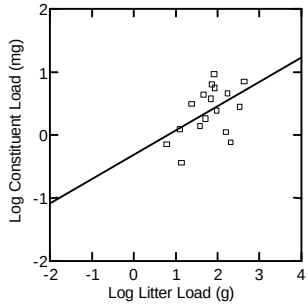
R^2 = 0.05

BMP: Modified Inlet

R^2 = 0.39



6-20E

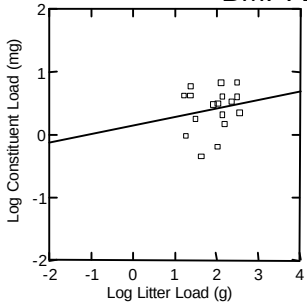


6-20F

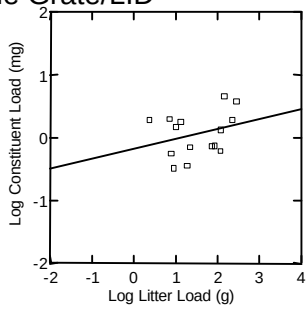
R^2 = 0.24

BMP: Bicycle Grate/LID

R^2 = 0.03



8-23C



8-B001

R^2 = 0.09

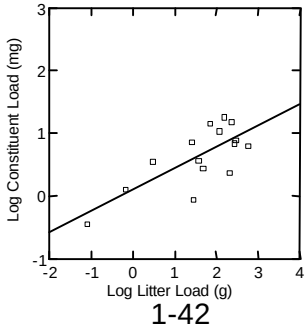
Water Quality Constituents Per Event Versus Litter Per Event

Cadmium, Total

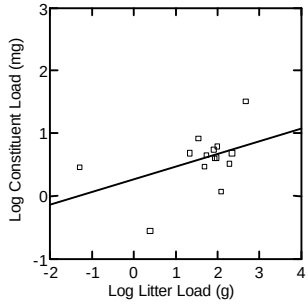
Units: mg

BMP: Litter Pick-Up

R^2 = 0.55



1-42

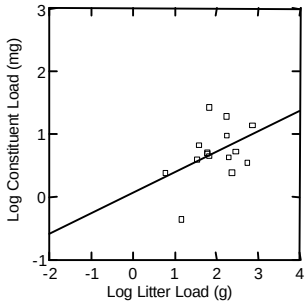


1-46

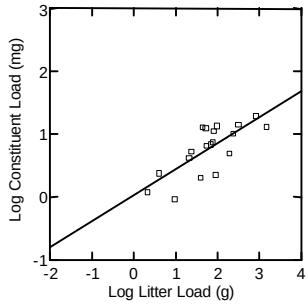
R^2 = 0.20

BMP: Street Sweeping

R^2 = 0.20



1-52

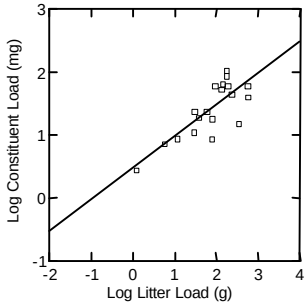


1-58

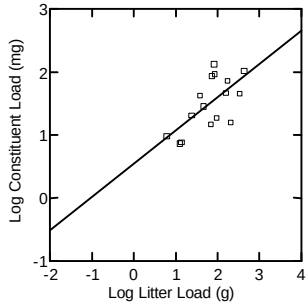
R^2 = 0.56

BMP: Modified Inlet

R^2 = 0.63



6-20E

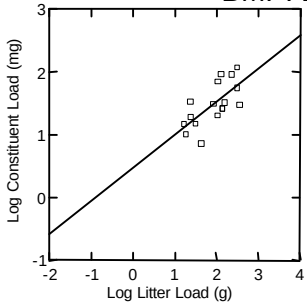


6-20F

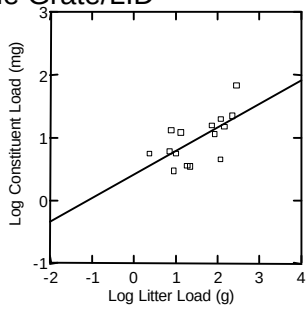
R^2 = 0.44

BMP: Bicycle Grate/LID

R^2 = 0.48



8-23C



8-B001

R^2 = 0.42

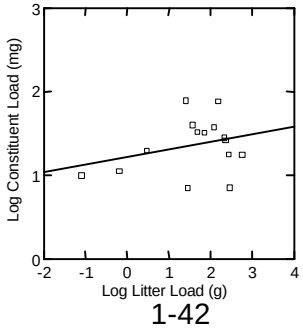
Water Quality Constituents Per Event Versus Litter Per Event

Chromium, Dissolve

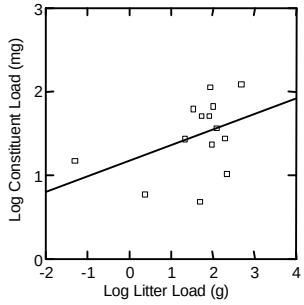
Units: mg

BMP: Litter Pick-Up

R^2 = 0.09



1-42

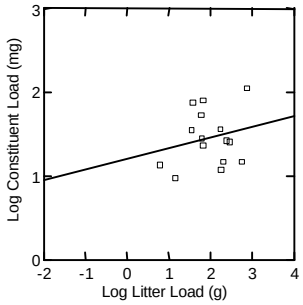


1-46

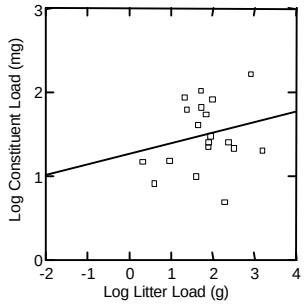
R^2 = 0.18

BMP: Street Sweeping

R^2 = 0.05



1-52

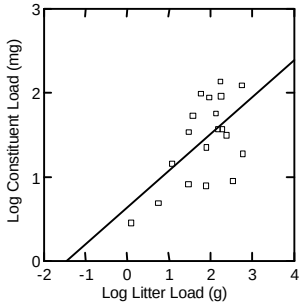


1-58

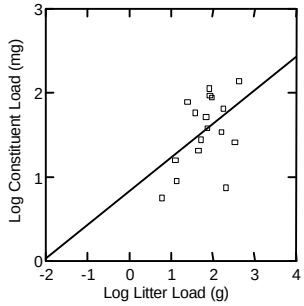
R^2 = 0.05

BMP: Modified Inlet

R^2 = 0.36



6-20E

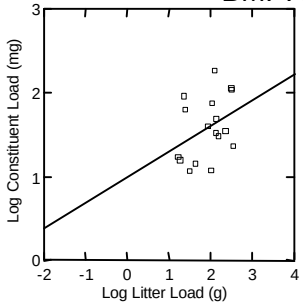


6-20F

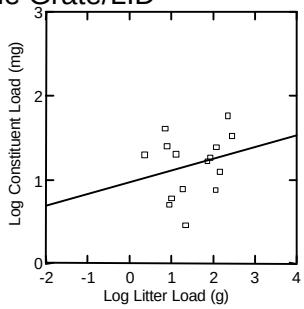
R^2 = 0.23

BMP: Bicycle Grate/LID

R^2 = 0.14



8-23C



8-B001

R^2 = 0.06

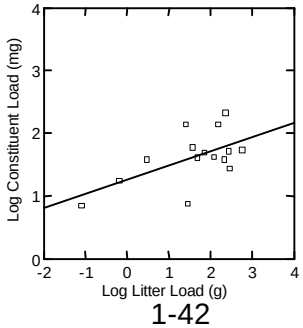
Water Quality Constituents Per Event Versus Litter Per Event

Chromium, Total

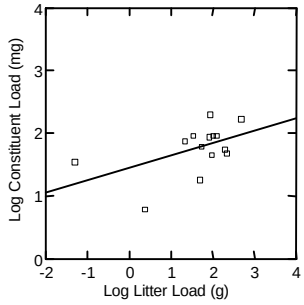
Units: mg

BMP: Litter Pick-Up

R^2 = 0.34



1-42

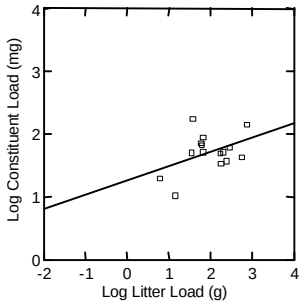


1-46

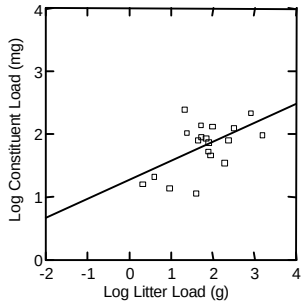
R^2 = 0.26

BMP: Street Sweeping

R^2 = 0.18



1-52

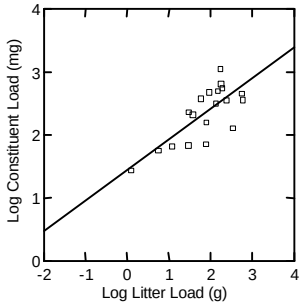


1-58

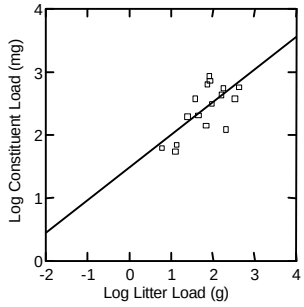
R^2 = 0.30

BMP: Modified Inlet

R^2 = 0.58



6-20E

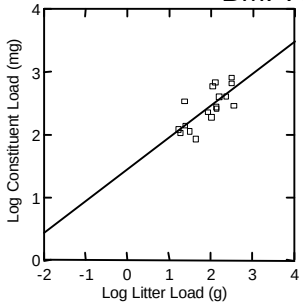


6-20F

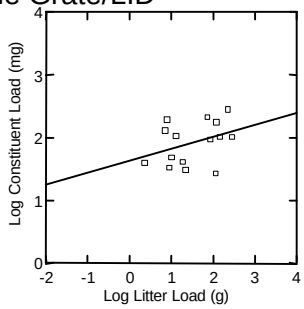
R^2 = 0.47

BMP: Bicycle Grate/LID

R^2 = 0.55



8-23C



8-B001

R^2 = 0.13

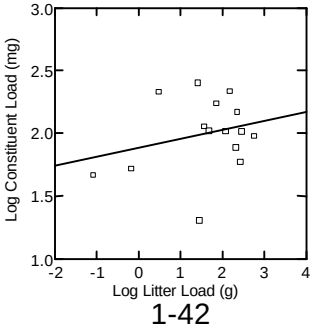
Water Quality Constituents Per Event Versus Litter Per Event

Copper, Dissolved

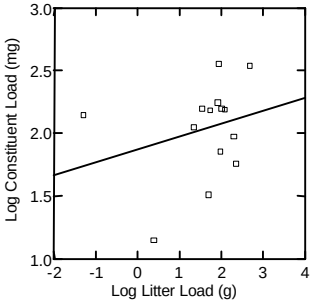
Units: mg

BMP: Litter Pick-Up

R^2 = 0.07



1-42

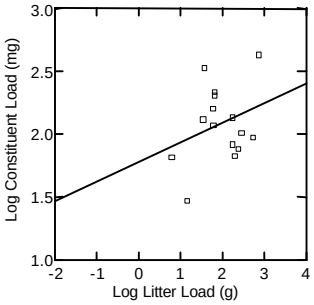


1-46

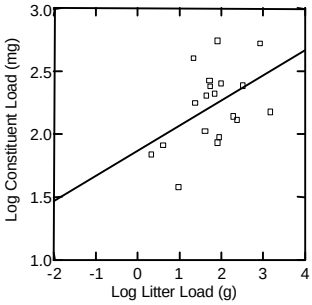
R^2 = 0.07

BMP: Street Sweeping

R^2 = 0.09



1-52

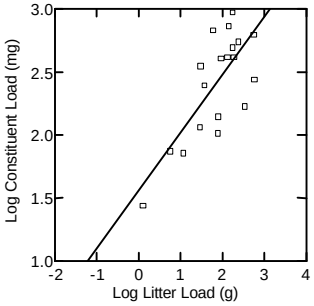


1-58

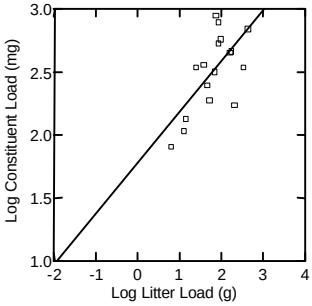
R^2 = 0.22

BMP: Modified Inlet

R^2 = 0.56



6-20E

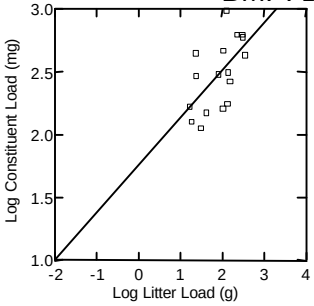


6-20F

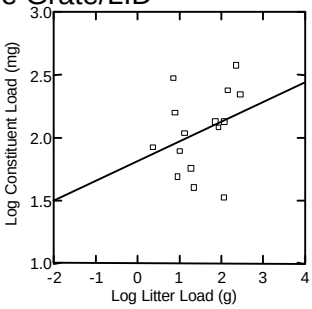
R^2 = 0.44

BMP: Bicycle Grate/LID

R^2 = 0.37



8-23C



8-B001

R^2 = 0.10

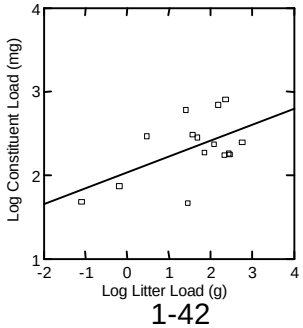
Water Quality Constituents Per Event Versus Litter Per Event

Copper, Total

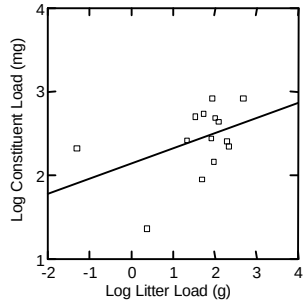
Units: mg

BMP: Litter Pick-Up

R^2 = 0.30



1-42

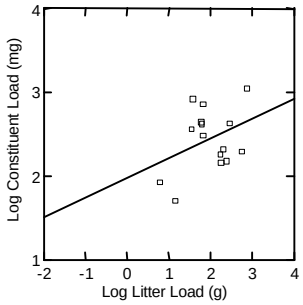


1-46

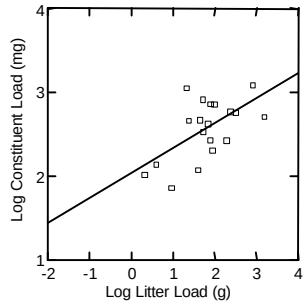
R^2 = 0.19

BMP: Street Sweeping

R^2 = 0.13



1-52

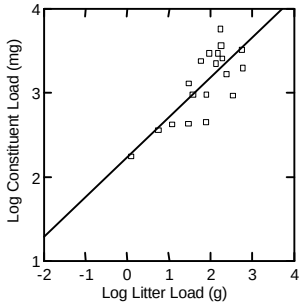


1-58

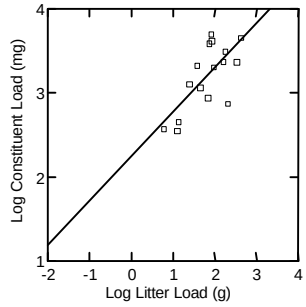
R^2 = 0.36

BMP: Modified Inlet

R^2 = 0.60



6-20E

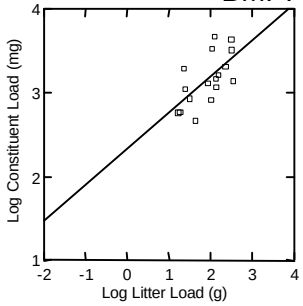


6-20F

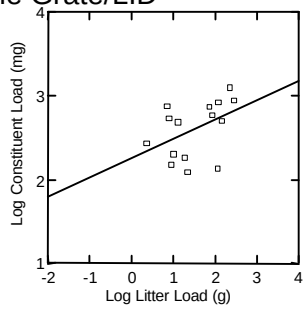
R^2 = 0.50

BMP: Bicycle Grate/LID

R^2 = 0.41



8-23C



8-B001

R^2 = 0.20

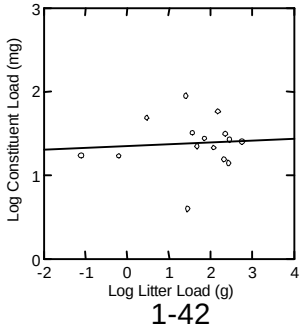
Water Quality Constituents Per Event Versus Litter Per Event

Nickel, Dissolved

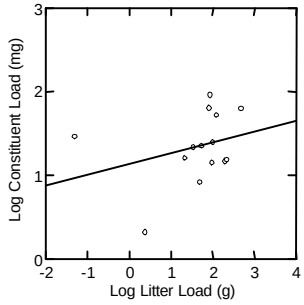
Units: mg

BMP: Litter Pick-Up

R^2 = 0.01



1-42

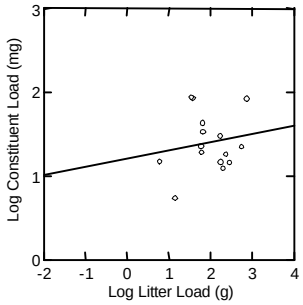


1-46

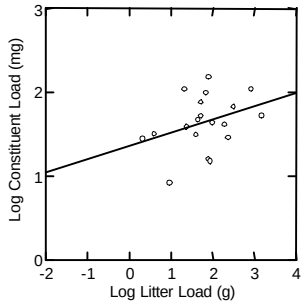
R^2 = 0.09

BMP: Street Sweeping

R^2 = 0.03



1-52

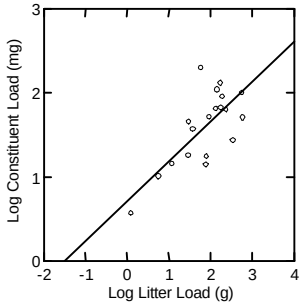


1-58

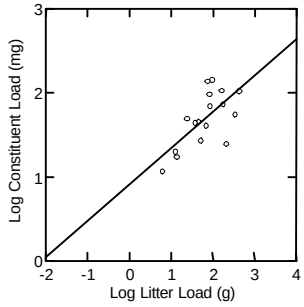
R^2 = 0.12

BMP: Modified Inlet

R^2 = 0.54



6-20E

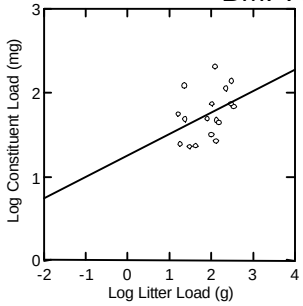


6-20F

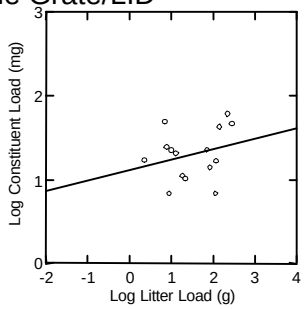
R^2 = 0.46

BMP: Bicycle Grate/LID

R^2 = 0.16



8-23C



8-B001

R^2 = 0.07

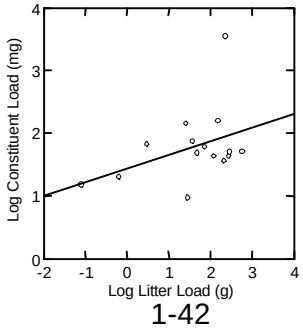
Water Quality Constituents Per Event Versus Litter Per Event

Nickel, Total

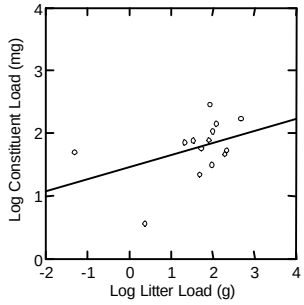
Units: mg

BMP: Litter Pick-Up

R^2 = 0.16



1-42

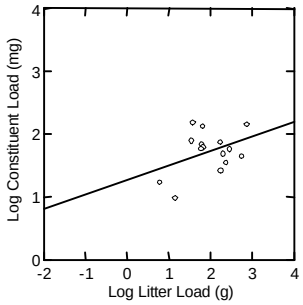


1-46

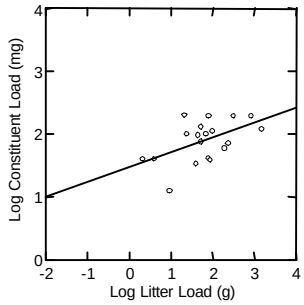
R^2 = 0.18

BMP: Street Sweeping

R^2 = 0.16



1-52

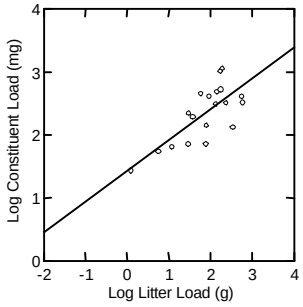


1-58

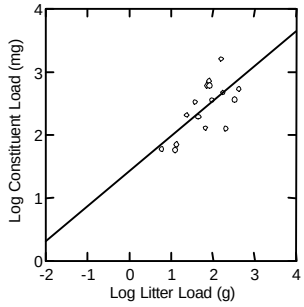
R^2 = 0.26

BMP: Modified Inlet

R^2 = 0.56



6-20E

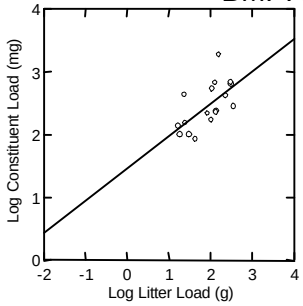


6-20F

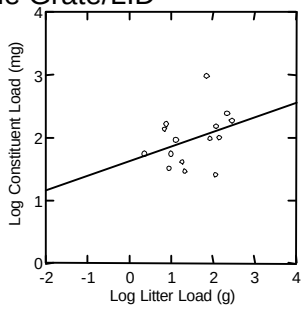
R^2 = 0.48

BMP: Bicycle Grate/LID

R^2 = 0.40



8-23C



8-B001

R^2 = 0.13

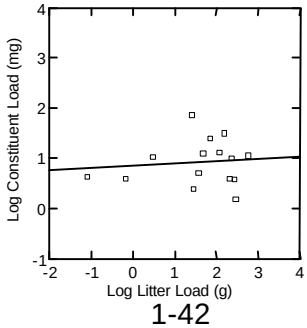
Water Quality Constituents Per Event Versus Litter Per Event

Lead, Dissolved

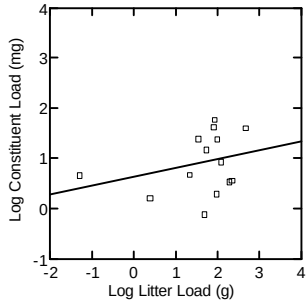
Units: mg

BMP: Litter Pick-Up

R^2 = 0.01



1-42

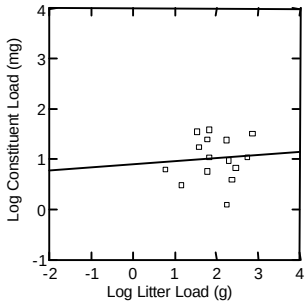


1-46

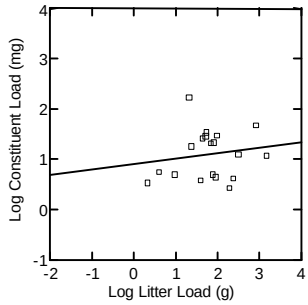
R^2 = 0.09

BMP: Street Sweeping

R^2 = 0.01



1-52

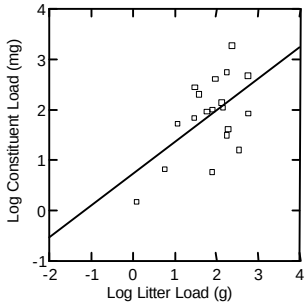


1-58

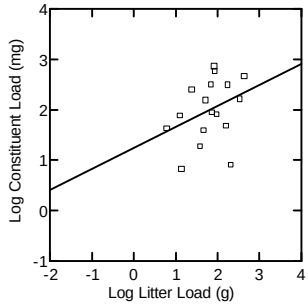
R^2 = 0.03

BMP: Modified Inlet

R^2 = 0.31



6-20E

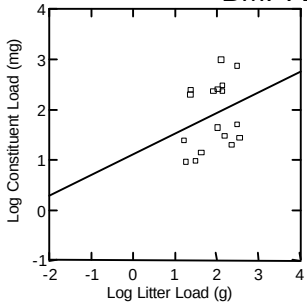


6-20F

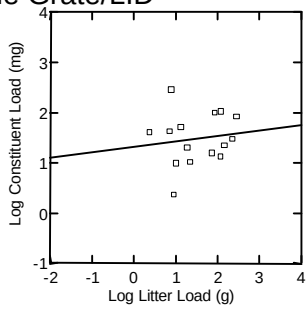
R^2 = 0.12

BMP: Bicycle Grate/LID

R^2 = 0.08



8-23C



8-B001

R^2 = 0.02

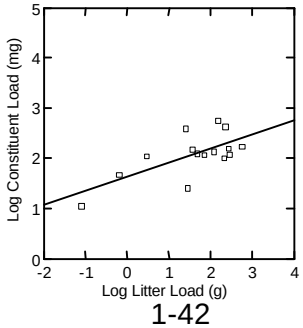
Water Quality Constituents Per Event Versus Litter Per Event

Lead, Total

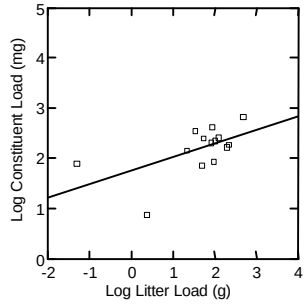
Units: mg

BMP: Litter Pick-Up

R^2 = 0.47



1-42

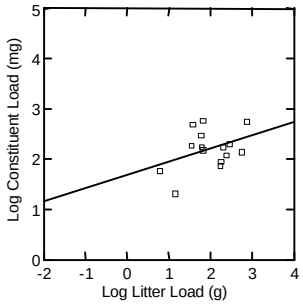


1-46

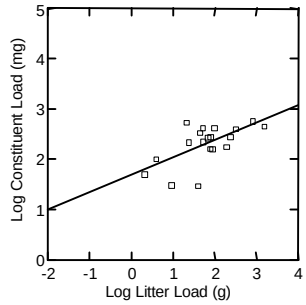
R^2 = 0.33

BMP: Street Sweeping

R^2 = 0.15



1-52

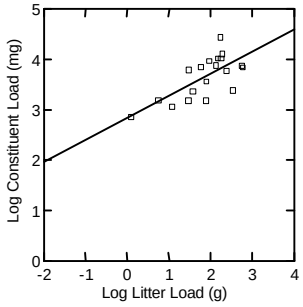


1-58

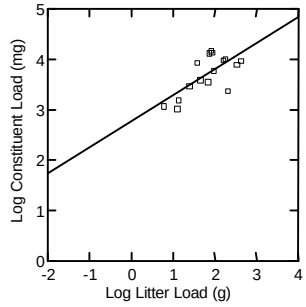
R^2 = 0.39

BMP: Modified Inlet

R^2 = 0.50



6-20E

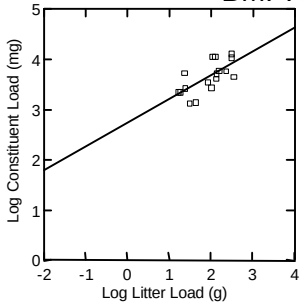


6-20F

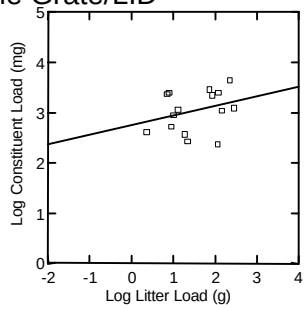
R^2 = 0.48

BMP: Bicycle Grate/LID

R^2 = 0.47



8-23C



8-B001

R^2 = 0.09

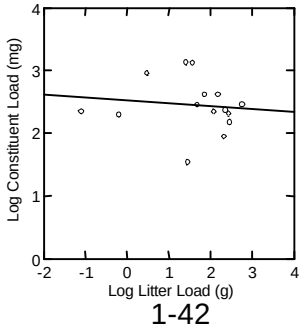
Water Quality Constituents Per Event Versus Litter Per Event

Zinc, Dissolved

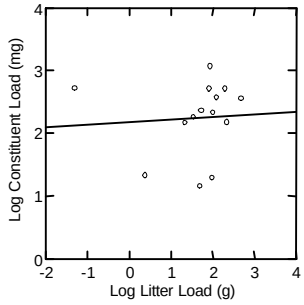
Units: mg

BMP: Litter Pick-Up

R^2 = 0.01



1-42

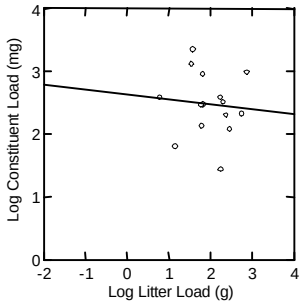


1-46

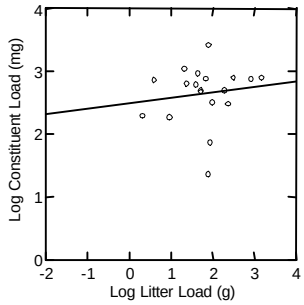
R^2 = 0.01

BMP: Street Sweeping

R^2 = 0.01



1-52

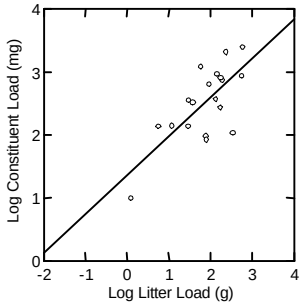


1-58

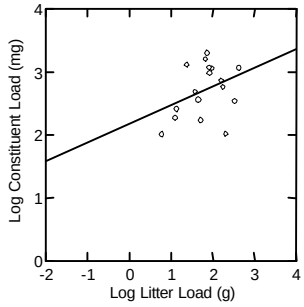
R^2 = 0.02

BMP: Modified Inlet

R^2 = 0.52



6-20E

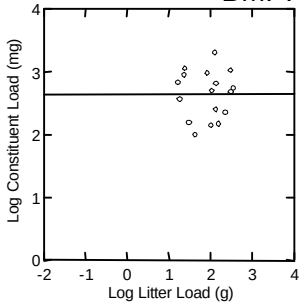


6-20F

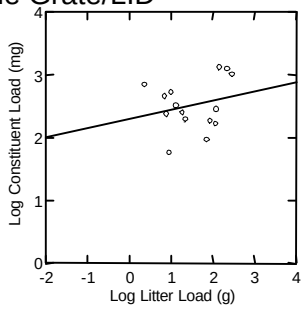
R^2 = 0.13

BMP: Bicycle Grate/LID

R^2 = 0.00



8-23C



8-B001

R^2 = 0.06

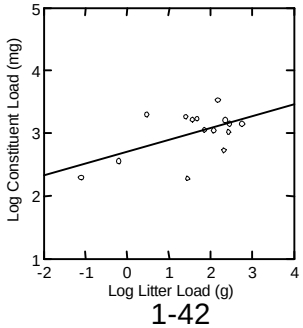
Water Quality Constituents Per Event Versus Litter Per Event

Zinc, Total

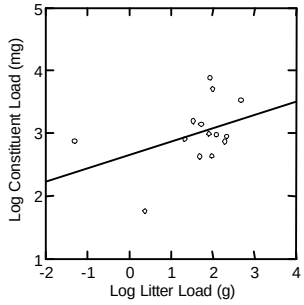
Units: mg

BMP: Litter Pick-Up

R^2 = 0.30



1-42

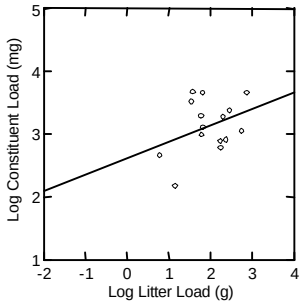


1-46

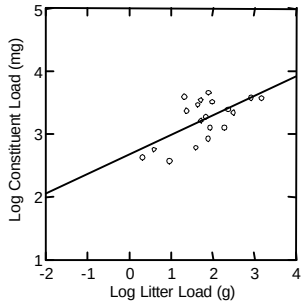
R^2 = 0.17

BMP: Street Sweeping

R^2 = 0.13



1-52

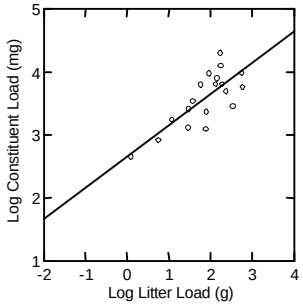


1-58

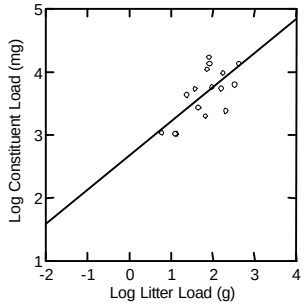
R^2 = 0.40

BMP: Modified Inlet

R^2 = 0.61



6-20E

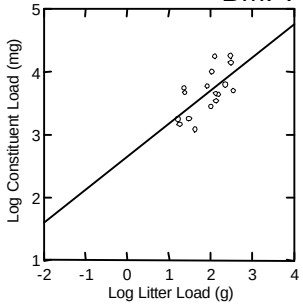


6-20F

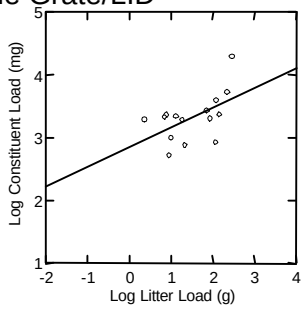
R^2 = 0.47

BMP: Bicycle Grate/LID

R^2 = 0.43



8-23C



8-B001

R^2 = 0.28

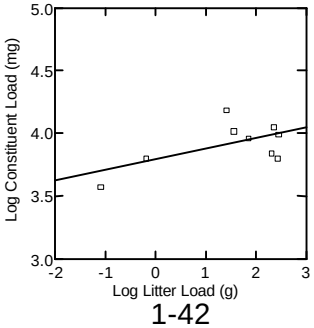
Water Quality Constituents Per Event Versus Litter Per Event

Nitrate Nitrogen 199

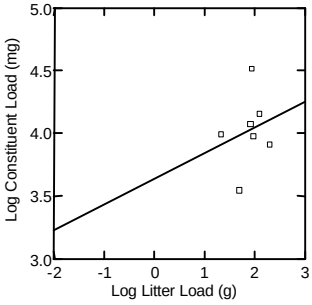
Units: mg

BMP: Litter Pick-Up

R^2 = 0.36



1-42

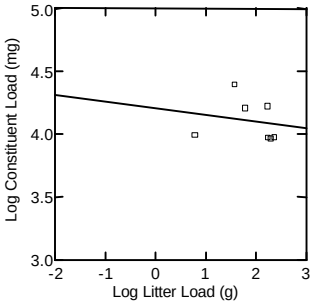


1-46

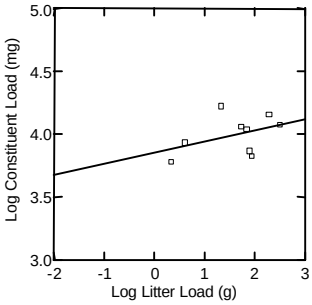
R^2 = 0.05

BMP: Street Sweeping

R^2 = 0.03



1-52

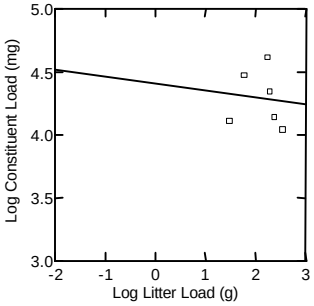


1-58

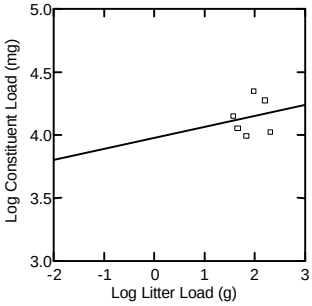
R^2 = 0.18

BMP: Modified Inlet

R^2 = 0.01



6-20E

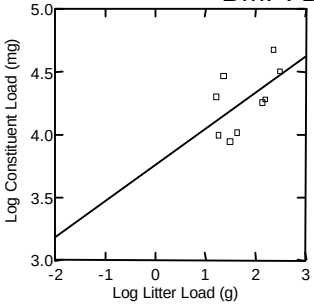


6-20F

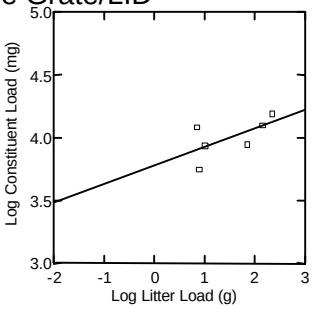
R^2 = 0.03

BMP: Bicycle Grate/LID

R^2 = 0.33



8-23C



8-B001

R^2 = 0.40

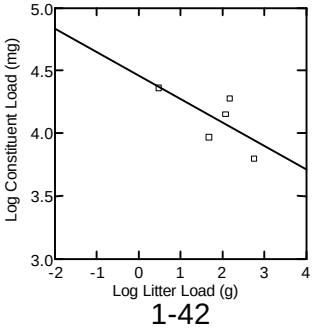
Water Quality Constituents Per Event Versus Litter Per Event

Nitrate Nitrogen 199

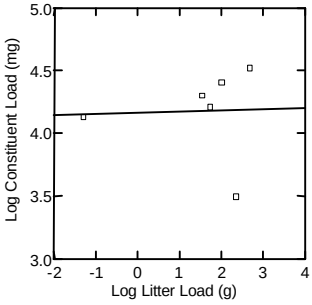
Units: mg

BMP: Litter Pick-Up

R^2 = 0.48



1-42

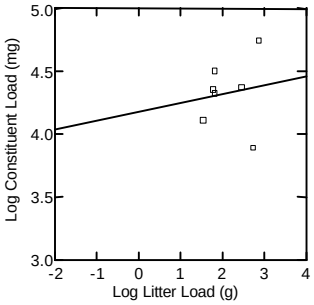


1-46

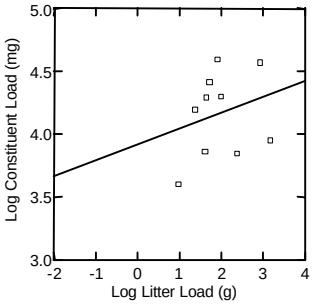
R^2 = 0.00

BMP: Street Sweeping

R^2 = 0.02



1-52

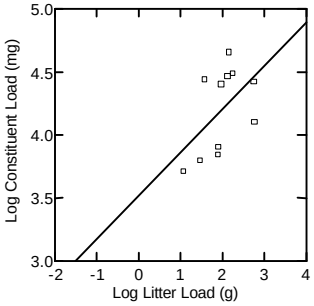


1-58

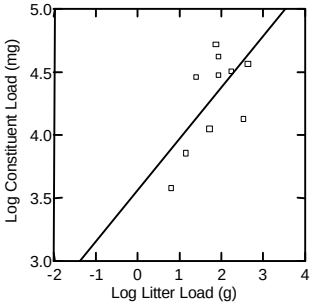
R^2 = 0.07

BMP: Modified Inlet

R^2 = 0.27



6-20E

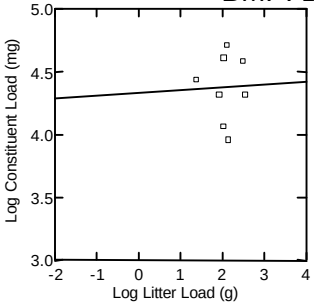


6-20F

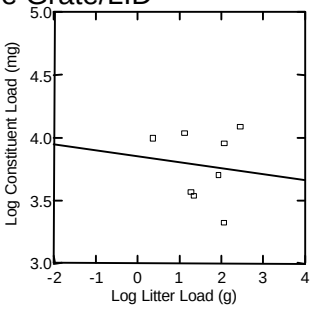
R^2 = 0.41

BMP: Bicycle Grate/LID

R^2 = 0.00



8-23C



8-B001

R^2 = 0.01

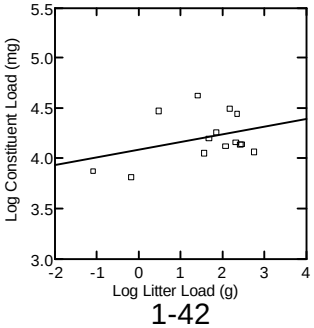
Water Quality Constituents Per Event Versus Litter Per Event

Total Kjedhal Nitrog

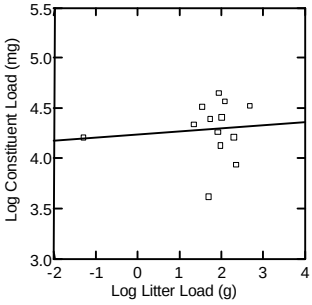
Units: mg

BMP: Litter Pick-Up

R^2 = 0.13



1-42

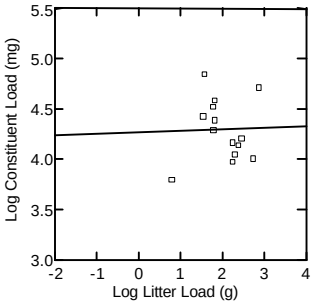


1-46

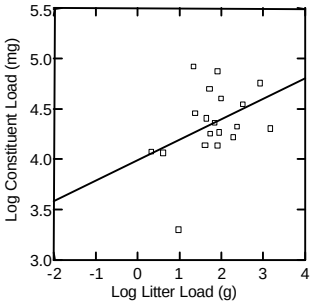
R^2 = 0.01

BMP: Street Sweeping

R^2 = 0.00



1-52

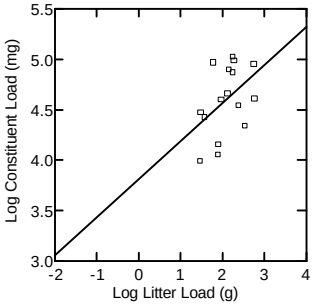


1-58

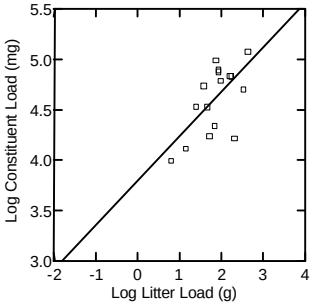
R^2 = 0.16

BMP: Modified Inlet

R^2 = 0.20



6-20E

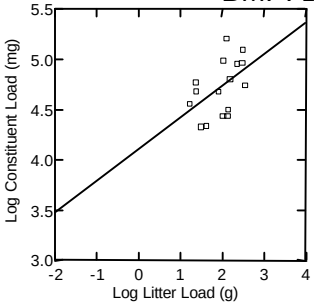


6-20F

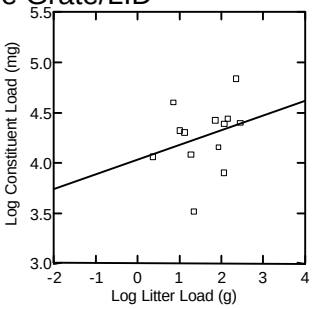
R^2 = 0.41

BMP: Bicycle Grate/LID

R^2 = 0.24



8-23C



8-B001

R^2 = 0.08

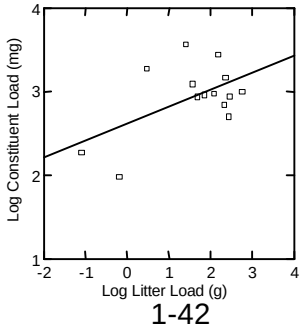
Water Quality Constituents Per Event Versus Litter Per Event

Ortho-Phosphorus

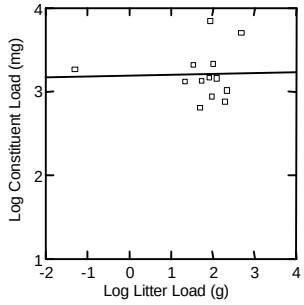
Units: mg

BMP: Litter Pick-Up

R^2 = 0.29



1-42

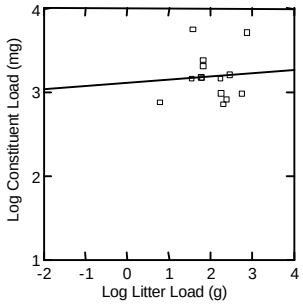


1-46

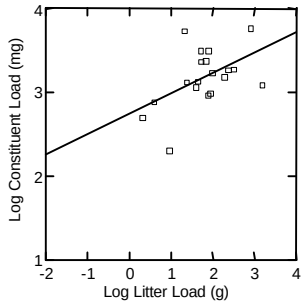
R^2 = 0.00

BMP: Street Sweeping

R^2 = 0.01



1-52

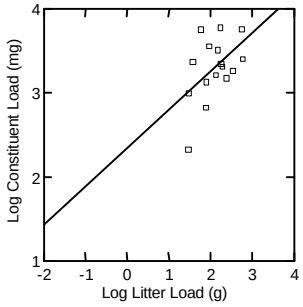


1-58

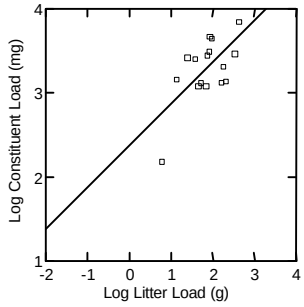
R^2 = 0.25

BMP: Modified Inlet

R^2 = 0.25



6-20E

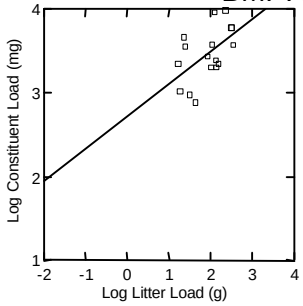


6-20F

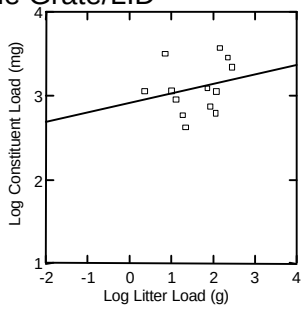
R^2 = 0.42

BMP: Bicycle Grate/LID

R^2 = 0.29



8-23C



8-B001

R^2 = 0.06

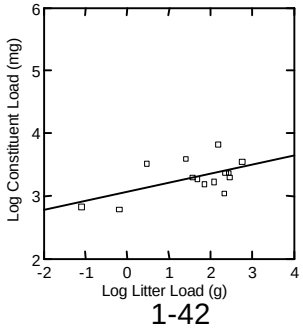
Water Quality Constituents Per Event Versus Litter Per Event

Total Phosphorus

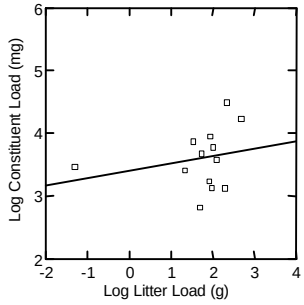
Units: mg

BMP: Litter Pick-Up

R^2 = 0.32



1-42

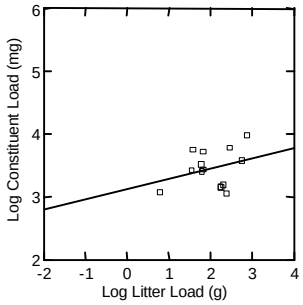


1-46

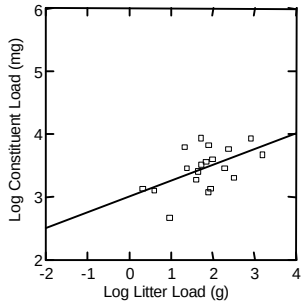
R^2 = 0.06

BMP: Street Sweeping

R^2 = 0.09



1-52

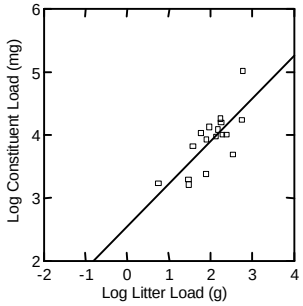


1-58

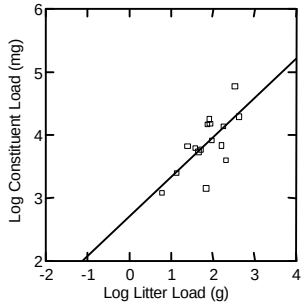
R^2 = 0.28

BMP: Modified Inlet

R^2 = 0.58



6-20E

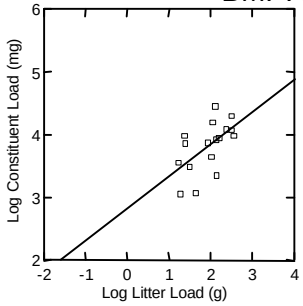


6-20F

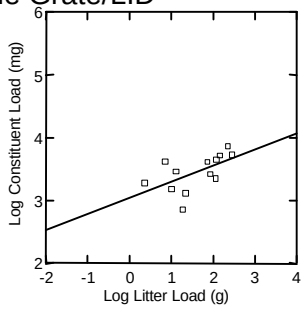
R^2 = 0.49

BMP: Bicycle Grate/LID

R^2 = 0.34



8-23C



8-B001

R^2 = 0.33

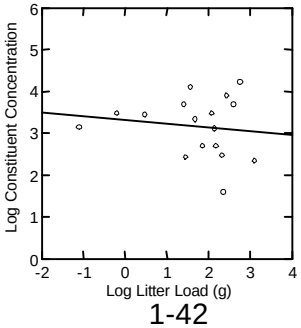
Water Quality Constituents Per Event Versus Litter Per Event

Coliforms, Total

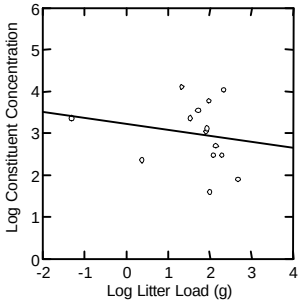
Units: MPN/100 ml

BMP: Litter Pick-Up

R^2 = 0.02



1-42

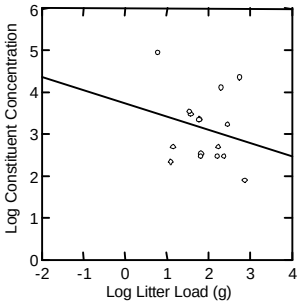


1-46

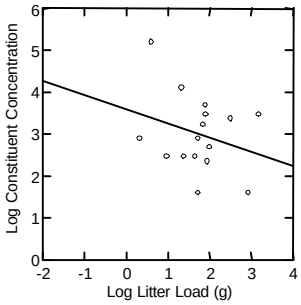
R^2 = 0.04

BMP: Street Sweeping

R^2 = 0.05



1-52

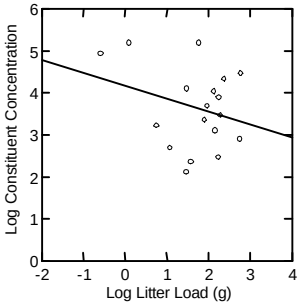


1-58

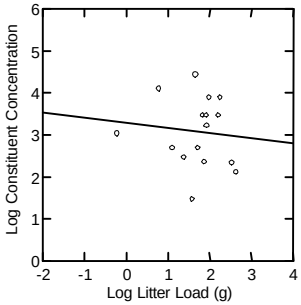
R^2 = 0.08

BMP: Modified Inlet

R^2 = 0.08



6-20E

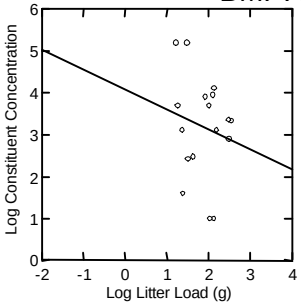


6-20F

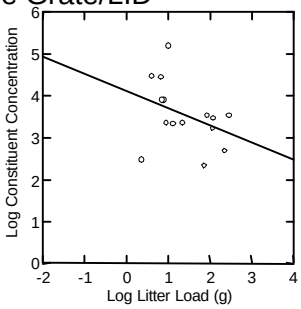
R^2 = 0.01

BMP: Bicycle Grate/LID

R^2 = 0.03



8-23C



8-B001

R^2 = 0.13

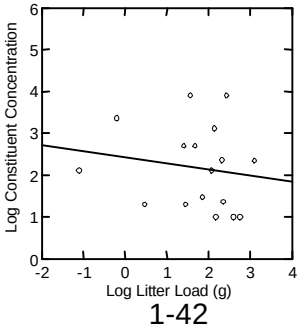
Water Quality Constituents Per Event Versus Litter Per Event

Coliforms, Fecal

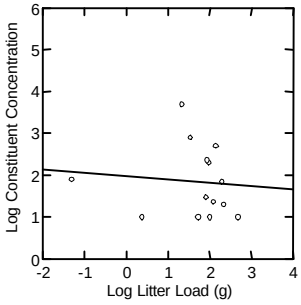
Units: MPN/100 ml

BMP: Litter Pick-Up

R^2 = 0.02



1-42

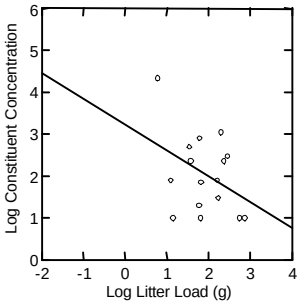


1-46

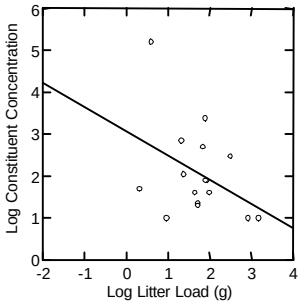
R^2 = 0.01

BMP: Street Sweeping

R^2 = 0.15



1-52

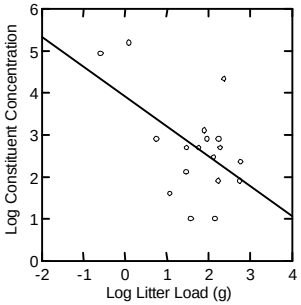


1-58

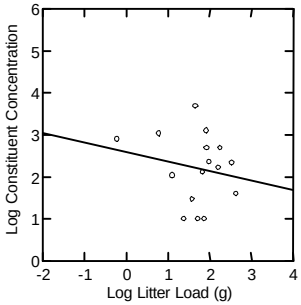
R^2 = 0.16

BMP: Modified Inlet

R^2 = 0.29



6-20E

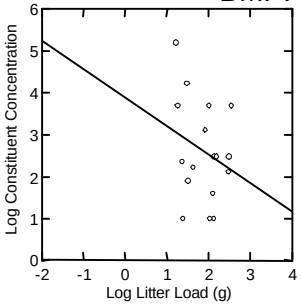


6-20F

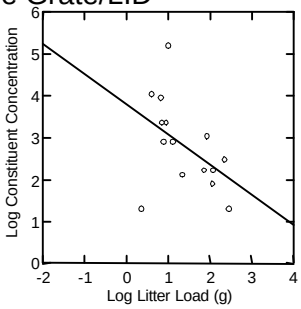
R^2 = 0.04

BMP: Bicycle Grate/LID

R^2 = 0.06



8-23C



8-B001

R^2 = 0.21

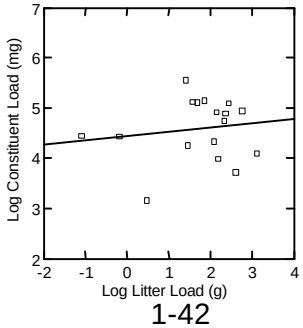
Water Quality Constituents Per Event Versus Litter Per Event

TPH (Diesel)

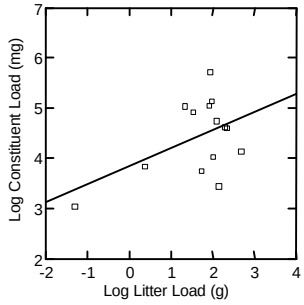
Units: mg

BMP: Litter Pick-Up

R^2 = 0.02



1-42

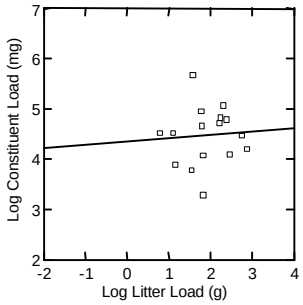


1-46

R^2 = 0.23

BMP: Street Sweeping

R^2 = 0.00



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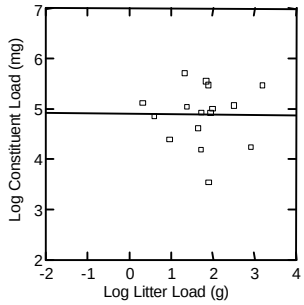
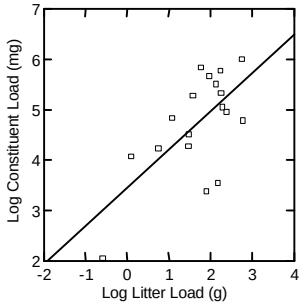


1-58

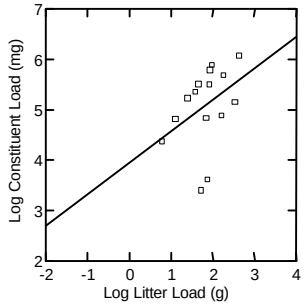
R^2 = 0.00

BMP: Modified Inlet

R^2 = 0.44



6-20E

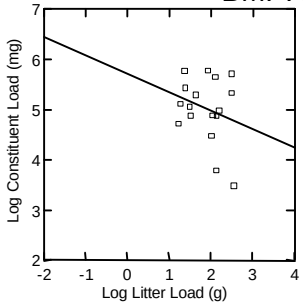


6-20F

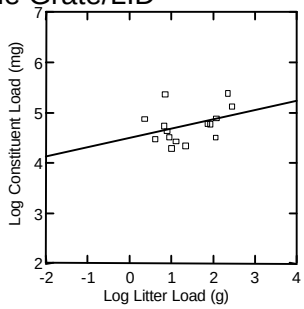
R^2 = 0.15

BMP: Bicycle Grate/LID

R^2 = 0.06



8-23C



8-B001

R^2 = 0.13

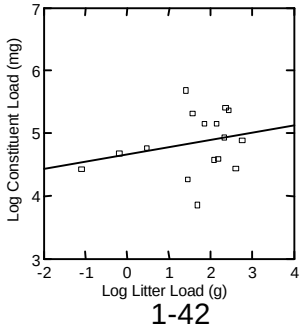
Water Quality Constituents Per Event Versus Litter Per Event

Oil & Grease

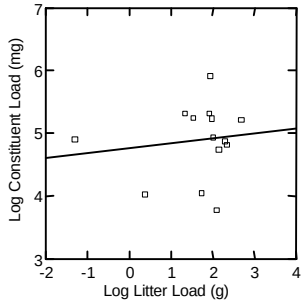
Units: mg

BMP: Litter Pick-Up

R^2 = 0.06



1-42

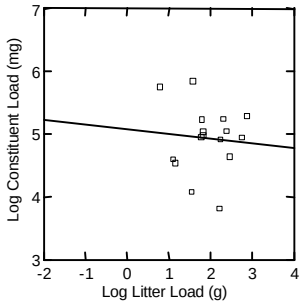


1-46

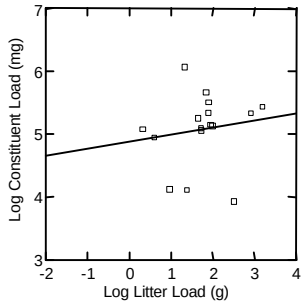
R^2 = 0.02

BMP: Street Sweeping

R^2 = 0.01



1-52

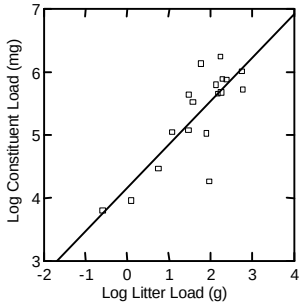


1-58

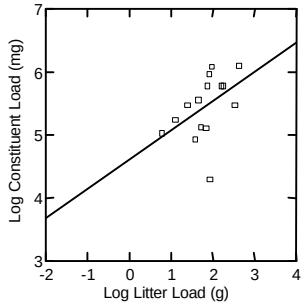
R^2 = 0.02

BMP: Modified Inlet

R^2 = 0.66



6-20E

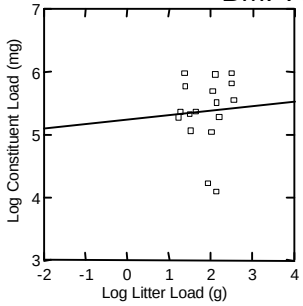


6-20F

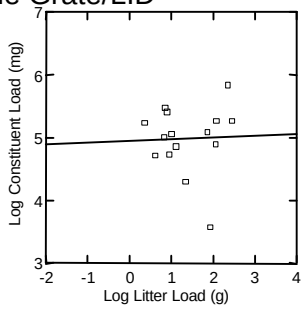
R^2 = 0.21

BMP: Bicycle Grate/LID

R^2 = 0.00



8-23C



8-B001

R^2 = 0.00

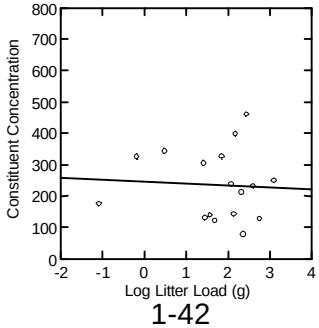
Water Quality Constituents Per Event Versus Litter Per Event

Conductivity

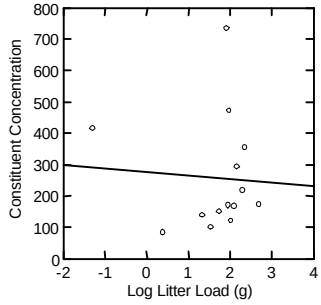
Units: umhos/cm

BMP: Litter Pick-Up

R^2 = 0.00



1-42

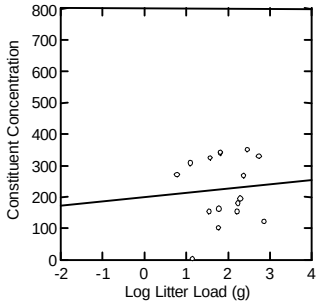


1-46

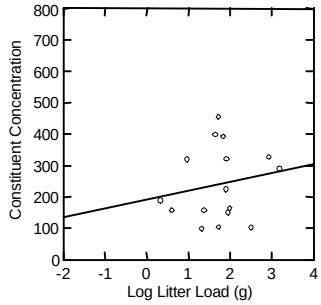
R^2 = 0.00

BMP: Street Sweeping

R^2 = 0.01



1-52

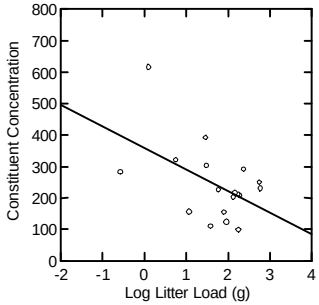


1-58

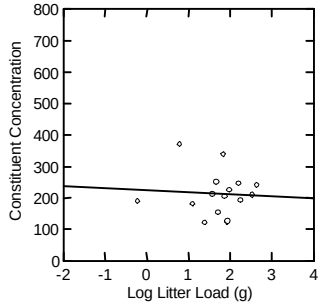
R^2 = 0.03

BMP: Modified Inlet

R^2 = 0.25



6-20E

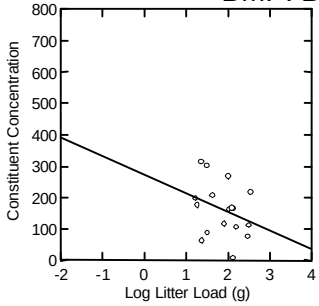


6-20F

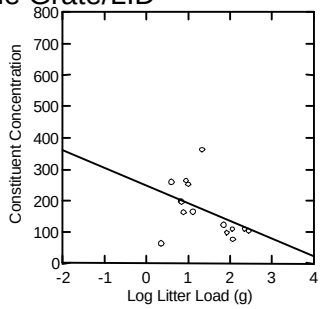
R^2 = 0.00

BMP: Bicycle Grate/LID

R^2 = 0.10



8-23C



8-B001

R^2 = 0.20

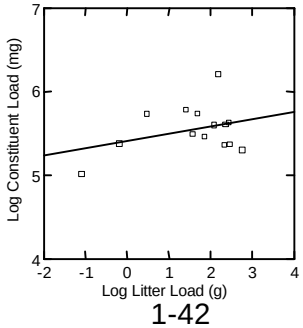
Water Quality Constituents Per Event Versus Litter Per Event

Hardness as $CaCO_3$

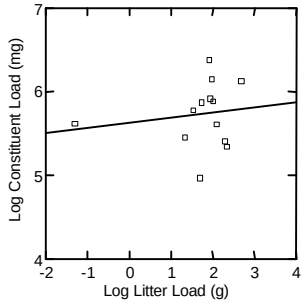
Units: mg

BMP: Litter Pick-Up

R^2 = 0.12



1-42

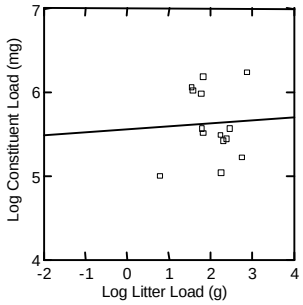


1-46

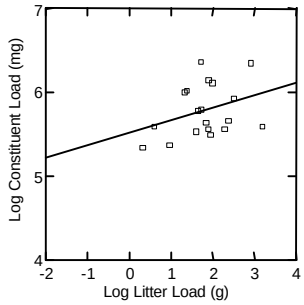
R^2 = 0.02

BMP: Street Sweeping

R^2 = 0.00



1-52

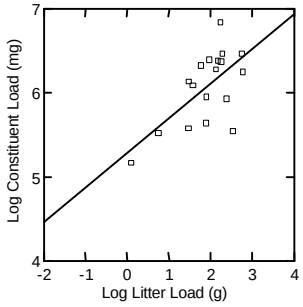


1-58

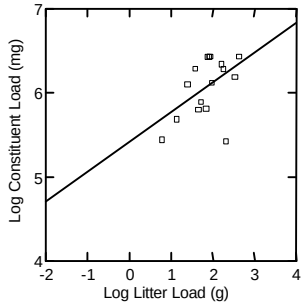
R^2 = 0.12

BMP: Modified Inlet

R^2 = 0.41



6-20E

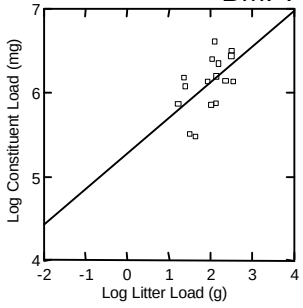


6-20F

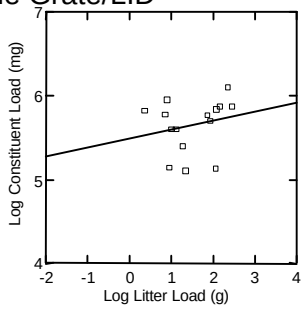
R^2 = 0.24

BMP: Bicycle Grate/LID

R^2 = 0.31



8-23C



8-B001

R^2 = 0.05

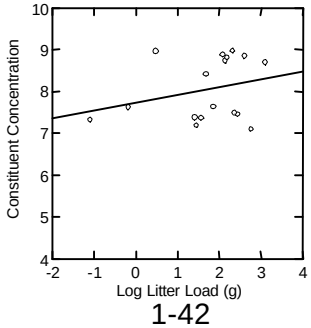
Water Quality Constituents Per Event Versus Litter Per Event

pH

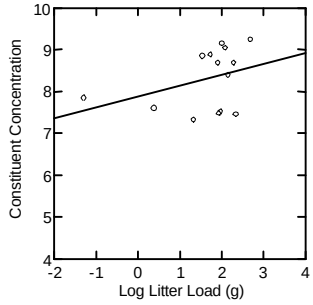
Units: pH units

BMP: Litter Pick-Up

R^2 = 0.07



1-42

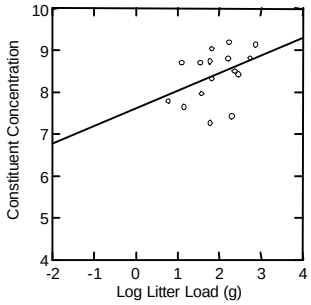


1-46

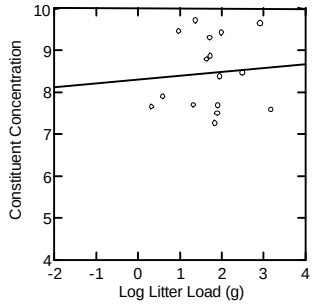
R^2 = 0.13

BMP: Street Sweeping

R^2 = 0.17



1-52

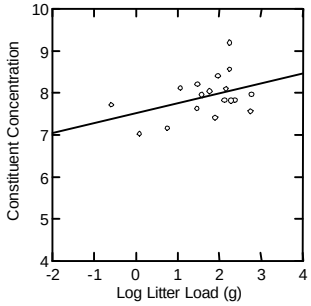


1-58

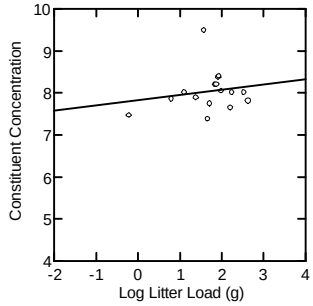
R^2 = 0.01

BMP: Modified Inlet

R^2 = 0.17



6-20E

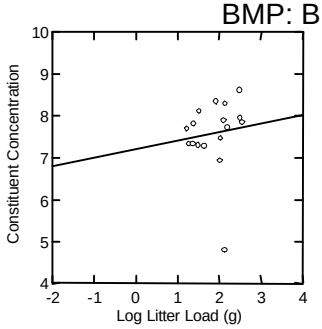


6-20F

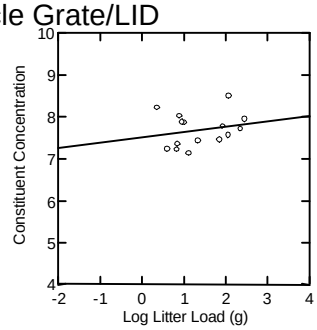
R^2 = 0.03

BMP: Bicycle Grate/LID

R^2 = 0.01



8-23C



8-B001

R^2 = 0.05

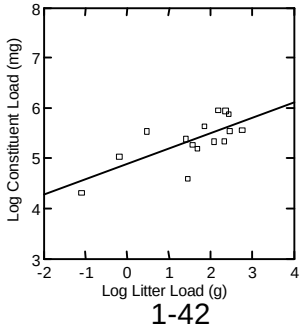
Water Quality Constituents Per Event Versus Litter Per Event

Total Suspended So

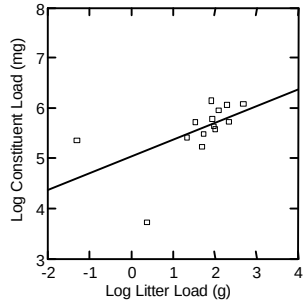
Units: mg

BMP: Litter Pick-Up

R^2 = 0.51



1-42

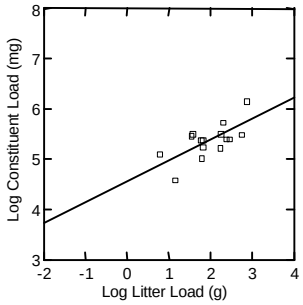


1-46

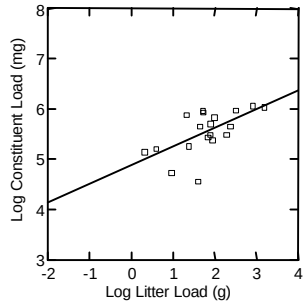
R^2 = 0.31

BMP: Street Sweeping

R^2 = 0.47



1-52

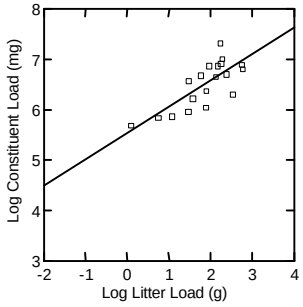


1-58

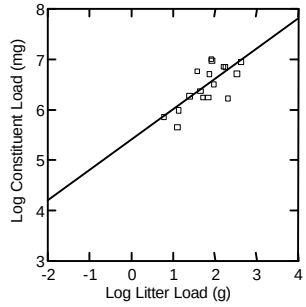
R^2 = 0.38

BMP: Modified Inlet

R^2 = 0.59



6-20E

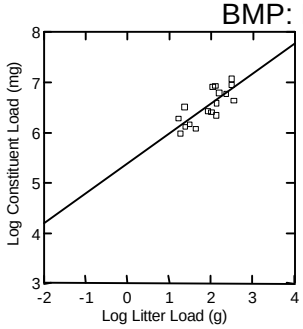


6-20F

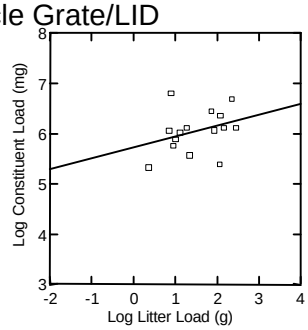
R^2 = 0.54

BMP: Bicycle Grate/LID

R^2 = 0.62



8-23C



8-B001

R^2 = 0.11

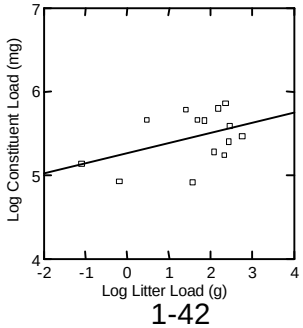
Water Quality Constituents Per Event Versus Litter Per Event

Total Volatile Solids

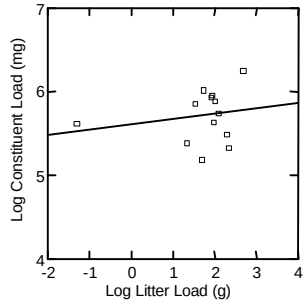
Units: mg

BMP: Litter Pick-Up

R^2 = 0.18



1-42

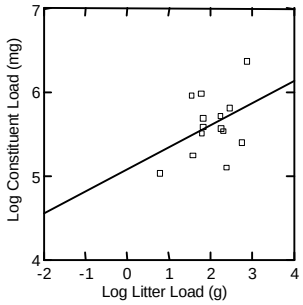


1-46

R^2 = 0.04

BMP: Street Sweeping

R^2 = 0.16



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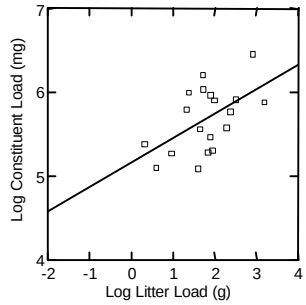
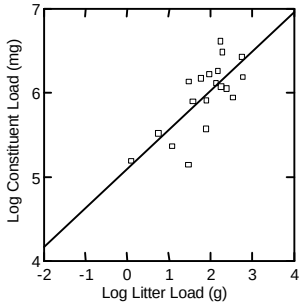


1-58

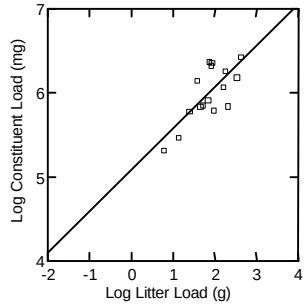
R^2 = 0.29

BMP: Modified Inlet

R^2 = 0.56



6-20E

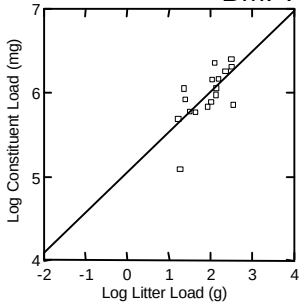


6-20F

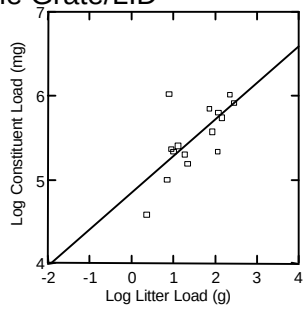
R^2 = 0.54

BMP: Bicycle Grate/LID

R^2 = 0.46



8-23C



8-B001

R^2 = 0.49

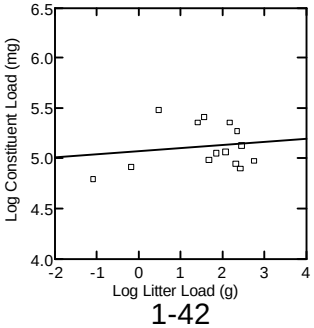
Water Quality Constituents Per Event Versus Litter Per Event

Total Organic Carbo

Units: mg

BMP: Litter Pick-Up

R^2 = 0.03



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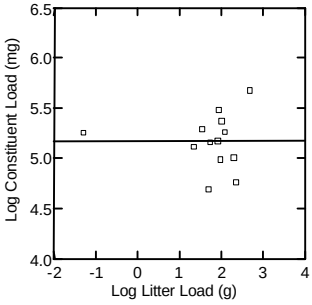
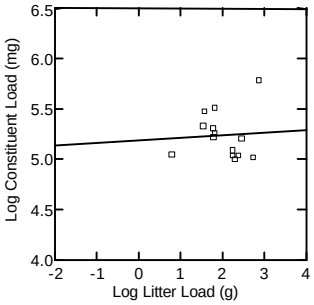


1-46

R^2 = 0.00

BMP: Street Sweeping

R^2 = 0.00



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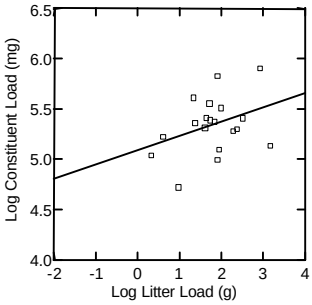
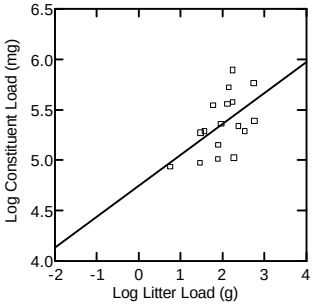


1-58

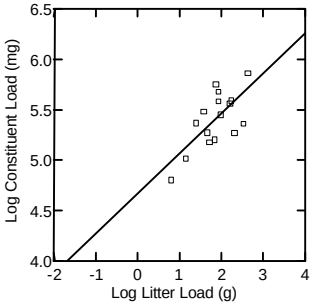
R^2 = 0.13

BMP: Modified Inlet

R^2 = 0.29



6-20E

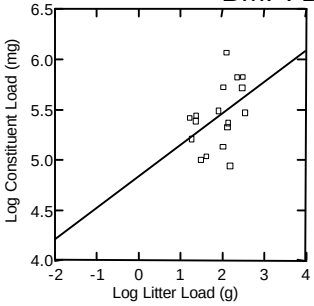


6-20F

R^2 = 0.48

BMP: Bicycle Grate/LID

R^2 = 0.20



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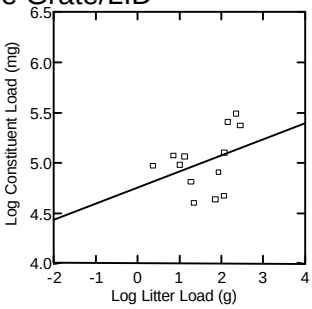


8-B001

R^2 = 0.13

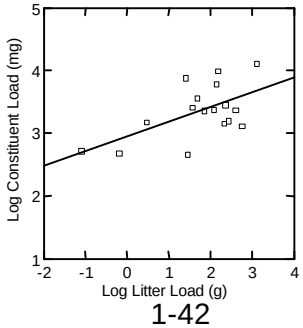
Water Quality Constituents Per Event Versus Litter Per Event

TPH (Gasoline)

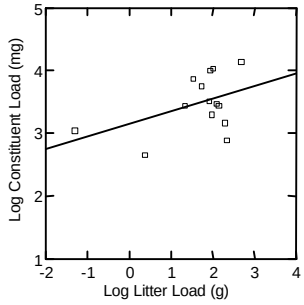
Units: mg

BMP: Litter Pick-Up

R^2 = 0.35



1-42

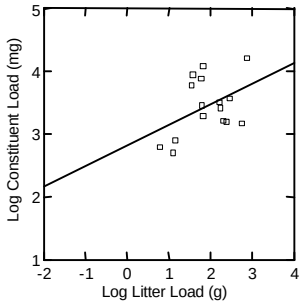


1-46

R^2 = 0.21

BMP: Street Sweeping

R^2 = 0.19



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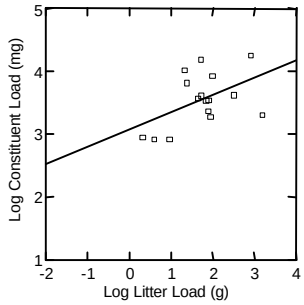
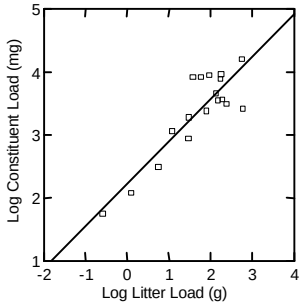


1-58

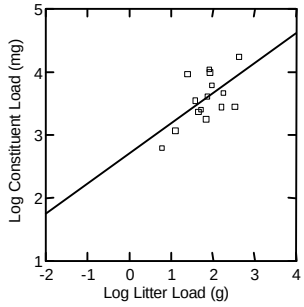
R^2 = 0.23

BMP: Modified Inlet

R^2 = 0.78



6-20E

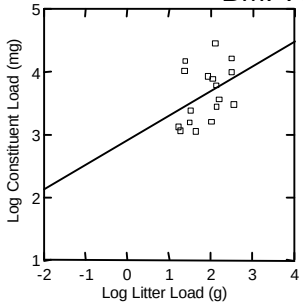


6-20F

R^2 = 0.36

BMP: Bicycle Grate/LID

R^2 = 0.15



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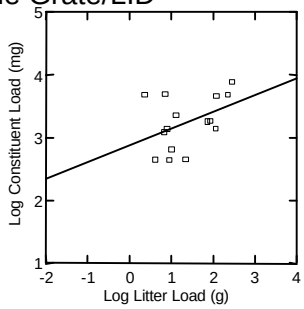

8-B001

R^2 = 0.18

Litter Inlet Deflector Feasibility Study Report

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Lee-Hyung Kim
Haejin Ha
Civil and Environmental Engineering Department
UCLA
May 16, 2000

Table of Contents

	Page
Introduction	3
Background	4
Test Protocol	11
Test Summary	11
Results and Discussion	13
Conclusions	16
Reference	16
Appendix	17
Tabular Results of Tests 2 through 18	
List of Figures	
Figure 1. Litter Inlet Deflector Test System with Vanes	6
Figure 2. Flume Showing Opening for Inlet Deflector	7
Figure 3. Flume Showing Inlet Deflector in Flume Opening	8
Figure 4. Litter Inlet Deflector with Bot Dots	10
Figure 5. Litter Inlet Deflector Efficiency versus Flow Rate for Various Conditions	14
Figure 6. Effect of Litter Inlet Deflector Angle for Various Conditions	15
Figure 7. Effect of Grooves, Slots and Tabs at 32 GPM	15
List of Tables	
Table 1. Test Summary	12
Table 2. Test 1 with 3 vanes and litter inlet deflector at 90 deg.	13

Introduction

Stormwater pollution has increased in importance over the past decade and it is now recognized as a greater source of many pollutants to receiving waters than point sources. Stormwater now transports more conventional pollutants to Santa Monica Bay than wastewater treatment plants (Wong et al., 1997). Landuses associated with vehicular activity, such as streets and highways are important sources of pollutants. Catch basins and stormwater inserts are the hydraulic devices that direct stormwater to stormdrains. Materials from highways, such as sediment, litter and debris travel through catch basins and inserts (both will be called inserts in this report) to receiving waters.

Southern California has distinct dry and wet periods. Typically there is no rain from April to November. During this dry period, sediment, litter and debris accumulate in inserts. The inserts must be cleaned or the accumulated material will be flushed into the environment during the first large storm. This in effect concentrates six to eight months' dry accumulation into a single discharge, called a "seasonal first flush." This large discharge magnifies the environmental impact of the pollutants. Large trash plumes along the shores of Santa Monica Bay are routinely observed after such events.

To avoid the negative impacts of the first seasonal flush, public agencies have adopted insert cleaning policies. For example, in the City of Santa Monica, inserts in sensitive areas, or areas of high pedestrian activity, may be cleaned twice per month; other inserts may only be cleaned yearly. When only annual cleaning is performed, it is most desirable to clean at the end of the dry season to remove the accumulated material before the first rain.

Catch basins along freeways are difficult to clean because of access and safety concerns. The crews that perform the cleaning must be protected from traffic. As a result, it may take three crews and several vehicles to create a cleaning team. Only one crew may perform the actual cleaning, while two crews direct traffic. This compares to city streets where cleaning teams can be composed of only one vehicle and two workers. In addition, cleaning disrupts traffic. Consequently cleaning may only be allowed at times of low freeway use.

In an effort to reduce cleaning cost, it is desirable to use alternative insert designs. Inserts that do not accumulate material in dry weather by passing sediment and debris are not a feasible alterative; there is no storm flow for transport. Also, this ignores an opportunity for environmental protection. An alternative is to develop inserts that are closed during dry periods. Debris would be retained on streets or shoulders where it could be removed by street sweepers.

A variant of this procedure has been used by the City of Santa Monica for several years. City crews cover the openings of inserts with plywood boards at the end of the rainy season. The boards are attached to curbs in such a way that a 0.5-inch gap exists to accommodate nuisance water flow. These boards effectively eliminate dry weather accumulation in inserts. They eliminate the need for summer cleaning and prevent putrefaction of accumulated material. Tests conducted by our research group showed that street sweepers remove material that accumulates

in front of the inserts and within the 0.5-inch gap below the board. Screens are also being evaluated for this purpose. The disadvantage of this technique is that the boards must be removed before the first winter storm. Unexpected rainstorms or failure to remove the boards may result in flood risk.

Preventing dry weather accumulation is attractive for several reasons. One is that street sweeping in most places is routinely performed. The additional removal of debris will only marginally increase cost. It is also easier to perform routine yearly maintenance than to implement an intensive maintenance program over one to two months. Finally, protection from accumulation is provided for the periods between storms, which may be as long as one month.

Installing and removing boards such as the Santa Monica Boards are expensive and inconvenient for CalTrans due to the additional cost freeway access and traffic control. A permanent insert cover that can be hydraulically operated was proposed by CalTrans and designed by URS in 1999. UCLA was asked to test prototypes in its full-scale catch basin and flume. This facility was constructed in an earlier project with the City of Santa Monica and the Santa Monica Bay Restoration Project. We have evaluated more than 12 different insert devices and one CDS unit in this laboratory. This report describes the testing program.

Background

CalTrans and URS proposed a "flap gate" or "litter inlet deflector" design in 1999. This design uses a hinged deflector that is kept closed by gravity and forced open by the hydraulic action of storm flows. The deflector is used with a sheet metal cover that transforms an existing insert from a top entering design to a side or curb entering design.

To evaluate the concept, two prototypes were constructed. The first was a modification of the UCLA's existing flume and was performed to test the concept. We cut a 12.5-inch wide opening into our existing flume. A piece of 12-inch wide sheet material with 0.5 inch steel rod formed the deflector and hinge. Various flow rates, deflector angles, deflector materials (aluminum, plastic, fiberglass, etc) and flow deflectors were qualitatively evaluated. Observations and qualitative measurements were made. Suggestions to improve the field prototypes were also made. The first prototype was valuable in that it provided early evidence that the insert deflector concept was feasible, and that the presence of flow deflectors was an important concept in the success of the design.

The second prototype benefited from experience with the first prototype, and used moving parts that were virtually identical to the field devices being evaluated by CalTrans. A new flume had to be constructed to accommodate the second prototype.

Figure 1 shows the testing system for the second prototype. The top and middle portions of the figure are plan and section views, respectively. The lower part of the figure shows details of the deflector and flow director designs.

City water is used for testing. The flume is connected by 3-inch diameter pipe to an isolated water supply that is protected from cross connections. Water flows to a stilling chamber and is controlled by an isolation valve (not shown) and a control valve. High flows rates are measured by an ultrasonic flow measuring device (not shown); low flow rates, used for virtually all the experiments described in this report, are measured by a paddle wheel flow meter (Cole Palmer). The operating range of the flume is approximately 15 to 175 gallons per minute (GPM). A larger range is possible with replumbing but was not necessary for these experiments.

The pipe size is reduced to 2-inch diameter and flows through a "tee" which accommodates the paddle wheel flow meter. After the flow meter, the water enters the stilling tank. The stilling tank dissipates the water pressure and removes velocity currents. The water flows under, over and under three baffles (better seen from the elevation view in the middle of Figure 1). Finally, the water enters the flume.

The flume is 25 inches wide and has a perpendicular slope of 1-inch per 24-inches or 4.2%. This slope simulates the slope of the shoulder of a roadway, and has been used consistently in our testing. Flow proceeds down the flume to the deflector and catch basin. There is no slope along the flume. The slope is provided by water elevation (i.e., the water level in the stilling basin rises to create sufficient head to flow to the catch basin).

The deflector is cut into the left side of the flume. Figures 2 and 3 show the flume opening and inlet deflector. The deflector is hinged at the top using a hollow 0.5-inch OD Teflon tube. A 3/8-inch diameter aluminum dowel is inserted through the center of the Teflon tube to provide support. The dowel is secured at each end to the flume wall. The deflector has two semi-circular hinges that partially wrap the outside of the Teflon tube. The deflector is free to swing around the Teflon tube through movement of the semi-circular hinges relative to Teflon tube, as well as the Teflon tube relative to the aluminum dowel. The second degree of freedom was provided in anticipation of dust or other debris interfering with the circular hinges. During this study, movement always occurred between the hinges and Teflon tube, which probably results because the surface area of contact is less (i.e., less friction).

The top of the deflector is secured using movable pillow blocks. The pillow blocks can be moved back and forth to allow different resting angles to be created. In this manner, the deflector angle can be changed from vertical to approximately 60 degrees (top sloping toward the flume). Various "set back" distances can be used as well. The deflector can be set so that the bottom of the deflector rests against the edge of the flume, which means the top of the deflector extends into the flume at deflector angles less than 90. Aluminum angles were constructed to allow the bottom of the flume edge to extend outward 1 or 2 inches. When these spacers were used, the deflector hinge is not required to rest above the flume with non-zero deflector angles.

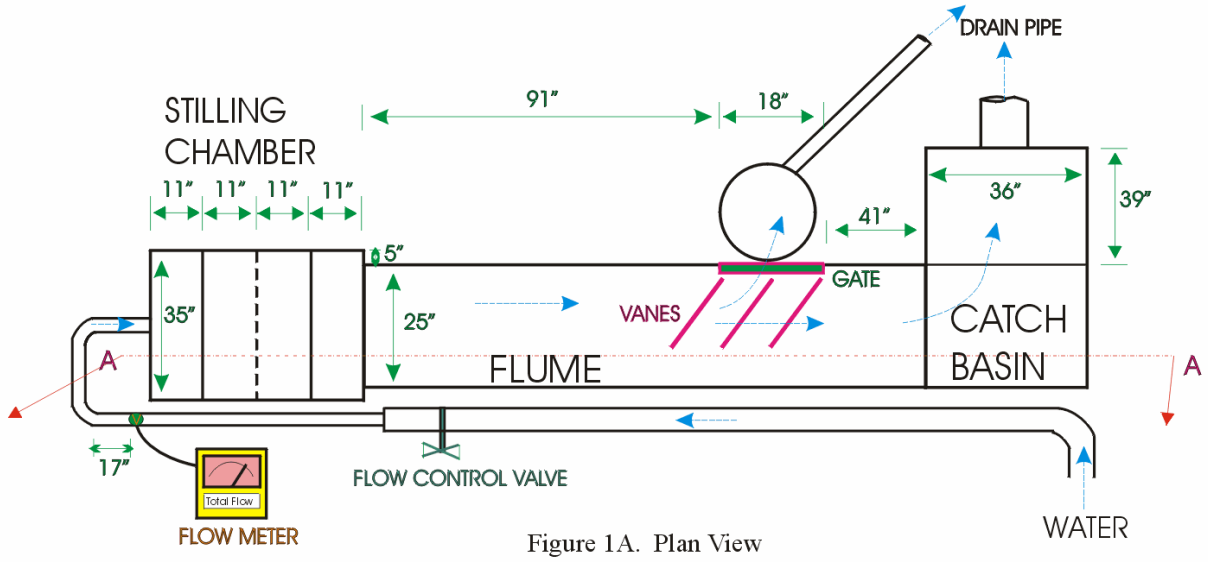


Figure 1A. Plan View

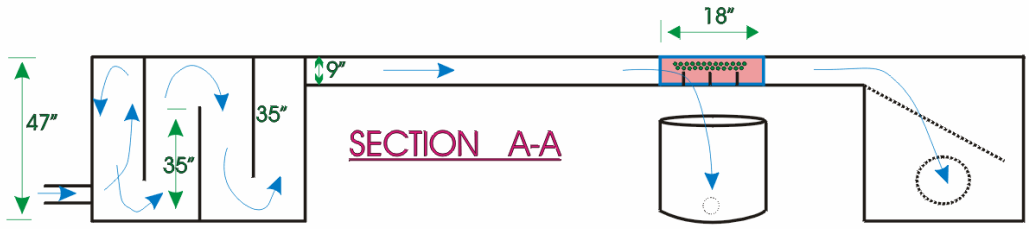


Figure 1B. Elevation View (Section A-A)

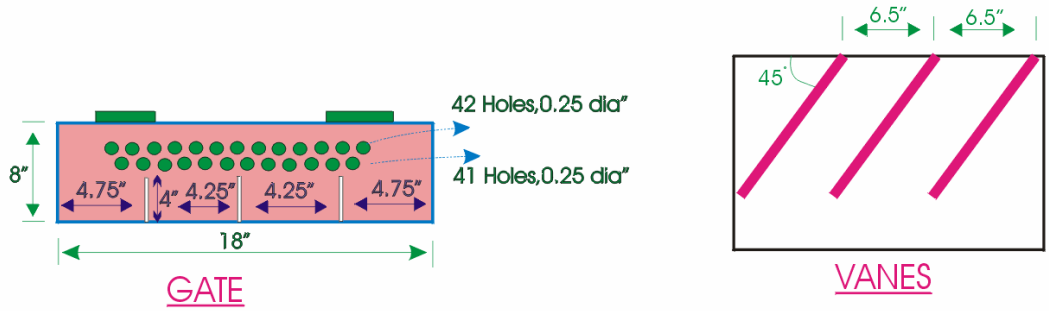


Figure 1C. Deflector and Vane Details

Figure 1. Litter Inlet Deflector Test System with Vanes

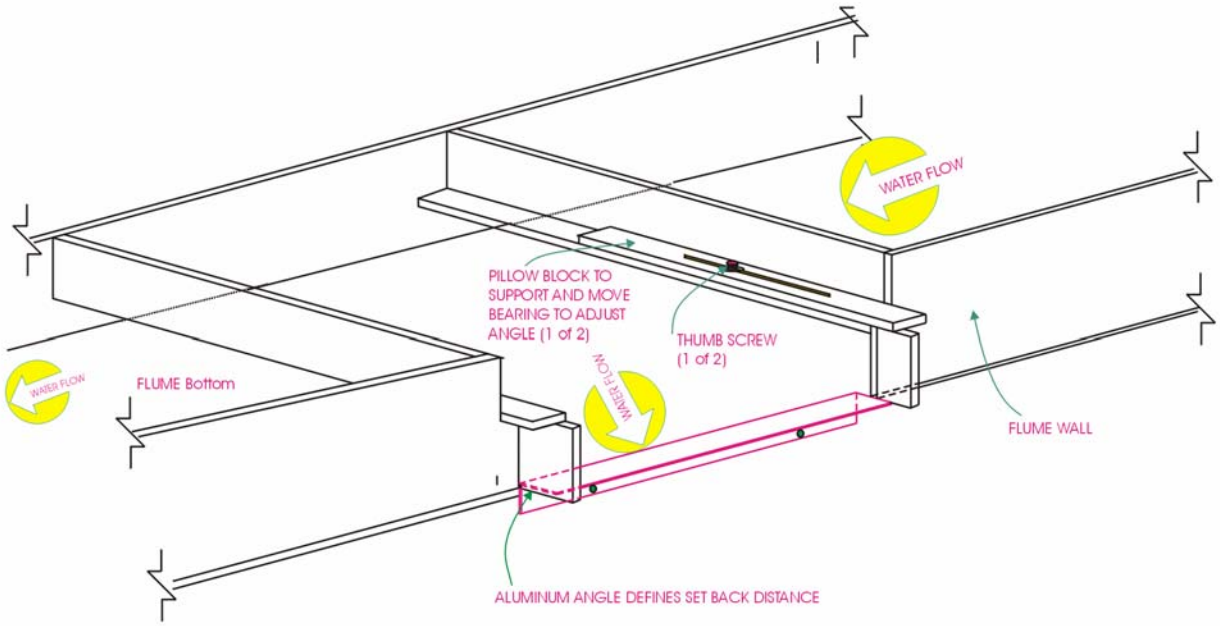


Figure 2. Flume Showing Opening for Inlet Deflector

Figure 2. Flume Showing Opening for Inlet Deflector

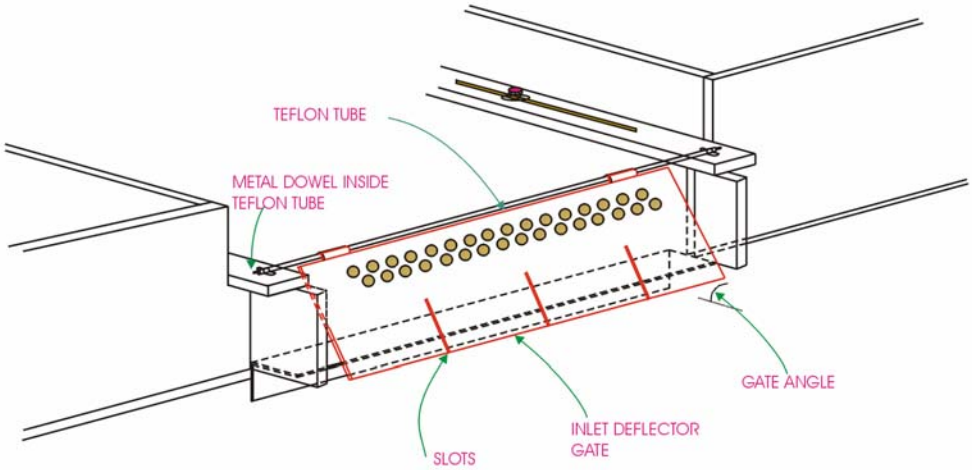


Figure 3. Flume Showing Inlet Deflector in Flume Opening

Figure 3. Flume Showing Litter Inlet Deflector in Flume Opening

The deflectors were constructed of 1/8-inch thick aluminum. This deflector size represents the smallest of the full-scale deflectors used in the field studies. Holes, 0.25 inches in diameter, were drilled in the top of the deflector to reduce weight and the center of gravity. The holes were specified by URS. Slots were also cut into the deflector to allow nuisance water to pass through the deflector without requiring the deflector to open. In the first designs, circular holes were specified, but slots were chosen to avoid clogging. Deflectors were constructed with slots that penetrated the deflector and grooves that created a vertical water path but did not penetrate the deflector. Grooves and slots were evaluated because water can pass through the slots, reducing the force to open the deflector. Experiments were performed with grooves, slots and taped slots.

Water flowing through the deflector was trapped in a plastic tank. The tank had a 1.5-inch diameter PVC pipe outlet. The pipe was connected to the tank with a short length of flexible hose. If the pipe is lowered to a horizontal position, the water flows out of the tank. If the pipe is lifted to the vertical position, water is retained in the tank. Water that bypasses the deflector flows to the catch basin and exits the system through the 12-inch diameter drainpipe.

Vanes were placed in front of the deflectors. The object of the vanes is to direct the flowing water against the deflector to force it open. Various devices were evaluated for directing water flow. The bulk of the tests used 0.5-inch square dowels, as shown in the bottom right corner of Figure 1. Bot dots and a 3/4-inch drop were also evaluated, and are shown in Figure 4.

The flow meters were calibrated with each other and using displaced volume. The time required to raise the water level in the stilling tank can be used to verify flow meter accuracy. The paddle wheel and ultrasonic flow meter were operated in parallel and agreed within 5%. The ultrasonic flow meter was not used during these experiments because of the time required to obtain stable conditions. The injected air to create target surface area was difficult adjust to an ideal rate. At higher flow rates, or with smaller feed pipes, the injected air is easier to adjust. The paddle wheel meter required no air injection and allowed more rapid flow measurement.

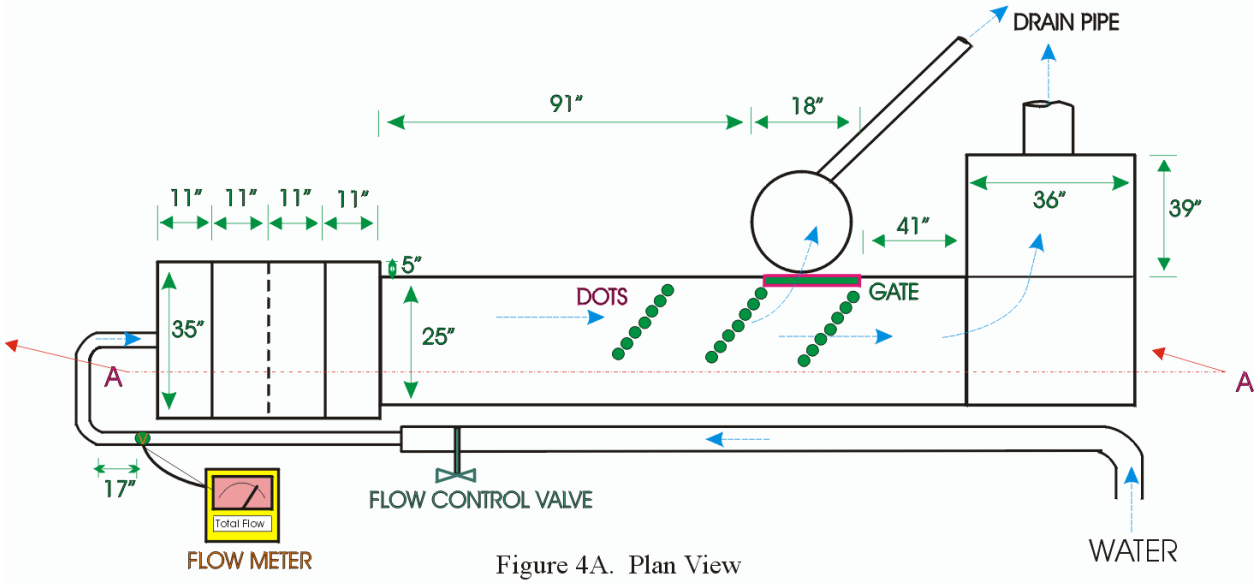


Figure 4A. Plan View

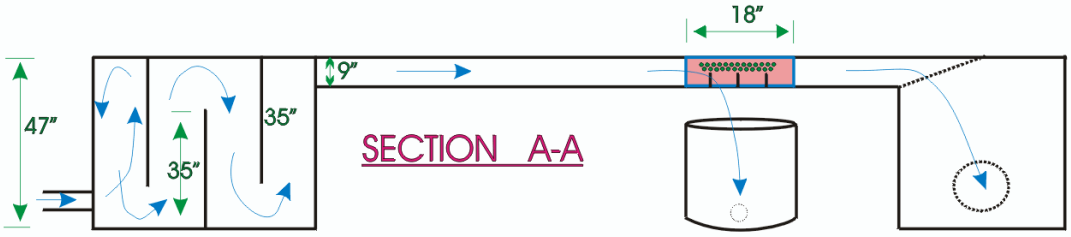


Figure 4B. Elevation View (Section A-A)

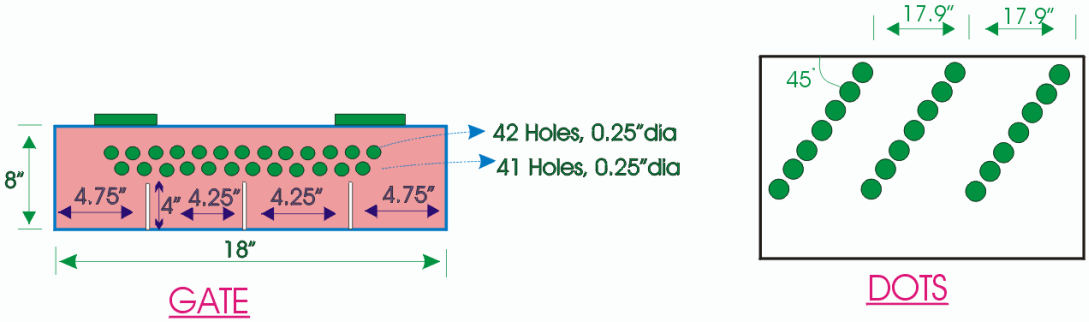


Figure 4C. Deflector and Vane Details

Figure 4. Litter Inlet Deflector System with Bot Dots.

Test Protocol

Tests were performed in the following way:

1. At the beginning of a new day of testing, city water was allowed to flow through the flume at high flow rate (~100 GPM) for a few minutes to allow corrosion products and dust to flush from the system. The building piping is old and corrosion products accumulate in the feed pipe after several days of non-use.
2. The flume was equipped with the desired deflector and vane configuration and flow rate was adjusted to the desired value.
3. The system was allowed to run for a few minutes to insure stable conditions.
4. The pipe was lifted to retain the water flowing through the deflector. At the same time a timer was started.
5. The experiment continued until the bypass tank filled. The time was recorded. Efficiency was calculated by dividing the volume of water collected in the tank (calculated by multiplying the height of water in the tank by the area of the tank) by the volume of water flowing through the system during the elapsed time. In general, each condition was replicated three times. Replications were very close, and usually agreed within 2 to 3%.

Test results were analyzed and plotted using a spreadsheet.

Test Summary

Table 1 summarizes test conditions. Eighteen tests or series of tests were performed. Column 1 shows the test number or series. Tables and graphs are presented later and correspond to this number. Flow rate is shown in column 2; "various" corresponds to a test when flow was varied to obtain efficiency over a range of flow rates. Columns 3 to 5 describe the deflector. In two experiments no deflector was present; these tests were used to compare the deflector and a bare opening. "Tape" refers to the slots shown and described previously. If the tape is present (Y), the slots were taped (making them grooves) which allowed less water to flow through the slots, and generally increased performance. Angle refers to the deflector angle; 90 degrees corresponds to a vertical deflector. When "various" appears, it means the test was conducted over a range of angles to evaluate the impact of angle.

Column 7 refers to the number of vanes used to direct the flow. The number zero refers to a flat flume with no vanes or flow directors. Blank refers to some other type of flow director, as shown in column 11 or 12. Column 8 and 9 show the amount of set back. The set back is the distance from the bottom of the deflector to the edge of the flume. The set back is created by inserting a machined aluminum piece to create the specified distance. In field installations, the set back distance is part of the design and does not require a machined piece. Column 10 shows the presence or absence of 3/8-inch tabs on the flume-side of the deflector. Tabs were evaluated because they appeared to be an excellent way of increasing the hydraulic force available to open the deflector.

Columns 11 and 12 refer to other flow directors. The drop cavity is a 3/4-inch drop in front of the deflector. This was created by elevating the level of the flume 3/4-inches by placing sections of 3/4-inch plywood in the flume. The plywood was not placed in front of the deflector. This arrangement resulted in a drop in front of the flume, and is important because it is the most efficient method of operation. "Bot dots" refers to the use of plastic circles commonly used on freeways. They were glued to the surface of the flume to create flow towards the deflector. Figure 4 shows this configuration.

Table 1. Test Summary

Test	Q_T	Deflector			Deflector angle	Vanes	Set Back		Tabs	Drop Cavity (3/4")	Dots
	(GPM)	Opening (no deflector)	Deflector (with tape)	Deflector (without tape)	Angle(degree)	Number of vanes	1"	2"			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	various			Y	90	3	Y				
2	various	Y				3	Y				
3	various			Y	90	0	Y				
4	various	Y				0	Y				
5	31.3		Y		various (67~90 degree)	3	Y				
6	31.3		Y		90	3	Y				
7	31.3			Y	90	3	Y				
8	31.3			Y	90	3	Y		Y		
9	31.6		Y		various (63~90 degree)	3		Y			
10	31.6			Y	90	3		Y			
11	31.6			Y	90	3		Y	Y		
12	various			Y	90	3		Y			
13	25.6		Y		various (63~90 degree)	3		Y			
14	35.6		Y		various (63~90 degree)	3		Y			
15	various			Y	80 and 85	3		Y			
16	various			Y	85			Y		Y	
17	various			Y	85			Y			2
18	various			Y	85			Y			3

Results and Discussion

The first few tests were conducted to determine the range of deflector operation and the range of deflector angle. Generally, flow rates of 20 to 40 GPM were selected for testing. Below 20 GPM, most alternatives were very efficient. Flow rates above 40 to 50 GPM are beyond the capacity of an 18-inch wide deflector; therefore testing was generally conducted between 20 and 40 GPM.

Results for the various conditions are reported in tabular and graphical format. Table 2 shows the results for test 1. Data for the remaining tests are shown in the Appendix. In Test 1, flow rates from 21 to 38 GPM were evaluated with three vanes and the inlet deflector. The angle of the deflector was 90 degrees (from Table 1).

Table 2. Test 1 with 3 vanes and litter inlet deflector at 90 deg.

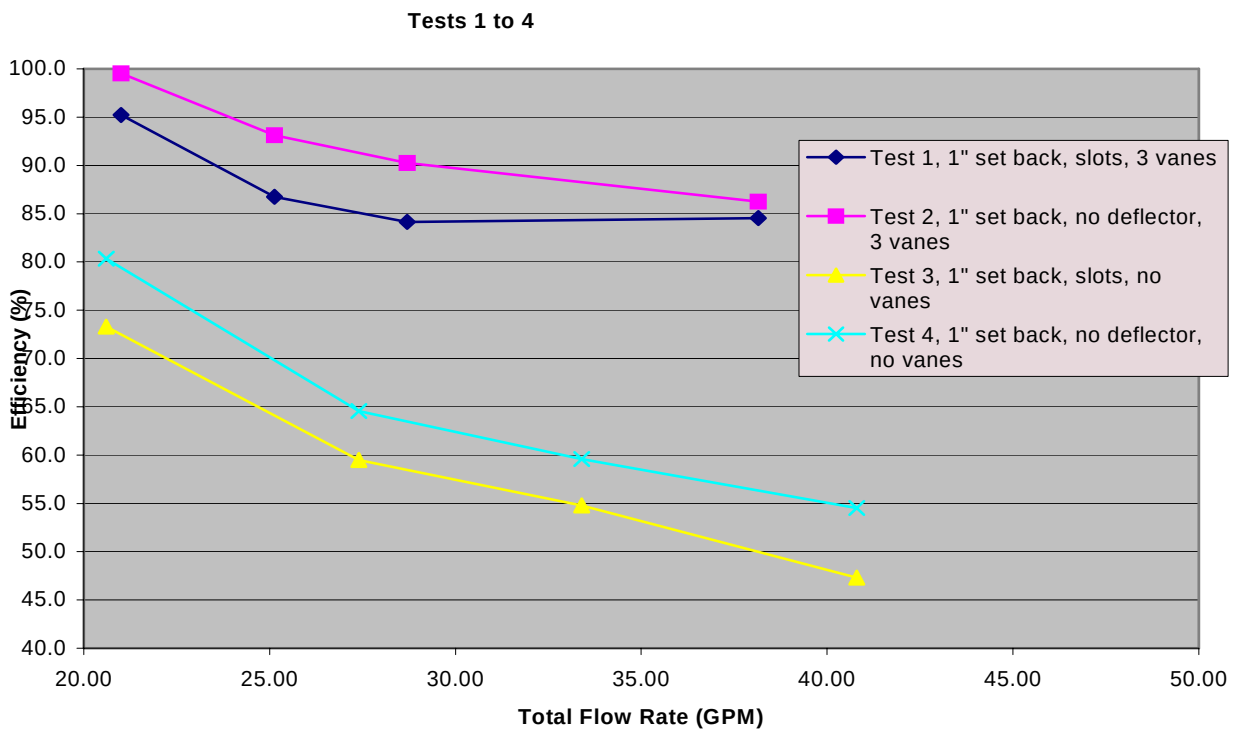
Q_T(GPM)	Q_G(GPM)	Q_B(GPM)=Q_T-Q_G	Efficiency for Q_G
21.00	20.00	1.00	95.24
25.13	21.80	3.33	86.75
28.70	24.15	4.55	84.15
38.15	32.26	5.89	84.56

Figure 5 compares the results all tests that had varying flow rates. Tests 1 to 4 are shown in the upper graph. This most basic series of tests compares vanes with no vanes and an inlet deflector with no deflector. The most important parameter observed in these tests is the method of directing flow towards the deflector. Without vanes, even an open flume does not efficiently divert flow. The defector reduces efficiency by only 5 to 10 percent.

The results of tests 12 and 15 through 18 are shown in the lower graph. These tests were performed after determining the optimum angle for the deflector (85 degrees). Test 12 is comparable to Test 1, showing that the 2-inch set back is more efficient that a 1-inch set back. Tests 17 and 18 evaluate bot dots, which are not as efficient as the vanes. Test 16 is the most efficient of the entire program, and used a 3/4 inch depression or drop in front of the deflector.

Figure 6 compares deflector angle for various conditions. The improved performance of the 2-inch set back over 1-inch set back is easily observable. One can conclude from this graph that the greatest angle that will keep the deflector closed in dry conditions is best for overall performance.

Figure 7 shows the effect of grooves, slots and tabs. The effect of these different treatments are small.



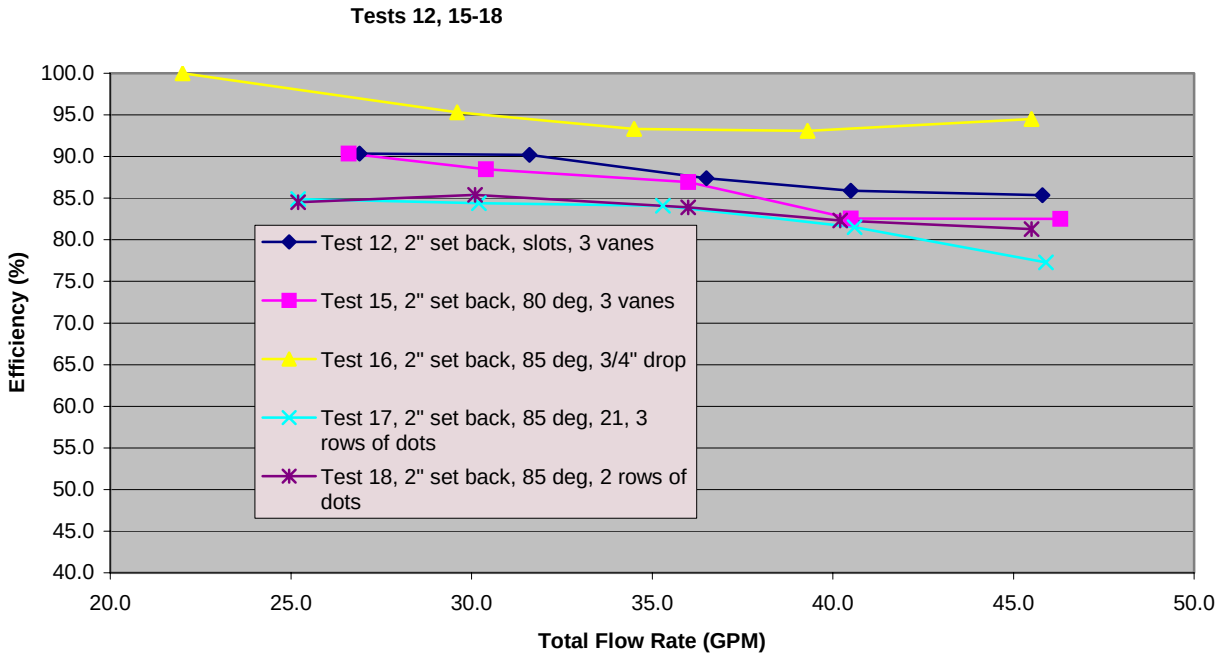


Figure 5. Litter Inlet Deflector Efficiency versus Flow Rate for Various Conditions.

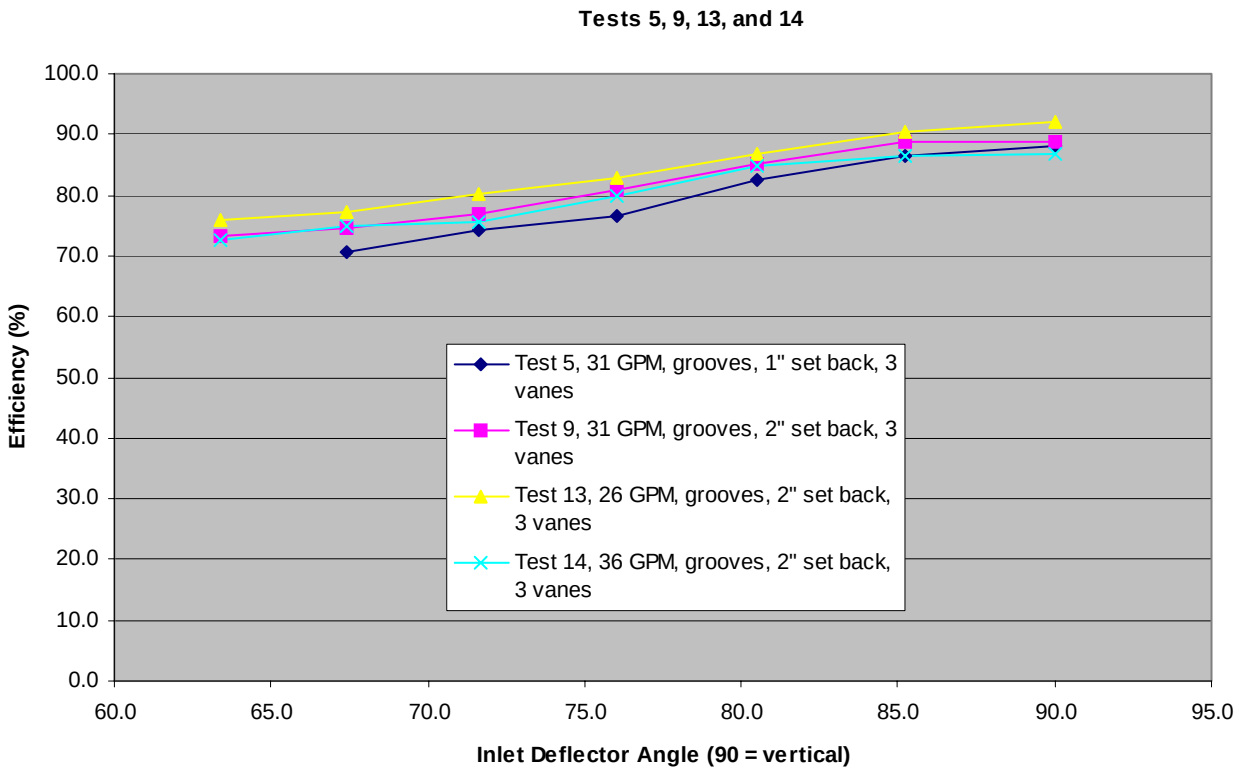


Figure 6. Effect of Inlet Deflector Angle for Various Conditions.

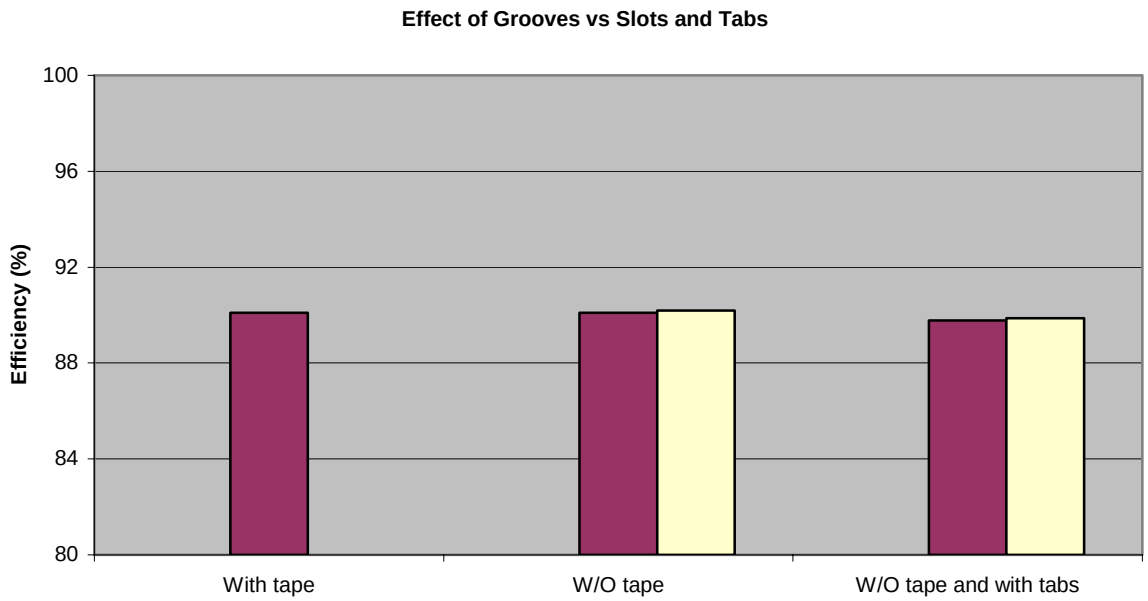


Figure 7. Effect of Grooves., Slots and Tabs at 32 GPM.

The raw data are in the Appendix and can be reviewed if more information is desired. .

The following observations are made:

At lower flow rates, an open flume (no deflector) flow diverters (3 vanes) was nearly 100% efficient. Flow diversion decreased to 86% at 38 GPM. These same conditions with an inlet deflector resulted in 95 and 84% diversion. Therefore the deflector only marginally reduced flow diversion. For the best case (3/4 drop, Test 16), the efficiency of the diversion efficiency of the litter inlet deflector was better than an open flume with three vanes.
The vanes or flow diverters are essential to litter inlet deflector operation. An open flume without vanes diverts only 54% of the flow at 40 GPM, as compared to 86% with vanes. The results are similar when an inlet deflector is installed.
The most efficient deflector angle is 90 degrees (vertical), which is not practical since there is insufficient force to keep the deflector closed in dry conditions. An angle of 85 degrees works nearly as well and is sufficient to keep the deflector closed. If lesser angles are required, the efficiency is reduced, which can be compensated by a longer litter inlet deflector for the same flow conditions. The angle of the deflector has about the same impact on efficiency at different flow rates.
The presence or absence of tabs on the deflector only marginally changed efficiency. They should not be used since they provide no benefit and they present an opportunity for clogging.
The performance of slots and grooves is quite similar. Grooves might be a better choice to reduce the chance of clogging and dust entry, although slots will be easier to manufacture.
Bot Dots were less efficient than other flow diverters.
The 3/4-in depression in front of the deflector was the best flow diverter.

Conclusions

A litter inlet deflector utilizing the action of flowing water to open can be constructed to collect freeway runoff. The deflector with flow diversion methods such as vanes or a depression in the street is more efficient that an opening without flow diversion. An 18-inch long deflector can divert 20 to 40 GPM at 100 to 95% efficiency, respectively.

Reference

Wong, K., E.W. Strecker and M.K. Stenstrom, “A Geographic Information System to Estimate Stormwater Pollutant Mass Loadings,” *Journal of the Environmental Engineering Division*, ASCE, Vol. 123, pp. 737-745, 1997.

Appendix

Test 2 Case with 3 vanes and no inlet deflector

Q_T(GPM)	Q_G(GPM)	Q_B(GPM)=Q_T-Q_G	Efficiency for Q_G
38.15	32.90	5.25	86.24
28.70	25.90	2.80	90.24
25.13	23.40	1.73	93.12
21.00	20.90	0.10	99.52

Test 3 Case with inlet deflector and no vanes

Q_T(GPM)	Q_G(GPM)	Q_B(GPM)=Q_T-Q_G	Efficiency for Q_G
40.80	19.30	21.50	47.30
33.40	18.30	15.10	54.79
27.40	16.30	11.10	59.49
20.60	15.10	5.50	73.30

Test 4 Case with no inlet deflector and no vanes

Q_T(GPM)	Q_G(GPM)	Q_B(GPM)=Q_T-Q_G	Efficiency for Q_G
40.80	22.24	18.56	54.51
33.40	19.90	13.50	59.58
27.40	17.69	9.71	64.56
20.60	16.55	4.05	80.34

Test 5 Different angle case with 1 inch set back, vanes and tape (Q_T=31.1 GPM)

Angle of inlet deflector	Q_G(GPM)	Q_B(GPM)=Q_T-Q_G	Efficiency for Q_G
90.0	27.4	3.7	88.2
85.2	26.9	4.2	86.5
80.5	25.7	5.4	82.6
76.0	23.8	7.3	76.5
71.6	23.1	8.0	74.3
67.4	22.0	9.1	70.7

Test 6, 7 and 8 Cases of 90 degree angle with Q_T=31.3 GPM

Test	Type of flap	Q_G(GPM)	Q_B(GPM)=Q_T-Q_G	Efficiency for Q_G
6	With tape	28.2	3.1	90.1
7	W/O tape	28.2	3.1	90.1
8	W/O tape and with tabs *	28.1	3.2	89.8

Test 9 Different angle case with 2 inch piece, vanes and tape (Q_T=31.6 GPM)

Angles of inlet deflector	Q_G(GPM)	Q_B(GPM)=Q_T-Q_G	Efficiency for Q_G
90.0	28.1	3.5	88.8
85.2	28.1	3.5	88.8
80.5	26.9	4.7	85.1
76.0	25.5	6.1	80.7
71.6	24.3	7.4	76.7
67.4	23.6	8.0	74.7
63.4	23.1	8.5	73.2

Test 10 and 11 Cases of 90 degree angle with Q_T=31.6 GPM

Test	Type of flap	Q_G(GPM)	Q_B(GPM)=Q_T-Q_G	Efficiency for Q_G
10	W/O tape	28.5	3.1	90.2
11	W/O tape and with tabs	28.4	3.2	89.9

Test 12 Case with 2 inch set back, 90 degree angle of inlet deflector, no tabs and no tape

Q_T(GPM)	Q_B(GPM)	Efficiency(%)
26.9	24.3	90.3
31.6	28.5	90.2
36.5	31.9	87.4
40.5	34.8	85.9
45.8	39.1	85.4

Test 13 Different angle case with 2 inch set back, vanes and tapes (Q_T=25.6 GPM)

Angles of inlet deflector	Q_G(GPM)	Q_B(GPM)=Q_T-Q_G	Efficiency for Q_G
90.0	23.6	2.0	92.2
85.2	23.1	2.5	90.4
80.5	22.2	3.4	86.7
76.0	21.2	4.4	82.8
71.6	20.5	5.1	80.1
67.4	19.8	5.8	77.3
63.4	19.5	6.1	76.1

Test 14 Different angle case with 2 inch set back, vanes and tape (Q_T=35.6 GPM)

Angles of inlet deflector	Q_G(GPM)	Q_B(GPM)=Q_T-Q_G	Efficiency for Q_G
90.0	30.9	4.7	86.9
85.2	30.8	4.9	86.4
80.5	30.2	5.4	84.9
76.0	28.5	7.2	79.9
71.6	26.9	8.7	75.6
67.4	26.7	8.9	75.0
63.4	25.9	9.7	72.8

Test 15 Cases of 80 and 85 degree inlet deflector angle with 2 inch set back, no tabs and no tape

Q_T(GPM)	85 degree		80 degree	
	Q_B(GPM)	Efficiency(%)	Q_B(GPM)	Efficiency(%)
26.6	24.0	90.3	22.8	85.7
30.4	26.9	88.5	26.5	87.2
36.0	31.3	86.9	30.0	83.3
40.5	33.4	82.5	32.7	80.7
46.3	38.2	82.5	37.0	79.9

Test 16 Case with ¾ inch board, 2 inch piece, no tape, no tabs and 85 degree inlet deflector angle

Q_T(GPM)	Q_G(GPM)	Efficiency (%) for Q_G
22.0	22.0	100.0
29.6	28.2	95.3
34.5	32.2	93.3
39.3	36.6	93.1
45.5	43.0	94.5

Test 17 Case with dots, 2 inch piece, no tape, no tabs and 85 degree inlet deflector angle (3 rows, each row=7 dots)

Q_T(GPM)	Q_G(GPM)	Efficiency (%) for Q_G
25.2	21.4	84.9
30.2	25.5	84.4
35.3	29.7	84.1
40.6	33.1	81.5
45.9	35.5	77.3

Test 18 Case with dots, 2 inch piece, no tape, no tabs and 85 degree inlet deflector angle (2 rows, each row=7 dots)

Q_T(GPM)	Q_G(GPM)	Efficiency (%) for Q_G
25.2	21.3	84.5
30.1	25.7	85.4
36.0	30.2	83.9
40.2	33.1	82.3
45.5	37.0	81.3