In cooperation with the City of Madison, Wisconsin, and the Wisconsin Department of Natural Resources

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Scientific Investigations Report 2007–5156

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Cover photos (clockwise from top):
Vacuum assist, regenerative air, and mechanical broom street sweepers.

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Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
millimeter (mm)	0.03937	inch (in.)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
liter (L)	0.2642	gallon (gal)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton per day (ton/d)	0.9072	metric ton per day
pounds per curb-mile	3.55	kilograms per curb-kilometer
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8 \times °C)+32$$

Concentrations of constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Particle sizes of sediment are given in micrometers (µm). A micrometer is one-thousandth of a millimeter.

Evaluation of Street Sweeping as a Stormwater-Quality-Management Tool in Three Residential Basins in Madison, Wisconsin

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Abstract

Recent technological improvements have increased the ability of street sweepers to remove sediment and other debris from street surfaces; the effect of these technological advancements on stormwater quality is largely unknown. The U.S. Geological Survey, in cooperation with the City of Madison and the Wisconsin Department of Natural Resources, evaluated three street-sweeper technologies from 2002 through 2006. Regenerative-air, vacuum-assist, and mechanical-broom street sweepers were operated on a frequency of once per week (high frequency) in separate residential basins in Madison, Wis., to measure each sweeper's ability to not only reduce street-dirt yield but also improve the quality of stormwater runoff. A second mechanical-broom sweeper operating on a frequency of once per month (low frequency) was also evaluated to measure reductions in street-dirt yield only. A paired-basin study design was used to compare street-dirt and stormwater-quality samples during a calibration (no sweeping) and a treatment period (weekly sweeping). The basis of this paired-basin approach is that the relation between paired street-dirt and stormwater-quality loads for the control and tests basins is constant until a major change is made at one of the basins. At that time, a new relation will develop. Changes in either street-dirt and/or stormwater quality as a result of street sweeping could then be quantified by use of statistical tests.

Street-dirt samples collected weekly during the calibration period and twice per week during the treatment period, once before and once after sweeping, were dried and separated into seven particle-size fractions ranging from less than 63 micrometers to greater than 2 millimeters. Street-dirt yield evaluation was based on a computed mass per unit length of pounds per curb-mile. An analysis of covariance was used to measure the significance of the effect of street sweeping at the end of the treatment period and to quantify any reduction in street-dirt yield. Both the regenerative-air and vacuum-assist sweepers produced reductions in street-dirt yield at the 5-percent significance level. Street-dirt yield was reduced by an average of 76, 63, and 20 percent in the regenerative-air, vacuum-assist, and high-frequency broom basins, respectively. The low-frequency broom basin showed no significant reductions in street-dirt yield. Sand-size particles (greater than 63 micrometers) recorded the greatest overall reduction. Street-sweeper pickup efficiency was determined by computing the difference between weekly street-dirt yields before and after sweeping cleaning. The regenerative-air and vacuum-assist sweepers had similar pickup efficiencies of 25 and 30 percent, respectively. The mechanical broom sweeper operating at high frequency was considerably less efficient, removing an average of 5 percent of street-dirt yield.

The effects of street sweeping on stormwater quality were evaluated by use of statistical tests to compare event mean concentrations and loads computed for individual storms at the control and test basins. Loads were computed by multiplying the event mean concentrations by storm-runoff volumes. Only ammonia-nitrogen for the test basin with the vacuum-assist sweeper showed significant load increases over the control basin, at the 10-percent significance level, of 63 percent. Difficulty in detecting significant changes in constituent stormwater-quality loads could be due, in part, to the large amount of variability in the data. Coefficients of variation for the majority of constituent loads were greater than 1, indicating substantial variability. The ability to detect changes in constituent stormwater-quality loads was likely hampered by an inadequate number of samples in the data set. However, sediment transport in the storm-sewer pipe, sediment washing onto the street from other source areas, winter

sand application, and sampling challenges were additional sources of variability within each study basin and may have increased the difficulty in evaluating street sweeping as a stormwater-quality-management tool.

Introduction

The Wisconsin Department of Natural Resources (WDNR) has promulgated a series of stormwater performance standards that attempt to mitigate both water-quantity and water-quality impacts associated with stormwater runoff (Wisconsin Administrative Code NR 151, 2002). Performance standards for established urban areas will require qualifying cities to reduce the annual total suspended solids (TSS) load by 40 percent. The City of Madison, along with more than 200 other Wisconsin cities, will be required to meet these performance standards by the year 2013 as part fulfillment of their U.S. Environmental Protection Agency National Pollution Discharge Elimination System (NPDES) Phase II permits.

Previous studies have indicated that runoff from street surfaces is a major contributor of constituents to receiving waters (Sartor and Boyd, 1972; Pitt and Amy, 1973; Amy and others, 1974; Waschbusch and others, 1999). Particulate and dissolved solids and organic and inorganic compounds resulting from vehicular wear and emissions, pavement degradation, maintenance, atmospheric deposition, and littering are commonly associated with urban drainage from paved areas (Sansalone and others, 1998). Although several structural best management practices (BMPs) have been designed to mitigate these constituents, most are only effective once constituents have already become entrained in urban runoff. Selection of one or more BMPs to address constituents in urban runoff may be limited by available space, existing infrastructure, and maintenance (Breault and others, 2005). One nonstructural way to control the quality of roadway or parking lot runoff is to use street sweeping as a means to remove constituents before they become entrained in runoff. Instead of facing the potentially high cost of installing and maintaining structural stormwater-treatment practices, street sweeping offers the promise of simply modifying an existing program to achieve stormwater-quality goals.

Like many other cities around the Nation, the City of Madison has limited open space available to construct new structural BMPs. The possibility of retrofitting existing areas remains an option for environmental managers, but costs may be prohibitive. The city already owns and operates nine street sweepers (A. Schumacher, City of Madison, written commun., 2007). Eight of the sweepers use a mechanical broom as the principal mechanism to clean a street. This technology has been around for decades and is used primarily for spring cleanup, trash removal, and fall leaf pickup. In addition to mechanical-broom sweepers, the city also owns and operates one street sweeper using vacuum-assist technology. The improved technology incorporated into these street sweepers has not been adequately field tested, especially when considering their effect on stormwater quality. In order to understand how best to protect the many lakes and rivers that surround the City of Madison, city officials were interested in evaluating the effectiveness of street sweeping as a stormwater-quality-management option.

The focus of the study described in this report was to characterize the effectiveness of street sweeping at reducing street-dirt yield, as well as evaluating street sweeping's effect on stormwater quality. Few studies have quantified the capabilities of street sweepers with improved technologies, such as regenerative-air or vacuum-assisted brooms, to remove street dirt. Even fewer studies have examined the benefits of street sweeping on stormwater quality. To augment previously collected data sets that characterize various street-sweeper technologies and to understand the stormwater-quality benefits from these sweepers, the U.S. Geological Survey, in cooperation with the City of Madison and the Wisconsin Department of Natural Resources, collected street-dirt from four residential basins in Madison. Stormwater-quality samples also were collected in three of the four basins. Samples were used to calculate loads during a calibration (no sweeping) and treatment (sweeping) phase. Relations were established between the loads for the control and test basins. These relations were tested for changes between the calibration and treatment periods. This study supports an ongoing effort to identify existing and new methods to reduce nopoint-source pollution from urban areas.

Purpose and Scope

This report describes the methods used in and the results from the City of Madison street-sweeping study. An analysis of potential street dirt and stormwater-quality-constituent load reductions are presented to provide an estimate of stormwater-quality benefits from street sweeping. A paired-basin design (Clausen and Spooner, 1993) was used to help evaluate the effectiveness of various street-sweeping programs at reducing street-dirt yields and improving stormwater quality in urban runoff.

Four basins were chosen to represent various sweeping scenarios. Specifically, this study examined the street-dirt-removal efficiencies and subsequent changes in stormwater-quality loads from a regenerative-air, vacuum-assisted, and mechanical-broom street sweeper operated on a frequency of once per week (high frequency). An additional mechanical-broom sweeper operating on a frequency of approximately once per month (low frequency) was also evaluated for street-dirt removal only. The study period began in 2002 and ended in 2006.

Concentrations of 26 constituents including particulate and dissolved solids, inorganic compounds, and trace metals in stormwater-runoff samples were used to compute storm loads for each constituent at the basin outfall. Reduction in constituent loads by use of different sweeper technologies was estimated based on differences between calibration and treatment phases. In addition to stormwater quality and quantity, street-dirt yields were characterized before and after street sweepers entered each basin.

Description of Study Area

Madison, Wis. has a population of 208,054 (based on the 2000 census). The climate is typical of interior North America, with a large annual temperature range and frequent short-period temperature changes. Nearly 60 percent of the 32.95 inches of average annual precipitation falls in the months of May through September (National Climatic Data Center, 2003). The study area is near the southwest limits of the city in a predominantly single-family residential setting (fig. 1). Study basins were within a 1-mile radius of each other to help reduce variation in storm rainfall. Selection of each basin was based on similarity in physical conditions, including basin area, land use, street condition, age of streets since last resurfacing, overhead tree canopy, topography, and lot size. Table 1 details some of the physical characteristics of each basin.

A naming convention based on the type of street-sweeper technology used was adopted to simplify discussion of each basin involved in the study. The control basin was appropriately named “control.” The test basin, where a regenerative air sweeper was used (later replaced by a vacuum-assisted sweeper) is referred to as the “air-sweeper” basin. The two basins that were swept with a mechanical broom sweeper are distinguished by the frequency at which the basin was swept, “low-frequency broom” representing a frequency of approximately once per month, and “high-frequency broom” representing a frequency of once per week.

The test basins selected for this study have similar drainage areas. The drainage area for the control basin is considerably larger, nearly double that of the test basins (table 1). Land use was categorized into seven major source areas: driveways, rooftops, lawns, streets, sidewalks, parking lot, and other. Lawns and grassy areas make up the majority of each basin, ranging from 65 to 69 percent. Streets make up approximately the same area for each basin, ranging from 8 percent in the low-frequency broom basin to 13 percent in the air-sweeper basin. Both the high-frequency broom basin and the control basin include small areas that do not fit into one of the major source-area categories. A city park occupies 4 percent of the high-frequency broom basin. This area was not included in the “lawn” category because the physical processes associated with a public park may be different from those of a typical residential lawn. Similarly, the control basin includes a small community swimming pool that makes up 1 percent of basin area. Drainage of stormwater in each basin is collected into a network of storm-sewer pipes that eventually flow into Dunn’s Marsh, approximately 1.0 mile southeast of the study area. Street widths within each basin typically measured 33 feet from curb to curb. Onstreet parking was minimal and considered negligible with respect to street-sweeper performance. Therefore, parking restrictions were not enforced during sweeper operation. There were no catch basins in the storm-drainage network for either the control or test basins.

The control and test basins, with the exception of the low-frequency broom basin, were equipped with monitoring stations to measure stormwater runoff and collect stormwater-quality data. The locations of the monitoring stations are identified in figure 1.

Methods of Data Collection

This study collected, characterized, and interpreted data derived from street-dirt and stormwater-quality samples collected in the four residential basins. Street-dirt data consists of street-dirt yields reported in units of mass per unit length. Constituent concentrations and loads were determined from data collected from a storm-sewer pipe near the basin outlet. Quality assurance and quality control methods and results can be found in appendix 2.

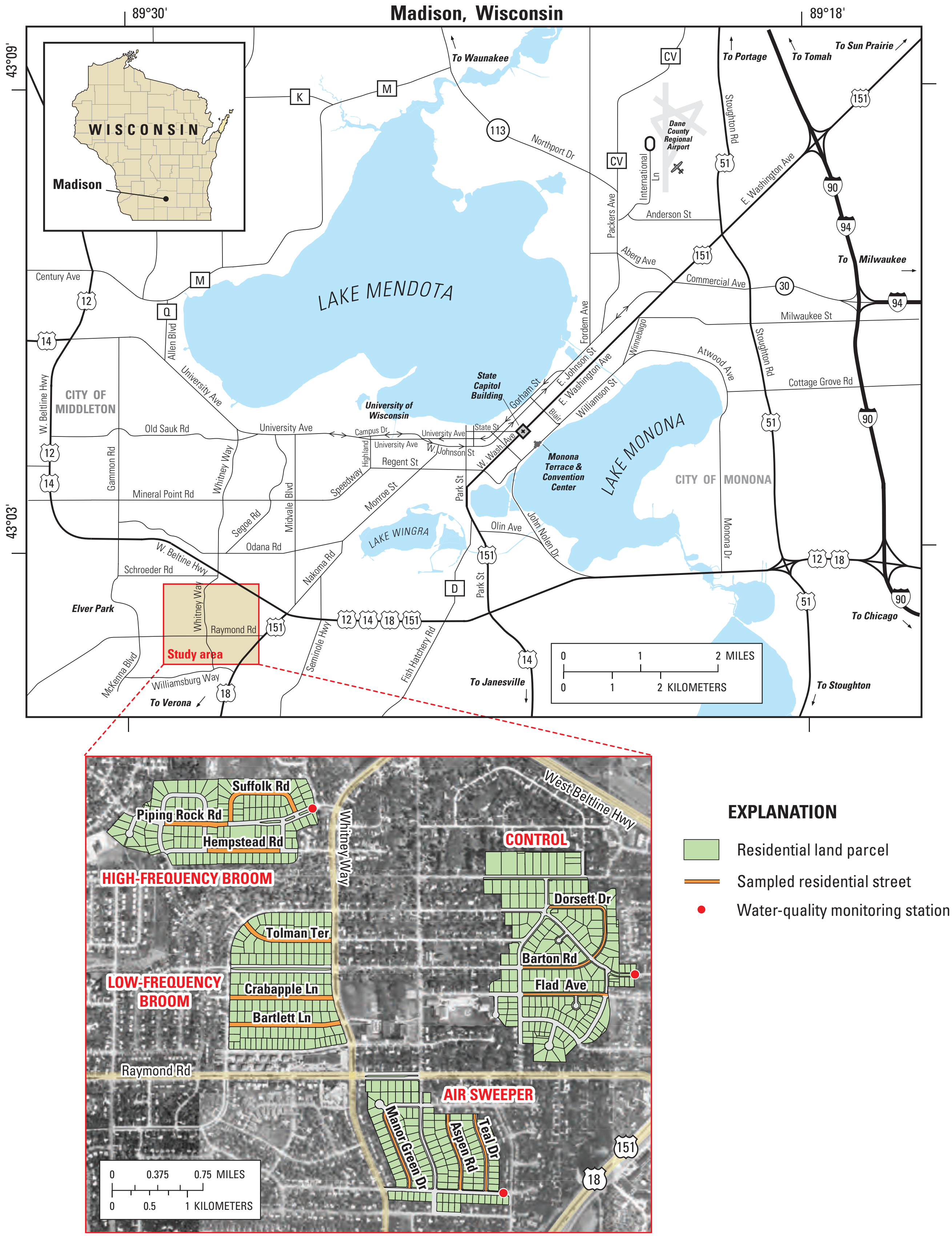

Figure 1. Location of study basins and water-quality monitoring stations, Madison, Wis.

Street-Dirt Collection and Processing

Street-dirt particulate sampling consisted of collecting available material from street surfaces within the designated test and control basins. Three streets within each basin were selected to represent overall basin street-dirt characteristics. Individual streets that were sampled are identified in figure 1 and described in table 2. Predetermined numbers of subsamples were collected at random locations across each street width and were later combined to make up a single street-dirt sample.

The equipment and sampling procedures were slightly modified from those described by Pitt (1979) and Bannerman and others (1983). Subsamples were collected with a single 9-gallon, stainless steel, wet/dry vacuum rated at 92 cubic feet per minute maximum air flow. The vacuum head was connected to a 25-foot black neoprene, wire-reinforced hose, which was in turn connected to a wand and 6-inch-wide aluminum nozzle. The vacuum and generator were transported by a trailer-mounted cargo carrier on a USGS field vehicle. Figure 2 shows the equipment used during street-dirt sample collection.

Samples were obtained by vacuuming several narrow strips across the street width, beginning from one curb edge and moving across the street to the other curb edge (fig. 2). Initially, 10 subsamples, consisting of a single curb-to-curb vacuum pass, were collected and weighed individually at each street selected in the study to determine the variability in street-dirt yields. The variability was then used to calculate the number of subsamples necessary per street to accurately represent a composite

Figure 2. Demonstration of equipment used to collect street dirt samples.

Table 1. Physical characteristics of the control and test basins selected for the Madison, Wis., street-sweeping study.

[%, percent; --, land use not present in basin; values in parentheses represent percentages of total basin area]

Characteristic	Control	Air sweeper	High-frequency broom (weekly)	Low-frequency broom (monthly)
Drainage area (acres)	89.7	52.5	58.9	58.6
Land use (acres):				
Driveway	4.5 (5%)	2.6 (5%)	2.9 (5%)	4.8 (8%)
Lawns	62.0 (69%)	34.4 (66%)	38.3 (65%)	40.7 (69%)
Roofs	10.7 (12%)	7.0 (13%)	7.3 (12%)	8.0 (14%)
Sidewalks	1.0 (1%)	1.5 (3%)	1.7 (3%)	<1.0 (1%)
Streets	10.5 (12%)	6.9 (13%)	6.6 (11%)	4.6 (8%)
Parking lot	<1.0 (<1%)	--	--	--
Other	1.0 (1%)	--	2.1 (4%)	--
Soil type	Silt loam	Silt loam	Silt loam	Silt loam
Average age of homes (years)	40	50	50	50
Years since streets last resurfaced	15	15	15	15
Street composition/condition	Asphalt/good	Asphalt/good	Asphalt/good	Asphalt/good
Street texture	Intermediate	Intermediate	Smooth/intermediate	Intermediate
Average slope	1.2%	0.8%	2.3%	0.9%
Average lot size (acres)	0.25	0.25	0.25	0.25

street-dirt yield. The number of subsamples, N, was determined as follows:

$$N = 4.25\ \frac{(s-1)^2}{(r\bar{y})^2}\ ,$$ (Hansen and others, 1984)

where

N is the estimated number of subsamples required to estimate residential street-dirt yield;

$\bar{y}$ is the average mass of measured subsamples;

s is the standard deviation of measured subsamples' mass; and

r is the allowable error.

The allowable error used for this study was 0.50, or plus or minus 50 percent. Lower error terms were not feasible because of subsequent increases in sampling effort. For example, an error term of 25 percent would increase the number of subsamples at one particular street from 9 to 34, making data collection cost prohibitive. A similar conclusion was reached for street-dirt data collected as part of the Nationwide Urban Runoff Program (NURP). At an allowable error of 25 percent, the number of required subsamples approached 25 (U.S. Environmental Protection Agency, 1983). Use of an allowable error of 50 percent kept the number of subsamples at or below 10 for each street in the study. To simplify the street-dirt collection effort, approximately 10 subsamples were collected at all streets selected for this study.

Each subsample was collected to represent the material that might be removed from a street surface during a heavy rainstorm. Therefore, the locations of the subsample strips were areas along each street that were not influenced by unusual loading conditions such as debris piles. Markers were painted on the curb of each street at approximately 100-foot increments to indicate to field crews the locations of subsample strips. Even though the markers served as means to identify where to collect subsamples, they were merely visual guides and not exact locations. Therefore, each subsample was collected with appropriate discretion. This flexibility artificially reduced variability in street-dirt yields by allowing field technicians to move the location of a subsample strip in the event of an unusual loading condition, such as a leaf pile or accumulated debris.

A test was set up to examine the reproducibility of the street-dirt sample-collection procedures. Street-dirt samples were collected on consecutive days during the 2004 sample-collection year in the control basin. A paired sample t-test, used to find differences between paired data sets, evaluated whether street dirt from the first sample set was different from that in the second sample set. Results of the test revealed no difference between the first and second collections of street-dirt samples at the 95-percent confidence level. Because the street-dirt samples showed good precision, any sources of variability in street-dirt yields were not likely caused by sample-collection techniques.

Because of differences in street textures, care was taken to ensure a proper rate at which the nozzle was moved across the street. A rough, pitted street surface required a slower rate than a smooth street did. Additionally, a greater amount of particulate material on a street

Table 2. Characteristics of streets sampled in the control and test basins.

Basin	Street name	Length (feet)	Width (feet)	Average annual weekday traffic (cars per day)
Control	Barton	936	33	226
	Flad	1,077	33	294
	Dorsett	1,008	33	151
Air sweeper	Manor Green	1,097	33	274
	Aspen	1,117	33	250
	Teal	1,129	33	207
Low-frequency broom (monthly)	Tolman	1,230	33	230
	Crabapple	1,356	33	270
	Bartlett	1,474	33	280
High-frequency broom (weekly)	Suffolk	1,286	33	200
	Piping Rock	850	33	1,236
	Hempstead	980	33	249

Figure 3. A vacuumed strip leaves a visible trail indicating the degree of available street dirt.

surface required more time for adequate sample collection. The average rate used during the course of this study was approximately 1 foot per second. However, confirmation of an adequate rate to move the nozzle came from both visual and audible observation of the street surface itself. The operator of the sample-collection wand was able not only to see the material removed from the street surface but could also hear particles moving through the vacuum hose. The operator would adjust the rate to ensure that as much of the stored dirt was removed as possible. At times, a visible trail was left behind where the nozzle had removed available street dirt (fig. 3). During the fall, leaves would often clog the vacuum nozzle; consequently, an effort was made to physically pick up by hand any leaves or other detritus that was within the 6-inch-wide swath. All material was later added to the vacuum collection bag. Ultimately, when the accumulating amount of vegetative material on the street made it impractical to collect such a large volume of leaves, street-dirt collection was suspended until the following spring.

Once all subsamples for a particular street were collected, the vacuum was shut off and disassembled. A cloth filter inside the vacuum head was first shaken vigorously inside the vacuum canister and then was carefully brushed with a soft broom to remove most of the filtered material. After the dust inside the vacuum canister settled for a few seconds, all contents were transferred into a plastic container and sealed. On days when winds were gusty, some of the dust captured by the filter became airborne and was lost. Measures were taken to minimize the loss by moving the filter into an area protected from the wind.

All street-dirt samples were taken back to the USGS Wisconsin Water Science Center's Middleton Field Office and dried overnight in an oven at 105˚C. The samples were then weighed and separated into eight different fractions including large detritus and particles in the ranges (micrometers) of: greater than 2,000; 1,000–2,000; 500–1,000; 250–500; 125–250; 63–125; and less than 63. Results of individual street-dirt yields for each basin broken down by particle size can be found in tables 1-1 through 1-4 in appendix 1.

Basin-Outlet Flow Measurement and Precipitation and Runoff-Sample Collection

Stormwater runoff was measured and collected at the basin outlets in the control, air-sweeper, and high-frequency broom basins. Locations of the monitoring stations are shown in figure 1. Each monitoring station was equipped with automated stormwater-quality samplers and instruments to measure water level and velocity. Measurement, control, and storage of data were done by way of electronic dataloggers. Data were automatically retrieved twice daily with telephone modems. In both the air-sweeper and high-frequency broom basins, precipitation data were collected by use of a tipping-bucket rain gage calibrated to 0.01 inch. Descriptive statistics for sampled runoff events in the control and test basins are detailed in tables 1-5 through 1-7 in appendix 1.

Flow Measurement

Monitoring stations measured flow and collected samples at the basin outlet from a 3.50-foot-diameter circular storm sewer at the control and air-sweeper basin and a 38 x 60-inch elliptical storm sewer in the high-frequency broom basin. A probe with two different sensor systems was mounted to the bottom of each pipe. Each probe contained a pressure transducer to measure water level and a pair of ultrasonic transducers to measure velocity. A fifth-order polynomial was used to convert water level into cross-sectional area for each pipe configuration. Instantaneous pipe discharge was then computed by multiplying the cross-sectional area of the pipe by the associated mean velocity. Storm-runoff volumes were computed by summing the 1-minute-interval instantaneous discharge during the sampled storm. When water level at the sensor was less than 1 inch, flow calculations were not considered reliable because the sensor itself was not fully submersed. Given the large diameter of the drainage pipe at each monitoring station, all flows occurring at less than 1-inch depth were considered insignificant to the overall event volume.

The area-velocity probe at the control-basin outlet frequently produced periods of unreliable water-level data during June–September, 2002 and April–September, 2003. Steps were taken to obtain the most accurate flow estimates possible for this basin. Because of the proximity of the control and air-sweeper basin and similarities in pipe diameter, storm-runoff hydrographs at each basin outlet mirrored each other quite closely when equipment at both stations was functional. A polynomial regression equation was developed for these periods over a wide range of water levels. The following equations were used to adjust questionable water-level data at the control-basin outlet given reliable water-level data from the air-sweeper basin:

Gage height (feet)	Equation
0.0–0.20	$S_c = 0.00196 + 1.01S_a + 3.72S_a^2 + 19.3S_a^3 - 125S_a^4$
0.20–0.50	$S_c = -0.0108 + 1.72S_a + 1.05S_a^2 - 8.63S_a^3 + 8.77S_a^4$
0.50–1.0	$S_c = 0.427 - 0.381S_a + 2.02S_a^2 - 1.66S_a^3 + 0.738S_a^4$
greater than 1.0	$S_c = 0.267 + 0.984S_a - 0.196S_a^2$

where

S_c is the gage height, in feet, at the control basin; and

S_a is the gage height, in feet, at the air-sweeper basin.

The regression equations were verified by applying them to periods of runoff when the control-basin water-level sensor was working properly. Figure 4 represents an event hydrograph comparing original water levels and those predicted by use of the regressions for the control basin during periods when the water levels were measured correctly.

Precipitation

Continuous precipitation data were collected by use of two tipping-bucket rain gages, one each in the air-sweeper and high-frequency broom basins. Although these rain gages were not designed to measure snowfall, there were several runoff events during winter months where precipitation was in the form of rain instead of snow. Precipitation data were compiled and statistical summaries were computed for both rain-gage locations. Precipitation data measured in the air-sweeper and the high-frequency broom basin are presented in tables 1-6 and 1-7, respectively, in appendix 1.

Runoff-Sample Collection

Sample collection was activated by a rise in water level in the pipe during a storm. Once the water-level threshold was exceeded, typically a depth of 0.15 ft from the pipe floor, the volume of water passing the station was measured and accumulated at 1-minute increments until a volumetric threshold was reached. At that point, the sampler collected a discrete water sample and the volumetric counter was reset. The process was repeated until the water level receded below the threshold. The Teflon-lined intake nozzle of the sampler orifice was approximately 1 inch above the pipe floor. One liter sub-samples were transferred through the Teflon-lined sample tubing into a 10-liter glass jar refrigerated at 4 degrees Celsius.

These flow-weighted samples were collected and composited into a single water sample, then split and processed for analysis. A Teflon-coated, stainless steel churn splitter was used to composite and split samples into smaller plastic bottles for chemical and physical analysis. Processed samples were kept in a refrigerator until picked up, usually within 48 hours after runoff cessation, by City of Madison Department of Public Health staff for determination of concentrations of the constituents listed in table 3. Because each discrete sample was composited into a single event sample, the resulting concentration represents the event mean concentration (EMC). An example of flow-weighted sampling from a storm on October 24, 2004, is shown in figure 5.

Changes to Sample-Processing and Analytical Methods

Previous studies have demonstrated that use of both churn splitting and aliquots can introduce significant bias and (or) poor precision into sediment and sediment-associated constituent-concentration results (Capel and Larson, 1996; Horowitz and others, 1997; Gray and others, 2000; Selbig and others, 2007). Much of the variability can be attributed to the presence of entrained sediment in urban runoff whose size can have a large mass fraction in the sand-size range (Horwatich and others, 2004). During the early stages of this study, whole-stormwater samples collected from the control and test basins were found to frequently contain suspended-sediment concentrations exceeding 1,000 milligrams per liter (appendix tables 1-8a and 1-8b), with a large percentage of sediment particles larger than 250 micrometers (table 15).

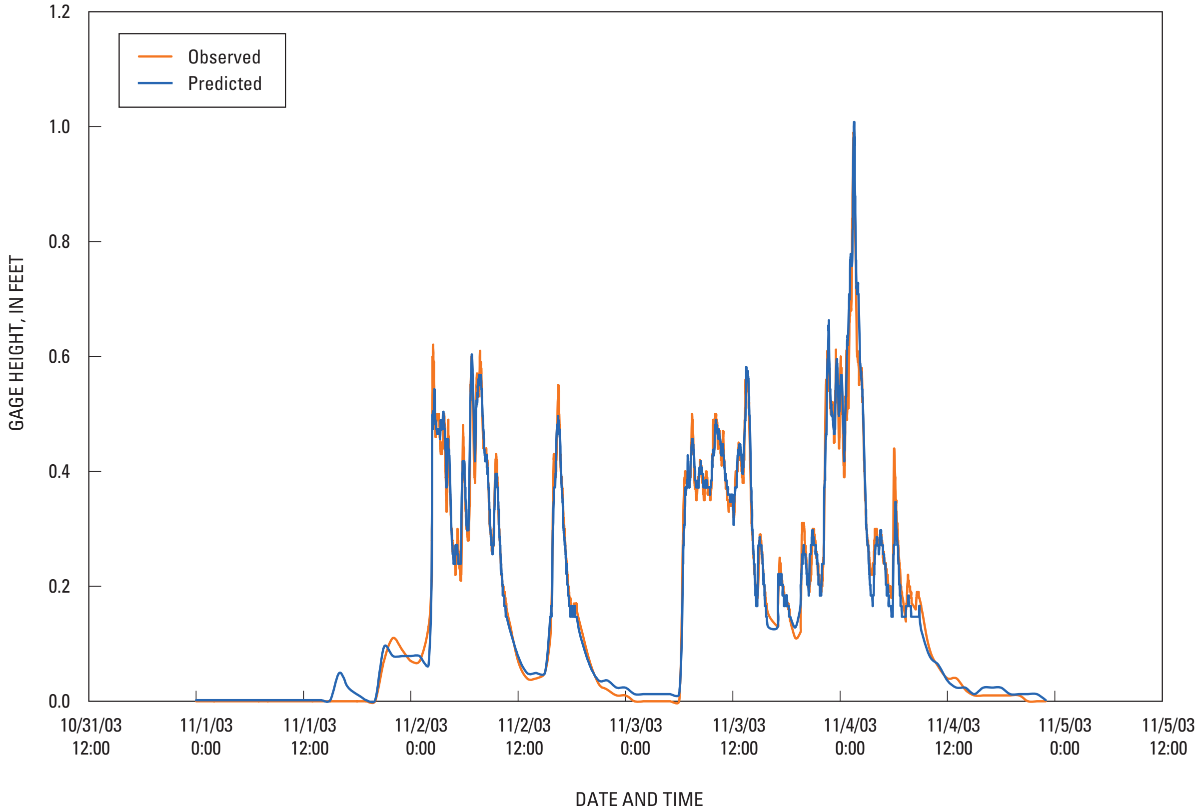

Figure 4. Verification of regression equations used to predict water levels in the control basin during periods when the water level sensor was faulty.

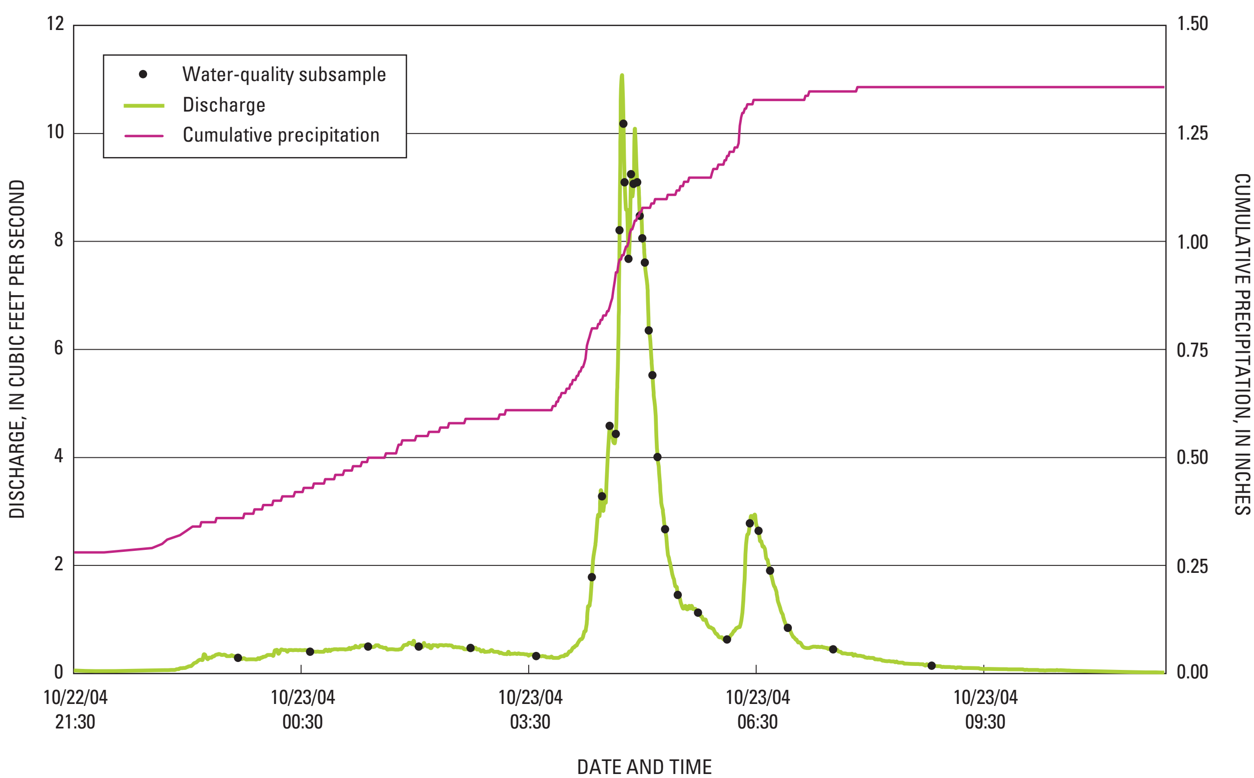

Figure 5. Typical subsample coverage of hydrograph.

Table 3. Constituents analyzed in samples of runoff at the air sweeper, high-frequency broom, and control study basins.

[N, nitrogen; MDPH, Madison Department of Public Health; USGS–ISL, U.S. Geological Survey Iowa Sediment Laboratory; WSLH, Wisconsin State Laboratory of Hygiene; USEPA, U.S. Environmental Protection Agency (U.S. Environmental Protection Agency, 1979); SM, Standard Methods (American Public Health Association and others, 1989)]

Constituent	Laboratory	Method or reference
Dissolved cadmium	MDPH	USEPA 200.7
Total cadmium	MDPH	USEPA 200.7
Total calcium	MDPH	USEPA 200.7
Dissolved copper	MDPH	USEPA 200.7
Total copper	MDPH	USEPA 200.7
Dissolved lead	MDPH	USEPA 200.7
Total lead	MDPH	USEPA 200.7
Total magnesium	MDPH	USEPA 200.7
Total phosphorus	MDPH	USEPA 200.7
Dissolved zinc	MDPH	USEPA 200.7
Total zinc	MDPH	USEPA 200.7
Total alkalinity	MDPH	USEPA 310.2
Dissolved chloride	MDPH	USEPA 300.0
Conductivity	MDPH	SM 2510
Total hardness	MDPH	SM 2340B
Ammonia N	MDPH	USEPA 350.1
Total Kjeldahl N	MDPH	USEPA 351.2
Dissolved N_2+N_3	MDPH	USEPA 300.0
Dissolved nitrate, as N	MDPH	USEPA 300.0
Dissolved nitrite, as N	MDPH	USEPA 300.0
Orthophosphorus	MDPH	USEPA 365.1
pH	MDPH	SM 4500-H
Total solids	MDPH	SM 2540B
Total dissolved solids	MDPH	SM 2540C
Total suspended solids	MDPH	SM 2540D
Suspended sediment	MDPH, USGS-ISL	ASTM D3977-97
Particle-size analyses		
Sand-silt split	USGS-ISL	Guy (1969)
Visual accumulation tube	USGS-ISL	Guy (1969)
Sedigraph	USGS-ISL	Guy (1969)
Laser diffraction	WSLH	Burton and Pitt (2002)
Wet-sieve	WSLH	Burton and Pitt (2002)
Microfiltration	WSLH	Burton and Pitt (2002)

In order to reduce the bias and improve precision of stormwater constituent-concentration data, sand-size particles were physically removed from the whole-stormwater sample by wet-sieving and were analyzed as a solid sample. The remaining filtrate was analyzed separately as an aqueous sample. Typically, sediment in a whole-stormwater sample was separated into one or more of the following particle-size ranges: 125–250, 250–500, and greater than 500 micrometers using nylon sieves. The methods used to wet-sieve a whole-stormwater sample, as well as the analytical techniques used to detect the presence of trace metals on resulting sieved solids, are described by Selbig and others (2007). These new methods were adopted as part of this study in May 2004.

Concentrations of some chemical constituents may have been compromised because of physical separation of sand-size particles during the wet-sieving process. Some of the constituents, such as total Kjeldahl nitrogen, are not quantifiable from a solid-phase sediment sample. Other constituents are affected because of the method by which concentrations are determined in the analytical laboratory. For example, sediment removed from a whole-water sample by wet-sieving will no longer be available when determining constituent concentrations from the aqueous phase of the sample. Therefore, total suspended solids cannot be adequately quantified because it is based on the dry weight of sediment from a known volume of a subsample of the original. Of those constituents listed in table 3, total solids, total suspended solids, and total Kjeldahl nitrogen were not considered reliable and therefore were eliminated from statistical interpretation.

Particle-Size Distribution

Analysis of particle sizes in stormwater-quality samples was done by one of three methods, depending on the amount of material available in the sample container. The first level of particle-size definition was a “sand/silt split,” which was used to determine the percentage of sediment, by mass, with a diameter greater than 63 micrometers (defined as sand) and less than 63 micrometers (defined as silt). If a sufficient quantity of sediment was available in the sample, a visual-accumulation (VA) tube analysis was used to further derive the percentage of sediment, by mass, with diameters less than 1,000, 500, 250, 125, and 63 micrometers (Guy, 1969). Often, the amount of material was insufficient for the VA tube analysis. For this reason, an alternative method described by Burton and Pitt (2002) was used to define the distribution of particles in a runoff sample. The new method, adopted as part of this study in July 2004, builds on the concept of wet-sieving by passing a stormwater-quality sample through a series of nylon-mesh sieves with mesh openings of 500, 250, 125, 63, and 32 micrometers. All material remaining on each sieve was dried and weighed to compute mass. Particles less than 32 micrometers remaining in the filtrate were further delimited into four additional particle sizes by means of laser diffraction. This process determined the percentage of sediment by mass with diameters less than 14, 8, 5, and 2 micrometers.

For those whole-stormwater samples that were wet-sieved during the sample-splitting process, the mass of sediment separated from the whole-stormwater sample was later included into the full particle-size distribution of the sample. The mass of sediment retained on each sieve, in milligrams, was divided by the volume of the whole-stormwater sample, in liters, to obtain a concentration of sediment per each particle-size fraction. This concentration was assumed to be the same in a subsample of the whole-stormwater sample had the particles not been removed by wet-sieving. The concentrations of the particles wet-sieved from the whole-stormwater sample were then included in the computation of particle-size distribution for the subsample submitted to the laboratory for particle-size analysis. Table 4 demonstrates the process of including the mass of sediment wet-sieved from the whole-stormwater sample back into the distribution of particle sizes in the subsample.

Of the 158 stormwater-quality samples analyzed for particle-size distribution, 23 samples were analyzed for sand/silt split only. Sixty of the runoff samples had sufficient sediment for the VA tube analysis. For the remaining 75 samples, a combination of wet-sieving and laser diffraction was used, resulting in a complete definition of the particle-size distribution. For all samples analyzed by either the VA tube or wet-sieving and laser-diffraction analysis, a sand/silt split was computed by subtracting the percentage of sediment, by mass, for particles less than 63 micrometers from 100. For example, if 60 percent of sediment in a runoff sample was less than 63 micrometers, then 40 percent (100 minus 60) would be greater than 63 micrometers.

Table 4. Process of including the mass of sediment wet-sieved from a whole-stormwater sample back into the distribution of particle sizes in a subsample.

[µm, micrometer; mg/L, milligram per liter; %, percent; >, greater than; <, less than; --, not analyzed]

Concentrations	Particle-size distribution										Concentration of sediment		Total concentration of sediment (mg/L)
	>500 µm (mg/L)	250–500 µm (mg/L)	125–250 µm (mg/L)	63–125 µm (mg/L)	32–63 µm (mg/L)	<500 µm (%)	<250 µm (%)	<125 µm (%)	<63 µm (%)	<32 µm (%)	<32 µm (mg/L)	>32 µm (mg/L)	
Aqueous subsample	<1	<1	9	16	14						48	39	87
Sieved fractions	--	107	29	--	--								136
Total	**<1**	**107**	**38**	**16**	**14**	**100**	**52**	**35**[a]	**28**	**22**			**223**

[a] 35% = 1 – [(<1 + 107 + 38) / 223]

Changes in Street-Sweeper Technology in the Air-Sweeper Basin

Traditional mechanical-broom sweepers have been the workhorse for many municipalities around the country. However, previous studies indicate they are not able to effectively pick up fine accumulated sediments (U.S. Environmental Protection Agency, 1983; Pitt, 1985; Sutherland and Jelen, 1997). One of the goals of this study was to evaluate some of the advancements in street-sweeper technology that have been made over the past several years. One such technology, regenerative-air sweeping, was initially evaluated in the air-sweeper basin from April 2003 to May 2004. Regenerative-air sweepers use a mechanical broom that passes debris and sediment near the center of the vehicle chassis, where air is blown onto the pavement and immediately vacuumed back in so as to entrain and filter out accumulated sediments (Sutherland and Jelen, 1997).

The regenerative-air sweeper was replaced with a different sweeper technology starting May 26, 2004. The new vacuum-assisted sweeper was considered by industry representatives to be more effective at removing street dirt than a regenerative-air sweeper. In addition to a wire-bristled broom, the vacuum-assisted sweeper had a powerful vacuum to capture debris and sediment quickly. The vacuum was placed along the vehicle chassis such that it was able to partially overlap the area of curb swept by the broom. The new vacuum-assisted sweeper remained in the air-sweeper basin for the remainder of the study. Where appropriate, street-sweeper performance on street-dirt removal and stormwater quality in the air-sweeper basin is reported as either regenerative-air or vacuum-assist.

Characterization of Street Dirt

The quantity of street dirt and the constituents associated with it can vary widely depending on street-sweeper technology and frequency. The street-sweeper technologies most often used today are mechanical broom, regenerative air, and vacuum assisted. Performance evaluations of vacuum-assisted and regenerative-air sweepers appear mostly in trade journals and are rarely documented in peer-reviewed literature (Zarriello and others, 2002). Mechanical-broom sweepers were extensively tested during the 1970s and 1980s as part of the National Urban Runoff Program (NURP); those studies concluded that mechanical-broom sweepers removed only coarser particles and did not result in any stormwater-quality benefit (Athayde and others, 1983). This study examined the removal efficiencies of these three most common street-sweeper technologies. The regenerative-air and vacuum-assisted sweepers were operated on a weekly schedule, whereas the mechanical-broom sweeper was evaluated at two levels of operating frequency, weekly and monthly.

Street-dirt samples were collected weekly in the control and test basins by means of techniques described earlier in this report. The study was separated into two phases: (1) calibration and (2) treatment (street sweeping) on a weekly schedule. The calibration phase ran from June 2001 through September 2002 for the air-sweeper and low-frequency-broom basins and May 2002 through September 2002, and April to May 2005 for the high-frequency-broom basin. The treatment phase was conducted from April 2003 through September 2004 for the high- and low-frequency-broom basins, and April 2003 through May 2005 for the air-sweeper basin. Street-dirt sample collection was typically done during April through September to avoid snow and ice on street surfaces during winter and large amounts of organic detritus during fall. Street sweepers were dispatched to each basin in late March, after all remaining snow had melted, for a single pass prior to street-dirt sample collection; this served as a method to normalize each basin by limiting any bias from winter sand application and creating a common baseline for measurement of initial street-dirt yields. Table 5 details the street-dirt sample-collection schedule.

Street-dirt yields are represented as pounds per curb-mile. Results of previous studies showed that pounds per curb-mile is a more meaningful unit than simply pounds when evaluating sweeper effectiveness because it represents actual mass of constituent removed from a street surface (Pitt, 1979). A composite street-dirt yield, in pounds per curb-mile, for each basin was calculated by means of the following formula:

$$P = \frac{\sum_{i=1}^{n} \left[\left(\frac{M \times 0.0022}{W \times N} \right) \times L_{ft} \right]}{\sum_{i=1}^{n} L_{mi}},$$

where

P is the mass of dirt on a street, in pounds per curb-mile;

n is the total number of streets in each basin;

i is an index to each street sampled in a study basin;

M is the total mass of sampled street-dirt, in grams;

W is the width of the vacuum nozzle, in feet;

N is the number of individual strips vacuumed per street;

L_{ft} is the length of each street, in feet;

L_{mi} is the length of each street, in miles; and

0.0022 is a unit conversion factor between grams and pounds.

Calibration Phase

Figure 6 characterizes basin street-dirt yields during the part of the study when street sweepers were not used. The calibration phase was established to develop relations between the control and test basins without the influence of normal street-sweeping operations. Street-dirt yields exhibited a non-normal distribution, as determined by an evaluation of normality with the Kolmogorov-Smirnov test at the 5-percent significance level. During this period, the air-sweeper basin had the highest median street-dirt yield, followed by the low-frequency broom, control, and high-frequency broom basins, respectively. However, results of the Kruskall-Wallis statistical test show no significant difference in median street-dirt yield between the four basins at the 5-percent significance level. Similarly, an examination of street dirt by particle size indicates no significant difference in distribution. The majority of particles in each basin were greater than 250 micrometers; 50 percent on average fell between the 250- and 1,000-micrometer particle-size fractions.

Previous studies indicate that dirt loading from street surfaces can vary widely and that the variation can be attributed to many factors, including differences in basin characteristics, study methods, and variation inherent in environmental factors (Steuer and others, 1997; Smith, 2002). Table 6 compares mean street-dirt yields in the control and test basins during the no-sweeping phase of this study to those measured in similar street-cleaning studies in other parts of the country. Given the similarities in

Table 5. Schedule for street-dirt sample collection.

Year of study					
2001	**2002**	**2003**	**2004**	**2005**	**2006**
January	January	January	January	January	January
February	February	February	February	February	February
March	March	March	March	March	March
April	April	April	April	April[1]	April
May	May	May	May	May[1]	May
June	June	June	June	June	June
July	July	July	July	July	July
August	August	August	August	August	August
September	September	September	September	September	September
October	October	October	October	October	October
November	November	November	November	November	November
December	December	December	December	December	December

[1] Sweeping in air-sweeper basin and no sweeping in high-frequency broom basin.

EXPLANATION

Calibration period

Treatment period

Equilibration period (sweep only once)

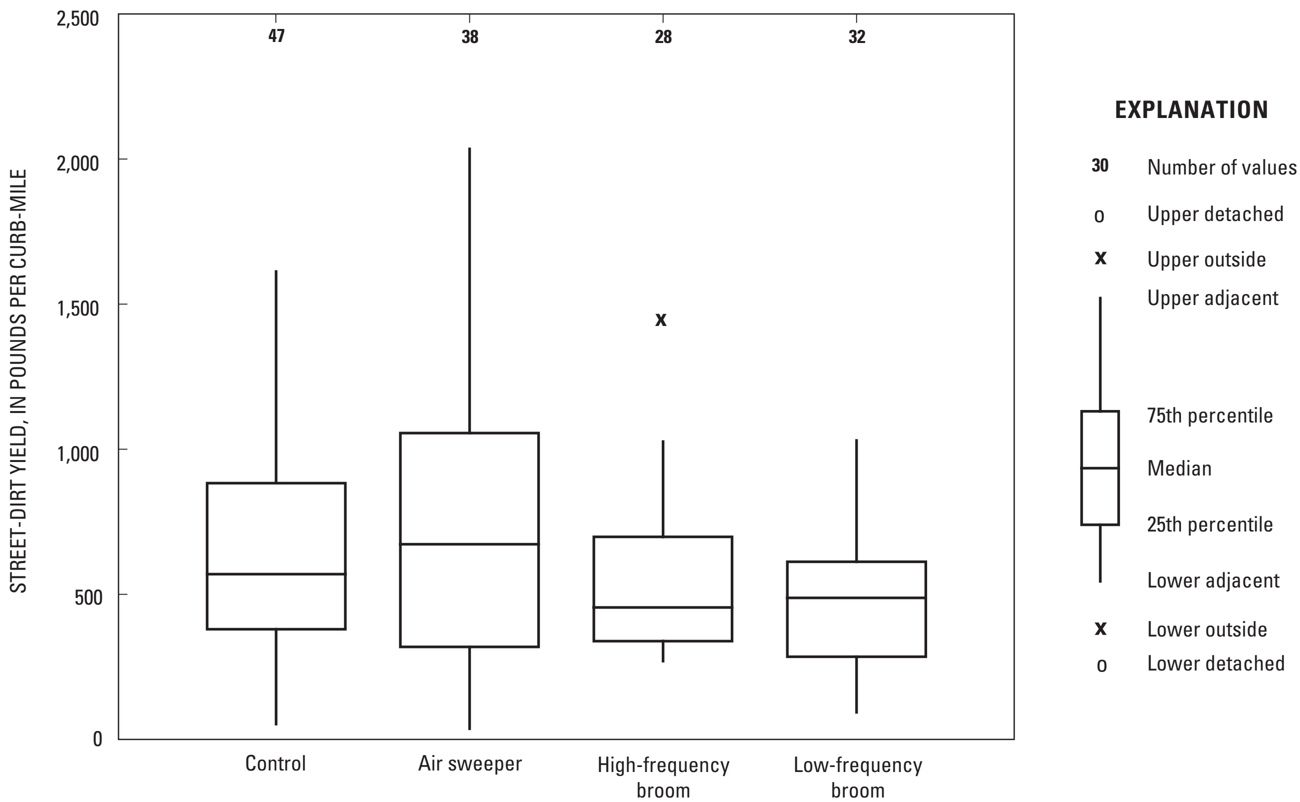

Figure 6. Average weekly street-dirt yields in the control and test basins during the calibration phase.

Table 6. Comparison of street-dirt yields, measured during the no-sweeping phase of this study in Madison, Wis., to those for other residential streets in the United States.

[--, no data; all values in pounds per curb-mile]

Statistic	Study basin				Previous studies			
	Control	Air sweeper	High-frequency broom	Low-frequency broom	Champaign, Ill.[1]	Bellevue, Wash.[2]	San Jose, Calif.[3]	U.S. nationwide[4]
Mean	614	776	559	486	408	815	310	391
Median	569	672	455	488	--	705	--	--

[1] Bender and Terstriep, 1984.

[2] Pitt, 1985.

[3] Pitt, 1979.

[4] Sartor and Boyd, 1972.

average basin street-dirt yield, conclusions drawn from this study may be transferable to other residential communities across the Nation.

The high-frequency broom basin was added to the study in May 2002; therefore, this report does not include any street-dirt sample data before that date. The late start in this basin may have had an effect on the summary statistics for the basin because the majority of street-dirt yield is often measured in early spring. Had the basin been added in March or April, the median street-dirt yield represented in figure 6 would likely have been greater. The influence of spring street-dirt yield is illustrated in both the control and air-sweeper basins, where the months of April and May were included in 2002 but not 2001 (fig. 7). Figure 8 further shows the seasonal influence on basin street-dirt yield by highlighting proportions of average load contributions during spring, summer, and fall for the control and air-sweeper basins during the 2002 sample-collection year. Average basin street-dirt yield during spring was 20 to 50 percent greater than loads measured during summer or fall in the control and study basins.

Each of the four basins was treated identically in that other than the single sweeper pass in March of each year, no street sweeping was done during a calibration period of 2 years. Street-dirt data collected from the control basin was paired with data from each of the test basins to establish a quantifiable relation. The basis of this paired-basin approach is that the relation between paired street-dirt yields for the control and tests basins is valid until a major change is made at one of the basins (Clausen and Spooner, 1993). At that time, a new relation will develop. The strength of this approach is that it does not require the assumption that the control and test basins are statistically the same; however, it does require that the two basins respond in a predictable manner together and that their relation remains the same over time except for the influence of street sweeping. Figure 9 represents the relations developed between the control and test basins during the calibration period. The relation is described by a simple linear regression. By use of analysis of variance (ANOVA), the significance of each linear regression was confirmed at the 5-percent significance level. There is a moderate to strong correlation between the control and test basin street-dirt yields, with correlation coefficients ranging from 0.73 to 0.80 for the high- and low-frequency broom basins, respectively.

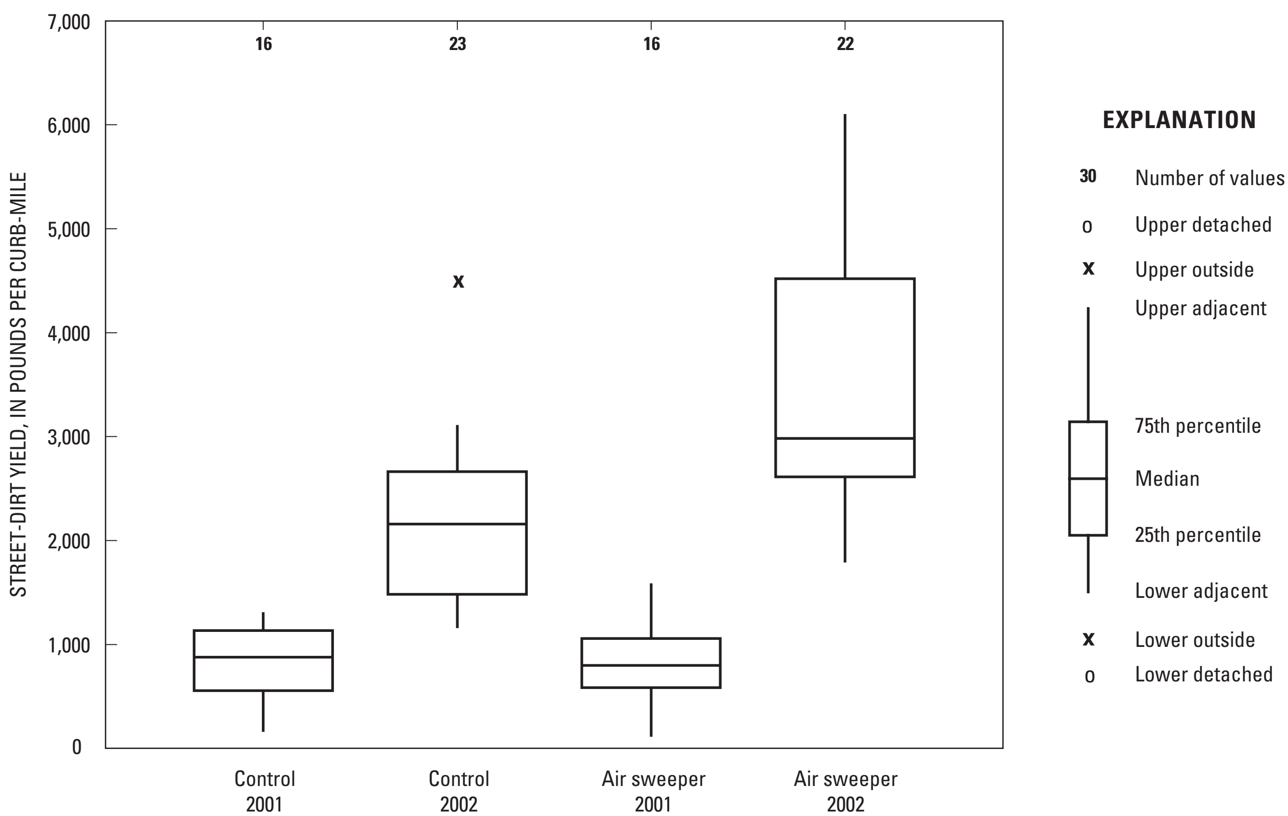

Figure 7. Influence of spring (April–May) street-dirt yield, in pounds per curb-mile, on total basin averages.

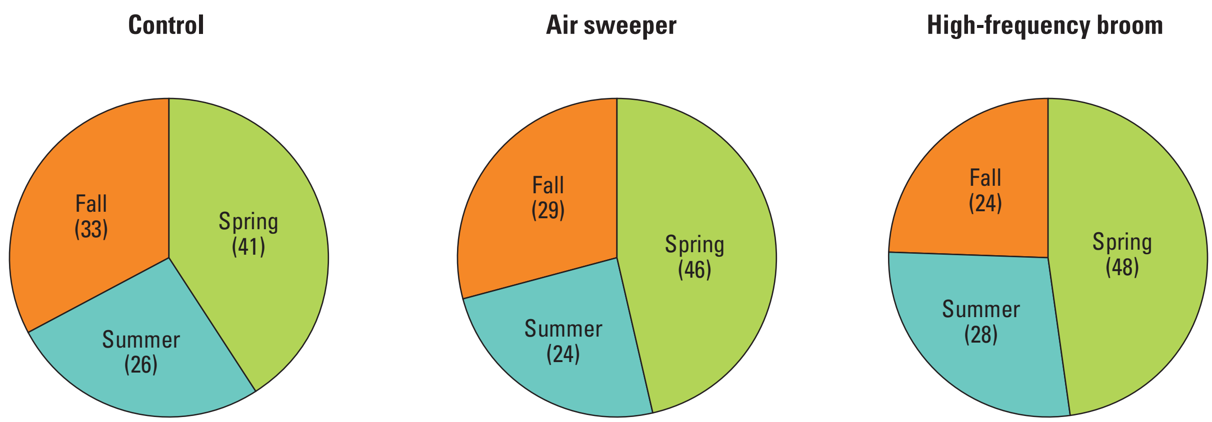

Figure 8. Average basin street-dirt yield categorized by season in the control and test basins during the 2002 calibration phase. Numbers in parentheses indicate percentage of street-dirt yield.

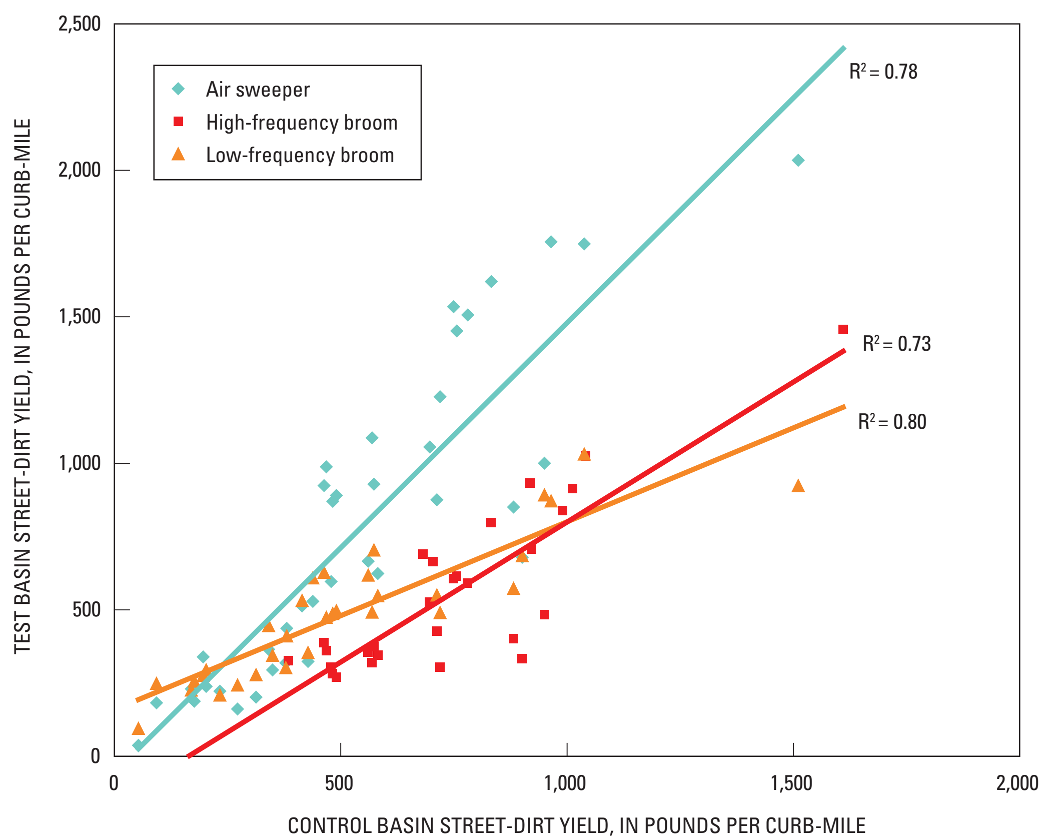

Figure 9. Paired-basin relation between the control and test basins during the calibration phase.

Treatment Phase

In spring 2003, street sweepers were dispatched weekly to the air-sweeper and high-frequency broom basins. The low-frequency broom basin resumed the normal sweeping schedule for the city (approximately once per month). Street-dirt samples were collected before and after street sweepers cleaned each basin. An effort was made to minimize the amount of time between presweeping and postsweeping operations each week. Typically, postsweeper street-dirt samples were collected within 24 to 48 hours after presweeping samples were collected. All street-dirt sample collection was suspended during rain and as long as street surfaces remained wet. If a rain event occurred after the presweeping sample was collected, the postsweeping sample collection effort was postponed up to 1 day until street surfaces were sufficiently dry. If the duration of wet streets persisted beyond 1 day, the postsweeping sample collection effort was canceled. Of the 103 sampling trips scheduled during the course of the study, only 16 were canceled because of weather or mechanical problems.

Weekly Street-Sweeper Performance

During the treatment phase of the study, street-dirt samples were collected weekly to determine the street-dirt-removal capabilities of each street-sweeping program. Samples were acquired before and after street sweepers cleaned each test basin. The performance of each sweeper was determined by analyzing the difference between presweeping and postsweeping street-dirt yields.

Because of limitations in the street-dirt sample-collection process, the percentage reductions presented herein are somewhat underestimated. The presweeping and postsweeping street-dirt samples represent the load across the entire width of a street surface. A street sweeper's path typically extends only 8 feet from the curb (M. Kinter, Elgin Sweepers, written commun., 2006), leaving the middle of the street unswept. It was necessary to measure the street-dirt yield across the entire street width to adequately quantify the load available for washoff during runoff events; however, inclusion of unswept dirt from the middle of the street confounded the presweeping versus postsweeping load computations.

An attempt was made to estimate the reduction in street-dirt that lies only within the sweeper path, excluding the part of the street that is normally unswept. Several samples were collected in the air-sweeper basin, characterizing the distribution of street-dirt yields across the width of a street. A logarithmic regression was fit to cumulative street-dirt yields at a distance of 3 and 13 feet from the curb. By use of the regression, a presweeping and postsweeping street-dirt yield was interpolated at a distance of 8 feet from the curb. On average, reduction in street-dirt yields increased only slightly (5 percent) when focusing on the actual sweeper path compared to the entire street width. This analysis suggests that sampling the entire street width has minor influence on assessment of overall street-sweeper performance. Therefore, discussion on sweeper performance refers to the reduction of street-dirt yield across the entire street width, and thus the total available load, rather than only that which lies in the path of the sweeper. Results of street-dirt distribution are presented and discussed in greater detail later in the report.

Table 7 details street-dirt removal statistics for each street sweeper evaluated during the study. A negative percentage indicates that more material was added than removed. The regenerative-air and vacuum-assist sweepers performed similarly over the range of measured values.

Table 7. Summary statistics of average basin street-dirt change for the regenerative-air, vacuum-assist, and high-frequency mechanical broom sweepers during the treatment phase. A negative value indicates an increase in street-dirt yield after sweeping.

[all values given in percent]

Statistic	Yield reduction, by sweeper type		
	Regenerative air	Vacuum assist	High-frequency broom
Maximum	51	52	46
Minimum	-3	-2	-41
Mean	25	30	5
Median	29	30	5
Number of samples	21	19	37

The vacuum-assist sweeper had slightly better removal capabilities with respect to the mean and median values. On average, the mechanical broom had minor removal capabilities and often would add to the overall street-dirt yield after cleaning. However, results of a Wilcoxon signed-ranks test (Helsel and Hirsch, 1992), used to find differences between non-normally distributed paired data sets, showed a slight but significant reduction from pre-sweeping to postsweeping street-dirt yields for the high-frequency broom basin at the 95-percent confidence level. Similar tests for the regenerative-air and vacuum-assist sweepers also showed a significant reduction in street-dirt yield at the 95-percent confidence level.

Many studies report a range of measured and simulated sediment removal capabilities ranging from 35 to over 90 percent for regenerative-air or vacuum-assist sweeper technologies (Sutherland and Jelen, 1997; The Terrene Institute, 1998; Bannerman, 1999; Shoemaker and others, 2000, as cited in Zarriello and others, 2002). Similarly, Breault and others (2005) measured overall average street-sweeper efficiency ranging from 60 to 92 percent for a vacuum-assist sweeper. The methods used to determine pickup efficiency in these cases typically involved one or more passes of a street sweeper over a premeasured, mechanically applied street-dirt mix on a test street surface. Although this approach may describe the performance of a street sweeper under a very specific set of controlled conditions, it may not fully test the range of loading conditions represented by a variety of street surfaces with varying initial street-dirt yields over time. In contrast, this study evaluated sweepers under the conditions in which they are typically used.

Of the 37 paired street-dirt samples collected in the high-frequency broom basin, 14 pairs showed an increase in street-dirt yield after the sweeper cleaned the basin; in contrast, 2 postsweeping loads were greater than pre-sweeping loads for the regenerative-air and vacuum-assist sweepers combined. One explanation for an increase in street-dirt yield after sweeping is the abrasive action of the wire bristles attached to the gutter brooms of each sweeper. By scouring the pavement, the wire-bristle brooms may loosen particles embedded in cracks found in the pavement or simply tear up the pavement itself. Although all three sweeper technologies make use of a wire-bristled gutter broom, the regenerative-air and vacuum-assist sweepers are better suited to remove a broader range of particles available for washoff by adding a powerful blast of air and (or) vacuum suction. The mechanical-broom sweeper simply passes any debris captured by the gutter broom into the path of a second, center-transfer broom.

The differences in street-dirt pickup efficiency between each sweeper can be further evaluated by analysis of particle size. Previous studies found mechanical-broom sweepers to be poorly suited for picking up particles of less than 10 to 250 micrometers (U.S. Environmental Protection Agency, 1983; Bender and Terstriep, 1984; Pitt, 1985; Wheaton and others, 1999; Shoemaker and others, 2000). Figure 10 illustrates the average weekly percent reduction of street dirt for particle sizes ranging from greater than 2,000 to less than 63 micrometers. As

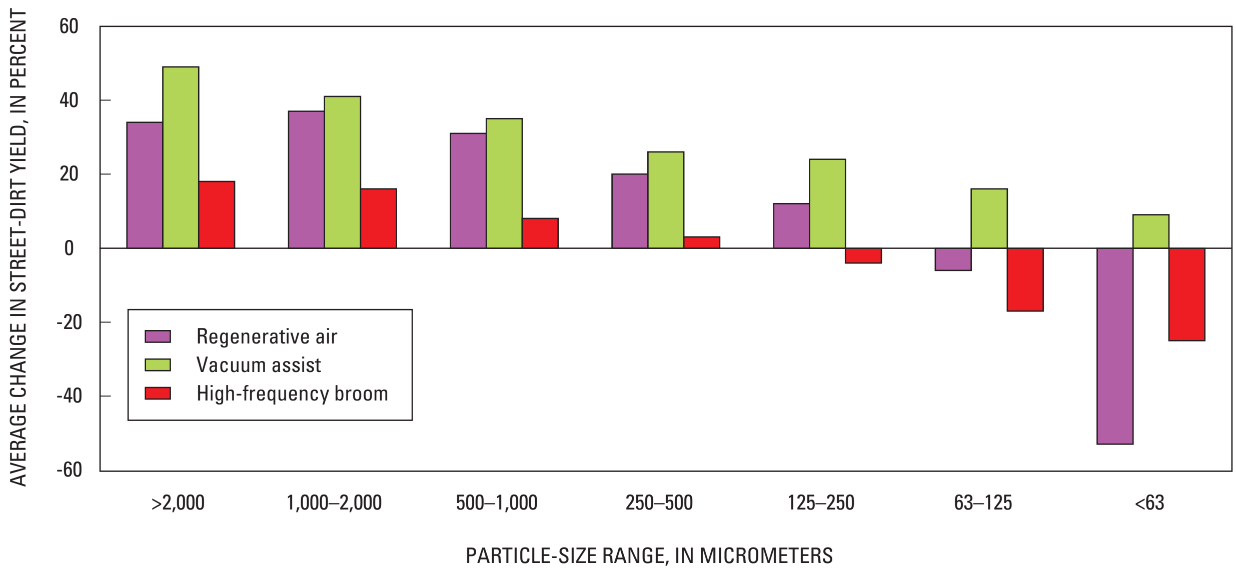

Figure 10. Average changes in weekly street-dirt yield as a function of particle size for three street-sweeping treatments in Madison, Wis. A negative value indicates an increase in street-dirt yield after sweeping.

in table 7, a negative percentage indicates more material was added than removed. Reductions of street-dirt yield decreased with decreasing particle size for all sweepers. The high-frequency mechanical broom and regenerative-air sweepers were unable to adequately pick up particles less than 250 and 125 micrometers, respectively. Only the vacuum-assist sweeper was capable of reducing street-dirt yield across the entire range of particle sizes measured. Even at the smallest particle-size fraction, less than 63 micrometers, the vacuum-assist sweeper was able to reduce a percentage of the street-dirt yield by incorporating a powerful vacuum that extends into the curb, overlapping part of the gutter-broom. The vacuum appears to capture most of what the gutter broom cannot.

Table 8. Distribution of street-dirt yield before and after street sweeping on a single street in the air-sweeper basin, April to June 2005.

[all values given in percent of total street-dirt yield]

Date	Curb		Center	
	Before	After	Before	After
April 21, 2005	30	27	70	73
April 28, 2005	44	25	56	75
May 5, 2005	46	29	54	71
May 18, 2005	64	23	36	77
May 25, 2005	71	30	29	70
June 2, 2005	74	27	26	73

Changes in Street-Dirt Distribution on a Street Surface

Pitt and Amy (1973) found that street dirt is unevenly distributed across the street surface and that 90 percent of the street-dirt total mass is within the first foot of the curb. A test was done during this study to identify the distribution of street dirt across a street width. Sampled streets in the air sweeper basin were split into "curb" and "center" lanes. The curb lanes stretched out 3 feet from the curb on each side of the street (fig. 11). The remaining 26 feet was considered the center lane (fig. 11). Table 8 shows the percentage contribution of street dirt for each lane from April through early June 2005. When normalized by area, the curb lanes contained less street dirt than the center lane during the early spring months. This result is likely due to remnants of winter sand, which is typically applied in residential areas for traction enhancement (A. Schumacher, City of Madison, written commun., 2006). However, each successive week recorded a transgression of street-dirt from the center to the curb lanes. By early summer, the curb lanes contained approximately 75 percent of the street dirt. This distribution was confirmed by an earlier test in August 2003 showing that 77 percent of street-dirt was contained in the curb lane. Furthermore, it appears the vacuum-assist sweeper operating in the basin during this test was able to reduce street dirt yield in the curb to a consistent level. This is evident from postsweeping street-dirt yield distribution percentages remaining relatively the same (approximately 25 percent) in the spring and summer, regardless of presweeping load (table 8). Despite more street dirt moving from the center lane to curb lanes, the vacuum-assist sweeper was able to remove the increased load and maintain a stable distribution across the street width.

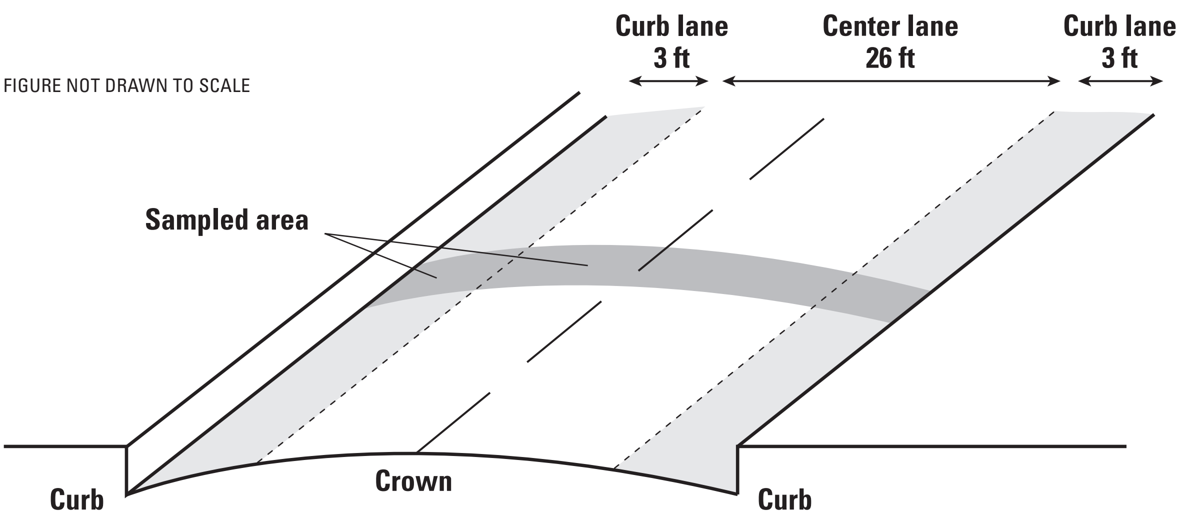

Figure 11. Location of sub-sampling strips to determine the distribution of street-dirt yield across a street.

The Nationwide Urban Runoff Program (NURP) recognized that street-dirt removal performance is higher with increasing street-dirt yield and that a certain residual load remains on each street at which no additional sweeping has any beneficial impact (Bannerman and others, 1983). Figure 12 illustrates how sweeper-removal rates vary proportionally to the available initial street-dirt yield in each of the test basins. For each sweeper evaluated, the amount of street dirt removed increased with increasing initial street-dirt yield. The mechanical broom sweeper appears to be relatively ineffective until the initial street-dirt yield approaches 1,000 pounds per curb-mile, whereas both the regenerative-air and vacuum-assist sweepers are effective at much lower initial street-dirt yields (fig. 12). Typically, street-dirt yields of this magnitude are measured during early spring months and are a reflection of the above-mentioned accumulated sand applied during the winter for better traction. Therefore, street-sweeping programs utilizing mechanical-broom sweepers could improve the overall reduction of street dirt by cleaning the entire street width rather than just the curb lanes during periods of heavy loading commonly associated with winter sand application in cold climates.

Changes in Basin Street Dirt as a Result of Street Sweeping

Figure 13 details average weekly street-dirt yields in each basin during the treatment phase. The data used to build figure 13 represent the weekly basin street-dirt yield before street sweepers entered each basin. The street-dirt yields presented in figure 13 for the air-sweeper basin represent a combined effect of the regenerative-air and vacuum-assist sweepers. The control basin (not swept) had the highest median street-dirt yield with decreasing yields in the low-frequency broom, high-frequency broom, and air-sweeper basins, respectively. Table 9 details the average basin percent distribution of particle sizes measured during the calibration and treatment phases. Similar to the calibration phase, the majority of particles in each basin during the treatment phase were greater than 250 micrometers. Both the regenerative-air and vacuum-assist sweepers produced slight reductions of particles greater than 250 and 500 micrometers, respectively. The broom sweeper, regardless of operating frequency, was only capable of reducing particles greater than 1,000 micrometers. All sweepers evaluated during this study produced slight increases in the percentage of particles less than 125 micrometers.

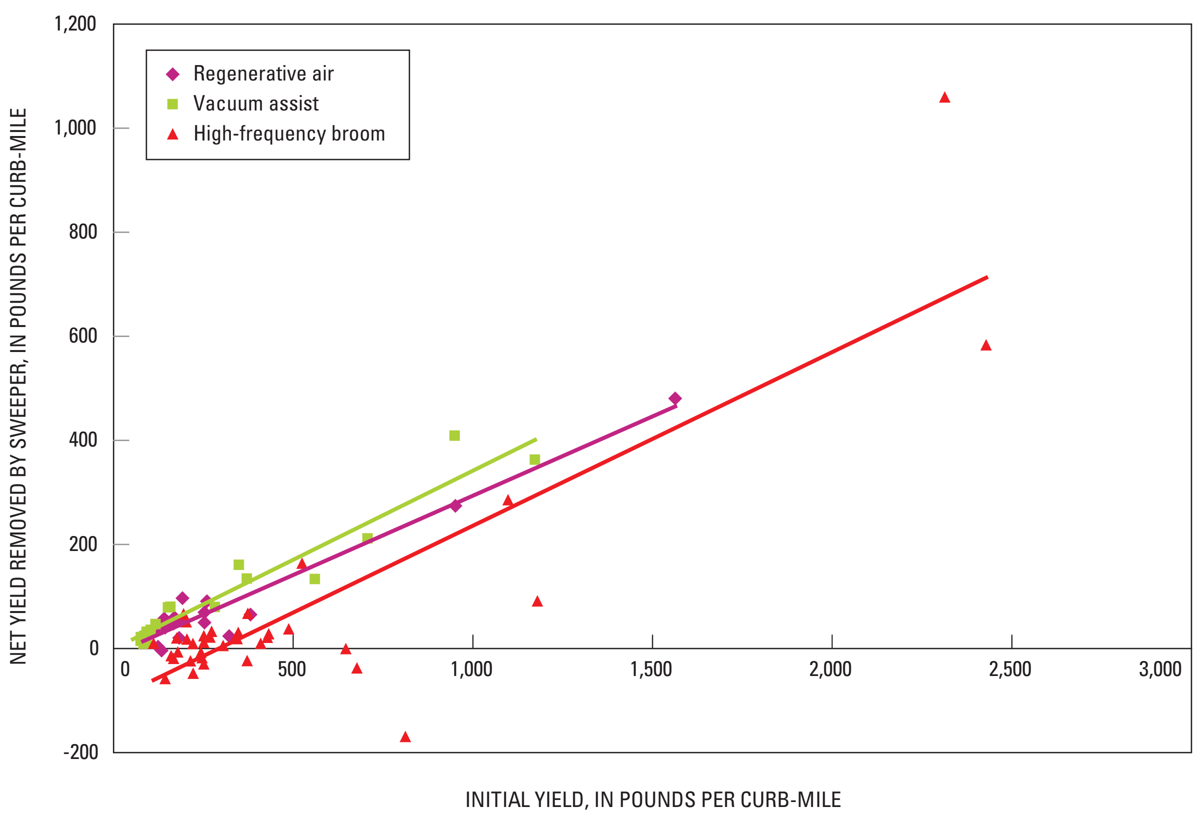

Figure 12. Street sweeper removal capabilities as a function of initial street-dirt yield, in pounds per curb-mile. A negative value for net yield removed indicates an increase in street-dirt yield after sweeping.

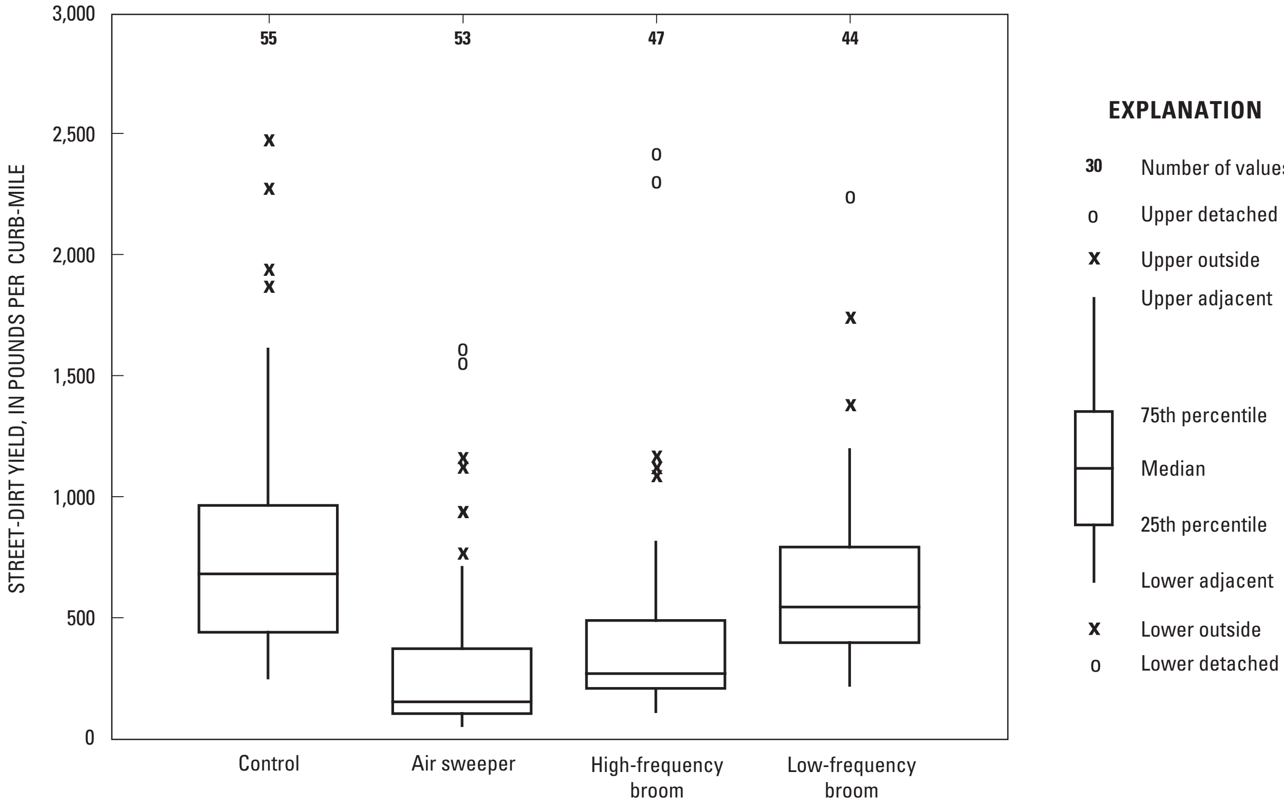

Figure 13. Average weekly street-dirt yield, in pounds per curb-mile, during the treatment phase.

Table 9. Distribution of particles measured from street surfaces in the control and test basins during the calibration and treatment phases.

[>, greater than; <, less than; all values given in percent of total mass; columns may not total to 100 percent because of independent rounding]

Particle size (micrometers)	Percent of total mass, by basin and phase of study								
	Regenerative air		Vacuum assist		High-frequency broom		Low-frequency broom		Control
	Calibration	Treatment	Calibration	Treatment	Calibration	Treatment	Calibration	Treatment	
Detritus	6	8	6	5	3	3	8	3	2
>2,000	9	6	9	8	8	7	10	8	10
1,000–2,000	12	9	12	9	12	11	12	11	12
500–1,000	20	16	20	16	21	22	18	19	19
250–500	31	30	31	33	32	33	27	31	30
125–250	15	18	15	17	15	16	15	17	16
63–125	4	7	4	7	5	5	6	6	6
<63	3	5	3	5	4	3	3	4	5

According to the paired-basin approach, any change in the relation established between the control and test basins during the calibration phase of the study can be attributed directly to street-sweeping activity. The magnitude of change may reflect upon the technology of the sweeper used, the frequency of sweeping, or both. Changes in the relation between paired data during the treatment phase of the study are highlighted in figures 14a-c. As with the calibration regression, an ANOVA test was performed on each treatment regression to confirm its significance at the 5-percent level.

At the end of the treatment period, the significance of the effect of street sweeping was determined using analysis of covariance (ANCOVA) (Clausen and Spooner, 1993). Results of the ANCOVA test indicate a significant change (95-percent confidence level) between the calibration and treatment relations in the air-sweeper basin for both the regenerative-air and vacuum-assist sweepers. The high-frequency broom basin also had a significant change (95-percent confidence level) in the intercept of the treatment regression. However, a change in slope between the calibration and treatment phases for the high-frequency broom basin was determined to be insignificant. This indicates an overall parallel shift in the regression equation. In this case, the treatment regression shifted below that of the calibration phase, demonstrating some level of benefit at reducing street-dirt yields. The low-frequency broom basin did not have a significant change for either the slope or intercept of the treatment regression, suggesting little to no change in street-dirt yields when compared to the calibration phase. If the results of the ANCOVA test for slope and (or) intercept reveal a significant difference between the calibration and treatment regressions, the regression equation representing the calibration period for the control basin can be used to quantify the degree of street-dirt reduction as a result of street sweeping by predicting what average weekly street-dirt yields should have been during the treatment phase in the absence of street sweeping. The overall reduction due to street sweeping can then be expressed as a percentage change on the basis of the average predicted and observed values during the treatment phase (Clausen and Spooner, 1993). The regenerative-air and vacuum-assist sweepers, used on a weekly basis, resulted in the largest reduction in street-dirt yields at 76 and 63 percent, respectively. These reductions are represented graphically in figure 14a. The broom sweeper at the high-frequency schedule had less influence, removing only 20 percent of the basin street-dirt yield (figure 14b). Because the results of the ANCOVA test indicated no significant difference between the calibration and treatment phases in the low-frequency broom basin, any reduction in street-dirt yield as a result of street sweeping was negligible (figure 14c). Table 10 lists street-dirt-yield summary statistics for each basin during the calibration and treatment phases.

Street sweepers can alter the amount of street-dirt washed off a street during a runoff event by increasing the percentage of fine particles (less than 63 micrometers) (Bannerman and others, 1983; Pitt and others, 2004). The increase in fines is typically a combination of the mechanical action of the gutter broom on the sediment adhered tightly to the pavement and the preferential removal of the larger particles on the street. Evidence exists that some of the fine particles are not available for washoff in the absence of street sweeping but are available only after the gutter broom dislodges them from the pits and cracks in the street (Pitt and others, 2004). The percentage of fines on streets in the air-sweeper and high-frequency broom basins sometimes increased after a street sweeper passed (fig. 10). By removing the majority of larger particles (greater than 63 micrometers) on a street surface, street sweepers also reduce the armoring of fine particles (Burton and Pitt, 2002).

Increasing the amount of fines on a street can change its washoff characteristics because rain can be more effective at removing smaller particles from streets than street sweepers (Pitt and others, 2004). Consistent with previous studies, the three types of street sweepers tested in this study were able to remove a greater percentage of larger particles than smaller particles (fig. 10). In contrast, work done by Pitt (1985) shows that the amount of particles washed off a street surface increases as particle size decreases. Stormwater-quality samples collected at the air-sweeper basin outlet also show a higher percentage of fines in the runoff than in the street dirt. During the treatment periods, the amount of fines in the runoff averaged about 40 percent (table 15), whereas only about 5 percent of the street dirt was in the less than 63-micrometer size fraction (table 9). If the amount of fines washed off a street surface is increased by street sweeping, the reduction in the street-dirt yield could be a function of both the street sweepers and the increased effect of rainfall.

Effect of Rainfall on Street Dirt

In addition to street sweeping, removal of street-dirt can occur naturally by wind, rain, or human activity, such as vehicular traffic. Previous studies have shown significant removal of street dirt (up to 90 percent) for rains exceeding 10 millimeters (0.39 inch) (Pitt and Amy,

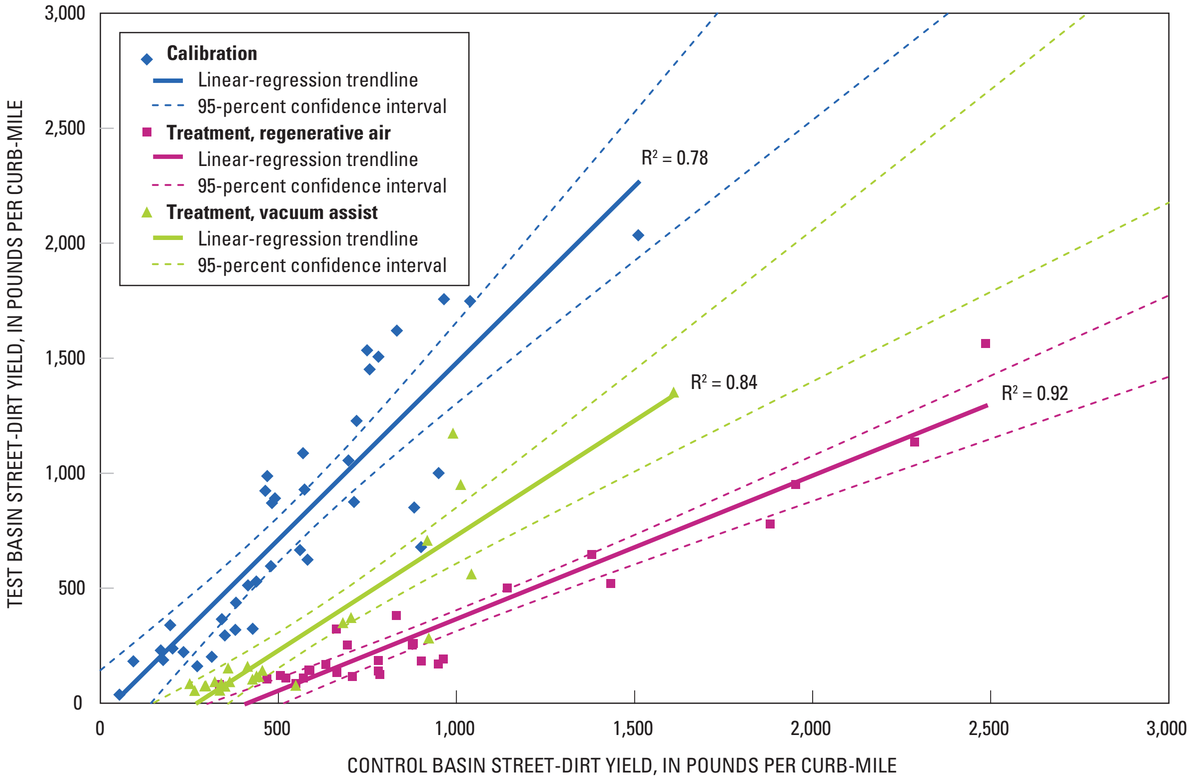

Figure 14a. Response of average weekly street-dirt yield, in pounds per curb-mile, to street sweeping in the air-sweeper basin.

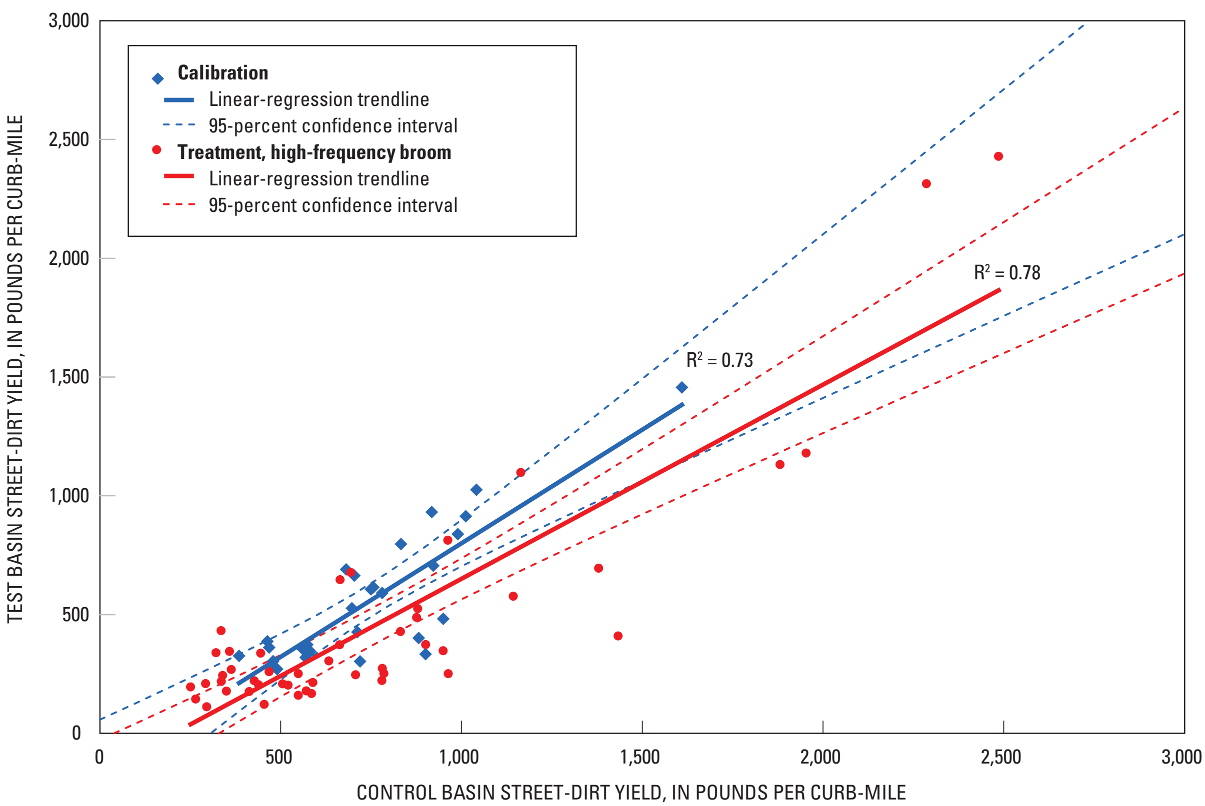

Figure 14b. Response of average weekly street-dirt yield, in pounds per curb-mile, to street sweeping in the high-frequency broom basin.

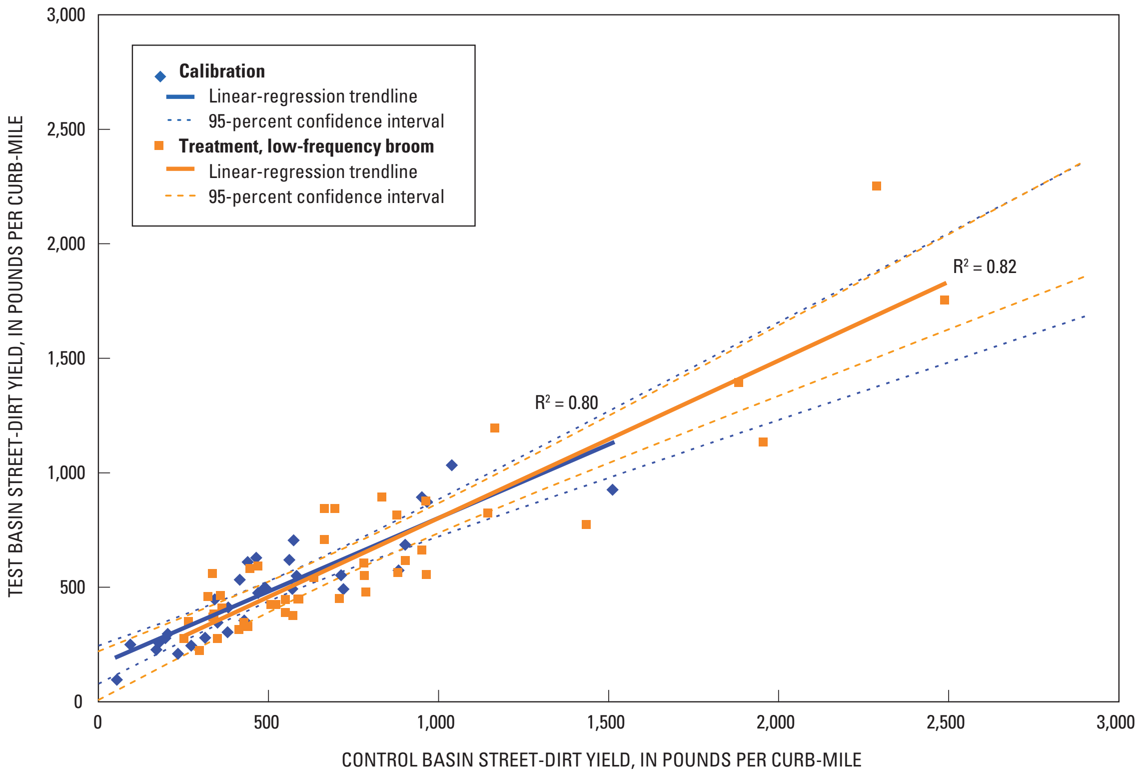

Figure 14c. Response of average weekly street-dirt yield, in pounds per curb-mile, to street sweeping in the low-frequency broom basin.

Table 10. Summary statistics of average basin street-dirt yields for the control and test basins during calibration and treatment phases.

[all values in pounds per curb-mile]

Statistic	Basin				
	Control	Air sweeper (type of sweeper)		High-frequency broom	Low-frequency broom
		Regenerative air	Vacuum assist		
		Calibration phase			
Maximum	1,610	2,034	2,034	1,457	1,030
Minimum	53	37	37	270	94
Mean	614	776	776	558	486
Median	569	672	672	455	488
Standard deviation	338	526	526	279	226
Coefficient of variation	0.56	0.69	0.69	0.51	0.47
Number of samples	47	38	38	28	32
		Treatment phase			
Maximum	2,486	1,563	1,352	2,428	2,250
Minimum	251	82	54	111	220
Mean	794	340	304	456	639
Median	681	182	116	269	544
Standard deviation	492	352	366	477	392
Coefficient of variation	0.63	1.03	1.20	1.06	0.62
Number of samples	55	31	24	47	44

1979). Frequent rains can also minimize the accumulation of street dirt over time. A study in Bellevue, Wash., concluded that frequent rains were more effective at keeping streets clean than street sweeping was (Pitt, 1985). Frequent rains add complexity when evaluating the performance of street sweepers simply because it is difficult to determine the amount of street dirt removed by rain or by the street sweeper. Furthermore, large storms can wash dirt onto street surfaces from surrounding areas (U.S. Environmental Protection Agency, 1982).

One solution is to collect street-dirt samples at frequent intervals, such as daily. However, financial limitations preclude such an undertaking in most studies. An example of how rainfall can affect total basin street-dirt yield is illustrated in figure 15. Of particular note is how total street-dirt yield in the control basin remained relatively constant in 2002 and 2003, then fell sharply in 2004. The majority of street-dirt yield measured during April and May was likely residual sand from application during prior winter months. The combined rainfall totals for April and May were 6.07, 7.18, and 13.61 inches in 2002, 2003, and 2004, respectively. Because of the large amount of available street dirt during this time, rainfall may have the greatest impact on available street-dirt yield. This is especially true if early spring rains precede sweeper deployment. If the monthly rainfall for April and May in 2004 had been similar to the corresponding values for previous years, one might expect a similar pattern of basin street-dirt yield. The control and test basins were located close to each other to reduce variability due to isolated rainstorms. However, the cleansing action of rain could have a more pronounced affect on sediment washoff in the study basins by altering the physical characteristics of street dirt caused by street sweeping.

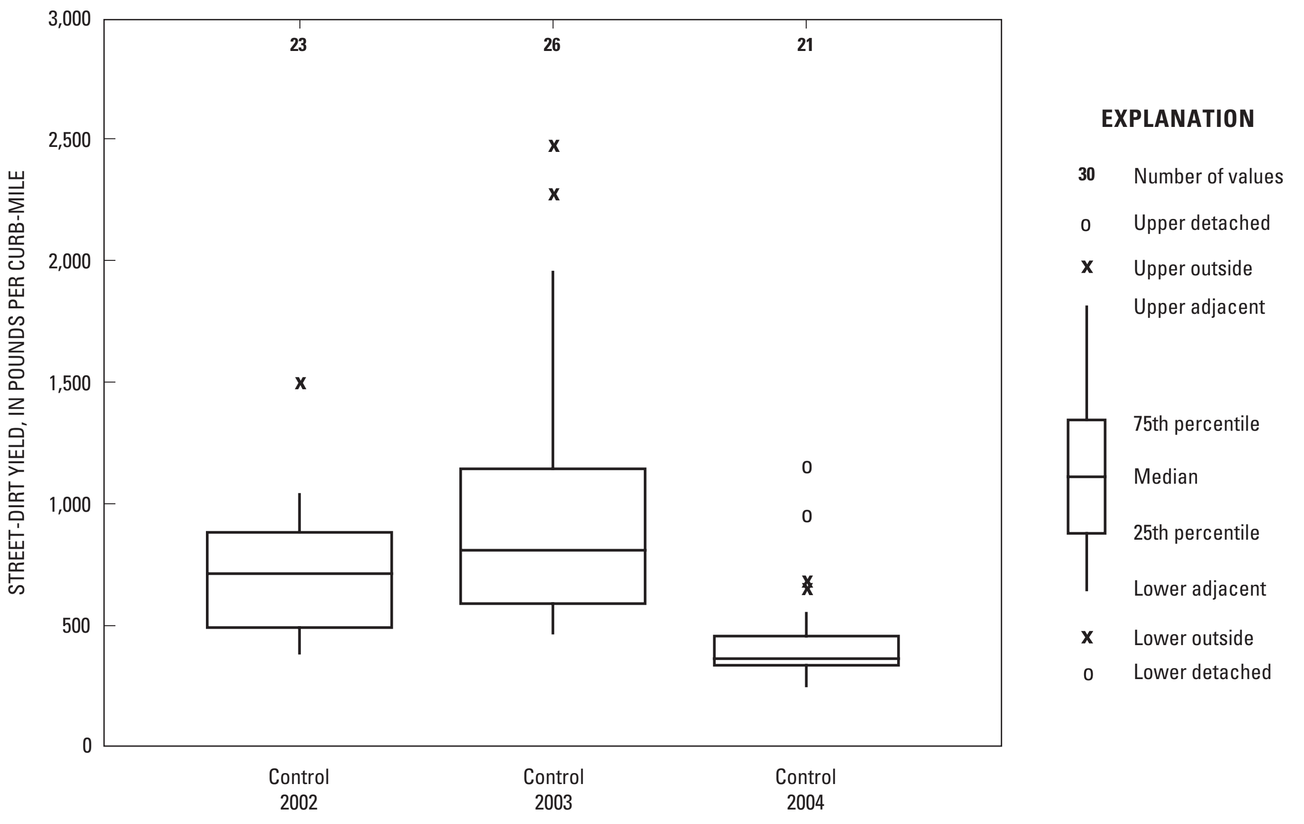

Figure 15. Comparison of street-dirt yields in the control basin, 2002–2004 (reduced yield in 2004 is the result of excessive rainfall during the period April to May 2004).

Effects of Street Sweeping on Stormwater-Runoff Quality

In addition to street-dirt removal, changes in the quality of stormwater runoff were measured to determine whether street sweeping could reduce sediment and sediment-associated constituent concentrations and loads at the basin outfall. The effects of street sweeping on stormwater-runoff quality were evaluated by use of statistical tests to compare flow-weighted event mean concentrations and loads computed for individual storms at the control and test basins. Loads were computed by multiplying the event mean concentrations by stormwater runoff volumes. Results of the tests indicate little probability that street sweeping, regardless of sweeper type, had any measurable affect on the quality of runoff.

Previous Studies

Literature reviews from previous studies (Zarriello and others, 2002; Breault and others, 2005) highlight a wide range of street-sweeper efficiencies for the reduction of end-of-pipe constituent concentrations and loads in urban runoff. The majority of street-sweeping studies in the late 1970s and early 1980s examined primarily mechanical-broom-type sweepers. More recent studies have included the evaluation of newer sweeper technologies, such as regenerative-air and vacuum-assist type sweepers. However, most studies evaluating these sweeper technologies are limited in the number of constituents measured during the course of the study. Removal of sediment is typically reported, but other sediment-associated constituent concentrations such as phosphorus and metals are rarely discussed (Zarriello and others, 2002).

Many of the studies done as part of the Nationwide Urban Runoff Program (NURP) examined the effectiveness of mechanical sweepers. Those studies concluded that street sweeping was not a viable stormwater-quality-management practice (Smith and Lord, 1990; Sartor and Gaboury, 1984; Atahyde and others, 1983; Sartor and Boyd, 1975, as cited in Zarriello and others, 2002). Bender and Terstriep (1984) and Prych and Ebbert (1986) also indicated the ineffectiveness of mechanical-broom sweepers by noting no significant differences in event mean concentrations before and after sweeping. Other mechanical-broom-sweeper studies reported as much as a 30-percent reduction in end-of-pipe sediment loads, but only under favorable conditions (Sartor and Gaboury, 1984).

As sweeper technology improved, so did the ability to pick up smaller particles that are readily available for washoff into nearby storm drains. Sutherland and Jelen (1997) reported simulated reductions of as much as 70 to 85 percent for average annual suspended solids and associated constituent loads with twice-weekly sweepings in a single-family residential neighborhood.

Examination of Stormwater-Quality Concentrations and Loads

Descriptive statistics for event mean concentrations and loads measured at the control, air, and high-frequency broom basins are summarized in tables 11 and 12. A complete list of event mean concentrations and loads can be found in tables 1-8 and 1-9 in appendix 1, respectively. Tables 1-8 and 1-9 also identify concentrations and loads measured when either the regenerative air or the vacuum-assist sweeper was operated in the air-sweeper basin. Several samples collected over the course of the study were excluded from statistical analyses. Typically, these samples were censored because of inadequate hydrograph coverage, suspicion of contamination due to unforeseen basin changes (such as road construction), flushing of fire hydrants, or runoff due to snowmelt.

The variability in constituent loads monitored during the calibration and treatment phases is illustrated in figure 16. Given the variability observed in the load data, it is difficult to discern any differences between study phases. Median values for orthophosphorus appear to exhibit the most noticeable decrease during the treatment phase. However, it is difficult to attribute this decrease to street sweeping by visual inspection alone because the control basin showed a similar decrease. Any reductions identified in the control and test basins could be a result of some environmental factor other than street sweeping. In some cases, median sample constituent loads increased during the treatment phase. Median loads for dissolved copper and zinc increased in the high-frequency broom basin, as did total copper and total phosphorus in the air-sweeper basin. However, examination of the median fails to explain the variability of loads measured in each basin, therefore making it difficult to detect any significant difference between the calibration and treatment phases.

Constituent loads were tested for normality/log-normality by means of the Shapiro-Wilk test statistic (Helsel and Hirsch, 1992). Distributions of constituent loads in the basins during calibration and treatment phases were not consistently normal or lognormal. Therefore, examination

Table 11a. Summary of water-quality concentrations in stormwater from the control and air-sweeper basins during calibration and treatment phases.

[ppb, parts per billion; ppm, parts per million]

Constituent	Statistic, by type of basin or sweeper				
	Number of samples		Mean		
	Control	Air sweeper	Control	Air sweeper	
Calibration phase					
Cadmium, total (ppb)	18	18	3.86	0.51	
Copper, total (ppb)	34	27	13.41	21.46	
Lead, total (ppb)	32	26	7.89	28.43	
Zinc, total (ppb)	34	27	65.92	122.85	
Calcium, total (ppm)	34	27	23.89	52.75	
Magnesium, total (ppm)	34	27	11.30	26.09	
Ammonia-nitrogen (ppm)	33	27	0.46	0.45	
Phosphorus, total (ppm)	34	27	0.91	0.88	
Suspended sediment (ppm)	34	27	469.01	1,187.69	
Copper, dissolved (ppb)	27	23	3.15	3.00	
Zinc, dissolved (ppb)	34	27	6.64	9.06	
Orthophosphorus, dissolved (ppm)	33	27	0.19	0.23	
Solids, dissolved (ppm)	34	27	68.59	70.00	
Nitrate plus nitrite, dissolved (ppm)	33	26	0.48	0.47	

Constituent	Control	Regenerative air	Vacuum assist	Control	Regenerative air	Vacuum assist
Treatment phase						
Cadmium, total (ppb)	19	8	8	2.08	0.30	0.23
Copper, total (ppb)	35	13	21	20.04	20.23	13.94
Lead, total (ppb)	34	13	21	11.84	17.71	11.97
Zinc, total (ppb)	35	13	21	68.70	106.63	82.13
Calcium, total (ppm)	35	13	21	40.17	52.88	19.94
Magnesium, total (ppm)	35	13	21	19.51	25.22	9.30
Ammonia-nitrogen (ppm)	35	13	21	0.56	0.59	0.47
Phosphorus, total (ppm)	35	13	21	0.73	0.76	0.52
Suspended sediment (ppm)	35	13	21	699.92	947.26	350.63
Copper, dissolved (ppb)	27	12	15	4.00	4.36	2.89
Zinc, dissolved (ppb)	35	13	21	7.04	19.61	7.33
Orthophosphorus, dissolved (ppm)	34	13	20	0.18	0.16	0.18
Solids, dissolved (ppm)	36	14	21	67.39	63.93	61.33
Nitrate plus nitrite, dissolved (ppm)	36	14	21	0.49	0.44	0.48

Statistic, by type of basin or sweeper							
Median		Minimum		Maximum		Standard deviation	
Control	Air sweeper	Control	Air sweeper	Control	Air sweeper	Control	Air sweeper
Calibration phase							
0.30	0.40	0.03	0.05	59.90	18.00	14.03	0.35
12.50	16.00	2.60	3.90	28.00	27.00	7.06	14.21
5.25	17.00	0.96	2.30	22.00	26.00	5.34	35.37
42.50	81.00	11.00	17.00	658.00	27.00	107.60	102.41
16.00	44.00	5.40	5.70	98.00	27.00	22.10	46.31
6.75	23.00	2.00	2.30	52.80	27.00	11.59	24.53
0.51	0.38	0.06	0.04	0.91	1.00	0.22	0.25
0.52	0.75	0.15	0.19	11.00	2.74	1.87	0.58
234.00	500.00	39.00	48.00	3,394.00	4,470.00	617.43	1,262.72
2.80	2.50	1.40	1.20	6.90	7.00	1.44	1.48
5.95	6.70	1.20	1.70	21.00	28.00	4.55	7.21
0.14	0.16	0.06	0.05	0.64	0.87	0.13	0.17
57.50	58.00	22.00	25.00	224.00	298.00	43.85	49.54
0.43	0.41	0.24	0.19	1.01	1.01	0.18	0.21

Control	Regen-erative air	Vacuum assist	Control	Regen-erative air	Vacuum assist	Control	Regen-erative air	Vacuum assist	Control	Regen-erative air	Vacuum assist
Treatment phase											
0.25	0.29	0.22	0.11	0.21	0.04	34.00	0.48	0.47	7.73	0.08	0.14
16.00	20.00	12.08	3.74	8.60	4.65	74.41	39.00	50.00	15.83	8.30	9.56
8.41	16.00	8.70	1.60	3.40	3.50	36.61	33.00	39.00	9.10	10.63	8.78
52.00	99.25	62.69	13.98	37.00	25.24	174.00	207.00	320.00	43.47	51.66	62.94
19.34	34.55	15.36	4.93	8.30	4.83	206.76	152.00	98.00	47.19	44.52	20.15
8.20	17.76	6.12	1.62	2.50	1.61	109.69	76.80	47.00	24.58	23.50	9.90
0.49	0.53	0.32	0.08	0.26	0.14	2.32	1.17	1.74	0.41	0.26	0.38
0.60	0.74	0.42	0.18	0.33	0.15	4.04	1.52	2.04	0.68	0.32	0.38
261.19	873.67	264.11	36.00	102.00	35.00	3,359.65	2,666.00	1,196.00	909.87	735.89	291.66
3.80	3.20	2.60	1.40	1.80	1.50	12.00	14.00	5.60	2.26	3.32	1.05
5.00	10.00	7.50	0.80	2.70	1.00	21.00	83.00	21.00	4.82	24.69	4.72
0.13	0.14	0.13	0.04	0.07	0.05	0.68	0.30	0.68	0.13	0.08	0.15
61.50	69.00	52.00	31.00	21.00	41.00	154.00	94.00	163.00	28.43	23.64	26.84
0.41	0.37	0.41	0.27	0.15	0.26	1.43	0.89	1.20	0.25	0.21	0.22

Table 11b. Summary of water-quality concentrations in stormwater from the control and high-frequency broom basins during calibration and treatment phases.

[ppb, parts per billion; ppm, parts per million]

Constituent	Statistic, by type of basin or sweeper			
	Number of samples		Mean	
	Control	High-frequency broom	Control	High-frequency broom
Calibration phase				
Cadmium, total (ppb)	21	10	3.35	0.44
Copper, total (ppb)	41	23	14.17	27.28
Lead, total (ppb)	39	22	8.86	12.79
Zinc, total (ppb)	41	23	69.22	162.56
Calcium, total (ppm)	41	23	24.21	56.89
Magnesium, total (ppm)	41	23	11.32	28.67
Ammonia-nitrogen (ppm)	40	21	0.55	0.51
Phosphorus, total (ppm)	41	23	0.87	0.88
Suspended sediment (ppm)	41	23	444.38	1,387.02
Copper, dissolved (ppb)	32	20	3.11	3.25
Zinc, dissolved (ppb)	41	23	6.72	8.01
Orthophosphorus, dissolved (ppm)	40	23	0.19	0.23
Solids, dissolved (ppm)	41	23	69.02	61.61
Nitrate plus nitrite, dissolved (ppm)	40	22	0.52	0.53
Treatment phase				
Cadmium, total (ppb)	16	6	2.42	0.31
Copper, total (ppb)	28	24	20.58	46.08
Lead, total (ppb)	27	23	11.45	24.28
Zinc, total (ppb)	28	24	64.56	143.83
Calcium, total (ppm)	28	24	43.78	107.93
Magnesium, total (ppm)	28	24	21.52	52.11
Ammonia-nitrogen (ppm)	28	24	0.46	0.41
Phosphorus, total (ppm)	28	24	0.74	0.80
Suspended sediment (ppm)	28	25	793.71	2,246.91
Copper, dissolved (ppb)	22	21	4.25	4.00
Zinc, dissolved (ppb)	28	24	7.03	10.30
Orthophosphorus, dissolved (ppm)	27	24	0.17	0.18
Solids, dissolved (ppm)	29	25	66.48	58.44
Nitrate plus nitrite, dissolved (ppm)	29	25	0.43	0.41

Statistic, by type of basin or sweeper							
Median		Minimum		Maximum		Standard deviation	
Control	High-frequency broom	Control	High-frequency broom	Control	High-frequency broom	Control	High-frequency broom
Calibration phase							
0.30	0.23	0.03	0.09	59.90	1.54	13.00	0.45
12.00	19.00	2.60	5.40	34.77	162.80	8.04	31.89
6.52	7.71	0.96	1.70	22.32	42.21	6.07	10.94
43.00	79.32	11.00	33.00	658.00	1,183.69	100.59	270.34
16.00	19.70	5.40	8.40	98.00	521.74	21.19	108.76
6.40	7.90	2.00	2.70	52.80	263.97	11.05	56.04
0.53	0.44	0.06	0.13	2.32	1.22	0.37	0.26
0.51	0.80	0.15	0.34	11.00	3.18	1.71	0.59
230.00	541.00	39.00	121.00	3,394.00	13,472.70	571.02	2,822.55
2.85	2.45	1.40	1.30	6.90	15.00	1.37	2.94
5.90	5.70	1.20	1.30	21.00	35.00	4.53	7.54
0.14	0.17	0.04	0.07	0.68	0.67	0.14	0.15
58.00	58.00	22.00	32.00	224.00	98.00	42.71	20.14
0.45	0.48	0.24	0.25	1.43	1.10	0.24	0.20
Treatment phase							
0.26	0.25	0.11	0.21	34.00	0.49	8.42	0.12
16.00	12.35	3.74	5.80	74.41	785.07	16.84	157.59
7.83	6.60	1.60	0.07	36.61	350.09	9.55	71.73
55.26	56.50	13.98	23.74	152.42	1,965.27	39.15	390.26
20.17	10.80	4.93	5.60	206.76	1,972.48	51.67	399.20
8.65	5.05	1.62	1.73	109.69	971.98	26.89	196.89
0.36	0.30	0.08	0.06	1.27	1.26	0.27	0.33
0.61	0.44	0.18	0.17	4.04	7.03	0.72	1.36
270.60	262.00	36.00	26.00	3,359.65	41,418.42	992.09	8,238.95
4.05	3.40	1.40	1.60	12.00	13.00	2.40	2.50
4.95	9.30	0.80	1.30	21.00	25.00	4.91	6.05
0.13	0.16	0.07	0.09	0.53	0.66	0.10	0.12
64.00	62.00	31.00	20.00	146.00	100.00	25.84	18.79
0.39	0.36	0.27	0.24	0.95	0.70	0.16	0.13

Table 12a. Summary of loads in the control and air-sweeper basins during calibration and treatment phases.

Constituent	Statistic, by type of basin or sweeper				
	Number of samples		Mean		
	Control	Air sweeper	Control	Air sweeper	
Calibration phase					
Cadmium, total (grams)	18	18	5.23	0.38	
Copper, total (grams)	34	27	11.86	15.35	
Lead, total (grams)	32	26	7.74	17.69	
Zinc, total (grams)	34	27	66.90	80.28	
Calcium, total (kilograms)	34	34	23.25	30.76	
Magnesium, total (kilograms)	34	27	11.13	19.73	
Ammonia-nitrogen (kilograms)	33	27	0.40	0.28	
Phosphorus, total (kilograms)	34	27	0.88	0.57	
Suspended sediment (kilograms)	34	27	485.87	906.93	
Copper, dissolved (grams)	27	23	2.60	1.62	
Zinc, dissolved (grams)	34	27	5.44	4.75	
Orthophosphorus, dissolved (kilograms)	33	27	0.14	0.12	
Solids, dissolved (kilograms)	34	27	74.21	39.16	
Nitrate plus nitrite, dissolved (kilograms)	33	26	0.43	0.26	

Constituent	Control	Regenerative air	Vacuum assist	Control	Regenerative air	Vacuum assist
Treatment phase						
Cadmium, total (grams)	19	8	8	1.11	0.21	0.10
Copper, total (grams)	35	13	21	10.60	11.95	6.04
Lead, total (grams)	34	13	21	6.25	11.33	6.14
Zinc, total (grams)	35	13	21	35.11	59.00	33.48
Calcium, total (kilograms)	35	13	22	22.49	30.52	8.15
Magnesium, total (kilograms)	35	13	21	11.08	14.73	4.16
Ammonia-nitrogen (kilograms)	35	13	21	0.26	0.32	0.18
Phosphorus, total (kilograms)	35	13	21	0.38	0.41	0.21
Suspended sediment (kilograms)	35	13	21	410.82	668.57	181.56
Copper, dissolved (grams)	27	12	15	1.90	3.59	1.10
Zinc, dissolved (grams)	35	13	21	3.24	18.48	2.45
Orthophosphorus, dissolved (kilograms)	34	13	20	0.07	0.09	0.06
Solids, dissolved (kilograms)	36	14	21	30.34	29.90	24.23
Nitrate plus nitrite, dissolved (kilograms)	36	14	21	0.22	0.22	0.18

Statistic, by type of basin or sweeper

Median		Minimum		Maximum		Standard deviation	
Control	**Air sweeper**	**Control**	**Air sweeper**	**Control**	**Air sweeper**	**Control**	**Air sweeper**
Calibration phase							
0.25	0.24	0.02	0.03	83.38	18.00	19.57	0.45
8.65	6.39	1.39	1.39	38.98	27.00	9.78	21.27
5.22	6.21	0.24	1.05	30.63	26.00	7.54	23.23
32.49	48.67	5.67	6.11	931.14	27.00	155.83	107.05
12.18	8.97	1.50	0.00	155.45	34.00	30.00	52.94
5.85	5.26	0.56	0.64	75.16	27.00	14.90	30.22
0.35	0.19	0.06	0.02	1.06	1.34	0.28	0.28
0.40	0.21	0.08	0.05	15.57	3.66	2.61	0.75
200.78	178.02	18.89	20.86	5,606.81	5564.72	970.05	1,349.12
2.29	1.13	0.50	0.24	10.08	4.54	1.97	1.19
3.43	3.26	0.79	0.78	24.78	21.29	4.74	4.56
0.12	0.11	0.03	0.02	0.31	0.39	0.08	0.09
42.39	25.21	9.95	7.19	658.19	128.71	120.14	30.42
0.31	0.27	0.04	0.04	1.74	0.68	0.34	0.17

Control	Regen-erative air	Vacuum assist	Control	Regen-erative air	Vacuum assist	Control	Regen-erative air	Vacuum assist	Control	Regen-erative air	Vacuum assist
Treatment phase											
0.13	0.19	0.10	0.03	0.07	0.01	17.50	0.54	0.16	3.98	0.14	0.05
5.44	10.72	5.05	1.21	2.15	0.56	77.19	31.16	16.64	13.73	8.27	4.81
3.98	9.59	3.53	0.45	0.61	0.48	26.58	30.10	33.82	6.18	9.51	7.59
24.79	56.30	29.22	4.31	9.67	3.04	133.23	120.47	80.74	29.78	35.65	24.10
6.65	22.53	5.77	1.34	2.04	0.00	142.94	86.60	23.82	33.44	29.12	7.60
2.99	10.05	2.82	0.48	0.57	0.19	71.79	41.96	12.66	17.46	14.79	4.01
0.23	0.30	0.16	0.02	0.05	0.03	0.79	0.73	0.43	0.19	0.19	0.12
0.24	0.45	0.21	0.04	0.09	0.02	2.94	0.75	0.68	0.50	0.21	0.16
118.65	413.59	102.80	9.21	16.73	4.21	3,104.03	2,523.73	673.33	664.41	726.64	202.17
1.97	1.20	0.82	0.56	0.55	0.28	3.77	26.29	4.11	0.96	7.21	1.01
3.03	4.17	1.84	0.09	1.16	0.82	8.37	118.30	6.27	2.23	36.01	1.64
0.07	0.08	0.06	0.01	0.02	0.01	0.22	0.24	0.15	0.04	0.07	0.04
24.86	30.45	20.71	6.91	8.14	7.54	74.88	55.78	55.38	17.40	14.42	14.85
0.20	0.23	0.20	0.04	0.04	0.03	0.62	0.62	0.45	0.13	0.15	0.10

Table 12b. Summary of loads in the control and high-frequency broom basins during calibration and treatment phases.

Constituent	Number of samples: Control	Number of samples: High-frequency broom	Mean: Control	Mean: High-frequency broom
Calibration phase				
Cadmium, total, in grams	21	10	4.51	0.34
Copper, total, in grams	41	23	11.18	43.01
Lead, total, in grams	39	22	7.50	9.35
Zinc, total, in grams	41	23	61.71	146.08
Calcium, total, in kilograms	41	23	21.43	43.01
Magnesium, total, in kilograms	41	23	10.21	22.41
Ammonia-Nitrogen, in kilograms	40	21	0.40	0.32
Phosphorus, total, in kilograms	41	23	0.78	0.57
Suspended sediment, in kilograms	41	23	429.00	1,076.20
Copper, dissolved, in grams	32	20	2.41	1.82
Zinc, dissolved, in grams	41	23	5.02	4.08
Orthophosphorus, dissolved, in kilograms	40	23	0.13	0.13
Solids, dissolved, in kilograms	41	23	67.00	39.79
Nitrate plus nitrite, dissolved, in kilograms	40	22	0.41	0.33
Treatment phase				
Cadmium, total, in grams	16	6	1.30	0.13
Copper, total, in grams	28	24	11.27	16.20
Lead, total, in grams	27	23	6.20	9.61
Zinc, total, in grams	28	24	34.76	51.31
Calcium, total, in kilograms	28	24	24.97	36.67
Magnesium, total, in kilograms	28	24	12.41	17.63
Ammonia-Nitrogen, in kilograms	28	24	0.23	0.16
Phosphorus, total, in kilograms	28	24	0.40	0.30
Suspended sediment, in kilograms	28	25	475.34	761.71
Copper, dissolved, in grams	22	21	2.01	1.63
Zinc, dissolved, in grams	28	24	3.31	4.19
Orthophosphorus, dissolved, in kilograms	27	24	0.07	0.07
Solids, dissolved, in kilograms	29	25	29.94	22.80
Nitrate plus nitrite, dissolved, in kilograms	29	25	0.20	0.16

Statistic, by type of basin or sweeper							
Median		Minimum		Maximum		Standard Deviation	
Control	High-frequency broom	Control	High-frequency broom	Control	High-frequency broom	Control	High-frequency broom
Calibration phase							
0.21	0.17	0.02	0.02	83.38	1.31	18.14	0.42
7.51	10.08	1.39	1.88	38.98	301.12	9.27	77.14
5.19	5.61	0.24	0.66	30.63	38.18	7.22	10.01
31.94	38.99	5.67	10.57	931.14	1,796.68	142.32	372.68
10.78	10.08	1.50	1.88	155.45	301.12	28.03	77.14
5.12	4.85	0.56	0.57	75.16	152.35	13.95	41.41
0.35	0.25	0.06	0.04	1.06	1.40	0.27	0.28
0.37	0.41	0.08	0.10	15.57	2.04	2.38	0.54
187.35	185.87	18.89	25.34	5,606.81	7,775.73	892.15	2,031.23
2.16	1.22	0.50	0.54	10.08	7.36	1.89	1.67
3.07	3.00	0.79	0.70	24.78	14.53	4.45	3.35
0.11	0.11	0.01	0.02	0.31	0.56	0.08	0.11
35.74	30.13	9.95	6.34	658.19	168.76	110.56	34.89
0.31	0.28	0.04	0.09	1.74	1.02	0.32	0.21
Treatment phase							
0.13	0.13	0.03	0.05	17.50	0.20	4.33	0.05
5.54	6.37	1.21	0.69	77.19	251.09	15.09	50.21
3.30	3.73	0.45	0.01	26.58	111.97	6.36	23.57
23.17	26.06	4.31	3.63	133.23	628.56	31.41	124.16
6.89	6.34	1.34	0.70	142.94	630.87	36.56	127.26
3.24	2.69	0.48	0.26	71.79	310.87	19.07	62.79
0.18	0.11	0.02	0.01	0.63	0.43	0.17	0.13
0.25	0.23	0.04	0.02	2.94	2.25	0.55	0.44
146.14	117.08	9.21	5.09	3,104.03	13,247.04	727.39	2,624.04
2.06	1.28	0.63	0.15	3.77	5.33	0.97	1.31
3.14	3.22	0.09	0.47	8.37	16.53	2.39	3.68
0.07	0.05	0.01	0.01	0.22	0.18	0.05	0.04
23.09	18.08	6.91	4.29	63.28	71.11	17.16	15.21
0.18	0.16	0.04	0.03	0.62	0.38	0.13	0.09

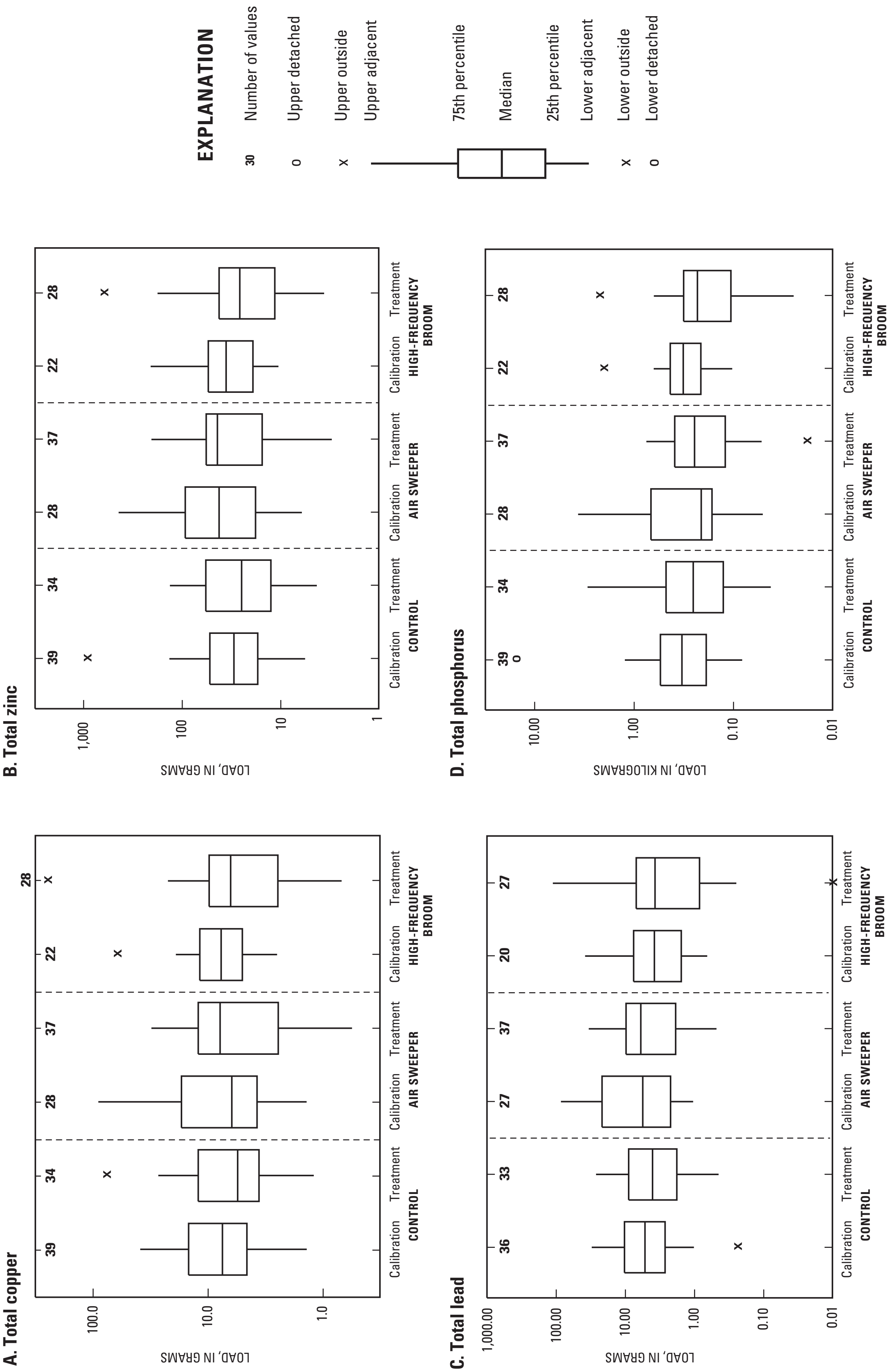

Figure 16. Control and test basin water-quality loads for selected constituents during calibration and treatment phases.

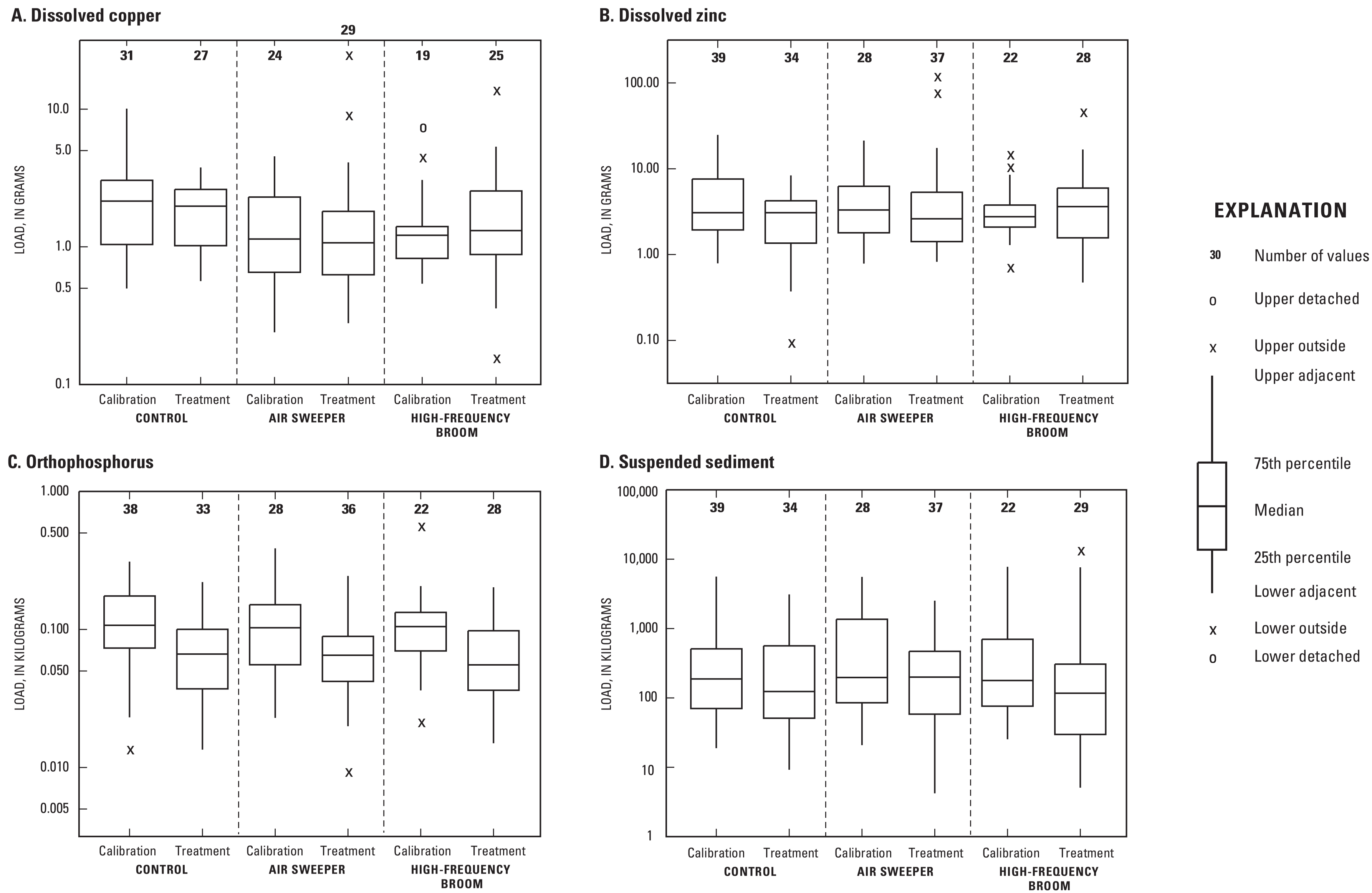

Figure 16. Control and test basin water-quality loads for selected constituents during calibration and treatment phases—Continued.

of constituent loads made use of nonparametric statistical tests because no assumptions about how the data are distributed are necessary (Helsel and Hirsch, 1992).

The Wilcoxon rank-sum test (Helsel and Hirsch, 1992) was used to assess the distribution of the data and to ultimately determine whether the contribution of loads significantly changed as a result of street sweeping. The null hypothesis states there is no difference in the distribution of loads for the particular test basin between the calibration and treatment phases. The alternative hypothesis is that there is a significant difference and that we can infer this difference is a result of street sweeping. Table 13 lists the probabilities, as percentages, associated with the Wilcoxon rank-sum statistic for stormwater-quality constituent and sweeper type. Higher percentages indicate greater likelihood that the distributions of calibration and treatment loads do not differ, whereas very low percentages indicate that the distributions are different. (For example, the probability for cadmium loads for the regenerative-air sweeper was calculated to be 92 percent (table 13); therefore, there appears to be no change in total cadmium load as a result of sweeping with a regenerative-air street sweeper.) For those constituent loads whose probability percentages were very low and for which the null hypothesis was rejected, additional testing was done to determine whether there was a significant increase or decrease as a result of street sweeping (indicated by either upward- or downward-facing arrows in table 13).

The majority of constituent loads did not differ significantly in magnitude from calibration to treatment phases. The high-frequency broom basin showed significant differences (at the 10-percent level) in load from the calibration to treatment phase for total copper, zinc, phosphorus, and suspended sediment. Further evaluation indicated a pattern of lower observations in load for these constituents during the treatment phase. Load data corresponding to both the regenerative-air and vacuum-assist sweepers also showed significant differences for some of the dissolved constituents between study phases. However, the observations during the treatment phase tended to be higher than those during the calibration phase.

Table 13. Probabilities that there is no difference in storm-runoff loads between calibration and treatment phases for the regenerative-air, vacuum-assist, and high-frequency broom sweepers. Direction of arrows indicates an increase or decrease in load due to street sweeping.

[probabilities are expressed as percent; the smaller the probability, the stronger the statistical significance]

Constituent	Street sweeper type		
	Regenerative air	Vacuum assist	High-frequency broom
Cadmium, total	92	59	93
Copper, total	84	44	10 ↓
Lead, total	49	49	43
Zinc, total	35	92	3 ↓
Calcium, total	13	94	27
Magnesium, total	11	99	20
Ammonia-nitrogen	18	<1 ↑	88
Phosphorus, total	69	68	7 ↓
Suspended sediment	14	84	1 ↓
Copper, dissolved	21	<1 ↑	17
Zinc, dissolved	94	82	55
Orthophosphorus, dissolved	10 ↑	12	47
Chloride, dissolved	22	3 ↑	47
Nitrate plus nitrite, dissolved	5 ↑	<1 ↑	38
Number of samples	13	20	24

For those constituent loads that fit a log-normal distribution, an analysis of covariance (ANCOVA) was done to determine whether the linear relation between control and test-basin loads during the treatment phase is significantly different from that during the calibration phase. If the result of the test was significant, the magnitude of change in average constituent load could then be quantified. Of the significant changes identified in table 13, only ammonia-nitrogen for the vacuum-assist sweeper phase in the air-sweeper basin showed significant differences at the 10-percent significance level. The degree of change was then quantified by calculating the percentage increase or decrease in the original, untransformed, average loads. For the vacuum-assist sweeper in the air-sweeper basin, increases in ammonia-nitrogen of 63 percent were recorded.

Inconsistencies in the statistical results detailed in table 13 cannot be easily explained. Numerous trace metals and other urban runoff constituents exhibit a strong association to sediment (Horowitz, 1985; German and Svensson, 2002). Therefore, one might expect to see trace-metal loads change in a similar pattern as suspended-sediment loads. Only the high-frequency broom basin exhibited an association of trace metals to sediment by showing reductions in total copper and zinc loads, as well as suspended-sediment load, at the 10-percent significance level. However, total calcium and magnesium, two elements that are strongly related to street sediments, showed no significant reductions. One explanation for these inconsistencies is the large amount of variability inherent in the constituent-load data.

An examination of the coefficient of variation (COV) is one way to quantify the variability of data. Table 14 details the COVs for the control and test basins during the calibration and treatment phases for each constituent load listed in table 13. A low COV value indicates a much smaller spread of data compared to a data set having a large COV value (Burton and Pitt, 2002). Several of the COVs in table 14 are greater than 1, indicating substantial variability in loads within the basin. Much of the variability could be a function of an insufficient number of paired samples collected to result in statistically relevant conclusions. Burton and Pitt (2002) describe methods to estimate the number of samples necessary to adequately describe the conditions to be tested given the COV of the data sets, an allowable error, and the degree of confidence and power for each parameter. For example, given a COV of 1.5 for suspended sediment during the calibration phase in the air-sweeper basin, and assuming a 95-percent confidence level and power of 0.5 (the larger the power, the less probable

Table 14. Coefficient of variation for constituent loads measured in stormwater from the control and test basins during the calibration and treatment phases.

Constituent	Test basin and phase of study				
	Air sweeper	Air sweeper (regenerative air)	Air sweeper (vacuum assist)	High-frequency broom	
	Calibration	Treatment	Treatment	Calibration	Treatment
Cadmium, total	1.2	0.8	0.7	0.6	0.9
Copper, total	1.4	.7	.8	1.1	3.0
Lead, total	1.4	.9	1.2	1.3	2.5
Zinc, total	1.4	.8	.7	1.0	2.2
Calcium, total	1.5	1.0	.8	1.3	2.9
Magnesium, total	1.5	1.0	.9	1.4	3.0
Ammonia-nitrogen	1.0	.6	.7	1.0	.8
Phosphorus, total	1.3	.5	.7	1.0	1.4
Suspended sediment	1.5	1.1	1.0	2.1	2.9
Copper, dissolved	.8	1.9	1.2	1.0	1.3
Zinc, dissolved	1.0	2.0	1.1	.9	1.5
Orthophosphorus, dissolved	.7	.7	.6	.9	.7
Chloride, dissolved	1.6	.6	.7	1.7	.7
Nitrate plus nitrite, dissolved	.6	.7	.5	.7	.6

the experimental result is due to chance) approximately 200 paired samples would need to be collected in order to detect a 25-percent difference between paired data sets (fig. 17). From figure 17, it becomes clear that smaller COVs require fewer samples to detect statistically relevant differences.

The ability to detect changes in sediment load at the basin outlet as a result of street sweeping relies on a direct relation between the amount of street-dirt available for washoff during a runoff event and the concentration and (or) load of sediment transported in runoff. The street sweepers tested during this study were able to significantly reduce the amount of street dirt. Therefore, a reduction in the amount of sediment transported into the stormwater-conveyance system should also have been measured. However, if a relation between street-dirt yield and sediment load in runoff did not exist, then it would be difficult to estimate the benefits of street sweeping on stormwater quality. A stepwise multivariate linear regression analysis incorporating precipitation depth, precipitation intensity, measured street-dirt yield prior to a runoff event, and suspended-sediment load was done to test whether a relation existed between street-dirt yield and suspended-sediment load. Results of the test indicated that street-dirt yields prior to a runoff event were unable to explain the variation in suspended-sediment loads at the 10-percent significance level. Owing to the lack of a significant relation between street-dirt yield and suspended-sediment load in stormwater runoff and the presence of large variation in measured data sets, determining the benefit of street sweepers as a stormwater-quality management tool becomes increasingly difficult.

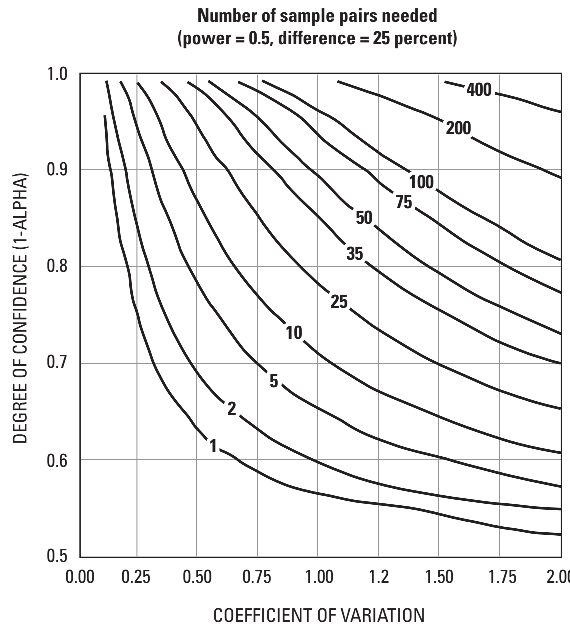

Figure 17. Estimated number of samples required to result in statistically relevant conclusions in a paired-basin study. (From Burton and Pitt, 2002, reproduced with permission.)

Potential Sources of Variability

The control and test basins used in this study were selected to be close to together in order to minimize rainfall variability between basins. There are, however, other potential sources of variability in stormwater-quality loads within each basin that are difficult or impossible to measure. When using a paired-basin study design, it is assumed that the physical characteristics of each basin do not change other than the imposed treatment to the test basin. In a residential setting, anthropogenic sources such as home construction, lawn maintenance, or driving habits may introduce bias to constituent concentrations and loads. For example, residents in one study basin tended to keep brush and other vegetative debris piles on the terrace until maintenance crews could remove them for disposal. In another study basin, the same type of organic debris was typically moved into the street gutter (fig. 18). Placement of debris in the gutter may not only act as a new source of phosphorus and nitrogen but also slow stormwater conveyed in the gutter during a runoff event, allowing sediment entrained in the runoff to settle. These brush piles were collected monthly and were avoided by street sweepers to prevent fouling of the mechanical equipment. Another human source of variability in constituent loads could have come from uneven distribution of sand during winter months for skid control (fig. 19). Applying more sand to the street surfaces in one study basin than another may have influenced sediment loads.

Other processes that may introduce variability are more mechanical. Despite the absence of catch basins in each basin's storm-sewer network, little is understood about the transport of sediment once it reaches the pipe. Sediment may accumulate and scour from one event to the next in various reaches of the storm sewer such that what is measured at the basin outlet may or may not have originated from the land surface. Figure 20 illustrates sediment that has accumulated in the irregularities of a manhole junction in the storm-sewer conveyance system. Similarly, during periods of heavy or intense rainfall, areas other than streets—such as lawns and roofs—may contribute to the sediment load measured near the basin outlet (fig. 21). Contributions of sediment from sources other than streets

Figure 18. Examples of lawn-maintenance practices in two study basins. The pile of debris moved into the street may introduce sources of variability in measured water-quality loads.

Figure 19. Residue from sand applied to a street surface to provide traction for vehicles.

Figure 20. Accumulation of sediment in the junction of a manhole with the storm-sewer conveyance system.

Figure 21. Contribution of sediment to a street from a residential lawn.

could have potentially masked any effect street sweepers may have had on reducing the amount of sediment from street surfaces.

Once sediment from the land surface reaches the stormwater-conveyance system, it is assumed that particles of all sizes are well mixed throughout the water column before reaching the point at which a stormwater-quality sample is drawn. Typically, particles less than about 40 micrometers are well mixed within the water-column profile (Butler and others, 1996); however, as the particle- size distribution increases to include sand-size material (larger than 63 micrometers), a vertical gradient may form, with the largest particles concentrating near the bed (Bent and others, 2000). Evidence of changing suspended-sediment concentrations was reported by Smith (2002) when evaluating a small highway drainage pipe. Even at relatively low flows, concentrations of suspended sediment measured near the bottom of the pipe were approximately double those measured only a few inches higher (Smith, 2002). Because stormwater-quality samples used to evaluate the performance of street sweeping were acquired from a fixed point in the storm sewer, constituent concentrations may not have been representative of the water column during periods of high flows (fig. 22). This factor could have been another source of variability in concentrations and loads between the control and test basins.

Figure 22. Water-quality sample intake located at a fixed point along the storm-sewer wall.

Comparison of Particle-Size Distribution in Stormwater-Quality Samples

Table 15 summarizes the average distribution of particles for stormwater-quality samples collected in the control and test basins during the calibration and treatment phases of the study. During periods of no sweeping, both the air-sweeper and high-frequency broom test basins showed a similar distribution of particle sizes in runoff. Most particles for these two basins were greater than 250 micrometers. This is consistent with the average distribution of particles measured on street surfaces within each basin (table 9). This same pattern is also true during the treatment phase in the high-frequency broom basin. However, the air-sweeper basin shows an increase in the percentage of particles less than 63 micrometers; therefore, street sweeping resulted in a shift toward smaller particles sizes (table 15). Examination of the percentage of sand and silt reveals an overall increase in particles of silt size for both the air-sweeper and high-frequency broom basins during the treatment phase (table 15). This shift toward silt-sized particles may be related to sweeping. Although only a small percentage of street dirt was of silt size, a much larger percentage of these particles were measured in runoff at the basin outlet. On average, 3 to 5 percent of street dirt measured on the street surface was less than 63 micrometers (table 9), yet as much as 40 percent was found in the stormwater-quality samples. One explanation may be changes to sediment-transport functions as a result of sweeping. By removing larger particles from a street surface, the smaller particles may have become more easily entrained in runoff during rainstorms.

Table 15. Average percent distribution, by mass, of particle sizes for water-quality samples collected in the control and test basins during calibration and treatment phases.

[µm, micrometer; all values expressed as percent less than corresponding particle size]

	Air sweeper basin		High-frequency broom basin		
Particle size	**Calibration**	**Treatment**	**Calibration**	**Treatment**	**Control**
500 µm	66	85	68	88	76
250 µm	43	54	46	49	53
125 µm	31	40	30	33	39
63 µm	24	34	22	28	29
32 µm	13	19	12	21	17
14 µm	9	14	8	16	13
8 µm	7	12	7	12	10
5 µm	5	10	5	9	8
2 µm	3	6	2	2	4
Percent sand[1]	76	60	78	72	65
Percent silt[1]	24	40	22	28	35

[1] Data sets used to determine the percentage of sand and silt were larger than those describing the full distribution.

Summary and Conclusions

As part of fulfillment of the Environmental Protection Agency National Pollution Discharge Elimination System (NPDES) Phase II permit, many cities nationwide will be required to reduce the amount of sediment entrained in runoff from entering receiving water bodies. Many structural controls, such as detention ponds, are available to help environmental managers meet the NPDES permit requirements. However, these practices typically require large tracts of land that may be expensive or simply unavailable in an urban setting. Street sweeping is a nonstructural control that could be used to remove sediment and sediment-associated constituents from street surfaces before they become entrained in runoff. Because most cities already have some sort of street-sweeping program, it is important to understand the stormwater-quality benefits of existing or modified programs. More information is especially needed about the street-dirt removal capabilities of newer street-sweeper technologies.

To this end, the U.S. Geological Survey, in cooperation with the City of Madison and the Wisconsin Department of Natural Resources evaluated the performance of three street-sweeper technologies from 2002 through 2006. Specifically, this study examined the street-dirt-removal efficiencies and subsequent changes in stormwater-quality loads from basins where regenerative-air, vacuum-assisted, and mechanical-broom street sweepers operated on a frequency of once per week (high frequency). An additional mechanical-broom sweeper operating on a frequency of approximately once per month (low frequency) was also evaluated for street-dirt removal only. A paired-basin study design was used to compare street-dirt and stormwater-quality samples during a calibration period (no sweeping) and a treatment period (weekly sweeping). The basis of this paired-basin approach is that the relation between paired street-dirt yields and stormwater-quality loads for the control and test basins is constant until a major change is made at one of the basins. At that time, a new relation will develop.

Results show there is little probability that street sweeping, regardless of street-sweeper type, had any measurable affect on the quality of runoff. Street sweeping as a stormwater-quality-management tool appears to be limited by the extreme variability in stormwater-quality loads. It might be difficult to isolate any changes in stormwater quality as a result of street sweeping because other factors might be affecting the movement and supply of constituents in the watershed. Examples of factors that might contribute to the high variability include the amount of sediment delivered from other source areas such as lawns and driveways, the efficiency of sediment delivery in the storm-sewer system, and the changes in the amount of sand applied to enhance vehicle traction each winter. With high variability in stormwater-quality loads, a much larger number of water samples would have to be collected in order to detect any significant change due to street sweeping. For example, an estimated 200 paired stormwater-quality samples would have been required to detect a 25-percent change between the calibration and treatment periods. Only about 40 paired stormwater-quality samples were collected during this study.

Although a significant change was not observed for most of the constituents, a significant change (at the 10-percent significance level) was detected for ammonia-nitrogen for the vacuum-assist sweeper in the air-sweeper basin. When the vacuum-assist sweeper was used, an increase in ammonia-nitrogen load of 63 percent was measured.

Variability in street-dirt yields was not as great as that for stormwater-quality loads. The ability to physically reduce the amount of dirt present on a street surface, described in this study as sweeper efficiency, was measured by comparing street-dirt yields after a sweeper cleaned the streets in a basin to those measured before sweeper cleaning. Both the regenerative-air and vacuum-assist sweepers averaged removal efficiencies of 25 and 30 percent, respectively. The mechanical-broom sweeper, operated on a weekly schedule, removed only 5 percent of street-dirt yield on average. Each sweeper showed increasing pickup efficiency with increasing street-dirt yield. The majority of street-dirt yield was measured during April and May of each study year. So in the spring, when the street-dirt yield was the highest, the street sweepers were somewhat more efficient. Street dirt during spring also appeared to be more uniformly distributed across the street surface than during the rest of the year. This is most likely due to residue from winter sand application. During the summer, 75 percent of the street-dirt yield is within 3 feet of the curb face. Therefore, street sweeping in spring might be more effective if the entire street is cleaned and not just the areas near the curb.

Differences in sweeper-removal efficiencies could be attributed to the advancements in technology incorporated into each sweeper. Combining a mechanical wire-bristle gutter broom with either a blast of air or vacuum suction appears to increase the ability of street sweepers to pick up available street dirt. This increase in street-dirt pickup efficiency was further demonstrated by comparing the overall reduction in street-dirt yield measured during the calibration and treatment periods. An analysis of covariance (ANCOVA) was used to quantify the average percent reduction of street dirt between study phases at the 5-percent significance level. Use of the regenerative-air and vacuum-assist sweepers resulted in the greatest reductions in average basin street-dirt yield of 76 and 63 percent, respectively. Use of the mechanical broom sweeper at high frequency resulted in a 20-percent reduction in average basin street-dirt yield.

Such large changes in basin street-dirt yield are not consistent with the pickup efficiencies observed at the street level for each machine. The relatively large change in basin street-dirt yield may be explained by the mechanical action of the gutter broom increasing the amount of fines available for washoff. Increasing the amount of fines on a street can change the washoff characteristics of a street, because rain can be more effective at removing smaller particles from a street than street sweeping. If the amount of solids washed off the street is increased by the action of the street sweepers, the reduction in basin street-dirt yield could be a function of both the street sweepers' pickup efficiency and the increased effect of rainfall. The effect of rainfall is not considered when determining a sweeper's pickup efficiency. Furthermore, changes in washoff characteristics of street dirt could also have added to the difficulty in detecting any stormwater-quality benefits of street sweeping. One possible reason for this may be the mechanical action of the gutter brooms increasing the amount of fine particles on the street due to abrasion and the breakdown of larger particles. Because rain can more effectively remove small particles from the street rather than large particles, the amount of solids washed off the street may increase, negating any stormwater-quality benefits from street sweeping.

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Appendixes

Appendix 1. Detailed street-dirt and water-quality data

Appendix table 1-1. Control basin street-dirt yield, in pounds per curb-mile, separated by particle size.

[mm/dd/yyyy, month/day/year; µm, micrometer; >, greater than; <, less than]

Date (mm/dd/yyyy)	Street-dirt yield (pounds per curb-mile)							
	>2,000 µm	1,000–2,000 µm	500–1,000 µm	250–500 µm	125–250 µm	63–125 µm	<63 µm	Total
05/17/2002	87	125	177	221	86	34	25	755
05/24/2002	81	118	176	207	95	38	33	748
05/31/2002	91	111	174	212	77	20	11	695
06/07/2002	69	93	118	132	46	12	9	479
06/14/2002	52	69	90	111	45	12	5	385
06/20/2002	70	94	124	158	70	23	11	549
06/28/2002	52	66	108	152	71	24	16	489
07/05/2002	88	96	151	202	95	30	48	710
07/12/2002	102	131	202	266	135	57	57	950
07/19/2002	70	101	163	229	145	68	100	876
07/26/2002	77	89	123	149	79	32	33	582
08/02/2002	78	86	120	155	77	29	27	571
08/09/2002	55	69	96	128	67	25	19	458
08/16/2002	64	69	101	134	70	24	19	482
08/30/2002	58	64	93	126	71	29	27	467
09/06/2002	80	103	139	180	107	51	58	717
09/13/2002	61	91	130	151	76	32	26	567
09/27/2002	95	120	172	239	141	65	71	902
04/01/2003	206	319	580	861	354	102	70	2,493
04/15/2003	199	281	495	705	341	126	135	2,282
04/23/2003	181	269	428	606	285	94	88	1,951
04/29/2003	142	223	373	542	329	130	139	1,878
05/06/2003	154	242	340	314	258	49	23	1,380
05/13/2003	172	234	321	409	189	64	42	1,431
05/20/2003	78	121	165	172	84	34	12	667
05/27/2003	100	161	229	289	192	90	78	1,139
06/03/2003	57	111	171	259	149	49	36	832
06/11/2003	68	116	183	267	152	59	34	878
06/17/2003	57	117	176	250	156	68	51	875
06/26/2003	54	92	116	140	73	21	8	503
07/01/2003	74	113	168	251	159	76	61	901
07/11/2003	41	78	112	147	105	27	12	522
07/23/2003	74	81	101	150	102	44	32	585
07/30/2003	67	93	148	221	140	62	49	781
08/05/2003	35	57	88	144	89	32	22	467
08/12/2003	51	62	99	208	111	49	52	632
08/20/2003	92	96	158	294	187	72	50	949
08/27/2003	116	108	127	212	145	51	26	785

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-1. Control basin street-dirt yield, in pounds per curb-mile, separated by particle size—Continued.

[mm/dd/yyyy, month/day/year; µm, micrometer; >, greater than; <, less than]

Date (mm/dd/yyyy)	Street-dirt yield (pounds per curb-mile)							
	>2,000 µm	1,000–2,000 µm	500–1,000 µm	250–500 µm	125–250 µm	63–125 µm	<63 µm	Total
09/02/2003	100	97	119	185	127	46	33	706
09/09/2003	76	99	133	213	149	61	50	782
09/16/2003	76	85	109	145	86	29	20	549
09/23/2003	88	92	109	154	85	28	14	571
09/30/2003	92	81	100	153	96	39	26	588
10/07/2003	113	131	218	285	240	56	40	1,082
04/06/2004	75	98	219	386	158	47	22	1,004
04/13/2004	61	95	221	452	217	91	73	1,211
04/27/2004	63	82	148	238	105	36	24	696
05/04/2004	65	89	146	710	109	46	38	1,202
05/19/2004	42	52	80	114	46	12	5	351
05/26/2004	43	46	68	122	66	20	15	382
06/02/2004	41	48	62	100	59	19	13	341
06/08/2004	48	56	85	144	82	34	25	473
06/15/2004	57	49	70	108	61	23	15	383
06/22/2004	32	45	82	125	48	17	7	356
06/29/2004	57	62	108	190	104	36	26	583
07/08/2004	38	34	48	81	50	17	12	279
07/14/2004	35	39	59	108	71	28	16	358
07/20/2004	34	41	64	97	49	18	10	313
07/27/2004	40	47	76	132	82	36	36	450
08/03/2004	39	46	82	127	53	17	12	375
08/10/2004	41	51	86	153	81	29	24	465
08/18/2004	66	65	91	132	73	33	23	482
08/31/2004	38	42	49	66	40	17	8	261
09/07/2004	56	59	71	107	74	36	29	431
09/17/2004	55	55	59	74	38	16	9	307
04/05/2005	65	84	255	671	317	127	85	1,603
04/13/2005	51	70	179	415	199	71	32	1,017
04/21/2005	62	75	175	405	206	80	44	1,047
04/28/2005	71	75	160	353	172	73	45	948
05/05/2005	67	95	186	401	197	89	45	1,080
05/18/2005	67	73	129	248	131	52	30	730
05/25/2005	64	80	128	236	119	47	31	704
06/02/2005	81	110	165	305	168	79	57	964

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-2. Air-sweeper basin street-dirt yield, in pounds per curb-mile, separated by particle size.

[mm/dd/yyyy, month/day/year; µm, micrometer; >, greater than; <, less than; NS, no sweeping in basin; --, no data]

Date (mm/dd/yyyy)	Sweeper cleaning	Street-dirt yield (pounds per curb-mile)							
		>2,000 µm	1,000–2,000 µm	500–1,000 µm	250–500 µm	125–250 µm	63–125 µm	<63 µm	Total
05/17/2002	NS	123	205	333	508	197	53	26	1,445
05/24/2002	NS	113	206	354	521	225	71	43	1,531
05/31/2002	NS	108	156	248	347	144	35	15	1,053
06/07/2002	NS	82	103	136	175	73	18	9	596
06/20/2002	NS	66	99	141	208	106	32	17	668
06/28/2002	NS	75	101	177	326	148	40	21	888
07/05/2002	NS	78	95	174	310	151	40	26	874
07/12/2002	NS	72	107	187	361	183	58	32	1,000
07/19/2002	NS	62	99	155	270	167	61	39	854
07/26/2002	NS	68	87	126	189	100	34	20	624
08/02/2002	NS	86	117	196	317	146	43	23	928
08/09/2002	NS	90	129	177	260	160	64	45	924
08/16/2002	NS	85	117	181	261	150	49	27	870
08/30/2002	NS	93	117	180	335	177	49	32	985
09/06/2002	NS	94	131	243	454	204	55	36	1,217
09/13/2002	NS	101	137	225	372	174	42	30	1,081
09/27/2002	NS	85	109	144	183	104	33	18	676
04/01/2003	Pre	72	140	373	652	251	54	21	1,563
04/02/2003	Post	31	62	196	433	236	74	49	1,082
04/15/2003	Pre	44	79	216	430	234	76	56	1,134
04/16/2003	Post	30	60	162	315	202	69	56	894
04/22/2003	Pre	39	71	186	357	209	58	30	949
04/23/2003	Post	24	45	116	224	168	59	41	677
04/29/2003	Pre	26	47	123	249	190	65	76	777
04/30/2003	Post	--	--	--	--	--	--	--	--
05/06/2003	Pre	40	71	139	195	151	34	15	646
05/07/2003	Post	--	--	--	--	--	--	--	--
05/12/2003	Pre	29	59	119	190	88	26	7	518
05/13/2003	Post	21	42	97	171	88	24	17	461
05/20/2003	Pre	26	41	75	109	49	13	7	320
05/21/2003	Post	13	29	56	99	62	23	14	298
05/27/2003	Pre	24	46	93	168	106	43	20	500
05/28/2003	Post	--	--	--	--	--	--	--	--
06/03/2003	Pre	19	40	66	119	84	37	17	382
06/04/2003	Post	14	26	51	90	71	33	30	316
06/11/2003	Pre	16	30	49	78	53	23	11	259
06/12/2003	Post	11	18	31	52	34	15	9	169

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-2. Air-sweeper basin street-dirt yield, in pounds per curb-mile, separated by particle size—Continued.

[mm/dd/yyyy, month/day/year; µm, micrometer; >, greater than; <, less than; NS, no sweeping in basin; --, no data]

Date (mm/dd/yyyy)	Sweeper cleaning	Street-dirt yield (pounds per curb-mile)							
		>2,000 µm	1,000–2,000 µm	500–1,000 µm	250–500 µm	125–250 µm	63–125 µm	<63 µm	Total
06/16/2003	Pre	21	26	40	68	48	28	23	253
06/17/2003	Post	9	18	32	57	43	23	20	202
06/26/2003	Pre	15	22	25	32	17	6	2	119
06/26/2003	Post	16	26	28	48	34	15	9	177
07/01/2003	Pre	14	25	31	38	52	16	8	183
07/02/2003	Post	10	16	26	47	35	17	11	162
07/11/2003	Pre	11	13	18	28	21	9	6	106
07/16/2003	Pre	18	18	25	40	28	11	6	146
07/17/2003	Post	9	12	17	30	24	11	5	108
07/22/2003	Pre	18	15	21	38	29	13	7	142
07/23/2003	Post	12	10	14	26	21	11	12	106
07/29/2003	Pre	15	19	26	45	38	21	21	185
07/30/2003	Post	10	12	18	33	29	16	14	132
08/05/2003	Pre	13	14	15	22	19	10	10	103
08/06/2003	Post	--	--	--	--	--	--	--	--
08/12/2003	Pre	19	20	24	42	35	11	16	167
08/13/2003	Post	12	12	17	29	26	13	10	119
08/19/2003	Pre	17	18	22	38	35	19	19	169
08/20/2003	Post	11	13	15	25	22	12	11	110
08/26/2003	Pre	16	19	19	29	24	11	7	124
08/27/2003	Post	11	14	18	28	22	13	14	121
09/02/2003	Pre	15	16	16	24	21	12	11	115
09/03/2003	Post	10	10	11	16	14	9	10	79
09/09/2003	Pre	17	18	20	28	24	16	18	140
09/10/2003	Post	9	11	12	17	14	9	11	82
09/16/2003	Pre	16	16	13	17	13	5	3	83
09/17/2003	Post	10	9	9	12	12	6	6	64
09/23/2003	Pre	17	22	18	17	24	7	4	109
09/24/2003	Post	11	11	11	16	14	8	7	79
09/30/2003	Pre	23	25	22	27	22	12	9	140
10/01/2003	Post	13	14	12	18	16	11	10	95
10/07/2003	Pre	25	59	31	31	25	16	13	200
10/08/2003	Post	24	24	19	24	21	13	16	141
04/06/2004	Pre	65	88	249	490	175	50	20	1,137
04/09/2004	Post	36	65	203	486	220	95	73	1,178
04/13/2004	Pre	31	57	174	419	202	78	51	1,012
04/16/2004	Post	11	18	53	136	68	26	14	326

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-2. Air-sweeper basin street-dirt yield, in pounds per curb-mile, separated by particle size—Continued.

[mm/dd/yyyy, month/day/year; µm, micrometer; >, greater than; <, less than; NS, no sweeping in basin; --, no data]

Date (mm/dd/yyyy)	Sweeper cleaning	Street-dirt yield (pounds per curb-mile)							
		>2,000 µm	1,000–2,000 µm	500–1,000 µm	250–500 µm	125–250 µm	63–125 µm	<63 µm	Total
04/27/2004	Pre	3	11	21	54	30	11	5	136
04/28/2004	Post	5	7	15	45	33	18	16	140
05/04/2004	Pre	13	17	31	78	60	34	24	258
05/05/2004	Post	9	10	18	51	41	28	30	186
05/19/2004	Pre	13	13	14	21	12	4	2	78
05/19/2004	Post	3	4	7	19	15	5	3	57
05/26/2004	Pre	21	23	25	44	30	7	2	152
05/27/2004	Post	9	9	11	22	17	5	2	74
06/02/2004	Pre	16	17	16	22	16	5	4	95
06/03/2004	Post	12	13	13	19	14	6	4	81
06/08/2004	Pre	17	19	19	26	19	9	7	115
06/10/2004	Post	--	--	--	--	--	--	--	--
06/15/2004	Pre	18	17	16	20	12	7	3	93
06/16/2004	Post	9	8	10	16	11	6	2	62
06/22/2004	Pre	11	11	10	12	7	3	2	56
06/23/2004	Post	--	--	--	--	--	--	--	--
06/29/2004	Pre	12	13	13	18	12	5	4	77
06/30/2004	Post	7	7	9	14	10	4	2	54
07/07/2004	Pre	12	9	9	14	9	2	1	56
07/08/2004	Post	8	8	9	15	11	4	2	56
07/14/2004	Pre	14	13	14	21	14	6	4	85
07/15/2004	Post	8	9	10	16	12	5	3	62
07/20/2004	Pre	12	12	13	20	12	5	2	75
07/21/2004	Post	--	--	--	--	--	--	--	--
07/27/2004	Pre	16	18	17	23	16	9	8	106
07/28/2004	Post	11	16	10	17	10	5	5	76
08/03/2004	Pre	13	16	14	16	9	4	2	74
08/04/2004	Post	--	--	--	--	--	--	--	--
08/10/2004	Pre	19	22	19	27	19	7	4	118
08/11/2004	Post	9	11	11	18	13	5	3	71
08/18/2004	Pre	38	35	25	22	13	5	2	141
08/19/2004	Post	--	--	--	--	--	--	--	--
08/31/2004	Pre	29	22	18	19	12	5	4	108
09/01/2004	Post	19	17	15	17	10	4	2	85
09/07/2004	Pre	30	31	29	35	23	9	5	161
09/08/2004	Post	11	14	14	18	13	6	4	81

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-2. Air-sweeper basin street-dirt yield, in pounds per curb-mile, separated by particle size—Continued.

[mm/dd/yyyy, month/day/year; µm, micrometer; >, greater than; <, less than; NS, no sweeping in basin; --, no data]

Date (mm/dd/yyyy)	Sweeper cleaning	Street-dirt yield (pounds per curb-mile)							
		>2,000 µm	1,000–2,000 µm	500–1,000 µm	250–500 µm	125–250 µm	63–125 µm	<63 µm	Total
09/16/2004	Pre	21	17	13	13	8	3	2	76
09/17/2004	Post	11	13	12	13	7	4	2	62
04/05/2005	Pre	98	122	316	695	255	96	59	1,641
04/05/2005	Post	39	55	183	453	171	61	44	1,005
04/13/2005	Pre	49	74	216	533	220	68	27	1,187
04/14/2005	Post	24	42	125	346	173	71	40	820
04/21/2005	Pre	41	61	160	394	186	75	44	962
04/21/2005	Post	14	23	70	219	124	57	39	546
04/28/2005	Pre	32	41	88	256	163	86	53	717
04/28/2005	Post	15	23	57	175	110	62	58	499
05/05/2005	Pre	26	31	64	183	121	72	71	568
05/05/2005	Post	15	19	47	143	98	57	55	434
05/18/2005	Pre	24	34	49	117	81	43	28	374
05/18/2005	Post	12	16	29	78	54	30	21	239
05/25/2005	Pre	29	45	55	98	71	36	18	351
05/25/2005	Post	10	22	27	55	40	22	15	192
06/02/2005	Pre	20	40	42	72	54	32	26	285
06/02/2005	Post	11	21	27	54	44	28	20	205
06/23/2005	Pre	12	16	22	33	24	14	11	132
06/23/2005	Post	5	8	13	24	16	8	5	79

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-3. High-frequency broom basin street-dirt yield, in pounds per curb-mile, separated by particle size.

[mm/dd/yyyy, month/day/year; µm, micrometer; >, greater than; <, less than; NS, no sweeping in basin; --, no data]

Date (mm/dd/yyyy)	Sweeper cleaning	Street-dirt yield (pounds per curb-mile)							
		>2,000 µm	1,000–2,000 µm	500–1,000 µm	250–500 µm	125–250 µm	63–125 µm	<63 µm	Total
05/17/2002	NS	47	79	148	201	88	32	21	614
05/24/2002	NS	47	83	144	186	87	32	27	606
05/31/2002	NS	40	75	129	174	75	21	12	527
06/07/2002	NS	34	60	79	86	33	8	5	304
06/14/2002	NS	35	66	81	93	40	9	2	326
06/20/2002	NS	37	62	88	103	46	12	7	356
06/28/2002	NS	29	47	68	78	35	9	5	270
07/05/2002	NS	37	60	102	136	64	17	10	427
07/12/2002	NS	34	69	112	149	79	26	14	482
07/19/2002	NS	38	58	88	118	63	21	15	401
07/26/2002	NS	36	57	74	99	52	17	10	344
08/02/2002	NS	42	67	86	105	49	15	9	373
08/09/2002	NS	37	61	91	119	56	16	9	388
08/16/2002	NS	32	49	67	80	38	11	6	282
08/30/2002	NS	39	56	80	105	52	16	12	361
09/06/2002	NS	32	51	70	86	43	14	8	303
09/13/2002	NS	32	55	78	92	42	13	7	319
09/27/2002	NS	32	58	79	93	47	16	8	333
04/01/2003	Pre	125	245	612	960	337	94	55	2,428
04/02/2003	Post	57	129	420	750	316	99	74	1,845
04/15/2003	Pre	121	202	515	883	357	116	119	2,313
04/16/2003	Post	41	73	234	469	264	95	78	1,254
04/22/2003	Pre	41	82	250	463	241	65	38	1,180
04/23/2003	Post	35	70	216	419	222	80	46	1,089
04/29/2003	Pre	37	65	203	396	257	96	77	1,131
04/30/2003	Post	--	--	--	--	--	--	--	--
05/06/2003	Pre	34	56	152	268	132	33	20	694
05/07/2003	Post	--	--	--	--	--	--	--	--
05/12/2003	Pre	25	43	96	152	68	16	9	410
05/13/2003	Post	17	32	86	153	78	23	11	400
05/20/2003	Pre	20	38	90	138	61	17	8	372
05/21/2003	Post	19	36	85	145	74	26	12	396
05/27/2003	Pre	24	48	114	203	118	43	28	577
05/28/2003	Post	--	--	--	--	--	--	--	--
06/03/2003	Pre	25	46	97	148	81	20	12	428
06/04/2003	Post	19	36	83	144	83	29	13	407
06/11/2003	Pre	26	50	115	179	108	32	14	524
06/12/2003	Post	14	34	80	127	73	22	11	361

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-3. High-frequency broom basin street-dirt yield, in pounds per curb-mile, separated by particle size—Continued.

[mm/dd/yyyy, month/day/year; µm, micrometer; >, greater than; <, less than; NS, no sweeping in basin; --, no data]

Date (mm/dd/yyyy)	Sweeper cleaning	Street-dirt yield (pounds per curb-mile)							
		>2,000 µm	1,000–2,000 µm	500–1,000 µm	250–500 µm	125–250 µm	63–125 µm	<63 µm	Total
06/16/2003	Pre	24	44	103	168	103	31	14	488
06/17/2003	Post	16	38	90	148	106	33	20	451
06/26/2003	Pre	13	28	54	69	33	8	3	208
07/01/2003	Pre	21	37	69	117	85	27	17	373
07/02/2003	Post	14	30	63	102	67	22	10	306
07/09/2003	Pre	18	25	46	66	35	9	3	203
07/11/2003	Post	10	17	34	37	41	10	2	152
07/16/2003	Pre	15	22	41	66	42	15	7	208
07/17/2003	Post	12	17	36	62	43	14	5	189
07/22/2003	Pre	14	19	34	53	34	9	3	167
07/23/2003	Post	14	22	39	59	36	12	5	186
07/29/2003	Pre	15	25	41	66	50	15	9	222
07/30/2003	Post	22	30	52	81	54	20	11	270
08/05/2003	Pre	23	27	47	79	54	14	14	259
08/12/2003	Pre	18	34	58	94	62	23	15	305
08/13/2003	Post	20	28	53	89	66	26	19	300
08/19/2003	Pre	23	36	63	106	71	30	19	347
08/20/2003	Post	15	28	55	96	73	30	21	317
08/26/2003	Pre	21	32	51	71	47	18	11	251
08/27/2003	Post	15	24	44	67	46	19	12	227
09/02/2003	Pre	19	29	50	73	47	18	10	246
09/03/2003	Post	17	25	49	79	56	22	17	264
09/09/2003	Pre	16	27	50	83	59	23	16	273
09/10/2003	Post	14	25	46	71	50	20	15	241
09/16/2003	Pre	14	24	35	46	27	8	5	160
09/17/2003	Post	15	26	38	50	30	10	6	174
09/23/2003	Pre	17	28	41	44	36	8	4	179
09/24/2003	Post	14	25	41	55	32	12	6	186
09/30/2003	Pre	18	29	44	61	38	15	9	214
10/01/2003	Post	18	28	47	68	46	19	11	238
10/07/2003	Pre	30	40	56	66	37	14	7	251
10/08/2003	Post	26	30	48	67	43	16	11	240
04/06/2004	Pre	70	125	216	276	92	24	11	812
04/07/2004	Post	66	111	227	354	138	51	35	982
04/13/2004	Pre	73	121	240	389	160	66	50	1,098
04/16/2004	Post	52	98	201	296	112	34	19	812
04/20/2004	Pre	61	105	174	232	91	29	17	709
04/21/2004	Post	--	--	--	--	--	--	--	--

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-3. High-frequency broom basin street-dirt yield, in pounds per curb-mile, separated by particle size—Continued.

[mm/dd/yyyy, month/day/year; µm, micrometer; >, greater than; <, less than; NS, no sweeping in basin; --, no data]

Date (mm/dd/ yyyy)	Sweeper cleaning	Street-dirt yield (pounds per curb-mile)							
		>2,000 µm	1,000–2,000 µm	500–1,000 µm	250–500 µm	125–250 µm	63–125 µm	<63 µm	Total
04/27/2004	Pre	55	95	165	214	80	24	14	647
04/28/2004	Post	41	82	155	224	92	32	21	647
05/04/2004	Pre	52	89	155	222	98	36	25	678
05/05/2004	Post	47	83	155	234	109	44	43	715
05/19/2004	Pre	36	66	105	151	58	12	5	432
05/19/2004	Post	26	52	91	145	66	16	6	404
05/26/2004	Pre	35	55	77	109	54	11	3	344
05/27/2004	Post	30	45	66	108	57	15	5	326
06/02/2004	Pre	31	51	72	111	57	13	4	339
06/04/2004	Post	27	43	68	106	55	14	6	319
06/08/2004	Pre	26	44	70	114	59	17	6	337
06/10/2004	Post	--	--	--	--	--	--	--	--
06/15/2004	Pre	20	41	62	87	44	11	4	269
06/16/2004	Post	17	33	57	85	41	11	4	247
06/22/2004	Pre	19	33	46	75	28	13	4	218
06/23/2004	Post	--	--	--	--	--	--	--	--
06/29/2004	Pre	20	34	58	80	43	11	6	251
06/30/2004	Post	18	33	62	95	52	14	7	281
07/07/2004	Pre	16	24	34	45	20	4	2	144
07/08/2004	Post	17	28	45	67	34	9	3	202
07/14/2004	Pre	21	40	49	75	40	10	8	243
07/15/2004	Post	17	31	53	85	45	13	7	251
07/20/2004	Pre	19	33	46	66	32	9	4	209
07/21/2004	Post	--	--	--	--	--	--	--	--
07/27/2004	Pre	18	34	47	68	36	11	5	221
07/28/2004	Post	17	30	45	68	35	11	6	212
08/03/2004	Pre	18	33	41	53	24	5	3	178
08/04/2004	Post	--	--	--	--	--	--	--	--
08/10/2004	Pre	21	34	44	61	31	9	4	204
08/11/2004	Post	16	26	40	59	32	9	5	187
08/18/2004	Pre	14	20	28	36	16	4	3	122
08/19/2004	Post	--	--	--	--	--	--	--	--
08/31/2004	Pre	25	26	43	63	27	7	4	195
09/01/2004	Post	18	23	31	36	16	4	2	129
09/07/2004	Pre	21	31	42	50	22	6	3	176
09/08/2004	Post	14	22	35	48	25	8	5	156

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-3. High-frequency broom basin street-dirt yield, in pounds per curb-mile, separated by particle size—Continued.

[mm/dd/yyyy, month/day/year; µm, micrometer; >, greater than; <, less than; NS, no sweeping in basin; --, no data]

Date (mm/dd/yyyy)	Sweeper cleaning	Street-dirt yield (pounds per curb-mile)							
		>2,000 µm	1,000–2,000 µm	500–1,000 µm	250–500 µm	125–250 µm	63–125 µm	<63 µm	Total
09/16/2004	Pre	14	20	29	31	12	3	2	111
09/17/2004	Post	13	19	25	29	12	3	2	102
04/05/2005	NS	65	97	260	588	265	108	73	1,457
04/13/2005	NS	55	74	176	334	136	44	19	838
04/21/2005	NS	53	77	175	342	167	63	36	914
04/28/2005	NS	46	75	173	340	168	75	55	932
05/05/2005	NS	52	76	184	371	188	83	72	1,026
05/18/2005	NS	46	66	127	229	116	49	31	664
05/25/2005	NS	57	81	133	222	120	49	29	690
06/02/2005	NS	60	85	143	224	113	47	34	706

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-4. Low-frequency broom basin street-dirt yield, in pounds per curb-mile, separated by particle size.

[mm/dd/yyyy, month/day/year; µm, micrometer; >, greater than; <, less than]

Date (mm/dd/yyyy)	Street-dirt yield (pounds per curb-mile)							
	>2,000 µm	1,000–2,000 µm	500–1,000 µm	250–500 µm	125–250 µm	63–125 µm	<63 µm	Total
06/20/2002	74	93	143	189	84	24	9	617
06/28/2002	64	69	102	152	74	23	11	495
07/05/2002	54	78	115	164	87	31	19	549
07/12/2002	86	112	177	275	148	55	39	891
07/19/2002	53	70	111	171	100	41	25	571
07/26/2002	67	74	105	161	88	33	18	547
08/02/2002	84	93	138	209	109	44	27	703
08/09/2002	77	84	125	179	96	40	26	626
08/16/2002	63	69	93	139	77	29	17	486
08/30/2002	50	63	92	138	77	32	20	472
09/06/2002	49	62	92	139	86	37	23	489
09/13/2002	48	67	101	145	81	32	17	490
09/27/2002	70	94	131	200	119	44	25	683
04/02/2003	136	188	389	618	266	96	59	1,753
04/15/2003	213	272	494	706	324	122	119	2,250
04/23/2003	79	111	227	389	203	73	51	1,132
04/29/2003	83	121	265	472	260	92	99	1,392
05/13/2003	54	100	185	268	115	36	13	770
05/21/2003	46	78	147	246	122	40	27	707
05/27/2003	51	89	168	268	157	40	48	821
06/04/2003	65	93	175	307	166	58	27	891
06/12/2003	35	61	127	182	98	37	20	561
06/17/2003	48	86	166	274	150	60	30	813
06/26/2003	38	52	85	133	72	27	16	422
07/02/2003	43	57	105	192	125	56	36	613
07/11/2003	38	53	89	134	74	24	9	421
07/16/2003	47	54	82	131	86	36	17	453
07/23/2003	43	47	74	126	89	44	22	446
07/30/2003	44	62	104	187	126	52	30	603
08/05/2003	44	60	97	170	125	52	41	590
08/13/2003	40	54	84	153	117	55	37	540
08/20/2003	44	62	106	193	141	69	45	659
08/27/2003	33	47	77	139	103	48	28	475
09/03/2003	35	48	75	124	90	44	31	448
09/10/2003	38	62	90	154	108	57	39	548
09/17/2003	32	45	66	112	80	32	17	385

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-4. Low-frequency broom basin street-dirt yield, in pounds per curb-mile, separated by particle size—Continued.

[mm/dd/yyyy, month/day/year; µm, micrometer; >, greater than; <, less than]

Date (mm/dd/yyyy)	Street-dirt yield (pounds per curb-mile)							
	>2,000 µm	1,000–2,000 µm	500–1,000 µm	250–500 µm	125–250 µm	63–125 µm	<63 µm	Total
09/24/2003	25	38	61	107	78	40	25	375
10/01/2003	35	50	74	126	92	45	24	446
10/08/2003	48	63	88	161	107	54	32	552
04/06/2004	90	120	213	320	94	25	11	873
04/13/2004	90	124	250	456	154	70	50	1,194
04/27/2004	78	108	190	303	107	35	19	841
05/04/2004	60	93	175	303	124	53	32	840
05/19/2004	56	79	122	194	76	22	8	557
05/26/2004	49	60	82	151	82	26	9	460
06/02/2004	53	62	85	150	77	23	6	455
06/08/2004	57	81	95	166	131	35	14	580
06/15/2004	47	57	75	121	71	27	9	407
06/22/2004	42	53	72	115	57	22	7	367
06/30/2004	45	55	74	127	87	36	19	443
07/09/2004	43	50	59	98	65	23	9	346
07/14/2004	39	47	61	111	76	31	17	381
07/28/2004	43	53	58	88	60	26	14	342
08/03/2004	38	45	49	74	45	15	7	273
08/10/2004	38	49	57	90	58	23	11	326
09/02/2004	37	44	50	76	46	16	5	274
09/08/2004	40	48	54	82	58	23	8	313
09/17/2004	34	42	43	55	30	11	4	220

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-5. Runoff-event characteristics for the control basin.

[mm/dd/yyyy, month/day/year; hh:mm, hour:minute; ft³, cubic feet; %, percent; ft³/s, cubic foot per second; --, data not available]

Sample ID	Start date (mm/dd/yyyy)	Start time (hh:mm)	End date (mm/dd/yyyy)	End time (hh:mm)	Duration (hours)	Total event volume (ft^3)	Runoff (%)	Peak flow (ft^3/s)	Volume of storm sampled (%)	Antecedent dry time (days)
1	08/25/2001	02:13	08/25/2001	15:30	13.28	64,915	12	29.1	84	
2	09/07/2001	12:33	09/09/2001	17:00	52.45	81,761	12	22.4	93	12.88
3	09/17/2001	05:51	09/18/2001	02:00	20.15	24,018	14	4.8	94	7.54
4	09/19/2001	00:14	09/19/2001	13:13	12.98	31,156	12	2.0	96	.93
5	09/20/2001	20:09	09/20/2001	22:15	2.10	9,859	10	3.6	98	1.29
6	10/22/2001	14:00	10/22/2001	23:32	9.53	61,291	12	11.7	93	31.66
7	10/24/2001	07:54	10/24/2001	22:00	14.10	9,058	10	1.4	95	1.35
8	11/23/2001	18:45	11/25/2001	03:00	32.25	35,158	10	3.8	98	29.86
9	02/18/2002	12:00	02/19/2002	11:05	23.08	33,976	--	1.9	98	7.79
10	02/19/2002	13:38	02/21/2002	01:00	35.37	61,161	--	4.6	98	.11
11	03/08/2002	04:18	03/09/2002	11:00	30.70	66,993	--	4.0	98	15.14
12	04/07/2002	03:45	04/09/2002	04:00	48.25	92,387	17	3.0	97	28.70
13	04/18/2002	07:54	04/18/2002	23:51	15.95	49,160	19	22.4	98	9.16
14	05/01/2002	12:17	05/02/2002	02:00	13.72	14,405	11	2.5	89	12.52
15	05/11/2002	10:43	05/12/2002	02:38	15.92	28,523	13	7.0	91	9.36
16	05/25/2002	05:39	05/25/2002	13:00	7.35	24,387	12	3.0	92	13.13
17	05/28/2002	21:16	05/29/2002	05:27	8.18	34,751	15	25.2	97	3.34
18	06/02/2002	18:02	06/03/2002	08:45	14.72	58,339	20	19.7	100	4.52
19	06/03/2002	21:45	06/04/2002	13:48	16.05	98,629	22	6.2	97	.54
20	06/10/2002	19:04	06/10/2002	20:32	1.47	17,120	23	12.7	82	6.22
21	06/26/2002	04:17	06/26/2002	05:00	.72	20,225	12	22.4	98	15.32
22	07/22/2002	01:08	07/22/2002	08:04	6.93	31,555	12	7.6	82	25.84
23	08/17/2002	07:06	08/17/2002	07:46	.67	11,805	14	8.4	86	3.95
24	08/21/2002	18:41	08/22/2002	06:45	12.07	36,228	9	10.5	92	4.45
25	09/02/2002	04:28	09/02/2002	08:56	4.47	47,477	14	5.8	95	10.90
26	09/19/2002	01:05	09/19/2002	06:00	4.92	19,617	12	3.0	96	16.67
27	09/19/2002	13:23	09/19/2002	13:55	.53	13,622	13	13.2	90	.31
28	09/20/2002	06:32	09/20/2002	09:49	3.28	11,702	9	6.0	99	.69
29	10/04/2002	01:34	10/04/2002	12:00	10.43	25,030	6	5.6	89	4.81
30	10/25/2002	01:03	10/25/2002	23:41	22.63	16,093	11	1.0	92	20.54
31	12/17/2002	23:22	12/18/2002	17:00	17.63	35,301	16	3.7	97	52.99
32	03/27/2003	08:29	03/28/2003	11:44	27.25	28,142	16	3.4	98	98.65
33	04/30/2003	06:24	04/30/2003	14:00	7.60	24,628	11	4.6	91	32.78
34	04/30/2003	20:51	04/30/2003	23:46	2.92	54,258	14	11.3	94	.29
35	05/04/2003	19:39	05/05/2003	10:00	14.35	25,729	11	1.7	99	3.83
36	05/08/2003	22:46	05/09/2003	02:37	3.85	17,808	11	1.8	74	3.53
37	05/10/2003	20:07	05/11/2003	19:05	22.97	23,164	10	4.0	96	1.73

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-5. Runoff-event characteristics for the control basin—Continued.

[mm/dd/yyyy, month/day/year; hh:mm, hour:minute; ft³, cubic feet; %, percent; ft³/s, cubic foot per second; --, data not available]

Sample ID	Start date (mm/dd/yyyy)	Start time (hh:mm)	End date (mm/dd/yyyy)	End time (hh:mm)	Duration (hours)	Total event volume (ft³)	Runoff (%)	Peak flow (ft³/s)	Volume of storm sampled (%)	Antecedent dry time (days)
38	05/14/2003	06:25	05/14/2003	15:58	9.55	12,005	10	1.0	91	2.47
39	05/19/2003	13:05	05/20/2003	02:02	12.95	18,178	13	3.6	80	4.88
40	05/30/2003	17:33	05/30/2003	17:55	.37	9,604	5	10.7	86	10.65
41	07/15/2003	01:37	07/15/2003	02:22	.75	40,338	7	12.4	89	16.25
42	07/21/2003	01:54	07/21/2003	03:00	1.10	14,069	11	1.9	98	5.98
43	08/05/2003	17:24	08/05/2003	18:00	.60	10,411	8	7.9	68	15.60
44	09/12/2003	13:00	09/12/2003	19:02	6.03	6,944	4	2.4	100	37.79
45	09/13/2003	05:14	09/14/2003	09:01	27.78	89,497	8	5.1	97	.42
46	10/13/2003	22:27	10/14/2003	11:00	12.55	11,534	6	1.1	96	1.98
47	10/24/2003	15:56	10/24/2003	23:00	7.07	13,608	6	2.4	91	10.21
48	11/01/2003	21:10	11/02/2003	20:00	22.83	46,172	9	4.0	82	7.92
49	11/03/2003	06:13	11/04/2003	10:00	27.78	119,111	12	18.0	92	.43
50	11/17/2003	22:10	11/18/2003	12:00	13.83	12,476	7	2.6	99	13.51
51	11/22/2003	22:54	11/23/2003	11:00	12.10	55,866	11	6.3	100	4.45
52	12/09/2003	12:51	12/10/2003	12:01	23.17	56,324	10	3.4	100	16.08
53	02/20/2004	05:00	02/20/2004	19:00	14.00	27,242	--	1.7	98	71.71
54	03/04/2004	18:11	03/05/2004	12:48	18.62	59,046	15	4.0	99	12.97
55	03/25/2004	20:51	03/26/2004	08:00	11.15	39,640	8	8.5	98	20.34
56	04/20/2004	08:26	04/21/2004	15:00	30.57	30,093	12	2.5	71	25.02
57	05/08/2004	22:32	05/09/2004	02:00	3.47	13,677	7	8.6	95	17.31
58	05/10/2004	03:58	05/10/2004	17:00	13.03	11,854	8	6.9	92	1.08
60	05/17/2004	20:25	05/18/2004	02:00	5.58	19,215	7	20.0	90	7.14
61	05/21/2004	07:36	05/21/2004	10:00	2.40	15,422	5	9.0	100	3.23
62	05/21/2004	16:36	05/22/2004	10:00	17.40	99,204	10	21.0	60	.28
63	05/29/2004	08:16	05/31/2004	17:00	56.73	36,634	7	7.0	97	6.93
64	06/10/2004	10:59	06/10/2004	14:00	3.02	6,679	6	2.3	96	9.75
65	06/10/2004	15:17	06/11/2004	09:00	17.72	25,307	8	3.1	95	.05
66	06/24/2004	08:36	06/24/2004	13:00	4.40	7,785	8	2.2	93	12.98
67	07/09/2004	11:46	07/09/2004	14:00	2.23	10,731	8	6.4	92	14.95
68	07/16/2004	10:37	07/16/2004	18:00	7.38	17,410	7	8.8	88	6.86
69	07/21/2004	08:17	07/21/2004	12:00	3.72	9,037	7	1.9	96	4.60
70	07/29/2004	15:05	07/30/2004	10:00	18.92	29,272	8	6.2	96	8.13
71	08/03/2004	19:41	08/03/2004	23:00	3.32	23,985	9	23.0	97	1.28
72	08/16/2004	20:06	08/17/2004	03:00	6.90	7,871	7	4.6	97	12.88
73	08/18/2004	17:42	08/18/2004	20:00	2.30	9,556	6	10.0	90	1.61
74	08/24/2004	18:00	08/25/2004	01:00	7.00	5,469	14	3.9	97	.13
75	08/27/2004	00:52	08/27/2004	03:00	2.13	4,113	4	3.7	88	1.99

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-5. Runoff-event characteristics for the control basin—Continued.

[mm/dd/yyyy, month/day/year; hh:mm, hour:minute; ft^3, cubic feet; %, percent; ft^3/s, cubic foot per second; --, data not available]

Sample ID	Start date (mm/dd/yyyy)	Start time (hh:mm)	End date (mm/dd/yyyy)	End time (hh:mm)	Duration (hours)	Total event volume (ft^3)	Runoff (%)	Peak flow (ft^3/s)	Volume of storm sampled (%)	Antecedent dry time (days)
76	09/01/2004	05:17	09/01/2004	08:00	2.72	18,291	6	9.8	95	3.39
77	09/15/2004	09:17	09/15/2004	18:00	8.72	14,671	9	2.4	97	9.05
78	10/08/2004	00:00	10/08/2004	06:00	6.00	23,216	8	8.3	97	6.04
79	10/22/2004	17:00	10/23/2004	10:00	17.00	40,435	10	6.9	99	3.38
80	11/01/2004	10:00	11/02/2004	04:00	18.00	12,882	6	.98	94	2.25
81	11/04/2004	01:00	11/04/2004	11:00	10.00	5,944	8	.81	89	1.88
82	11/26/2004	14:00	11/27/2004	19:00	29.00	19,086	10	1.3	92	6.33
83	12/05/2004	22:00	12/06/2004	10:00	12.00	13,815	9	1.3	90	8.13
84	12/07/2004	01:00	12/07/2004	14:00	13.00	32,970	13	3.7	97	.63
85	04/06/2005	16:00	04/07/2005	02:00	10.00	30,750	9	11	97	5.75
86	04/12/2005	00:00	04/12/2005	19:00	19.00	16,140	12	4	92	4.92
87	04/19/2005	23:00	04/20/2005	02:00	3.00	5,106	8	2.7	80	7.17
88	05/06/2005	06:00	05/06/2005	15:00	9.00	11,336	8	4.7	90	10.21
89	05/11/2005	03:00	05/11/2005	14:00	11.00	29,134	9	3.7	97	4.50
90	05/13/2005	00:00	05/13/2005	11:00	11.00	16,969	8	4.4	97	1.42
91	05/18/2005	22:00	05/19/2005	08:00	10.00	16,572	9	2.5	93	5.46
92	4/13/2006	21:31	04/14/2006	2:00	4.48	4,743	7	5	78	1.48
93	4/16/2006	2:04	04/16/2006	20:00	17.93	42,932	9	23	98	2.00
94	4/29/2006	14:29	04/30/2006	19:00	28.52	49,974	11	3.9	89	7.44
95	05/01/2006	17:36	05/02/2006	0:00	6.40	12,450	8	11	79	.94
96	05/09/2006	10:26	05/09/2006	19:00	8.57	12,260	8	2.3	86	7.43
97	05/17/2006	15:57	05/17/2006	19:00	3.05	4,087	6	1.9	92	.79
98	05/24/2006	18:33	05/25/2006	3:00	8.45	23,293	5	26	98	.40
99	05/30/2006	13:07	05/31/2006	9:00	19.88	21,047	7	19	95	4.38
100	06/09/2006	22:44	06/10/2006	9:00	10.27	21,833	8	2.1	93	3.53
101	06/18/2006	4:51	06/18/2006	17:00	12.15	8,381	7	5.2	90	3.62
102	07/11/2006	7:31	07/11/2006	18:00	10.48	55,564	9	6.1	96	1.40
103	07/20/2006	2:31	07/20/2006	9:00	6.48	24,114	7	10	93	8.35
104	07/27/2006	12:07	07/27/2006	17:00	4.88	33,333	8	18	97	1.38
105	08/06/2006	5:49	08/06/2006	13:00	7.18	19,025	7	2.9	93	9.53
106	08/17/2006	12:30	08/17/2006	20:00	7.50	8,087	6	5.7	91	10.98
107	08/23/2006	22:25	08/24/2006	6:00	7.58	64,990	8	27	76	6.10
108	08/24/2006	13:19	08/24/2006	18:00	4.68	40,280	10	28	99	.14
109	08/25/2006	6:10	08/25/2006	13:00	6.83	26,179	10	6.6	92	.51
110	09/03/2006	19:04	09/04/2006	10:00	14.93	20,399	8	3.2	95	6.04
111	09/10/2006	8:32	09/13/2006	0:00	63.47	103,766	30	13	98	5.94

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-6. Runoff-event characteristics for the air-sweeper basin.

[mm/dd/yyyy, month/day/year; hh:mm, hour:minute; precip., precipitation; in/hr, inches per hour; ft^3, cubic feet; %, percent; ft^3/s, cubic foot per second; --, data not available; NA, not applicable]

Sample ID	Start date (mm/dd/yyyy)	Start time (hh:mm)	End date (mm/dd/yyyy)	End time (hh:mm)	Duration (hours)	Precip. depth (inches)	15-min precip. intensity (in/hr)	30-min precip. intensity (in/hr)	60-min precip. intensity (in/hr)	Total event volume (ft^3)	Runoff (%)	Peak flow (ft^3/s)	Volume of storm sampled (%)	Antecedent dry time (days)
1	08/25/2001	02:13	08/25/2001	14:53	12.67	1.63	2.80	1.76	1.03	72,988	24	83.0	94	0.26
2	09/07/2001	12:33	09/09/2001	17:00	52.45	2.09	1.88	1.00	.60	52,721	13	19.9	98	12.90
3	09/17/2001	05:51	09/17/2001	13:13	7.37	.54	.28	.20	.18	15,253	15	6.4	90	7.54
4	09/19/2001	00:14	09/19/2001	13:00	12.77	.83	.20	.18	.16	15,348	10	1.1	90	1.46
5	09/20/2001	20:09	09/20/2001	23:00	2.85	.31	.32	.28	.27	5,507	9	1.8	74	1.30
6	10/22/2001	14:00	10/22/2001	23:26	9.43	1.63	.88	.72	.58	53,486	17	10.0	93	8.78
7	10/24/2001	07:54	10/24/2001	20:00	12.10	.27	.16	.14	.12	4,234	8	.8	63	1.35
8	11/23/2001	18:45	11/25/2001	01:57	31.20	1.05	.40	.32	.26	28,964	14	3.0	97	4.69
9	02/09/2002	22:50	02/10/2002	17:00	18.17	snowmelt	NA	NA	NA	12,528	--	1.0	93	49.18
10	02/18/2002	22:13	02/19/2002	11:00	12.78	snowmelt	NA	NA	NA	15,525	--	1.2	95	8.22
11	02/19/2002	13:50	02/21/2002	05:00	39.17	snowmelt	NA	NA	NA	34,935	--	2.6	94	.12
12	03/08/2002	04:17	03/09/2002	10:40	30.38	snowmelt	NA	NA	NA	41,908	--	2.8	97	14.97
13	04/07/2002	03:45	04/09/2002	01:00	45.25	1.67	.24	.20	.15	38,822	12	1.4	95	4.50
14	04/18/2002	17:02	04/18/2002	23:12	6.17	.80	1.36	.84	.42	24,901	16	17.4	98	3.93
15	05/01/2002	12:17	05/02/2002	02:00	13.72	.39	.20	.16	.13	6,388	9	.9	75	3.28
16	05/11/2002	10:43	05/12/2002	03:01	16.30	.68	.20	.18	NA	18,937	15	12.5	89	2.24
17	05/25/2002	04:46	05/25/2002	13:53	9.12	.62	.24	.20	.17	27,570	23	2.4	89	13.07
18	05/28/2002	21:04	05/29/2002	02:30	5.43	.70	1.84	1.00	.51	23,903	18	20.3	94	3.30
19	06/03/2002	02:05	06/03/2002	09:02	6.95	.91	1.24	.92	.52	34,864	20	17.4	97	4.98
20	06/03/2002	21:54	06/04/2002	14:14	16.33	1.37	.84	.56	.40	35,222	13	2.5	75	.54
21	06/10/2002	18:47	06/10/2002	20:49	2.03	.23	.56	.32	.19	7,429	17	7.1	85	6.19
22	06/26/2002	04:16	06/26/2002	05:02	.77	.51	1.00	.60	.33	13,876	14	20.0	92	11.40
23	07/22/2002	00:56	07/22/2002	08:25	7.48	.84	1.00	.52	.29	11,075	7	3.3	84	1.37
24	08/12/2002	17:21	08/13/2002	08:25	15.07	.79	.80	.46	.24	13,439	9	3.4	92	8.30

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-6. Runoff-event characteristics for the air-sweeper basin—Continued.

[mm/dd/yyyy, month/day/year; hh:mm, hour:minute; precip., precipitation; in/hr, inches per hour; ft^3, cubic feet; %, percent; ft^3/s, cubic foot per second; --, data not available; NA, not applicable]

Sample ID	Start date (mm/dd/yyyy)	Start time (hh:mm)	End date (mm/dd/yyyy)	End time (hh:mm)	Duration (hours)	Precip. depth (inches)	15-min precip. intensity (in/hr)	30-min precip. intensity (in/hr)	60-min precip. intensity (in/hr)	Total event volume (ft^3)	Runoff (%)	Peak flow (ft^3/s)	Volume of storm sampled (%)	Antecedent dry time (days)
25	08/17/2002	06:59	08/17/2002	08:08	1.15	.26	1.32	NA	NA	5,598	11	5.8	81	3.94
26	08/21/2002	18:25	08/22/2002	09:18	14.88	1.21	1.28	.92	.46	29,977	13	16.5	95	4.43
27	09/02/2002	03:58	09/02/2002	09:20	5.37	1.04	.72	.64	.44	20,038	10	6.2	95	10.78
28	09/19/2002	00:56	09/19/2002	06:00	5.07	0.50	0.48	0.34	0.21	6,219	7	1.0	50	16.65
29	09/19/2002	13:16	09/19/2002	14:16	1.00	.31	.52	NA	NA	7,058	12	7.4	94	.30
30	09/20/2002	05:12	09/20/2002	11:21	6.15	.42	.76	.46	.24	5,392	7	3.1	92	.62
31	09/28/2002	21:54	09/29/2002	06:11	8.28	.61	.80	.50	.34	12,244	11	4.1	82	8.44
32	12/17/2002	23:19	12/18/2002	17:00	17.68	.67	.56	.28	.21	18,515	15	2.4	95	28.87
33	03/28/2003	04:09	03/28/2003	20:00	15.85	.53	.20	.20	.16	9,940	10	1.3	95	8.17
34	04/30/2003	06:11	04/30/2003	14:33	8.37	.67	.44	.40	.28	22,640	18	3.7	97	10.09
35	04/30/2003	20:53	05/01/2003	08:38	11.75	1.15	.80	.74	.50	43,770	20	11.1	100	.26
36	05/04/2003	19:32	05/05/2003	10:00	14.47	.72	.24	.22	.18	14,731	11	1.7	94	3.45
37	05/08/2003	20:41	05/09/2003	03:46	7.08	.49	.28	.24	.22	11,420	12	1.9	97	1.40
38	05/10/2003	20:03	05/11/2003	20:42	24.65	.74	.52	.28	.23	13,979	10	5.0	99	1.68
39	05/14/2003	06:11	05/14/2003	16:36	10.42	.38	.28	.16	.12	6,322	9	.8	84	2.40
40	05/19/2003	21:37	05/20/2003	02:51	5.23	.43	1.12	.64	.38	15,779	19	12.1	94	5.21
41	05/30/2003	17:28	05/30/2003	18:21	.88	.55	2.16	NA	NA	15,160	14	23.0	90	10.61
42	06/24/2003	07:17	06/24/2003	08:23	1.10	.34	.84	.54	NA	7,174	11	8.3	89	24.54
43	06/25/2003	15:29	06/25/2003	23:13	7.73	.45	.88	.64	.33	6,918	8	4.6	96	1.30
44	06/28/2003	01:15	06/28/2003	13:00	11.75	1.11	.88	.78	.63	26,434	13	9.5	93	2.08
45	07/15/2003	01:38	07/15/2003	03:37	1.98	1.81	2.60	2.06	1.78	66,313	19	47.3	92	6.57
46	08/05/2003	16:30	08/05/2003	18:38	2.13	.41	1.16	.62	NA	29,040	37	45.9	99	2.09
47	09/12/2003	12:40	09/12/2003	19:31	6.85	.59	.44	.28	.20	6,499	6	2.0	93	14.50
48	09/13/2003	04:33	09/14/2003	10:15	29.70	3.56	1.16	.88	.63	84,006	12	12.2	67	.38

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-6. Runoff-event characteristics for the air-sweeper basin—Continued.

[mm/dd/yyyy, month/day/year; hh:mm, hour:minute; precip., precipitation; in/hr, inches per hour; ft³, cubic feet; %, percent; ft³/s, cubic foot per second; --, data not available; NA, not applicable]

Sample ID	Start date (mm/dd/yyyy)	Start time (hh:mm)	End date (mm/dd/yyyy)	End time (hh:mm)	Duration (hours)	Precip. depth (inches)	15-min precip. intensity (in/hr)	30-min precip. intensity (in/hr)	60-min precip. intensity (in/hr)	Total event volume (ft³)	Runoff (%)	Peak flow (ft³/s)	Volume of storm sampled (%)	Antecedent dry time (days)
49	10/13/2003	23:00	10/14/2003	11:00	12.00	.64	.28	.20	.15	7,223	6	.8	77	1.71
50	10/24/2003	15:56	10/25/2003	01:00	9.07	.75	.48	.46	.41	13,556	9	3.8	91	10.21
51	11/01/2003	21:00	11/02/2003	20:00	23.00	1.66	.60	.42	.34	32,167	10	3.6	80	7.83
52	11/03/2003	06:21	11/04/2003	11:00	28.65	2.98	.88	.72	.63	89,104	16	14.0	96	.43
53	11/17/2003	22:10	11/18/2003	12:00	13.83	.54	.36	.24	.19	8,217	8	2.0	97	13.47
54	11/22/2003	22:00	11/23/2003	12:00	14.00	1.60	.80	.58	.45	54,147	18	7.7	99	4.42
55	12/09/2003	12:51	12/11/2003	01:00	36.15	1.65	0.40	0.34	0.27	49,896	16	5.2	96	16.04
56	02/20/2004	04:00	02/20/2004	18:00	14.00	snowmelt	NA	NA	NA	15,198	--	1.1	96	71.13
57	03/04/2004	18:17	03/05/2004	13:00	18.72	1.23	.32	.26	.26	35,700	15	3.3	98	13.01
58	03/25/2004	20:51	03/26/2004	05:00	8.15	1.50	.88	.78	.66	34,897	12	11.0	100	20.33
59	04/20/2004	15:13	04/21/2004	07:00	15.78	.74	.52	.34	.19	10,351	7	2.3	89	25.43
60	05/08/2004	22:00	05/09/2004	03:00	5.00	.57	.68	.50	.32	10,835	10	5.8	98	17.63
61	05/10/2004	03:58	05/10/2004	17:00	13.03	.46	1.04	.54	.37	11,526	13	7.1	96	1.04
63	05/17/2004	20:25	05/18/2004	02:00	5.58	.88	2.56	1.44	.74	32,219	19	49.0	97	7.14
64	05/21/2004	07:36	05/21/2004	10:00	2.40	.87	1.88	1.12	.78	25,099	15	21.0	97	3.23
65	05/21/2004	16:36	05/22/2004	09:00	16.40	2.93	2.16	1.32	.93	148,954	27	91.0	74	.28
66	05/29/2004	08:16	05/31/2004	11:00	50.73	1.52	.80	.56	.46	25,894	9	7.1	99	6.97
67	06/10/2004	10:59	06/10/2004	13:00	2.02	.33	.44	.36	.27	5,020	8	2.3	81	10.00
68	06/16/2004	21:15	06/17/2004	04:02	6.78	.78	1.04	.70	.45	11,413	8	6.1	97	6.34
69	06/24/2004	08:36	06/24/2004	13:00	4.40	.29	.20	.16	.11	4,251	8	1.6	91	7.19
70	07/09/2004	11:53	07/09/2004	14:00	2.12	.41	.88	.70	.39	13,452	17	12.0	93	14.95
71	07/16/2004	10:37	07/16/2004	18:00	7.38	.79	1.56	.84	.43	24,702	16	21.0	92	6.86
72	07/21/2004	08:17	07/21/2004	12:00	3.72	.40	.60	.34	.19	5,720	8	1.8	89	4.60
73	07/29/2004	15:05	07/30/2004	09:00	17.92	1.08	7.48	3.74	1.94	24,322	12	10.0	97	8.13

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-6. Runoff-event characteristics for the air-sweeper basin—Continued.

[mm/dd/yyyy, month/day/year; hh:mm, hour:minute; precip., precipitation; in/hr, inches per hour; ft^3, cubic feet; %, percent; ft^3/s, cubic foot per second; --, data not available; NA, not applicable]

Sample ID	Start date (mm/dd/yyyy)	Start time (hh:mm)	End date (mm/dd/yyyy)	End time (hh:mm)	Duration (hours)	Precip. depth (inches)	15-min precip. intensity (in/hr)	30-min precip. intensity (in/hr)	60-min precip. intensity (in/hr)	Total event volume (ft^3)	Runoff (%)	Peak flow (ft^3/s)	Volume of storm sampled (%)	Antecedent dry time (days)
74	08/03/2004	19:48	08/03/2004	22:00	2.20	.83	2.48	1.34	.75	42,440	27	67.0	97	1.28
75	08/16/2004	20:06	08/17/2004	03:00	6.90	.35	.56	.40	.29	8,545	13	5.5	91	12.92
76	08/18/2004	17:42	08/18/2004	20:00	2.30	.53	1.68	.98	NA	18,524	18	26.0	94	1.61
77	08/24/2004	11:18	08/24/2004	23:00	11.70	.26	.20	.16	.10	5,797	12	5.0	92	5.64
78	08/27/2004	00:17	08/27/2004	02:00	1.72	.36	.76	.50	.35	11,318	17	9.6	98	2.05
79	09/01/2004	05:03	09/01/2004	08:00	2.95	.90	2.00	1.28	.82	45,481	27	54.0	99	3.42
80	09/15/2004	09:15	09/15/2004	19:00	9.75	.51	.32	.20	.15	9,262	10	1.8	96	9.05
81	10/08/2004	00:35	10/08/2004	10:00	9.42	.83	.76	.74	.49	29,281	19	12	96	5.52
82	10/22/2004	17:59	10/23/2004	03:00	9.02	1.19	.72	.54	.41	47,028	21	11	99	3.21
83	11/01/2004	08:45	11/02/2004	06:00	21.25	0.52	0.16	0.12	0.08	17,375	18	0.56	93	2.32
84	11/04/2004	01:05	11/05/2004	01:00	23.92	.25	.16	.12	.1	5,564	12	.34	72	1.80
85	11/26/2004	13:00	11/27/2004	22:00	33.00	.56	.12	.12	.1	7,249	7	.56	91	6.29
86	12/05/2004	22:00	12/06/2004	16:00	18.00	.48	.2	.16	.15	14,653	16	1.2	85	8.00
87	12/06/2004	23:00	12/07/2004	20:00	21.00	.8	.4	.36	.28	29,635	19	4	95	.29
88	04/06/2005	17:33	04/07/2005	01:00	7.45	.86	1.16	.8	.55	17,747	11	7.6	97	5.90
89	04/12/2005	07:12	04/12/2005	18:00	10.80	.43	.32	.28	.19	5,124	6	1.5	85	5.26
90	04/19/2005	23:00	04/20/2005	02:00	3.00	.31	.96	.6	-9	5,901	10	5.7	88	7.21
91	05/06/2005	07:02	05/06/2005	17:00	9.97	.6	.72	.48	.39	12,191	11	5	92	10.17
92	05/11/2005	04:14	05/11/2005	14:00	9.77	.99	.48	.38	.31	19,380	10	2.9	95	4.47
93	05/13/2005	01:40	05/13/2005	11:00	9.33	.57	.56	.42	.35	14,075	13	5.8	96	1.49
94	05/18/2005	22:52	05/19/2005	07:00	8.13	.55	.36	.26	.25	9,634	9	1.7	96	5.49
95	06/25/2005	00:36	06/26/2005	03:00	26.40	1.27	1.07	1.44	1.14	23,682	10	12	98	11.40
96	04/12/2006	04:57	04/12/2006	10:00	5.05	.41	.4	.32	.28	5,625	7	1.4	87	4.75
97	04/13/2006	21:31	04/14/2006	00:00	2.48	.2	.76	.38	.19	3,188	8	3.4	86	1.48

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-6. Runoff-event characteristics for the air-sweeper basin—Continued.

[mm/dd/yyyy, month/day/year; hh:mm, hour:minute; precip., precipitation; in/hr, inches per hour; ft^3, cubic feet; %, percent; ft^3/s, cubic foot per second; --, data not available; NA, not applicable]

Sample ID	Start date (mm/dd/yyyy)	Start time (hh:mm)	End date (mm/dd/yyyy)	End time (hh:mm)	Duration (hours)	Precip. depth (inches)	15-min precip. intensity (in/hr)	30-min precip. intensity (in/hr)	60-min precip. intensity (in/hr)	Total event volume (ft^3)	Runoff (%)	Peak flow (ft^3/s)	Volume of storm sampled (%)	Antecedent dry time (days)
98	04/16/2006	02:04	04/16/2006	20:00	17.93	1.43	2.76	1.6	.94	67,668	25	67	86	2.09
99	04/29/2006	14:29	04/30/2006	20:00	29.52	1.42	.28	.24	.21	26,853	10	1.8	98	7.48
100	05/01/2006	17:36	05/02/2006	02:00	8.40	.45	1.2	.66	.34	13,712	16	13	93	.90
101	05/09/2006	10:26	05/09/2006	21:00	10.57	.48	.28	.24	.16	7,733	8	1.7	87	7.35
102	05/17/2006	15:57	05/17/2006	20:00	4.05	.22	.52	--	--	4,260	10	3.2	92	.71
103	05/24/2006	18:33	05/24/2006	20:00	1.45	1.32	4.72	2.46	1.23	47,174	19	110	92	.40
104	05/30/2006	13:07	05/31/2006	08:00	18.88	.99	1.72	1.14	.60	20,727	11	18	99	4.75
105	06/18/2006	04:51	06/18/2006	15:00	10.15	.39	.68	.38	.22	7,050	9	7.4	94	3.70
106	07/11/2006	07:31	07/11/2006	14:54	7.38	1.81	.92	.84	.61	22,395	6	3.7	98	1.48
107	08/06/2006	05:49	08/06/2006	15:00	9.18	.86	.4	.36	.30	13,504	8	2.4	87	9.66
108	08/17/2006	12:30	08/17/2006	23:00	10.50	.42	.88	.58	.32	9,444	12	5.3	85	10.90
109	08/23/2006	23:30	08/24/2006	06:00	6.50	2.44				47,010	14	19	92	6.02

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-7. Runoff-event characteristics for the high-frequency broom basin.

[mm/dd/yyyy, month/day/year; hh:mm, hour:minute; precip., precipitation; in/hr, inches per hour; ft^3, cubic feet; %, percent; ft^3/s, cubic foot per second; --, data not available; NA, not applicable]

Sample ID	Start date (mm/dd/yyyy)	Start time (hh:mm)	End date (mm/dd/yyyy)	End time (hh:mm)	Duration (hours)	Precip. depth (inches)	15-min precip. intensity (in/hr)	30-min precip. intensity (in/hr)	60-min precip. intensity (in/hr)	Total event volume (ft^3)	Runoff (%)	Peak flow (ft^3/s)	Volume of storm sampled (%)	Antecedent dry time (days)
1	07/22/2002	00:56	07/22/2002	9:03	8.12	0.84	1.00	0.52	0.29	10,466	6	2.4	85	1.32
2	08/12/2002	17:21	08/13/2002	8:05	14.73	.88	.80	.46	.24	13,528	7	3.7	89	.92
3	08/17/2002	06:59	08/17/2002	8:45	1.77	.38	1.32	NA	NA	4,988	6	5.8	56	3.95
4	09/02/2002	03:58	09/02/2002	10:00	6.03	1.04	.72	.64	.44	16,542	7	3.8	84	10.74
5	09/19/2002	00:56	09/19/2002	6:00	5.07	.47	.48	.34	.21	4,299	4	.7	64	16.62
6	09/20/2002	05:12	09/20/2002	12:08	6.93	.42	.76	.46	.24	7,128	8	2.9	71	.61
7	09/28/2002	21:54	09/29/2002	6:00	8.10	.61	.80	.50	.34	6,229	5	3.2	74	8.41
8	10/03/2002	21:21	10/04/2002	13:30	16.15	1.37	1.20	1.06	.68	22,645	8	9.7	98	.72
9	12/17/2002	23:08	12/18/2002	17:00	17.87	.73	.48	.26	.25	16,151	10	2.7	97	29.01
10	03/27/2003	23:37	03/28/2003	13:00	13.38	.56	.24	.22	.17	9,614	8	1.2	92	8.03
11	04/30/2003	05:46	04/30/2003	14:05	8.32	.76	.40	.38	.29	6,456	4	.8	81	9.78
12	04/30/2003	18:37	05/01/2003	1:41	7.07	1.24	1.00	.88	.62	28,234	11	9.1	99	.19
13	05/04/2003	18:58	05/05/2003	8:06	13.13	.74	.32	.26	.20	11,960	8	1.5	95	3.72
14	05/08/2003	22:23	05/09/2003	3:22	4.98	.57	.32	.30	.26	9,940	8	1.7	88	1.50
15	05/10/2003	19:59	05/11/2003	19:42	23.72	.57	1.12	.58	.29	23,345	19	3.6	89	1.69
16	05/14/2003	05:31	05/14/2003	16:18	10.78	.43	.20	.18	.11	6,913	8	.4	89	2.41
17	05/19/2003	12:47	05/20/2003	2:30	13.72	.72	.76	.60	.38	11,295	7	3.5	94	4.85
18	05/30/2003	17:19	05/30/2003	18:20	1.02	.56	2.16	1.12	.56	6,643	6	9.8	96	2.13
19	06/25/2003	15:18	06/25/2003	23:20	8.03	.53	.76	.64	.36	5,228	5	3.2	99	1.28
20	06/28/2003	00:29	06/28/2003	12:09	11.67	1.45	1.52	1.30	.89	21,900	7	9.6	97	2.05
21	07/15/2003	01:38	07/15/2003	3:29	1.85	1.81	2.60	2.06	1.78	36,404	9	23.7	96	6.58
22	07/21/2003	01:03	07/21/2003	3:41	2.63	.40	.64	.52	.31	5,126	6	4.0	73	5.90
23	09/12/2003	11:40	09/12/2003	19:47	8.12	.86	.60	.38	.29	7,889	4	2.4	87	14.46
24	09/13/2003	03:32	09/14/2003	10:27	30.92	4.65	1.00	.82	.69	69,707	7	6.3	54	.32

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-7. Runoff-event characteristics for the high-frequency broom basin—Continued.

[mm/dd/yyyy, month/day/year; hh:mm, hour:minute; precip., precipitation; in/hr, inches per hour; ft³, cubic feet; %, percent; ft³/s, cubic foot per second; --, data not available; NA, not applicable]

Sample ID	Start date (mm/dd/yyyy)	Start time (hh:mm)	End date (mm/dd/yyyy)	End time (hh:mm)	Duration (hours)	Precip. depth (inches)	15-min precip. intensity (in/hr)	30-min precip. intensity (in/hr)	60-min precip. intensity (in/hr)	Total event volume (ft³)	Runoff (%)	Peak flow (ft³/s)	Volume of storm sampled (%)	Antecedent dry time (days)
25	10/13/2003	21:00	10/14/2003	12:00	15.00	.68	.24	.20	.16	8,269	6	1.0	76	1.83
26	10/24/2003	15:34	10/25/2003	0:01	8.45	.74	.48	.44	.39	13,323	8	2.5	96	10.15
27	11/01/2003	20:09	11/02/2003	20:00	23.85	1.75	0.48	0.42	0.33	39,001	10	3.7	83	7.84
28	11/03/2003	05:46	11/04/2003	9:24	27.63	3.62	1.44	1.20	.93	123,595	16	16.0	93	.41
29	11/22/2003	22:48	11/23/2003	10:30	11.70	1.90	.96	.64	.58	60,601	15	10.0	99	4.47
30	12/09/2003	12:47	12/10/2003	12:15	23.47	1.70	.40	.34	.26	46,552	13	2.9	99	16.10
31	02/19/2004	13:00	02/20/2004	17:00	28.00	snowmelt	NA	NA	NA	21,730	--	1.2	100	71.03
32	03/04/2004	18:06	03/05/2004	11:00	16.90	1.35	.40	.30	.29	55,866	19	5.1	98	13.05
33	04/20/2004	15:02	04/21/2004	7:00	15.97	.68	.40	.28	.19	14,990	10	1.7	98	46.17
34	05/08/2004	22:40	05/09/2004	2:20	3.67	.74	1.68	.92	.51	12,096	8	8.0	90	17.65
35	05/10/2004	03:53	05/10/2004	18:00	14.12	.79	2.12	1.20	.69	23,293	14	24.0	97	1.06
37	05/17/2004	20:21	05/18/2004	1:42	5.35	.96	2.96	1.66	.85	21,116	10	17.0	96	7.10
38	05/21/2004	16:21	05/22/2004	9:50	17.48	3.46	2.60	1.64	1.19	137,894	19	25.0	57	3.61
39	05/29/2004	08:12	05/31/2004	16:06	55.90	1.62	.84	.56	.47	41,852	12	7.8	100	6.93
40	06/10/2004	09:29	06/10/2004	13:16	3.78	.49	.60	.54	.41	9,547	9	4.0	91	9.72
41	06/10/2004	15:14	06/11/2004	9:23	18.15	.66	.56	.32	.20	22,369	16	2.4	96	.08
42	06/16/2004	21:04	06/17/2004	4:50	7.77	.73	.96	.68	.42	15,172	10	6.9	98	5.49
43	06/24/2004	07:58	06/24/2004	13:05	5.12	.32	.28	.20	.14	5,288	8	1.6	99	7.13
44	07/03/2004	15:03	07/04/2004	1:25	10.37	2.20	1.88	1.62	1.13	51,728	11	20.0	97	9.08
45	07/16/2004	10:34	07/16/2004	18:16	7.70	.79	1.68	.90	.46	17,721	10	17.0	90	12.38
46	07/21/2004	08:16	07/21/2004	11:51	3.58	.37	.36	.22	.18	5,452	7	1.1	92	4.58
47	07/29/2004	15:02	07/30/2004	9:00	17.97	3.10	7.48	3.74	1.94	23,077	3	6.8	99	8.13
48	08/03/2004	18:56	08/03/2004	21:37	2.68	.96	2.96	1.60	.87	21,125	10	21.0	98	4.41
49	08/16/2004	17:33	08/17/2004	3:00	9.45	.46	1.12	.72	.39	6,644	7	4.6	94	12.83

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-7. Runoff-event characteristics for the high-frequency broom basin—Continued.

[mm/dd/yyyy, month/day/year; hh:mm, hour:minute; precip., precipitation; in/hr, inches per hour; ft^3, cubic feet; %, percent; ft^3/s, cubic foot per second; --, data not available; NA, not applicable]

Sample ID	Start date (mm/dd/yyyy)	Start time (hh:mm)	End date (mm/dd/yyyy)	End time (hh:mm)	Duration (hours)	Precip. depth (inches)	15-min precip. intensity (in/hr)	30-min precip. intensity (in/hr)	60-min precip. intensity (in/hr)	Total event volume (ft^3)	Runoff (%)	Peak flow (ft^3/s)	Volume of storm sampled (%)	Antecedent dry time (days)
50	08/18/2004	17:33	08/18/2004	20:00	2.45	.38	1.20	.70	NA	7,595	9	7.9	98	1.61
51	08/24/2004	12:04	08/24/2004	22:31	10.45	.34	.76	.38	.20	7,733	11	7.2	69	5.67
52	08/27/2004	23:45	08/28/2004	9:30	9.75	.27	.32	.26	.19	3,292	6	1.5	93	.86
53	09/15/2004	09:04	09/15/2004	19:00	9.93	.62	.36	.26	.19	9,729	7	1.7	89	9.00
54	10/07/2004	23:33	10/09/2004	15:00	39.45	0.88	0.72	0.62	0.49	19,397	10	6.2	94	4.44
55	10/22/2004	17:16	10/23/2004	13:00	19.73	1.26	.6	.48	.39	24,140	9	3.8	82	.34
56	11/01/2004	08:47	11/02/2004	17:00	32.22	.61	.16	.12	.09	9,521	7	.55	78	.12
57	11/26/2004	23:24	12/02/2004	10:00	130.60	.56	.12	.12	.1	18,058	15	.59	53	4.22
58	12/05/2004	21:45	12/06/2004	14:00	16.25	.48	.2	.16	.15	8,320	8	.91	91	3.49
59	12/07/2004	00:07	12/09/2004	07:00	54.88	.8	.4	.36	.28	23,449	14	2.9	84	.42
60	04/06/2005	16:25	04/07/2005	02:56	10.52	1.03	1.4	1.04	.67	23,941	11	11	97	6.68
61	04/12/2005	00:59	04/15/2005	21:01	92.03	.43	.32	.26	.19	17,384	19	2	77	4.92
62	05/05/2005	14:00	05/07/2005	20:00	54.00	.43	.52	.42	.33	11,526	13	3.8	80	8.54
63	05/11/2005	03:15	05/12/2005	04:00	24.75	1.05	.56	.44	.3	25,021	11	3.5	94	3.30
64	05/13/2005	00:47	05/15/2005	17:00	64.22	.63	.76	.6	.45	19,060	14	5.7	87	.87
65	05/18/2005	21:53	05/20/2005	18:00	44.12	.65	.48	.28	.25	20,520	15	2.9	86	3.20
66	04/13/2006	21:31	04/15/2006	06:00	32.48	.2	.76	.38	.19	4,069	10	3.1	67	1.52
67	04/16/2006	02:04	04/16/2006	23:00	20.93	1.43	2.76	1.6	.94	28,123	9	11	95	.84
68	04/29/2006	14:27	04/30/2006	11:48	21.35	1.6	.28	.26	.23	27,000	8	1.6	96	7.48
69	05/01/2006	18:19	05/01/2006	22:00	3.68	.49	1.32	.84	.42	14,316	14	17	100	1.27
70	05/09/2006	10:31	05/09/2006	20:00	9.48	.52	.2	.18	.14	7,396	7	.82	85	7.52
71	05/24/2006	18:33	05/24/2006	23:00	4.45	1.32	4.72	2.46	1.23	63,400	22	79	98	.43
72	05/30/2006	13:07	05/31/2006	08:34	19.45	.99	1.72	1.14	.60	18,887	9	10	100	4.62
P73	06/09/2006	22:44	06/10/2006	07:48	9.07	.84	.4	.3	.26	12,770	7	1.5	95	3.53

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-7. Runoff-event characteristics for the high-frequency broom basin—Continued.

[mm/dd/yyyy, month/day/year; hh:mm, hour:minute; precip., precipitation; in/hr, inches per hour; ft^3, cubic feet; %, percent; ft^3/s, cubic foot per second; --, data not available; NA, not applicable]

Sample ID	Start date (mm/dd/yyyy)	Start time (hh:mm)	End date (mm/dd/yyyy)	End time (hh:mm)	Duration (hours)	Precip. depth (inches)	15-min precip. intensity (in/hr)	30-min precip. intensity (in/hr)	60-min precip. intensity (in/hr)	Total event volume (ft^3)	Runoff (%)	Peak flow (ft^3/s)	Volume of storm sampled (%)	Antecedent dry time (days)
74	06/25/2006	15:44	06/26/2006	14:00	22.27	.65	.64	.36	.18	8,562	6	2.6	93	4.11
75	07/11/2006	07:31	07/11/2006	18:00	10.48	1.81	.92	.84	.61	32,962	9	5.6	100	1.46
76	07/20/2006	02:31	07/20/2006	08:26	5.92	.99	1.52	.92	.52	20,382	10	12	96	8.35
77	07/27/2006	12:07	07/27/2006	17:00	4.88	1.32	2.72	1.94	1.28	22,404	8	13	96	.38
78	08/06/2006	05:49	08/06/2006	17:00	11.18	.86	.4	.36	.30	12,364	7	1.6	91	9.53
79	08/17/2006	12:30	08/17/2006	21:00	8.50	.42	.88	.58	.32	4,147	5	3.2	95	10.81
80	08/23/2006	22:25	08/24/2006	06:00	7.58	2.44	--	--	--	50,509	10	19	94	6.06
81	08/24/2006	13:19	08/24/2006	17:00	3.68	1.2	2.16	1.34	1.04	35,433	14	20	97	.14
82	08/25/2006	05:10	08/27/2006	19:00	61.83	.99	.88	.58	.44	22,257	11	4.9	80	.51
83	09/03/2006	18:06	09/04/2006	15:00	20.90	.45	.44	.32	.22	12,666	13	2.1	91	5.71
84	09/10/2006	08:13	09/13/2006	03:00	66.78	3.03	1.04	.86	.52	53,603	8	4.4	98	5.72

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-8a. Constituent event mean concentrations measured at the control and air-sweeper basin outlets during the calibration phase.

[µg/L, microgram per liter; mg/L, milligram per liter; <, less than; --, no data]

Event date	Cadmium, total recoverable (µg/L)		Calcium, total recoverable (mg/L)		Copper, dissolved (µg/L)		Copper, total recoverable (µg/L)		Lead, total recoverable (µg/L)	
	Control	Air	Control	Air	Control	Air	Control	Air	Control	Air
09/07/2001	0.18	0.16	12.9	32.1	<0.9	2	4.5	11.0	4.9	15.0
09/17/2001	<0.20	<0.20	31.0	44.0	3.1	2.2	8.9	14.0	2.9	13.0
09/19/2001	<0.20	<0.20	6.0	5.7	3	<1.46	2.6	3.9	3.2	3.5
04/07/2002	<0.20	.20	14.1	10.3	2	2.5	9.1	12.0	4.6	7.8
04/18/2002	59.90	.62	59.9	91.8	2.8	3.2	28.0	41.0	22.0	44.0
05/11/2002	.28	.65	42.7	98.5	3.8	3	26.0	33.0	15.0	30.0
05/25/2002	.26	<0.20	14.1	10.8	4.4	3	14.0	14.0	2.7	4.3
05/28/2002	.38	.61	36.1	154.0	4.2	5.9	23.0	40.0	14.0	29.0
06/02/2002	.37	.40	94.1	67.0	6.1	4.6	18.0	30.0	16.0	22.0
06/10/2002	.31	1.43	32.7	71.8	4.8	2.5	21.0	27.0	12.0	26.0
06/26/2002	.50	.61	23.0	103.0	4.1	4.4	13.0	26.0	13.0	130.0
07/22/2002	.37	.39	24.6	18.3	4.8	7	16.0	12.0	10.0	145.0
08/17/2002	.49	.56	32.0	60.0	4.4	5	19.0	18.0	10.0	14.0
08/21/2002	.27	.36	16.0	67.0	2.3	3.2	10.0	15.0	7.5	16.0
09/02/2002	<0.20	<0.20	13.5	13.0	2.6	2	11.0	8.1	5.0	12.0
09/19/2002	<0.20	.36	98.0	54.3	1.9	2	15.0	21.0	12.0	22.0
09/20/2002	<0.17	<0.17	5.5	10.2	6.9	3.5	14.0	9.1	3.4	20.0
04/16/2006	.30	.80	34.5	101.6	<1.2	<1.2	17.5	39.6	17.2	41.1
04/29/2006	5.10	.24	22.0	13.0	1.4	2.4	26.0	12.0	12.0	2.3
05/09/2006	<0.20	<0.20	29.0	8.9	2.3	2.1	20.0	16.0	3.9	<1.47
05/17/2006	.30	<0.20	13.0	24.0	<1.2	<1.2	12.0	16.0	2.1	8.7
05/24/2006	.12	1.20	23.2	172.1	2	<1.2	23.9	67.5	14.1	63.8
05/30/2006	.04	.34	17.8	94.5	3.6	1.9	17.9	30.2	7.6	36.4
06/10/2006	<0.20	--	5.4	--	2.6	--	6.3	--	<1.47	--
06/18/2006	.27	.23	12.0	61.0	2.1	1.2	11.0	32.0	5.0	18.0
07/11/2006	.03	.05	6.9	7.4	<1.2	1.2	6.8	9.9	1.0	4.7
07/20/2006	<0.20	--	14.0	--	1.9	--	11.0	--	4.9	--
07/27/2006	<0.20	--	9.0	--	<1.2	--	7.2	--	5.5	--
08/06/2006	<0.20	<0.20	6.7	14.0	1.4	1.9	6.1	7.2	1.9	4.0
08/17/2006	<0.20	<0.20	16.0	16.0	3.2	2.2	15.0	14.0	6.2	6.7
08/24/2006	<0.20	--	9.8	--	<1.2	--	6.7	--	4.6	--
08/25/2006	<0.20	--	6.0	--	<1.2	--	4.2	--	3.4	--
09/03/2006	<0.20	--	6.9	--	1.8	--	4.0	--	<1.47	--
09/10/2006	<0.20	--	24.0	--	1.5	--	7.1	--	4.8	--

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-8a. Constituent event mean concentrations measured at the control and air-sweeper basin outlets during the calibration phase—Continued.

[µg/L, microgram per liter; mg/L, milligram per liter; <, less than; --, no data]

	Magnesium, total recoverable (mg/L)		Phosphorus, total recoverable (mg/L)		Orthophosphorus, dissolved (mg/L)		Zinc, dissolved (µg/L)		Zinc, total recoverable (µg/L)	
Event date	**Control**	**Air**	**Control**	**Air**	**Control**	**Air**	**Control**	**Air**	**Control**	**Air**
09/07/2001	6.4	16.6	0.30	0.45	0.13	0.14	4.6	7.4	28.0	54.0
09/17/2001	17.0	25.0	.28	.47	.13	.13	4.4	2.4	27.0	56.0
09/19/2001	2.4	2.3	.19	.24	.12	.14	8.6	8.7	11.0	17.0
04/07/2002	6.2	4.3	.15	.19	<0.05	.05	2.8	7.6	29.0	53.0
04/18/2002	30.8	48.8	.64	1.01	.11	.10	5.9	5	97.0	191.0
05/11/2002	18.8	49.4	.69	1.27	.10	.12	7.6	4.6	65.0	203.0
05/25/2002	5.5	3.5	.90	1.42	.25	.50	11	11	43.0	63.0
05/28/2002	18.2	78.1	.67	1.19	.19	.32	9.7	18	100.0	194.0
06/02/2002	45.5	31.3	.72	.68	.18	.15	15	6.7	56.0	98.0
06/10/2002	15.3	32.9	1.17	2.20	.64	.87	12	28	82.0	297.0
06/26/2002	11.1	47.5	.84	1.08	.43	.44	16	15	70.0	431.0
07/22/2002	11.1	7.8	.58	.57	.20	.35	10	22	66.0	67.0
08/17/2002	16.0	23.0	.50	.62	.14	.19	8.1	12	73.0	102.0
08/21/2002	7.1	34.0	.29	.54	.08	.15	3.6	6.4	40.0	81.0
09/02/2002	6.0	5.8	.40	.33	.20	.17	6.4	5.9	34.0	36.0
09/19/2002	52.8	26.3	.51	.80	.12	.15	4.1	5.1	69.0	106.0
09/20/2002	2.4	4.8	.25	.33	.10	.15	8.4	8.4	23.0	40.0
04/16/2006	18.6	53.3	.53	1.09	.06	.06	1.2	1.7	83.4	205.2
04/29/2006	9.1	4.6	11.00	.64	.13	.18	9	28	658.0	64.0
05/09/2006	8.9	2.9	3.57	.75	.42	.16	21	7.7	92.0	56.0
05/17/2006	4.8	9.9	.88	1.21	.29	.25	7.4	6.5	49.0	90.0
05/24/2006	11.7	91.9	.80	2.74	.12	.20	1.2	2.4	65.5	331.1
05/30/2006	8.6	54.3	.66	1.36	.29	.26	3.4	3.1	40.3	153.2
06/10/2006	2.0	--	.65	--	.29	--	1.8	--	24.0	--
06/18/2006	5.0	30.0	.64	.83	.22	.14	7.6	4.4	43.0	184.0
07/11/2006	2.8	3.2	.27	.33	.09	.10	1.9	2.8	27.2	41.4
07/20/2006	6.1	--	.48	--	.15	--	4.5	--	42.0	--
07/27/2006	4.3	--	.29	--	.09	--	3.6	--	35.0	--
08/06/2006	2.3	6.3	.39	.55	.25	.36	3.6	5.8	22.0	28.0
08/17/2006	5.6	6.7	.76	.77	.32	.41	8	7.9	66.0	75.0
08/24/2006	4.4	--	.28	--	.10	--	2.4	--	24.0	--
08/25/2006	2.4	--	.18	--	.07	--	2.5	--	16.0	--
09/03/2006	2.8	--	.32	--	.20	--	6	--	17.0	--
09/10/2006	12.0	--	.23	--	.09	--	2.6	--	24.0	--

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-8a. Constituent event mean concentrations measured at the control and air-sweeper basin outlets during the calibration phase—Continued.

[µg/L, microgram per liter; mg/L, milligram per liter; <, less than; --, no data]

	Ammonia-nitrogen (mg/L)		Nitrate plus nitrite, dissolved (mg/L)		Dissolved solids, total (mg/L)		Suspended sediment, total (mg/L)	
Event date	**Control**	**Air**	**Control**	**Air**	**Control**	**Air**	**Control**	**Air**
09/07/2001	0.19	0.19	0.42	0.29	0.42	0.29	230	956
09/17/2001	<0.05	.06	.67	.52	.67	.52	161	410
09/19/2001	.18	.18	.58	.57	.58	.57	39	48
04/07/2002	.30	.32	.27	.28	.27	.28	227	107
04/18/2002	.76	.68	.40	.40	.40	.40	1,241	2,535
05/11/2002	.38	.34	.35	.19	.35	.19	853	2,657
05/25/2002	.58	.54	.37	.39	.37	.39	428	180
05/28/2002	.91	.87	1.01	1.01	1.01	1.01	851	4,470
06/02/2002	.57	.50	.49	.42	.49	.42	3,394	1,966
06/10/2002	.73	.92	.61	.75	.61	.75	688	1,333
06/26/2002	.76	.65	.85	.90	.85	.90	450	3,047
07/22/2002	.56	.38	.46	.60	.46	.60	932	429
08/17/2002	.47	.49	.76	.74	.76	.74	611	1,123
08/21/2002	.23	.25	.29	.34	.29	.34	440	1,536
09/02/2002	.61	.52	.67	.52	.67	.52	440	500
09/19/2002	.25	.34	.32	.32	.32	.32	1,324	1,088
09/20/2002	.20	.23	.24	.23	.24	.23	57	205
04/16/2006	.32	.36	.27	.28	.27	.28	602	1,938
04/29/2006	.56	.65	.44	.54	.44	.54	113	125
05/09/2006	.55	.66	.39	.28	.39	.28	392	140
05/17/2006	.55	.35	.38	.32	.38	.32	203	479
05/24/2006	.77	1.00	.42	.42	.42	.42	555	4,166
05/30/2006	.65	.70	.49	.48	.49	.48	253	1,782
06/10/2006	.23	--	.26	--	.26	--	51	--
06/18/2006	.52	.35	.58	.35	.58	.35	183	243
07/11/2006	.06	.04	<.18	<.18	<.18	<.18	119	171
07/20/2006	.49	--	.53	--	.53	--	191	--
07/27/2006	.60	--	.33	--	.33	--	150	--
08/06/2006	.30	.22	.42	.38	.42	.38	65	149
08/17/2006	.51	.41	.76	.73	.76	.73	238	285
08/24/2006	.56	--	.43	--	.43	--	173	--
08/25/2006	.48	--	.52	--	.52	--	95	--
09/03/2006	.15	--	.31	--	.31	--	63	--
09/10/2006	.18	--	.59	--	.59	--	135	--

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-8b. Constituent event mean concentrations measured at the control and high-frequency broom basin outlets during the calibration phase.

[µg/L, microgram per liter; mg/L, milligram per liter; <, less than; --, no data]

	Cadmium, total recoverable (µg/L)		Calcium, total recoverable (mg/L)		Copper, dissolved (µg/L)		Copper, total recoverable (µg/L)		Lead, total recoverable (µg/L)	
Event date	Control	Broom	Control	Broom	Control	Broom	Control	Broom	Control	Broom
09/07/2001	0.18	--	12.9	--	<0.9	--	4.5	--	4.9	--
09/17/2001	<0.20	--	31.0	--	3.1	--	8.9	--	2.9	--
09/19/2001	<0.20	--	6.0	--	3	--	2.6	--	3.2	--
04/07/2002	<0.20	--	14.1	--	2	--	9.1	--	4.6	--
04/18/2002	59.90	--	59.9	--	2.8	--	28.0	--	22.0	--
05/11/2002	.28	--	42.7	--	3.8	--	26.0	--	15.0	--
05/25/2002	.26	--	14.1	--	4.4	--	14.0	--	2.7	--
05/28/2002	.38	--	36.1	--	4.2	--	23.0	--	14.0	--
06/02/2002	.37	--	94.1	--	6.1	--	18.0	--	16.0	--
06/10/2002	.31	--	32.7	--	4.8	--	21.0	--	12.0	--
06/26/2002	.50	--	23.0	--	4.1	--	13.0	--	13.0	--
07/22/2002	.37	0.50	24.6	19.7	4.8	15	16.0	21.0	10.0	5.3
08/17/2002	.49	--	32.0	--	4.4	--	19.0	--	10.0	--
08/21/2002	.27	--	16.0	--	2.3	--	10.0	--	7.5	--
09/02/2002	<0.20	<0.2	13.5	8.4	2.6	1.7	11.0	5.4	5.0	3.3
09/19/2002	<0.20	--	98.0	--	1.9	--	15.0	--	12.0	--
09/20/2002	<0.17	--	5.5	--	6.9	--	14.0	--	3.4	--
04/06/2005	.24	<0.23	48.7	75.6	2.5	1.8	22.1	28.1	22.3	19.3
04/12/2005	<0.23	<0.23	12.0	15.3	<1.34	2.2	11.0	13.2	5.4	6.1
04/19/2005	<0.23	--	46.0	--	3.9	--	32.0	--	22.0	--
05/06/2005	.37	.23	37.2	35.5	3.8	4.2	34.8	36.2	19.4	17.4
05/11/2005	<0.23	<0.23	12.1	15.0	2.9	2.6	9.0	17.2	6.5	7.8
05/13/2005	<0.23	<0.23	11.1	60.1	<1.34	<1.34	6.5	19.2	8.1	40.3
05/18/2005	.25	.23	13.1	14.7	1.4	2.4	9.8	10.4	9.5	5.9
04/16/2006	.30	.23	34.5	36.2	<1.2	<1.2	17.5	23.5	17.2	20.4
04/29/2006	5.10	<0.20	22.0	11.0	1.4	4	26.0	16.0	12.0	1.7
05/09/2006	<0.20	<0.20	29.0	9.0	2.3	3	20.0	12.0	3.9	<1.47
05/17/2006	.30	--	13.0	--	<1.2	--	12.0	--	2.1	--
05/24/2006	.12	.15	23.2	47.4	2	4.1	23.9	34.7	14.1	21.3
05/30/2006	.04	.09	17.8	22.4	3.6	1.9	17.9	15.1	7.6	14.2
06/10/2006	<0.20	<0.20	5.4	14.0	2.6	2.1	6.3	19.0	<1.47	7.4
06/18/2006	.27	--	12.0	--	2.1	--	11.0	--	5.0	--
07/11/2006	.03	.39	6.9	147.2	<1.2	1.3	6.8	44.2	1.0	13.2
07/20/2006	<0.20	1.54	14.0	521.7	1.9	2.3	11.0	162.8	4.9	42.2
07/27/2006	<0.20	<0.20	9.0	37.0	<1.2	1.3	7.2	16.0	5.5	10.0
08/06/2006	<0.20	<0.20	6.7	9.3	1.4	3.2	6.1	24.0	1.9	3.2
08/17/2006	<0.20	.20	16.0	26.0	3.2	4.6	15.0	26.0	6.2	5.6
08/24/2006	<0.20	<0.20	9.8	9.3	<1.2	1.4	6.7	11.0	4.6	7.6
08/25/2006	<0.20	<0.20	6.0	16.0	<1.2	<1.2	4.2	8.0	3.4	6.7
09/03/2006	<0.20	<0.20	6.9	9.0	1.8	3.3	4.0	10.0	<1.47	5.9
09/10/2006	<0.20	.86	24.0	148.4	1.5	2.5	7.1	54.6	4.8	16.6

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-8b. Constituent event mean concentrations measured at the control and high-frequency broom basin outlets during the calibration phase—Continued.

[µg/L, microgram per liter; mg/L, milligram per liter; <, less than; --, no data]

	Magnesium, total recoverable (mg/L)		Phosphorus, total recoverable (mg/L)		Orthophosphorus, dissolved (mg/L)		Zinc, dissolved (µg/L)		Zinc, total recoverable (µg/L)	
Event date	Control	Broom	Control	Broom	Control	Broom	Control	Broom	Control	Broom
09/07/2001	6.4	--	0.30	--	0.13	--	4.6	--	28.0	--
09/17/2001	17.0	--	.28	--	.13	--	4.4	--	27.0	--
09/19/2001	2.4	--	.19	--	.12	--	8.6	--	11.0	--
04/07/2002	6.2	--	.15	--	<0.05	--	2.8	--	29.0	--
04/18/2002	30.8	--	.64	--	.11	--	5.9	--	97.0	--
05/11/2002	18.8	--	.69	--	.10	--	7.6	--	65.0	--
05/25/2002	5.5	--	.90	--	.25	--	11	--	43.0	--
05/28/2002	18.2	--	.67	--	.19	--	9.7	--	100.0	--
06/02/2002	45.5	--	.72	--	.18	--	15	--	56.0	--
06/10/2002	15.3	--	1.17	--	.64	--	12	--	82.0	--
06/26/2002	11.1	--	.84	--	.43	--	16	--	70.0	--
07/22/2002	11.1	7.9	.58	1.51	.20	0.67	10	35	66.0	119.0
08/17/2002	16.0	--	.50	--	.14	--	8.1	--	73.0	--
08/21/2002	7.1	--	.29	--	.08	--	3.6	--	40.0	--
09/02/2002	6.0	3.6	.40	.35	.20	.15	6.4	7.8	34.0	38.0
09/19/2002	52.8	--	.51	--	.12	--	4.1	--	69.0	--
09/20/2002	2.4	--	.25	--	.10	--	8.4	--	23.0	--
04/06/2005	24.6	36.5	.60	.81	.13	.10	4.4	2.6	96.7	135.9
04/12/2005	4.9	6.2	.38	.87	.15	.14	4.9	8.5	40.0	71.8
04/19/2005	20.0	--	1.68	--	.68	--	17	--	174.0	--
05/06/2005	16.6	16.0	.83	.88	.04	.07	8.6	7.8	156.2	172.9
05/11/2005	4.6	6.3	.44	.57	.14	.17	7	12	46.5	79.3
05/13/2005	4.4	30.1	.29	.41	.05	.07	5.5	1.3	35.7	100.8
05/18/2005	5.1	5.1	.47	.59	.12	.17	2.3	7.2	47.7	63.3
04/16/2006	18.6	17.8	.53	.80	.06	.14	1.2	2.9	83.4	109.8
04/29/2006	9.1	3.7	11.00	.53	.13	.12	9	19	658.0	51.0
05/09/2006	8.9	2.7	3.57	.85	.42	.23	21	18	92.0	66.0
05/17/2006	4.8	--	.88	--	.29	--	7.4	--	49.0	--
05/24/2006	11.7	25.1	.80	1.14	.12	.31	1.2	2.7	65.5	116.3
05/30/2006	8.6	11.8	.66	.74	.29	.22	3.4	4.4	40.3	68.3
06/10/2006	2.0	5.4	.65	1.39	.29	.57	1.8	4	24.0	84.0
06/18/2006	5.0	--	.64	--	.22	--	7.6	--	43.0	--
07/11/2006	2.8	81.0	.27	1.05	.09	.14	1.9	3.9	27.2	173.8
07/20/2006	6.1	264.0	.48	3.18	.15	.23	4.5	5.2	42.0	794.9
07/27/2006	4.3	19.0	.29	.68	.09	.14	3.6	3.3	35.0	67.0
08/06/2006	2.3	3.4	.39	.64	.25	.39	3.6	6.8	22.0	43.0
08/17/2006	5.6	12.0	.76	.88	.32	.40	8	11	66.0	90.0
08/24/2006	4.4	5.0	.28	.43	.10	.17	2.4	2.5	24.0	39.0
08/25/2006	2.4	7.7	.18	.34	.07	.12	2.5	2.6	16.0	33.0
09/03/2006	2.8	3.5	.32	.50	.20	.31	6	10	17.0	38.0
09/10/2006	12.0	85.7	.23	1.07	.09	.19	2.6	5.7	24.0	1,183.7

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-8b. Constituent event mean concentrations measured at the control and high-frequency broom basin outlets during the calibration phase—Continued.

[µg/L, microgram per liter; mg/L, milligram per liter; <, less than; --, no data]

	Ammonia-nitrogen (mg/L)		Nitrate plus nitrite, dissolved (mg/L)		Dissolved solids, total (mg/L)		Suspended sediment, total (mg/L)	
Event date	Control	Broom	Control	Broom	Control	Broom	Control	Broom
09/07/2001	0.19	--	0.42	--	148	--	230	--
09/17/2001	<0.05	--	.67	--	168	--	161	--
09/19/2001	.18	--	.58	--	56	--	39	--
04/07/2002	.30	--	.27	--	72	--	227	--
04/18/2002	.76	--	.40	--	54	--	1,241	--
05/11/2002	.38	--	.35	--	59	--	853	--
05/25/2002	.58	--	.37	--	70	--	428	--
05/28/2002	.91	--	1.01	--	58	--	851	--
06/02/2002	.57	--	.49	--	46	--	3,394	--
06/10/2002	.73	--	.61	--	80	--	688	--
06/26/2002	.76	--	.85	--	42	--	450	--
07/22/2002	.56	<0.05	.46	<0.18	40	94	932	506
08/17/2002	.47	--	.76	--	60	--	611	--
08/21/2002	.23	--	.29	--	92	15	440	--
09/02/2002	.61	.33	.67	.56	62	--	440	154
09/19/2002	.25	--	.32	--	38	--	1,324	--
09/20/2002	.20	--	.24	--	58	50	57	--
04/06/2005	.90	.76	.41	.43	86	78	549	1,381
04/12/2005	.84	.84	1.04	1.10	60	76	100	130
04/19/2005	2.32	--	1.43	--	154	--	536	--
05/06/2005	1.08	1.22	.64	.74	56	58	644	569
05/11/2005	.52	.57	.35	.39	40	60	144	240
05/13/2005	.49	.45	.48	.44	40	55	159	1,697
05/18/2005	.64	.70	.76	.84	62	72	141	173
04/16/2006	.32	.41	.27	.38	24	46	602	878
04/29/2006	.56	.61	.44	.48	40	67	113	266
05/09/2006	.55	.68	.39	.56	130	98	392	121
05/17/2006	.55	--	.38	--	86	--	203	--
05/24/2006	.77	.78	.42	.57	72	94	555	1,228
05/30/2006	.65	.40	.49	.43	122	76	253	703
06/10/2006	.23	.44	.26	.25	44	49	51	443
06/18/2006	.52	--	.58	--	77	--	183	--
07/11/2006	.06	<0.025	<0.18	.55	30	44	119	3,282
07/20/2006	.49	.38	.53	.49	44	36	191	13,473
07/27/2006	.60	.50	.33	.35	42	40	150	841
08/06/2006	.30	.13	.42	.47	31	48	65	150
08/17/2006	.51	.31	.76	.85	54	54	238	648
08/24/2006	.56	.39	.43	.44	30	32	173	541
08/25/2006	.48	.39	.52	.54	22	32	95	129
09/03/2006	.15	.25	.31	.35	57	84	63	203
09/10/2006	.18	.15	.59	.35	224	74	135	4,145

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-8c. Constituent event mean concentrations measured at the control and air-sweeper basin outlets during the treatment phase.

[µg/L, microgram per liter; mg/L, milligram per liter; <, less than; --, no data]

Sweeper type	Event date	Cadmium, total recoverable (µg/L)		Calcium, total recoverable (mg/L)		Copper, dissolved (µg/L)		Copper, total recoverable (µg/L)		Lead, total recoverable (µg/L)	
		Control	Air	Control	Air	Control	Air	Control	Air	Control	Air
Treatment—regenerative air	04/30/2003	0.50	0.27	18.9	18.5	4.1	5.9	17.0	19.0	12.0	9.6
	04/30/2003	.79	<0.17	68.9	66.5	1.4	<1.34	17.5	25.1	10.0	19.6
	05/04/2003	.58	<0.17	25.4	8.3	2	2.7	13.0	8.6	4.2	3.6
	05/10/2003	.30	.34	40.9	34.2	4.8	2.7	40.0	20.0	19.0	13.0
	05/14/2003	<0.17	<0.17	21.0	11.4	3	3.1	16.0	12.0	5.3	3.4
	05/19/2003	34.00	.30	206.8	47.0	6.3	3.7	52.7	24.0	13.0	16.0
	05/30/2003	.46	.48	97.0	152.0	2.3	1.8	48.0	39.0	33.0	27.0
	07/15/2003	.17	.29	39.0	12.0	3.3	14	16.0	9.7	13.0	12.0
	09/12/2003	.17	<0.17	24.0	20.0	12	4.5	27.0	13.0	9.9	6.9
	05/08/2004	<0.2	<0.2	158.0	82.9	8.4	5.8	43.9	26.8	36.6	31.9
	05/10/2004	.24	.21	79.4	105.2	4.5	3	24.7	24.1	19.8	29.4
	05/13/2004	--	--	--	--	--	--	--	--	--	--
	05/17/2004	<0.20	.25	41.6	94.9	4.8	3.3	22.4	23.1	22.2	33.0
	05/21/2004	<0.20	.28	83.4	34.5	1.8	1.8	23.5	18.6	22.0	24.8
Treatment—vacuum assist	05/29/2004	<0.20	<0.20	137.8	15.4	2.1	5.6	74.4	12.6	25.6	8.7
	06/10/2004	<0.20	<0.20	7.5	17.3	5.3	3.5	10.5	12.9	3.8	8.4
	06/10/2004	<0.20	--	4.9	--	4.7	--	3.7	--	1.6	--
	06/24/2004	.30	<0.20	6.1	4.8	3	2.6	5.5	4.6	3.6	4.0
	07/09/2004	.25	.21	9.0	24.0	5.8	4.2	11.9	16.6	6.8	15.3
	07/16/2004	<0.20	.21	11.9	18.3	4	2.6	12.3	13.1	6.7	13.5
	07/21/2004	<0.20	<0.20	6.3	7.0	4.2	2.8	5.9	6.4	<1.49	4.0
	07/29/2004	.20	.22	7.1	11.0	2.6	2.6	5.1	8.7	2.4	8.1
	08/03/2004	.21	.06	11.2	19.8	<1.64	<1.64	7.0	13.5	8.7	13.8
	08/17/2004	<0.20	<0.20	9.2	13.1	<1.64	<1.64	7.8	9.5	5.0	8.5
	08/18/2004	.21	<0.20	9.5	22.9	<1.64	<1.64	20.8	16.2	3.9	16.9
	08/24/2004	.26	<0.20	19.3	11.4	<1.64	1.7	10.8	12.1	2.9	6.5
	08/27/2004	<0.20	.35	57.0	11.0	<1.64	<1.64	17.0	10.0	6.9	8.9
	09/01/2004	.11	<0.20	11.7	17.3	<1.64	<1.64	8.9	12.9	7.8	26.3
	09/15/2004	<0.23	<0.23	13.0	9.1	3.2	3.2	13.0	8.7	3.5	3.5
	04/06/2005	.24	.32	48.7	46.9	2.5	3.6	22.1	26.1	22.3	22.5
	04/12/2005	<0.23	<0.23	12.0	6.8	<1.34	2.1	11.0	10.0	5.4	4.1
	04/19/2005	<0.23	.47	46.0	98.0	3.9	2.9	32.0	50.0	22.0	39.0
	05/06/2005	.37	.04	37.2	28.4	3.8	2.4	34.8	20.7	19.4	17.8
	05/11/2005	<0.23	<0.23	12.1	9.9	2.9	1.5	9.0	9.2	6.5	6.4
	05/13/2005	<0.23	<0.23	11.1	15.4	<1.34	<1.34	6.5	10.0	8.1	8.8
	05/18/2005	.25	<0.23	13.1	11.0	1.4	2	9.8	9.0	9.5	6.4

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-8c. Constituent event mean concentrations measured at the control and air-sweeper basin outlets during the treatment phase—Continued.

[µg/L, microgram per liter; mg/L, milligram per liter; <, less than; --, no data]

Sweeper type	Event Date	Magnesium, total recoverable (mg/L)		Phosphorus, total recoverable (mg/L)		Orthophosphorus, dissolved (mg/L)		Zinc, dissolved (µg/L)		Zinc, total recoverable (µg/L)	
		Control	Air	Control	Air	Control	Air	Control	Air	Control	Air
Treatment—regenerative air	04/30/2003	8.2	7.7	0.72	0.75	0.20	0.30	12	16	86.0	89.0
	04/30/2003	37.5	33.3	.63	.61	.08	.07	4.4	4.7	86.7	95.6
	05/04/2003	9.1	2.5	4.04	.36	<0.05	.14	7.2	10	111.0	37.0
	05/10/2003	17.2	13.7	.83	.87	.11	.13	5	6.6	95.0	111.0
	05/14/2003	6.6	3.2	.95	.73	.31	.26	9.5	12	52.0	54.0
	05/19/2003	109.7	22.5	1.34	.87	.19	.18	4.9	9.9	152.4	126.0
	05/30/2003	48.1	76.8	1.34	1.21	.18	.18	4.7	2.7	150.0	207.0
	07/15/2003	19.0	5.2	.60	.33	.10	.13	5.5	63	64.0	37.0
	09/12/2003	11.0	6.2	.72	.51	.32	.27	12	6.5	64.0	70.0
	05/08/2004	76.7	34.3	1.23	1.52	.12	.09	21	24	148.9	164.2
	05/10/2004	39.2	58.7	.68	.76	.07	.07	9.3	12	83.8	164.1
	05/13/2004	--	--	--	--	--	--	--	--	--	--
	05/17/2004	21.3	46.0	.52	.74	.18	.19	6	83	86.9	132.0
	05/21/2004	43.8	17.8	.62	.63	.20	.14	3.4	4.5	72.2	99.3
Treatment—vacuum assist	05/29/2004	69.2	7.4	.66	.33	.13	.09	4.1	7.5	64.3	55.8
	06/10/2004	2.9	6.1	.65	.43	.35	.17	16	11	36.9	73.3
	06/10/2004	1.6	--	.18	--	.08	--	4.4	--	14.0	--
	06/24/2004	2.2	1.6	.19	.15	.09	.08	4.7	8.2	22.6	25.2
	07/09/2004	4.4	12.0	.32	.29	.11	.10	11	8.2	46.1	82.7
	07/16/2004	5.5	9.1	.43	.35	.17	.12	8.6	5.5	58.5	76.7
	07/21/2004	2.2	2.6	.24	.32	.13	.15	16	21	19.0	46.0
	07/29/2004	3.1	5.2	.36	.42	.12	.11	9.6	9.1	26.0	51.0
	08/03/2004	5.6	10.5	.32	.42	.08	.10	2	1	36.5	63.2
	08/17/2004	3.9	6.1	.50	.50	.23	.21	2	3.4	43.6	120.8
	08/18/2004	4.3	12.4	.37	.57	.13	.14	3.4	1.8	38.0	89.6
	08/24/2004	9.6	5.3	.43	.47	.24	.23	2.4	9.4	29.1	64.8
	08/27/2004	30.0	5.2	.56	.48	.12	.20	.8	4.4	37.0	49.0
	09/01/2004	5.8	9.4	.29	.52	.13	.12	2.6	1.6	35.1	62.7
	09/15/2004	5.0	3.3	1.05	.91	.53	.47	4.2	4.9	48.0	51.0
	04/06/2005	24.6	22.6	.60	.65	.13	.11	4.4	4.3	96.7	147.7
	04/12/2005	4.9	2.2	.38	.31	.15	.15	4.9	13	40.0	43.0
	04/19/2005	20.0	47.0	1.68	2.04	.68	.68	17	11	174.0	320.0
	05/06/2005	16.6	12.7	.83	.66	.04	<0.03	8.6	11	156.2	140.5
	05/11/2005	4.6	3.5	.44	.38	.14	.17	7	9.7	46.5	51.2
	05/13/2005	4.4	7.1	.29	.29	.05	.05	5.5	2.8	35.7	60.4
	05/18/2005	5.1	4.0	.47	.41	.12	.09	2.3	5.2	47.7	50.0

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-8c. Constituent event mean concentrations measured at the control and air-sweeper basin outlets during the treatment phase—Continued.

[µg/L, microgram per liter; mg/L, milligram per liter; <, less than; --, no data]

Sweeper type	Event Date	Ammonia-nitrogen (mg/L)		Nitrate plus nitrite, dissolved (mg/L)		Dissolved solids, total (mg/L)		Suspended sediment, total (mg/L)	
		Control	Air	Control	Air	Control	Air	Control	Air
Treatment—regenerative air	04/30/2003	0.78	0.86	0.49	0.50	64	87	308	301
	04/30/2003	.32	.29	.29	.24	36	42	1,270	1,074
	05/04/2003	.38	.42	.29	.15	86	71	280	102
	05/10/2003	.62	.43	.45	.25	76	94	972	549
	05/14/2003	.58	.26	.41	.39	146	90	171	111
	05/19/2003	.91	.84	.78	.61	90	70	3,193	847
	05/30/2003	.77	.70	.40	.49	75	68	1,754	2,666
	07/15/2003	.55	.39	.54	.33	46	21	794	1,344
	09/12/2003	.77	.75	.95	.82	102	94	--	--
	05/08/2004	1.27	1.17	.75	.89	52	64	3,360	1,348
	05/10/2004	.70	.62	.49	.42	56	32	1,756	1,540
	05/13/2004	--	--	.27	.34	52	72	155	148
	05/17/2004	.62	.53	.35	.31	50	42	1,036	1,410
	05/21/2004	.48	.43	.42	.35	79	48	1,543	874
Treatment—vacuum assist	05/29/2004	.30	.29	.30	.33	61	62	2,992	366
	06/10/2004	.49	.28	.39	.42	84	81	132	252
	06/10/2004	.22	--	.28	--	66	70	55	--
	06/24/2004	.26	.26	.29	.28	78	64	62	35
	07/09/2004	.32	.32	.37	.38	52	48	233	448
	07/16/2004	.29	.22	.48	.36	54	41	261	386
	07/21/2004	.28	.30	.52	.54	66	60	36	78
	07/29/2004	.34	.35	.36	.41	42	56	197	290
	08/03/2004	.15	.14	.30	.26	34	44	282	555
	08/17/2004	.38	.38	.52	.56	31	42	188	264
	08/18/2004	.30	.34	.33	.29	32	46	188	564
	08/24/2004	.21	.22	.50	.42	98	49	146	240
	08/27/2004	.21	.25	.33	.35	98	48	589	182
	09/01/2004	.26	.31	.32	.35	42	43	207	523
	09/15/2004	.08	.17	.32	.49	80	80	64	71
	04/06/2005	.90	.85	.41	.39	86	86	549	936
	04/12/2005	.84	.77	1.04	.80	60	52	100	50
	04/19/2005	2.32	1.74	1.43	1.20	154	163	536	1,196
	05/06/2005	1.08	1.09	.64	.65	56	60	644	414
	05/11/2005	.52	.52	.35	.37	40	45	144	155
	05/13/2005	.49	.50	.48	.52	40	50	159	258
	05/18/2005	.64	.59	.76	.79	62	68	141	102

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-8d. Constituent event mean concentrations measured at the control and high-frequency broom basin outlets during the treatment phase.

[µg/L, microgram per liter; mg/L, milligram per liter; <, less than; --, no data]

Event date	Cadmium, total recoverable (µg/L)		Calcium, total recoverable (mg/L)		Copper, dissolved (µg/L)		Copper, total recoverable (µg/L)		Lead, total recoverable (µg/L)	
	Control	Broom	Control	Broom	Control	Broom	Control	Broom	Control	Broom
04/30/2003	0.50	<0.17	18.9	18.8	4.1	4.9	17.0	15.0	12.0	5.6
04/30/2003	.79	.25	68.9	23.1	1.4	1.6	17.5	13.0	10.0	45.0
05/04/2003	.58	<0.17	25.4	8.6	2	2.6	13.0	7.6	4.2	2.5
05/10/2003	.30	.25	40.9	22.5	4.8	2.3	40.0	11.0	19.0	7.0
05/14/2003	<0.17	<0.17	21.0	8.2	3	13	16.0	12.0	5.3	2.2
05/19/2003	34.00	.43	206.8	1,972.5	6.3	4.1	52.7	785.1	13.0	350.1
05/30/2003	.46	.49	97.0	192.0	2.3	1.9	48.0	42.0	33.0	29.0
07/15/2003	.17	<0.17	39.0	35.0	3.3	2.5	16.0	15.0	13.0	13.0
09/12/2003	.17	<0.17	24.0	66.0	12	4.2	27.0	20.0	9.9	8.9
05/08/2004	<0.2	<0.2	158.0	34.3	8.4	6.6	43.9	24.4	36.6	13.4
05/10/2004	.24	<0.2	79.4	23.9	4.5	3.4	24.7	14.3	19.8	10.6
05/13/2004	--	--	--	--	--	--	--	--	--	--
05/17/2004	<0.20	.22	41.6	87.7	4.8	5.1	22.4	25.5	22.2	17.9
05/21/2004	<0.20	--	83.4	--	1.8	--	23.5	--	22.0	--
05/29/2004	<0.20	<0.20	137.8	6.0	2.1	4.5	74.4	8.6	25.6	3.1
06/10/2004	<0.20	<0.20	7.5	6.6	5.3	4	10.5	9.6	3.8	2.5
06/10/2004	<0.20	<0.20	4.9	5.6	4.7	6.4	3.7	10.7	1.6	.4
06/24/2004	.30	<0.20	6.1	5.6	3	3.1	5.5	6.0	3.6	.1
07/09/2004	.25	--	9.0	--	5.8	--	11.9	--	6.8	--
07/16/2004	<0.20	<0.20	11.9	12.7	4	2.8	12.3	13.1	6.7	12.3
07/21/2004	<0.20	<0.20	6.3	7.0	4.2	3.4	5.9	5.8	<1.49	<1.49
07/29/2004	.20	<0.20	7.1	11.1	2.6	<1.64	5.1	12.7	2.4	6.0
08/03/2004	.21	<0.20	11.2	10.6	<1.64	<1.64	7.0	10.3	8.7	7.3
08/17/2004	<0.20	<0.20	9.2	7.5	<1.64	2.3	7.8	14.0	5.0	6.4
08/18/2004	.21	.21	9.5	7.7	<1.64	<1.64	20.8	11.0	3.9	5.5
08/24/2004	.26	--	19.3	--	<1.64	--	10.8	--	2.9	--
08/27/2004	<0.20	<0.20	57.0	7.5	<1.64	1.66	17.0	7.4	6.9	6.6
09/01/2004	.11	--	11.7	--	<1.64	--	8.9	--	7.8	--
09/15/2004	<0.23	<0.23	13.0	10.0	3.2	3.6	13.0	12.0	3.5	3.2

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-8d. Constituent event mean concentrations measured at the control and high-frequency broom basin outlets during the treatment phase—Continued.

[µg/L, microgram per liter; mg/L, milligram per liter; <, less than; --, no data]

Event date	Magnesium, total recoverable (mg/L)		Phosphorus, total recoverable (mg/L)		Orthophosphorus, dissolved (mg/L)		Zinc, dissolved (µg/L)		Zinc, total recoverable (µg/L)	
	Control	Broom	Control	Broom	Control	Broom	Control	Broom	Control	Broom
04/30/2003	8.2	7.7	0.72	0.73	0.20	0.30	12	16	86.0	86.0
04/30/2003	37.5	9.1	.63	.30	.08	.09	4.4	5.5	86.7	51.0
05/04/2003	9.1	2.4	4.04	.25	<0.05	.09	7.2	11	111.0	36.0
05/10/2003	17.2	8.6	.83	.50	.11	.11	5	25	95.0	62.0
05/14/2003	6.6	2.0	.95	.39	.31	.11	9.5	18	52.0	45.0
05/19/2003	109.7	972.0	1.34	7.03	.19	.11	4.9	7.1	152.4	1,965.3
05/30/2003	48.1	90.6	1.34	1.61	.18	.23	4.7	7.9	150.0	232.0
07/15/2003	19.0	17.0	.60	.52	.10	.14	5.5	7.2	64.0	61.0
09/12/2003	11.0	31.0	.72	.65	.32	.19	12	10	64.0	111.0
05/08/2004	76.7	17.0	1.23	.64	.12	.16	21	17	148.9	101.2
05/10/2004	39.2	11.2	.68	.42	.07	.11	9.3	8.9	83.8	58.3
05/13/2004	--	--	--	--	--	--	--	--	--	--
05/17/2004	21.3	41.8	.52	.79	.18	.20	6	6.7	86.9	99.8
05/21/2004	43.8	--	.62	--	.20	--	3.4	--	72.2	--
05/29/2004	69.2	2.1	.66	.26	.13	.11	4.1	7.7	64.3	37.0
06/10/2004	2.9	2.6	.65	.41	.35	.19	16	18	36.9	49.3
06/10/2004	1.6	1.8	.18	.19	.08	.10	4.4	15	14.0	23.7
06/24/2004	2.2	1.7	.19	.17	.09	.10	4.7	11	22.6	24.3
07/09/2004	4.4	--	.32	--	.11	--	11	--	46.1	--
07/16/2004	5.5	5.7	.43	.76	.17	.22	8.6	12	58.5	65.7
07/21/2004	2.2	2.4	.24	.39	.13	.23	16	18	19.0	36.0
07/29/2004	3.1	4.8	.36	.44	.12	.16	9.6	1.3	26.0	57.9
08/03/2004	5.6	5.3	.32	.44	.08	.15	2	1.6	36.5	45.0
08/17/2004	3.9	3.5	.50	.54	.23	.23	2	4.3	43.6	56.0
08/18/2004	4.3	3.4	.37	.39	.13	.17	3.4	2.2	38.0	50.4
08/24/2004	9.6	--	.43	--	.24	--	2.4	--	29.1	--
08/27/2004	30.0	3.3	.56	.42	.12	.18	.8	6.2	37.0	41.0
09/01/2004	5.8	--	.29	--	.13	--	2.6	--	35.1	--
09/15/2004	5.0	3.6	1.05	1.03	.53	.66	4.2	9.7	48.0	57.0

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-8d. Constituent event mean concentrations measured at the control and high-frequency broom basin outlets during the treatment phase—Continued.

[µg/L, microgram per liter; mg/L, milligram per liter; <, less than; --, no data]

Event date	Ammonia-nitrogen (mg/L)		Nitrate plus nitrite, dissolved (mg/L)		Dissolved solids, total (mg/L)		Suspended sediment, total (mg/L)	
	Control	Broom	Control	Broom	Control	Broom	Control	Broom
04/30/2003	0.78	0.98	0.49	0.64	64	76	308	262
04/30/2003	.32	.30	.29	.24	36	34	1,270	422
05/04/2003	.38	.38	.29	.35	86	64	280	88
05/10/2003	.62	.43	.45	.34	76	60	972	325
05/14/2003	.58	.31	.41	.39	146	70	171	26
05/19/2003	.91	.91	.78	.58	90	64	3,193	41,418
05/30/2003	.77	.99	.40	.50	75	66	1,754	5,357
07/15/2003	.55	.30	.54	.37	46	32	794	1,063
09/12/2003	.77	.64	.95	.70	102	66	--	2,180
05/08/2004	1.27	1.26	.75	.68	52	42	3,360	599
05/10/2004	.70	.62	.49	.44	56	20	1,756	464
05/13/2004	--	--	.27	.28	52	100	155	76
05/17/2004	.62	.59	.35	.41	50	66	1,036	1,971
05/21/2004	.48	--	.42	--	79	--	1,543	--
05/29/2004	.30	.24	.30	.30	61	60	2,992	99
06/10/2004	.49	.25	.39	.30	84	62	132	131
06/10/2004	.22	.13	.28	.29	66	82	55	30
06/24/2004	.26	.22	.29	.35	78	72	62	40
07/09/2004	.32	--	.37	--	52	--	233	--
07/16/2004	.29	.08	.48	.36	54	50	261	330
07/21/2004	.28	.06	.52	.47	66	63	36	48
07/29/2004	.34	.14	.36	.30	42	45	197	264
08/03/2004	.15	.14	.30	.34	34	44	282	364
08/17/2004	.38	.29	.52	.50	31	36	188	213
08/18/2004	.30	.30	.33	.34	32	50	188	191
08/24/2004	.21	--	.50	--	98	--	146	--
08/27/2004	.21	.18	.33	.33	98	46	589	124
09/01/2004	.26	--	.32	--	42	--	207	--
09/15/2004	.08	.20	.32	.40	80	91	64	86

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-9a. Constituent event mean loads measured at the control and air-sweeper basin outlets during the calibration phase.

[<, less than; nd, no detect; --, no data]

Event date	Cadmium, total recoverable (grams)		Calcium, total recoverable (kilograms)		Copper, dissolved (grams)		Copper, total recoverable (grams)		Lead, total recoverable (grams)	
	Control	Air	Control	Air	Control	Air	Control	Air	Control	Air
09/07/2001	0.42	0.24	29.9	47.9	nd	2.99	10.42	16.42	11.34	22.39
09/17/2001	nd	nd	21.1	19.0	2.11	.95	6.05	6.05	1.97	5.61
09/19/2001	nd	nd	5.3	2.5	2.65	nd	2.29	1.69	2.82	1.52
04/07/2002	nd	.22	36.9	11.3	5.23	2.75	23.81	13.19	12.03	8.57
04/18/2002	83.38	.44	83.4	64.7	3.90	2.26	38.98	28.91	30.63	31.03
05/11/2002	.23	.35	34.5	52.8	3.07	1.61	21.00	17.70	12.12	16.09
05/25/2002	.18	nd	9.7	8.4	3.04	2.34	9.67	10.93	1.86	3.36
05/28/2002	.37	.41	35.5	104.2	4.13	3.99	22.63	27.07	13.78	19.63
06/02/2002	.61	.39	155.5	66.1	10.08	4.54	29.74	29.62	26.43	21.72
06/10/2002	.15	.30	15.9	15.1	2.33	.53	10.18	5.68	5.82	5.47
06/26/2002	.29	.24	13.2	40.5	2.35	1.73	7.45	10.22	7.45	51.08
07/22/2002	.33	.12	22.0	5.7	4.29	2.20	14.30	3.76	8.94	45.47
08/17/2002	.16	.09	10.7	9.5	1.47	.79	6.35	2.85	3.34	2.22
08/21/2002	.28	.31	16.4	56.9	2.36	2.72	10.26	12.73	7.69	13.58
09/02/2002	nd	nd	18.1	7.4	3.50	1.13	14.79	4.60	6.72	6.81
09/19/2002	nd	.07	37.8	10.9	.73	.40	5.79	4.20	4.63	4.40
09/20/2002	nd	nd	1.8	1.6	2.29	.53	4.64	1.39	1.13	3.05
04/16/2006	.36	1.53	41.9	194.7	nd	nd	21.23	75.95	20.85	78.78
04/29/2006	7.22	.18	31.1	9.9	1.98	1.82	36.79	9.12	16.98	1.75
05/09/2006	nd	nd	10.1	1.9	.80	.46	6.94	3.50	1.35	nd
05/17/2006	.03	nd	1.5	2.9	nd	nd	1.39	1.93	.24	1.05
05/24/2006	.08	1.60	15.3	230.0	1.32	nd	15.79	90.10	9.32	85.23
05/30/2006	.02	.20	10.6	55.5	2.15	1.12	10.67	17.71	4.56	21.39
06/10/2006	nd	--	3.3	.0	1.61	--	3.89	--	nd	--
06/18/2006	.06	.05	2.8	12.2	.50	.24	2.61	6.39	1.19	3.59
07/11/2006	.05	.03	10.8	4.7	nd	.76	10.73	6.27	1.51	2.95
07/20/2006	nd	--	9.6	.0	1.30	--	7.51	--	3.35	--
07/27/2006	nd	--	8.5	.0	nd	--	6.80	--	5.19	--
08/06/2006	nd	nd	3.6	5.4	.75	.73	3.29	2.75	1.02	1.53
08/17/2006	nd	nd	3.7	4.3	.73	.59	3.43	3.74	1.42	1.79
08/24/2006	nd	--	11.2	.0	nd	--	7.64	--	5.25	--
08/25/2006	nd	--	4.4	.0	nd	--	3.11	--	2.52	--
09/03/2006	nd	--	4.0	.0	1.04	--	2.31	--	nd	--
09/10/2006	nd	--	70.5	.0	4.41	--	20.86	--	14.10	--

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-9a. Constituent event mean loads measured at the control and air-sweeper basin outlets during the calibration phase—Continued.

[<, less than; nd, no detect; --, no data]

Event date	Magnesium, total recoverable (kilograms)		Phosphorus, total recoverable (kilograms)		Orthophosphorus, dissolved (kilograms)		Zinc, dissolved (grams)		Zinc, total recoverable (grams)	
	Control	Air	Control	Air	Control	Air	Control	Air	Control	Air
09/07/2001	14.82	24.78	0.70	0.67	0.30	0.21	10.65	11.05	64.83	80.62
09/17/2001	11.56	10.80	.19	.20	.09	.06	2.99	1.04	18.36	24.19
09/19/2001	2.12	1.00	.17	.10	.11	.06	7.59	3.78	9.70	7.39
04/07/2002	16.22	4.73	.38	.21	nd	.05	7.33	8.35	75.87	58.26
04/18/2002	42.88	34.41	.89	.71	.15	.07	8.21	3.53	135.03	134.68
05/11/2002	15.18	26.49	.56	.68	.08	.06	6.14	2.47	52.50	108.86
05/25/2002	3.80	2.73	.62	1.11	.17	.39	7.60	8.59	29.69	49.18
05/28/2002	17.91	52.86	.66	.81	.19	.22	9.55	12.18	98.40	131.31
06/02/2002	75.16	30.90	1.20	.67	.30	.15	24.78	6.61	92.51	96.75
06/10/2002	7.42	6.92	.57	.46	.31	.18	5.82	5.89	39.75	62.48
06/26/2002	6.36	18.66	.48	.42	.25	.17	9.16	5.89	40.09	169.35
07/22/2002	9.92	2.45	.52	.18	.18	.11	8.94	6.90	58.97	21.01
08/17/2002	5.35	3.65	.17	.10	.05	.03	2.71	1.90	24.40	16.17
08/21/2002	7.28	28.86	.30	.45	.08	.13	3.69	5.43	41.03	68.76
09/02/2002	8.07	3.29	.54	.19	.27	.10	8.60	3.35	45.71	20.43
09/19/2002	20.37	5.26	.20	.16	.05	.03	1.58	1.02	26.62	21.19
09/20/2002	.80	.73	.08	.05	.03	.02	2.78	1.28	7.62	6.11
04/16/2006	22.62	102.15	.65	2.10	.08	.12	1.46	3.26	101.34	393.13
04/29/2006	12.88	3.50	15.57	.49	.18	.14	12.74	21.29	931.14	48.67
05/09/2006	3.09	.64	1.24	.16	.15	.04	7.29	1.69	31.94	12.26
05/17/2006	.56	1.19	.10	.15	.03	.03	.86	.78	5.67	10.86
05/24/2006	7.75	122.74	.53	3.66	.08	.27	.79	3.21	43.19	442.34
05/30/2006	5.12	31.88	.39	.80	.17	.15	2.03	1.82	24.03	89.92
06/10/2006	1.24	--	.40	--	.18	--	1.11	--	14.84	--
06/18/2006	1.19	5.99	.15	.17	.05	.03	1.80	.88	10.20	36.73
07/11/2006	4.41	2.04	.42	.21	.14	.06	2.99	1.78	42.78	26.22
07/20/2006	4.17	--	.33	--	.10	--	3.07	--	28.68	--
07/27/2006	4.06	--	.28	--	.09	--	3.40	--	33.04	--
08/06/2006	1.24	2.41	.21	.21	.13	.14	1.94	2.22	11.85	10.71
08/17/2006	1.28	1.79	.17	.21	.07	.11	1.83	2.11	15.11	20.06
08/24/2006	5.02	--	.32	--	.11	--	2.74	--	27.37	--
08/25/2006	1.78	--	.13	--	.05	--	1.85	--	11.86	--
09/03/2006	1.62	--	.18	--	.12	--	3.47	--	9.82	--
09/10/2006	35.26	--	.68	--	.26	--	7.64	--	70.52	--

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-9a. Constituent event mean loads measured at the control and air-sweeper basin outlets during the calibration phase—Continued.

[<, less than; nd, no detect; --, no data]

	Ammonia-nitrogen (kilograms)		Nitrate plus nitrite, dissolved (kilograms)		Dissolved solids, total (kilograms)		Suspended sediment, total (kilograms)	
Event date	Control	Air	Control	Air	Control	Air	Control	Air
09/07/2001	0.44	0.28	0.97	0.43	343	66	532	1,427
09/17/2001	nd	.03	.45	.22	114	129	109	177
09/19/2001	.16	.08	.51	.25	49	25	34	21
04/07/2002	.78	.35	.72	.31	188	86	594	118
04/18/2002	1.06	.48	.56	.28	75	49	1,728	1,787
05/11/2002	.31	.18	.28	.10	48	31	689	1,425
05/25/2002	.40	.42	.26	.30	48	80	296	141
05/28/2002	.89	.59	.99	.68	57	49	837	3,026
06/02/2002	.93	.49	.81	.42	76	39	5,607	1,941
06/10/2002	.35	.19	.29	.16	39	22	334	280
06/26/2002	.43	.26	.49	.35	24	22	257	1,197
07/22/2002	.50	.12	.41	.19	36	16	832	134
08/17/2002	.16	.08	.25	.12	20	10	204	178
08/21/2002	.24	.21	.30	.29	94	53	451	1,304
09/02/2002	.81	.30	.90	.29	83	24	592	284
09/19/2002	.10	.07	.12	.06	15	7	511	217
09/20/2002	.07	.03	.08	.04	19	8	19	31
04/16/2006	.39	.68	.33	.53	29	75	732	3,714
04/29/2006	.80	.50	.62	.41	57	58	160	95
05/09/2006	.19	.14	.14	.06	45	21	136	31
05/17/2006	.06	.04	.04	.04	10	9	23	58
05/24/2006	.51	1.34	.28	.56	47	77	366	5,565
05/30/2006	.39	.41	.29	.28	73	42	151	1,046
06/10/2006	.14	--	.16	--	27	--	32	--
06/18/2006	.12	.07	.14	.07	18	12	43	49
07/11/2006	.10	.02	nd	nd	47	16	187	109
07/20/2006	.34	--	.36	--	30	--	130	--
07/27/2006	.56	--	.31	--	40	--	142	--
08/06/2006	.16	.08	.22	.15	17	15	35	57
08/17/2006	.12	.11	.17	.20	12	16	55	76
08/24/2006	.64	--	.48	--	34	--	197	--
08/25/2006	.35	--	.39	--	16	--	70	--
09/03/2006	.09	--	.18	--	33	--	36	--
09/10/2006	.52	--	1.74	--	658	--	397	--

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-9b. Constituent event mean loads measured at the control and high-frequency broom basin outlets during the calibration phase.

[<, less than; nd, no detect; --, no data]

Event date	Cadmium, total recoverable (grams)		Calcium, total recoverable (kilograms)		Copper, dissolved (grams)		Copper, total recoverable (grams)		Lead, total recoverable (grams)	
	Control	Broom	Control	Broom	Control	Broom	Control	Broom	Control	Broom
09/07/2001	0.42	--	29.9	--	nd	--	10.42	--	11.34	--
09/17/2001	nd	--	21.1	--	2.11	--	6.05	--	1.97	--
09/19/2001	nd	--	5.3	--	2.65	--	2.29	--	2.82	--
04/07/2002	nd	--	36.9	--	5.23	--	23.81	--	12.03	--
04/18/2002	83.38	--	83.4	--	3.90	--	38.98	--	30.63	--
05/11/2002	.23	--	34.5	--	3.07	--	21.00	--	12.12	--
05/25/2002	.18	--	9.7	--	3.04	--	9.67	--	1.86	--
05/28/2002	.37	--	35.5	--	4.13	--	22.63	--	13.78	--
06/02/2002	.61	--	155.5	--	10.08	--	29.74	--	26.43	--
06/10/2002	.15	--	15.9	--	2.33	--	10.18	--	5.82	--
06/26/2002	.29	--	13.2	--	2.35	--	7.45	--	7.45	--
07/22/2002	.33	0.15	22.0	5.8	4.29	4.45	14.30	6.22	8.94	1.57
08/17/2002	.16	--	10.7	--	1.47	--	6.35	--	3.34	--
08/21/2002	.28	--	16.4	--	2.36	--	10.26	--	7.69	--
09/02/2002	nd	nd	18.1	3.9	3.50	.80	14.79	2.53	6.72	1.55
09/19/2002	nd	--	37.8	--	.73	--	5.79	--	4.63	--
09/20/2002	nd	--	1.8	--	2.29	--	4.64	--	1.13	--
04/06/2005	.21	nd	42.4	51.2	2.18	1.22	19.26	19.06	19.44	13.10
04/12/2005	nd	nd	5.5	7.6	nd	1.08	5.03	6.51	2.47	2.98
04/19/2005	nd	--	6.7	--	.56	--	4.63	--	3.18	--
05/06/2005	.12	.08	11.9	11.6	1.22	1.37	11.16	11.80	6.22	5.68
05/11/2005	nd	nd	9.9	10.7	2.39	1.84	7.38	12.16	5.38	5.54
05/13/2005	nd	nd	5.3	32.4	nd	nd	3.14	10.37	3.91	21.77
05/18/2005	.12	.13	6.2	8.6	.66	1.39	4.60	6.05	4.45	3.44
04/16/2006	.36	.19	41.9	28.8	nd	nd	21.23	18.72	20.85	16.23
04/29/2006	7.22	nd	31.1	8.4	1.98	3.06	36.79	12.23	16.98	1.30
05/09/2006	nd	nd	10.1	1.9	.80	.63	6.94	2.51	1.35	nd
05/17/2006	.03	--	1.5	--	nd	--	1.39	--	.24	--
05/24/2006	.08	.26	15.3	85.1	1.32	7.36	15.79	62.28	9.32	38.18
05/30/2006	.02	.05	10.6	12.0	2.15	1.02	10.67	8.06	4.56	7.60
06/10/2006	nd	nd	3.3	5.1	1.61	.76	3.89	6.87	nd	2.68
06/18/2006	.06	--	2.8	--	.50	--	2.61	--	1.19	--
07/11/2006	.05	.36	10.8	137.4	nd	1.21	10.73	41.23	1.51	12.36
07/20/2006	nd	.89	9.6	301.1	1.30	1.33	7.51	93.96	3.35	24.36
07/27/2006	nd	nd	8.5	23.5	nd	.82	6.80	10.15	5.19	6.34
08/06/2006	nd	nd	3.6	3.3	.75	1.12	3.29	8.40	1.02	1.12
08/17/2006	nd	.02	3.7	3.1	.73	.54	3.43	3.05	1.42	.66
08/24/2006	nd	nd	11.2	9.3	nd	1.40	7.64	11.04	5.25	7.63
08/25/2006	nd	nd	4.4	10.1	nd	nd	3.11	5.04	2.52	4.22
09/03/2006	nd	nd	4.0	3.2	1.04	1.18	2.31	3.59	nd	2.12
09/10/2006	nd	1.31	70.5	225.2	4.41	3.79	20.86	82.88	14.10	25.18

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-9b. Constituent event mean loads measured at the control and high-frequency broom basin outlets during the calibration phase—Continued.

[<, less than; nd, no detect; --, no data]

	Magnesium, total recoverable (kilograms)		Phosphorus, total recoverable (kilograms)		Orthophosphorus, dissolved (kilograms)		Zinc, dissolved (grams)		Zinc, total recoverable (grams)	
Event date	Control	Broom	Control	Broom	Control	Broom	Control	Broom	Control	Broom
09/07/2001	14.82	--	0.70	--	0.30	--	10.65	--	64.83	--
09/17/2001	11.56	--	.19	--	.09	--	2.99	--	18.36	--
09/19/2001	2.12	--	.17	--	.11	--	7.59	--	9.70	--
04/07/2002	16.22	--	.38	--	nd	--	7.33	--	75.87	--
04/18/2002	42.88	--	.89	--	.15	--	8.21	--	135.03	--
05/11/2002	15.18	--	.56	--	.08	--	6.14	--	52.50	--
05/25/2002	3.80	--	.62	--	.17	--	7.60	--	29.69	--
05/28/2002	17.91	--	.66	--	.19	--	9.55	--	98.40	--
06/02/2002	75.16	--	1.20	--	.30	--	24.78	--	92.51	--
06/10/2002	7.42	--	.57	--	.31	--	5.82	--	39.75	--
06/26/2002	6.36	--	.48	--	.25	--	9.16	--	40.09	--
07/22/2002	9.92	2.34	.52	0.45	.18	0.20	8.94	10.37	58.97	35.27
08/17/2002	5.35	--	.17	--	.05	--	2.71	--	24.40	--
08/21/2002	7.28	--	.30	--	.08	--	3.69	--	41.03	--
09/02/2002	8.07	1.69	.54	.16	.27	.07	8.60	3.65	45.71	17.80
09/19/2002	20.37	--	.20	--	.05	--	1.58	--	26.62	--
09/20/2002	.80	--	.08	--	.03	--	2.78	--	7.62	--
04/06/2005	21.43	24.72	.52	.55	.11	.07	3.83	1.76	84.21	92.17
04/12/2005	2.24	3.06	.18	.43	.07	.07	2.24	4.18	18.28	35.33
04/19/2005	2.89	--	.24	--	.10	--	2.46	--	25.16	--
05/06/2005	5.31	5.22	.27	.29	.01	.02	2.76	2.55	50.15	56.44
05/11/2005	3.78	4.48	.37	.40	.11	.12	5.77	8.50	38.35	56.20
05/13/2005	2.11	16.23	.14	.22	.02	.04	2.64	.70	17.14	54.38
05/18/2005	2.41	2.99	.22	.34	.06	.10	1.08	4.18	22.39	36.79
04/16/2006	22.62	14.15	.65	.64	.08	.11	1.46	2.31	101.34	87.42
04/29/2006	12.88	2.83	15.57	.41	.18	.09	12.74	14.53	931.14	38.99
05/09/2006	3.09	.57	1.24	.18	.15	.05	7.29	3.77	31.94	13.82
05/17/2006	.56	--	.10	--	.03	--	.86	--	5.67	--
05/24/2006	7.75	45.05	.53	2.04	.08	.56	.79	4.85	43.19	208.85
05/30/2006	5.12	6.30	.39	.39	.17	.12	2.03	2.35	24.03	36.52
06/10/2006	1.24	1.95	.40	.50	.18	.21	1.11	1.45	14.84	30.37
06/18/2006	1.19	--	.15	--	.05	--	1.80	--	10.20	--
07/11/2006	4.41	75.61	.42	.98	.14	.13	2.99	3.64	42.78	162.22
07/20/2006	4.17	152.35	.33	1.84	.10	.13	3.07	3.00	28.68	458.79
07/27/2006	4.06	12.05	.28	.43	.09	.09	3.40	2.09	33.04	42.50
08/06/2006	1.24	1.19	.21	.22	.13	.14	1.94	2.38	11.85	15.05
08/17/2006	1.28	1.41	.17	.10	.07	.05	1.83	1.29	15.11	10.57
08/24/2006	5.02	5.02	.32	.43	.11	.17	2.74	2.51	27.37	39.13
08/25/2006	1.78	4.85	.13	.21	.05	.08	1.85	1.64	11.86	20.80
09/03/2006	1.62	1.26	.18	.18	.12	.11	3.47	3.59	9.82	13.63
09/10/2006	35.26	130.06	.68	1.63	.26	.29	7.64	8.65	70.52	1,796.68

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-9b. Constituent event mean loads measured at the control and high-frequency broom basin outlets during the calibration phase—Continued.

[<, less than; nd, no detect; --, no data]

	Ammonia-nitrogen (kilograms)		Nitrate plus nitrite, dissolved (kilograms)		Dissolved solids, total (kilograms)		Suspended sediment, total (kilograms)	
Event date	Control	Broom	Control	Broom	Control	Broom	Control	Broom
09/07/2001	0.44	--	0.97	--	343	--	532	--
09/17/2001	nd	--	.45	--	114	--	109	--
09/19/2001	.16	--	.51	--	49	--	34	--
04/07/2002	.78	--	.72	--	188	--	594	--
04/18/2002	1.06	--	.56	--	75	--	1,728	--
05/11/2002	.31	--	.28	--	48	--	689	--
05/25/2002	.40	--	.26	--	48	--	296	--
05/28/2002	.89	--	.99	--	57	--	837	--
06/02/2002	.93	--	.81	--	76	--	5,607	--
06/10/2002	.35	--	.29	--	39	--	334	--
06/26/2002	.43	--	.49	--	24	--	257	--
07/22/2002	.50	nd	.41	nd	36	28	832	150
08/17/2002	.16	--	.25	--	20	--	204	--
08/21/2002	.24	--	.30	--	94	--	451	--
09/02/2002	.81	.16	.90	.26	83	23	592	72
09/19/2002	.10	--	.12	--	15	--	511	--
09/20/2002	.07	--	.08	--	19	--	19	--
04/06/2005	.79	.52	.36	.29	75	53	478	936
04/12/2005	.38	.41	.47	.54	27	37	46	64
04/19/2005	.34	--	.21	--	22	--	78	--
05/06/2005	.35	.40	.20	.24	18	19	207	186
05/11/2005	.43	.41	.29	.27	33	43	119	170
05/13/2005	.23	.24	.23	.24	19	30	76	916
05/18/2005	.30	.41	.36	.49	29	42	66	100
04/16/2006	.39	.33	.33	.30	29	37	732	699
04/29/2006	.80	.47	.62	.37	57	51	160	203
05/09/2006	.19	.14	.14	.12	45	21	136	25
05/17/2006	.06	--	.04	--	10	--	23	--
05/24/2006	.51	1.40	.28	1.02	47	169	366	2,204
05/30/2006	.39	.21	.29	.23	73	41	151	376
06/10/2006	.14	.16	.16	.09	27	18	32	160
06/18/2006	.12	--	.14	--	18	--	43	--
07/11/2006	.10	nd	nd	.51	47	41	187	3,063
07/20/2006	.34	.22	.36	.28	30	21	130	7,776
07/27/2006	.56	.31	.31	.22	40	25	142	534
08/06/2006	.16	.05	.22	.16	17	17	35	53
08/17/2006	.12	.04	.17	.10	12	6	55	76
08/24/2006	.64	.39	.48	.44	34	32	197	543
08/25/2006	.35	.25	.39	.34	16	20	70	81
09/03/2006	.09	.09	.18	.12	33	30	36	73
09/10/2006	.52	.22	1.74	.52	658	112	397	6,292

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-9c. Constituent event mean loads measured at the control and air-sweeper basin outlets during the treatment phase.

[<, less than; nd, no detect; --, no data]

Sweeper type	Event date	Cadmium, total recoverable (grams)		Calcium, total recoverable (kilograms)		Copper, dissolved (grams)		Copper, total recoverable (grams)		Lead, total recoverable (grams)	
		Control	Air	Control	Air	Control	Air	Control	Air	Control	Air
Treatment—regenerative air	04/30/2003	0.35	0.17	13.2	11.9	2.86	3.78	11.86	12.18	8.37	6.15
	04/30/2003	1.22	nd	105.9	82.4	2.15	nd	26.95	31.16	15.36	24.29
	05/04/2003	.42	nd	18.5	3.5	1.46	1.13	9.47	3.59	3.06	1.50
	05/10/2003	.20	.13	26.8	13.5	3.15	1.07	26.24	7.92	12.46	5.15
	05/14/2003	nd	nd	7.1	2.0	1.02	.55	5.44	2.15	1.80	.61
	05/19/2003	17.50	.13	106.4	21.0	3.24	1.65	27.11	10.72	6.69	7.15
	05/30/2003	.13	.21	26.4	65.3	.63	.77	13.05	16.74	8.97	11.59
	07/15/2003	.19	.54	44.5	22.5	3.77	26.29	18.28	18.21	14.85	22.53
	09/12/2003	.03	nd	4.7	3.7	2.36	.83	5.31	2.39	1.95	1.27
	05/08/2004	nd	nd	61.2	25.4	3.25	1.78	17.00	8.22	14.18	9.80
	05/10/2004	.08	.07	26.7	34.3	1.51	.98	8.28	7.86	6.64	9.59
	05/13/2004	--	--	--	--	--	--	--	--	--	--
	05/17/2004	nd	.23	22.6	86.6	2.61	3.01	12.20	21.04	12.09	30.10
	05/21/2004	nd	.20	36.4	24.6	.79	1.28	10.28	13.19	9.60	17.61
Treatment—vacuum assist	05/29/2004	nd	nd	142.9	11.3	2.18	4.11	77.19	9.23	26.58	6.38
	06/10/2004	nd	nd	1.4	2.5	1.00	.50	1.98	1.83	.72	1.19
	06/10/2004	nd	--	3.5	.0	3.37	--	2.68	--	1.15	--
	06/24/2004	.07	nd	1.3	.6	.66	.31	1.21	.56	.79	.48
	07/09/2004	.08	.08	2.7	9.1	1.76	1.60	3.61	6.31	2.07	5.82
	07/16/2004	nd	.15	5.8	12.8	1.97	1.82	6.04	9.15	3.30	9.43
	07/21/2004	nd	nd	1.6	1.1	1.07	.45	1.51	1.04	nd	.65
	07/29/2004	.17	.15	5.9	7.6	2.16	1.79	4.23	5.99	1.99	5.58
	08/03/2004	.14	.07	7.6	23.8	nd	nd	4.75	16.20	5.91	16.58
	08/17/2004	nd	nd	2.0	3.2	nd	nd	1.74	2.30	1.11	2.06
	08/18/2004	.06	nd	2.6	12.0	nd	nd	5.64	8.48	1.06	8.87
	08/24/2004	.04	nd	3.0	1.9	nd	.28	1.67	1.98	.45	1.07
	08/27/2004	nd	.11	6.6	3.5	nd	nd	1.98	3.21	.80	2.85
	09/01/2004	.06	nd	6.0	22.2	nd	nd	4.61	16.64	4.06	33.82
	09/15/2004	nd	nd	5.4	2.4	1.33	.84	5.40	2.28	1.45	.92
	04/06/2005	.21	.16	42.4	23.6	2.18	1.81	19.26	13.14	19.44	11.29
	04/12/2005	nd	nd	5.5	1.0	nd	.30	5.03	1.45	2.47	.59
	04/19/2005	nd	.08	6.7	16.4	.56	.48	4.63	8.36	3.18	6.52
	05/06/2005	.12	.01	11.9	9.8	1.22	.83	11.16	7.14	6.22	6.14
	05/11/2005	nd	nd	9.9	5.4	2.39	.82	7.38	5.05	5.38	3.53
	05/13/2005	nd	nd	5.3	6.1	nd	nd	3.14	4.00	3.91	3.51
	05/18/2005	.12	nd	6.2	3.0	.66	.55	4.60	2.46	4.45	1.75

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-9c. Constituent event mean loads measured at the control and air-sweeper basin outlets during the treatment phase—Continued.

[<, less than; nd, no detect; --, no data]

Sweeper type	Event date	Magnesium, total recoverable (kilograms)		Phosphorus, total recoverable (kilograms)		Orthophosphorus, dissolved (kilograms)		Zinc, dissolved (grams)		Zinc, total recoverable (grams)	
		Control	Air	Control	Air	Control	Air	Control	Air	Control	Air
Treatment—regenerative air	04/30/2003	5.72	4.94	0.50	0.48	0.14	0.19	8.37	10.26	59.98	57.06
	04/30/2003	57.63	41.32	.97	.75	.12	.09	6.76	5.83	133.23	118.47
	05/04/2003	6.63	1.04	2.94	.15	nd	.06	5.25	4.17	80.87	15.43
	05/10/2003	11.28	5.42	.55	.34	.07	.05	3.28	2.61	62.31	43.94
	05/14/2003	2.24	.57	.32	.13	.11	.05	3.23	2.15	17.68	9.67
	05/19/2003	56.46	10.05	.69	.39	.10	.08	2.52	4.42	78.46	56.30
	05/30/2003	13.08	32.97	.36	.52	.05	.08	1.28	1.16	40.79	88.86
	07/15/2003	21.70	9.76	.69	.63	.11	.24	6.28	118.30	73.10	69.48
	09/12/2003	2.16	1.14	.14	.09	.06	.05	2.36	1.20	12.58	12.88
	05/08/2004	29.69	10.51	.48	.47	.05	.03	8.13	7.36	57.69	50.37
	05/10/2004	13.16	19.16	.23	.25	.02	.02	3.12	3.92	28.13	53.55
	05/13/2004	--	--	--	--	--	--	--	--	--	--
	05/17/2004	11.58	41.96	.28	.67	.10	.17	3.26	75.72	47.30	120.47
	05/21/2004	19.14	12.62	.27	.45	.09	.10	1.48	3.20	31.54	70.54
Treatment—vacuum assist	05/29/2004	71.79	5.43	.69	.24	.13	.07	4.25	5.50	66.67	40.93
	06/10/2004	.56	.87	.12	.06	.07	.02	3.03	1.56	6.99	10.42
	06/10/2004	1.16	--	.13	--	.06	--	3.15	--	10.02	--
	06/24/2004	.48	.19	.04	.02	.02	.01	1.04	.99	4.99	3.04
	07/09/2004	1.34	4.55	.10	.11	.03	.04	3.34	3.12	13.99	31.49
	07/16/2004	2.71	6.38	.21	.25	.08	.08	4.24	3.85	28.85	53.67
	07/21/2004	.56	.42	.06	.05	.03	.02	4.09	3.40	4.86	7.45
	07/29/2004	2.57	3.58	.30	.29	.10	.08	7.96	6.27	21.55	35.12
	08/03/2004	3.79	12.66	.22	.50	.05	.12	1.36	1.20	24.79	75.92
	08/17/2004	.87	1.47	.11	.12	.05	.05	.45	.82	9.72	29.22
	08/18/2004	1.17	6.52	.10	.30	.04	.08	.92	.94	10.28	47.00
	08/24/2004	1.49	.86	.07	.08	.04	.04	.37	1.54	4.50	10.64
	08/27/2004	3.49	1.67	.07	.15	.01	.06	.09	1.41	4.31	15.70
	09/01/2004	2.99	12.15	.15	.68	.07	.15	1.35	2.06	18.17	80.74
	09/15/2004	2.08	.87	.44	.24	.22	.12	1.74	1.29	19.94	13.38
	04/06/2005	21.43	11.36	.52	.33	.11	.06	3.83	2.16	84.21	74.21
	04/12/2005	2.24	.32	.18	.04	.07	.02	2.24	1.89	18.28	6.24
	04/19/2005	2.89	7.85	.24	.34	.10	.11	2.46	1.84	25.16	53.47
	05/06/2005	5.31	4.37	.27	.23	.01	nd	2.76	3.80	50.15	48.50
	05/11/2005	3.78	1.90	.37	.21	.11	.09	5.77	5.32	38.35	28.11
	05/13/2005	2.11	2.82	.14	.12	.02	.02	2.64	1.12	17.14	24.08
	05/18/2005	2.41	1.09	.22	.11	.06	.02	1.08	1.42	22.39	13.64

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-9c. Constituent event mean loads measured at the control and air-sweeper basin outlets during the treatment phase—Continued.

[<, less than; nd, no detect; --, no data]

Sweeper type	Event date	Ammonia-nitrogen (kilograms)		Nitrate plus nitrite, dissolved (kilograms)		Dissolved solids, total (kilograms)		Suspended sediment, total (kilograms)	
		Control	Air	Control	Air	Control	Air	Control	Air
Treatment—regenerative air	04/30/2003	0.54	0.55	0.34	0.32	45	56	215	193
	04/30/2003	.49	.36	.45	.30	55	52	1,951	1,332
	05/04/2003	.28	.18	.21	.06	63	30	204	43
	05/10/2003	.41	.17	.29	.10	50	37	638	217
	05/14/2003	.20	.05	.14	.07	50	16	58	20
	05/19/2003	.47	.38	.40	.27	46	31	1,643	378
	05/30/2003	.21	.30	.11	.21	20	29	477	1,144
	07/15/2003	.63	.73	.62	.62	53	39	907	2,524
	09/12/2003	.15	.14	.19	.15	20	17	--	--
	05/08/2004	.49	.36	.29	.27	20	20	1,301	414
	05/10/2004	.23	.20	.16	.14	19	10	589	503
	05/13/2004	--	--	.04	.04	8	8	25	17
	05/17/2004	.34	.48	.19	.29	27	38	564	1,287
	05/21/2004	.21	.30	.18	.25	35	34	674	621
Treatment—vacuum assist	05/29/2004	.31	.21	.31	.24	63	45	3,104	268
	06/10/2004	.09	.04	.07	.06	16	12	25	36
	06/10/2004	.16	--	.20	--	47	--	40	--
	06/24/2004	.06	.03	.06	.03	17	8	14	4
	07/09/2004	.10	.12	.11	.15	16	18	71	171
	07/16/2004	.14	.15	.24	.25	27	29	129	270
	07/21/2004	.07	.05	.13	.09	17	10	9	13
	07/29/2004	.28	.24	.30	.28	35	39	164	200
	08/03/2004	.10	.17	.20	.31	23	53	191	666
	08/17/2004	.08	.09	.12	.14	7	10	42	64
	08/18/2004	.08	.18	.09	.15	9	24	51	296
	08/24/2004	.03	.04	.08	.07	15	8	23	39
	08/27/2004	.02	.08	.04	.11	11	15	69	58
	09/01/2004	.14	.40	.17	.45	22	55	107	673
	09/15/2004	.03	.04	.13	.13	33	21	27	19
	04/06/2005	.79	.43	.36	.20	75	43	478	470
	04/12/2005	.38	.11	.47	.12	27	8	46	7
	04/19/2005	.34	.29	.21	.20	22	27	78	200
	05/06/2005	.35	.38	.20	.23	18	21	207	143
	05/11/2005	.43	.28	.29	.20	33	25	119	85
	05/13/2005	.23	.20	.23	.21	19	20	76	103
	05/18/2005	.30	.16	.36	.21	29	19	66	28

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-9d. Constituent event mean loads measured at the control and high-frequency broom basin outlets during the treatment phase.

[<, less than; nd, no detect; --, no data]

Event date	Cadmium, total recoverable (grams)		Calcium, total recoverable (kilograms)		Copper, dissolved (grams)		Copper, total recoverable (grams)		Lead, total recoverable (grams)	
	Control	Broom	Control	Broom	Control	Broom	Control	Broom	Control	Broom
04/30/2003	0.35	nd	13.2	3.4	2.86	0.90	11.86	2.74	8.37	1.02
04/30/2003	1.22	.20	105.9	18.5	2.15	1.28	26.95	10.39	15.36	35.98
05/04/2003	.42	nd	18.5	2.9	1.46	.88	9.47	2.57	3.06	.85
05/10/2003	.20	.17	26.8	14.9	3.15	1.52	26.24	7.27	12.46	4.63
05/14/2003	nd	nd	7.1	1.6	1.02	2.54	5.44	2.35	1.80	.43
05/19/2003	17.50	.14	106.4	630.9	3.24	1.31	27.11	251.09	6.69	111.97
05/30/2003	.13	.09	26.4	36.1	.63	.36	13.05	7.90	8.97	5.46
07/15/2003	.19	nd	44.5	36.1	3.77	2.58	18.28	15.46	14.85	13.40
09/12/2003	.03	nd	4.7	15.0	2.36	.95	5.31	4.54	1.95	2.02
05/08/2004	nd	nd	61.2	11.8	3.25	2.26	17.00	8.37	14.18	4.58
05/10/2004	.08	nd	26.7	15.8	1.51	2.24	8.28	9.41	6.64	6.98
05/13/2004	--	--	--	--	--	--	--	--	--	--
05/17/2004	nd	.13	22.6	52.4	2.61	3.05	12.20	15.24	12.09	10.68
05/21/2004	nd	--	36.4	--	.79	--	10.28	--	9.60	--
05/29/2004	nd	nd	142.9	7.1	2.18	5.33	77.19	10.17	26.58	3.73
06/10/2004	nd	nd	1.4	1.8	1.00	1.08	1.98	2.59	.72	.68
06/10/2004	nd	nd	3.5	3.5	3.37	4.05	2.68	6.76	1.15	.25
06/24/2004	.07	nd	1.3	.8	.66	.46	1.21	.89	.79	.01
07/09/2004	.08	--	2.7	--	1.76	--	3.61	--	2.07	--
07/16/2004	nd	nd	5.8	6.4	1.97	1.41	6.04	6.57	3.30	6.15
07/21/2004	nd	nd	1.6	1.1	1.07	.52	1.51	.90	nd	nd
07/29/2004	.17	nd	5.9	7.2	2.16	nd	4.23	8.30	1.99	3.89
08/03/2004	.14	nd	7.6	6.3	nd	nd	4.75	6.18	5.91	4.37
08/17/2004	nd	nd	2.0	1.4	nd	.43	1.74	2.63	1.11	1.20
08/18/2004	.06	.05	2.6	1.7	nd	nd	5.64	2.37	1.06	1.18
08/24/2004	.04	--	3.0	--	nd	--	1.67	--	.45	--
08/27/2004	nd	nd	6.6	.7	nd	.15	1.98	.69	.80	.62
09/01/2004	.06	--	6.0	--	nd	--	4.61	--	4.06	--
09/15/2004	nd	nd	5.4	2.8	1.33	.99	5.40	3.31	1.45	.88

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-9d. Constituent event mean loads measured at the control and high-frequency broom basin outlets during the treatment phase—Continued.

[<, less than; nd, no detect; --, no data]

	Magnesium, total recoverable (kilograms)		Phosphorus, total recoverable (kilograms)		Orthophosphorus, dissolved (kilograms)		Zinc, dissolved (grams)		Zinc, total recoverable (grams)	
Event date	Control	Broom	Control	Broom	Control	Broom	Control	Broom	Control	Broom
04/30/2003	5.72	1.41	0.50	0.13	0.14	0.05	8.37	2.93	59.98	15.72
04/30/2003	57.63	7.28	.97	.24	.12	.07	6.76	4.40	133.23	40.77
05/04/2003	6.63	.81	2.94	.09	nd	.03	5.25	3.73	80.87	12.19
05/10/2003	11.28	5.69	.55	.33	.07	.07	3.28	16.53	62.31	40.99
05/14/2003	2.24	.39	.32	.08	.11	.02	3.23	3.52	17.68	8.81
05/19/2003	56.46	310.87	.69	2.25	.10	.04	2.52	2.27	78.46	628.56
05/30/2003	13.08	17.04	.36	.30	.05	.04	1.28	1.49	40.79	43.64
07/15/2003	21.70	17.52	.69	.54	.11	.14	6.28	7.42	73.10	62.88
09/12/2003	2.16	7.04	.14	.15	.06	.04	2.36	2.27	12.58	25.22
05/08/2004	29.69	5.84	.48	.22	.05	.05	8.13	5.82	57.69	34.65
05/10/2004	13.16	7.37	.23	.27	.02	.07	3.12	5.87	28.13	38.47
05/13/2004	--	--	--	--	--	--	--	--	--	--
05/17/2004	11.58	25.01	.28	.47	.10	.12	3.26	4.01	47.30	59.66
05/21/2004	19.14	--	.27	--	.09	--	1.48	--	31.54	--
05/29/2004	71.79	2.52	.69	.30	.13	.13	4.25	9.13	66.67	43.81
06/10/2004	.56	.71	.12	.11	.07	.05	3.03	4.87	6.99	13.33
06/10/2004	1.16	1.15	.13	.12	.06	.06	3.15	9.50	10.02	15.04
06/24/2004	.48	.26	.04	.02	.02	.01	1.04	1.65	4.99	3.63
07/09/2004	1.34	--	.10	--	.03	--	3.34	--	13.99	--
07/16/2004	2.71	2.86	.21	.38	.08	.11	4.24	6.02	28.85	32.98
07/21/2004	.56	.37	.06	.06	.03	.04	4.09	2.78	4.86	5.56
07/29/2004	2.57	3.12	.30	.29	.10	.11	7.96	.85	21.55	37.84
08/03/2004	3.79	3.19	.22	.26	.05	.09	1.36	.96	24.79	26.90
08/17/2004	.87	.66	.11	.10	.05	.04	.45	.81	9.72	10.54
08/18/2004	1.17	.72	.10	.08	.04	.04	.92	.47	10.28	10.85
08/24/2004	1.49	--	.07	--	.04	--	.37	--	4.50	--
08/27/2004	3.49	.31	.07	.04	.01	.02	.09	.58	4.31	3.82
09/01/2004	2.99	--	.15	--	.07	--	1.35	--	18.17	--
09/15/2004	2.08	.99	.44	.28	.22	.18	1.74	2.67	19.94	15.70

Appendix 1. Detailed street-dirt and water-quality data—Continued.

Appendix table 1-9d. Constituent event mean loads measured at the control and high-frequency broom basin outlets during the treatment phase—Continued.

[<, less than; nd, no detect; --, no data]

	Ammonia-nitrogen (kilograms)		Nitrate plus nitrite, dissolved (kilograms)		Dissolved solids, total (kilograms)		Suspended sediment, total (kilograms)	
Event date	Control	Broom	Control	Broom	Control	Broom	Control	Broom
04/30/2003	0.54	0.18	0.34	0.12	45	14	215	48
04/30/2003	.49	.24	.45	.19	55	27	1,951	337
05/04/2003	.28	.13	.21	.12	63	22	204	30
05/10/2003	.41	.28	.29	.22	50	40	638	215
05/14/2003	.20	.06	.14	.08	50	14	58	5
05/19/2003	.47	.29	.40	.18	46	20	1,643	13,247
05/30/2003	.21	.19	.11	.09	20	12	477	1,008
07/15/2003	.63	.31	.62	.38	53	33	907	1,096
09/12/2003	.15	.15	.19	.16	20	15	--	495
05/08/2004	.49	.43	.29	.23	20	14	1,301	205
05/10/2004	.23	.41	.16	.29	19	13	589	306
05/13/2004	--	--	.04	.05	8	18	25	14
05/17/2004	.34	.35	.19	.24	27	39	564	1,179
05/21/2004	.21	--	.18	--	35	--	674	--
05/29/2004	.31	.28	.31	.35	63	71	3,104	117
06/10/2004	.09	.07	.07	.08	16	17	25	35
06/10/2004	.16	.08	.20	.18	47	52	40	19
06/24/2004	.06	.03	.06	.05	17	11	14	6
07/09/2004	.10	--	.11	--	16	--	71	--
07/16/2004	.14	.04	.24	.18	27	25	129	166
07/21/2004	.07	.01	.13	.07	17	10	9	7
07/29/2004	.28	.09	.30	.20	35	29	164	173
08/03/2004	.10	.08	.20	.20	23	26	191	218
08/17/2004	.08	.05	.12	.09	7	7	42	40
08/18/2004	.08	.06	.09	.07	9	11	51	41
08/24/2004	.03	--	.08	--	15	--	23	--
08/27/2004	.02	.02	.04	.03	11	4	69	12
09/01/2004	.14	--	.17	--	22	--	107	--
09/15/2004	.03	.06	.13	.11	33	25	27	24

Appendix 2. Quality assurance and quality control

Field and sample-processing equipment blanks were collected at the control and test-basin monitoring stations to evaluate the integrity of the stormwater-quality sampling process, identify if sample contamination existed and if so, to identify possible sources. Blank samples were obtained by drawing deionized water through the suction line and sampler into a collection bottle. The Teflon sample line and automatic sampler were not cleaned before obtaining blank samples. Blank water collected in the 10-liter glass sample bottle was then split using a Teflon-lined churn splitter into plastic laboratory-prepared sample bottles. Samples were placed on ice and delivered to the Madison Department of Public Health (MDPH) for analysis. Deionized blank water was also used to isolate individual elements of the sampling process from source to delivery. These samples were not delivered to the MDPH unless erroneous concentrations were found in the original blank sample. Blank-sample results are detailed in table 2-1. Replicate samples were also collected to evaluate the inherent variability in the sampling analyses and methods. The bias and variability identified by analysis of blanks and replicates were within acceptable limits except for dissolved zinc, dissolved chloride, and total cadmium.

Total zinc concentrations often were above detectable limits but were typically an order of magnitude lower than those measured in stormwater-quality samples. Dissolved zinc concentrations, however, were detected in blanks at concentrations greater than in field samples at each of the stormwater-quality monitoring stations. The median dissolved zinc concentration, for all blank samples with dissolved zinc concentrations above the limit of detection, was 1.0 micrograms per liter. The minimum dissolved zinc concentration from a stormwater-quality sample taken at the control, air-sweeper, and high-frequency basins was 0.8, 1.0, and 1.3, respectively. Analyses of deionized water used for blank samples, with no exposure to sample or processing equipment, indicated a presence of total and dissolved zinc concentrations that was greater than the detectable range in field samples. It is possible that zinc concentrations detected in many blank samples may have come from the deionized water. Contamination of dissolved zinc could also have come from a source other than the deionized water. Additional blank samples taken to isolate individual elements of the sampling process had dissolved zinc concentrations that were slightly higher than the deionized water. Deionized water was used only as a rinse during sample bottle cleaning, therefore any dissolved zinc residue remaining on field sample collection bottles after cleaning would be insignificant when compared to the mass of water in the field samples.

Dissolved chloride concentrations in blanks were also greater than the detectable limit and concentration in field samples at each of the monitoring stations on several occasions. Follow-up tests of the deionized water used in the blank sample process resulted in concentrations of dissolved chloride less than the detectable limit. One explanation for elevated dissolved chloride levels in the control basin may be due to the periodic drainage of a private swimming pool into basin storm drains. Similarly, fire hydrants in each basin were flushed twice per year onto adjacent streets. Water feeding the hydrants originated from a chlorinated city water supply. For these reasons, and since no obvious source of chloride was detected in the stormwater-quality sampling equipment, dissolved chloride was disregarded from statistical evaluation.

Finally, total cadmium was detected in the control basin blank sample on one occasion. This sample had been contaminated in the analytical laboratory and does not reflect the efficacy of the stormwater-quality sampling equipment.

Replicate samples were submitted to verify reproducibility in the sample acquisition and splitting process as well as analytical methods conducted in the laboratory. Replicate samples were checked for precision on the basis of an absolute relative percent difference (RPD). Replicate-sample results are detailed in table 2-2. On several occasions within each basin, the RPD values exceeded 50 percent. The majority of these samples were acquired prior to identifying the potential bias in concentration data due to the presence of sand-size particles in a whole-water sample (Selbig and others, 2007). Changes to the sample-splitting and laboratory analytical techniques were implemented in May 2004. The RPD values for replicate samples collected after May 2004 were mostly within an acceptable range of error. Of the RPD values exceeding 50 percent after the new methods were used, the majority occurred from a single replicate (table 2-2). Due to laboratory error, the new sample-splitting techniques were not used to process this sample which was likely the cause of the differences. This sample was therefore not used as part of the replicate analysis.

Appendix 2. Quality assurance and quality control—Continued.

Appendix table 2-1. Results of blank-sample analyses.

[mm/dd/yyyy, month/day/year; µg/L, microgram per liter; mg/L, milligram per liter; <, less than]

Sample ID	Date (mm/dd/yyyy)	Cadmium, total recoverable (µg/L)	Calcium, total recoverable (mg/L)	Copper, dissolved (µg/L)	Copper, total recoverable (µg/L)	Lead, total recoverable (µg/L)	Magnesium, total recoverable (mg/L)	Phosphorus, total recoverable (mg/L)
Control basin								
QA-1	03/22/2002	<0.2	<0.012	<1.46	<1.46	<1.44	<0.012	<12.4
QA-2	09/19/2003	<.20	.054	<1.64	<1.64	<1.49	<.021	<.0098
QA-3	06/08/2004	<.20	.043	<1.64	<1.64	<1.49	<.021	<.0098
QA-4	05/31/2005	<.23	.031	<1.34	<1.34	<1.4	<.014	<.01
QA-5	05/23/2006	.33	.050	<1.2	2.0	<1.47	<.020	<.012
Air-sweeper basin								
QA-1	03/22/2002	<.2	.05	<1.46	1.8	<1.44	.022	<12.4
QA-2	09/19/2003	<.20	.034	<1.64	<1.64	<1.49	<.021	<.0098
QA-3	06/08/2004	<.20	.042	<1.64	<1.64	<1.49	<.021	<.0098
QA-4	05/31/2005	<.23	.037	<1.34	<1.34	<1.4	<.014	<.01
QA-5	05/23/2006	<.20	.034	<1.2	2.2	<1.47	<.020	<.012
High-frequency broom basin								
QA-1	07/11/2002	<.2	<.012	<1.46	<1.46	<1.44	<.012	<.012
QA-2	09/19/2003	<.20	.215	<1.64	<1.64	<1.49	.055	<.0098
QA-3	06/07/2004	<.20	.055	<1.64	<1.64	<1.49	<.021	<.0098
QA-4	05/31/2005	<.23	.048	<1.34	<1.34	<1.4	<.014	<.01
QA-5	05/18/2006	<.20	.065	<1.2	<1.2	<1.47	.026	<.012

Appendix 2. Quality assurance and quality control—Continued.

Appendix table 2-1. Results of blank-sample analyses—Continued.

[mm/dd/yyyy, month/day/year; µg/L, microgram per liter; mg/L, milligram per liter; <, less than]

Sample ID	Date (mm/dd/yyyy)	Zinc, dissolved (µg/L)	Zinc, total recoverable (µg/L)	Chloride, dissolved (mg/L)	Ammonia-nitrogen, flow injection (mg/L)	Nitrate plus nitrite, dissolved (mg/L)	Orthophosphorus, flow injection dissolved (mg/L)	Total dissolved solids (mg/L)	Suspended sediment (mg/L)
Control basin									
QA-1	03/22/2002	0.6	0.9	<1.204	<0.05	<0.176	<0.05	<6	<1
QA-2	09/19/2003	<.46	.46	2.059	<.05	<.138	<.05	<6	<1
QA-3	06/08/2004	1	1.7	<1.203	<.05	<.141	<.025	<6	<1
QA-4	05/31/2005	<.55	<.55	<1.200	<.025	<.180	<.025	<6	<1
QA-5	05/23/2006	1.0	1.8	<1.200	<.025	<.180	<.01	<6	<1
Air-sweeper basin									
QA-1	03/22/2002	3.9	5.4	1.264	<.05	<.176	<.05	6	<1
QA-2	09/19/2003	.5	.3	1.98	<.05	<.138	<.05	<6	<1
QA-3	06/08/2004	6.2	1	<1.203	<.05	<.141	<.025	<6	<1
QA-4	05/31/2005	<.55	<.55	1.505	<.025	<.180	<.025	6	<1
QA-5	05/23/2006	<.66	1.0	<1.200	<.025	<.180	<.01	<6	3
High-frequency broom basin									
QA-1	07/11/2002	<.37	<.37	<1.204	<.05	<.176	<.05	<6	<1
QA-2	09/19/2003	.8	.7	2.572	<.05	<.138	<.05	<6	<1
QA-3	06/07/2004	2.9	3.1	1.228	<.05	<.141	<.025	8	1
QA-4	05/31/2005	<.55	<.55	1.498	<.025	<.180	<.025	<6	<1
QA-5	05/18/2006	<.66	.7	<1.200	<.025	<.180	<.01	8	1

Appendix 2. Quality assurance and quality control—Continued.

Appendix table 2-2. Results of replicate-sample analyses.

[mm/dd/yyyy, month/day/year; µg/L, microgram per liter; mg/L, milligram per liter; RPD, relative percent difference; %, percent; --, not applicable; values in **bold** indicate exceedance of allowable error]

Sample ID	Date (mm/dd/yyyy)	Cadmium,		Calcium		Copper		Copper		Lead		Magnesium	
		Total recoverable (µg/L)	Absolute RPD (%)	Total recoverable (mg/L)	Absolute RPD (%)	Dissolved (µg/L)	Absolute RPD (%)	Total recoverable (µg/L)	Absolute RPD (%)	Total recoverable (µg/L)	Absolute RPD (%)	Total recoverable (mg/L)	Absolute RPD (%)
45R	09/13/2003	0.23	--	56	**107**	2.7	33	8.8	6	8.1	**170**	28	**115**
45	09/13/2003	<.17		27		4		8.3		3		13	
48R	09/13/2003	<.17	--	18	20	2	5	9.7	3	9.3	**91**	7.8	3
48	09/13/2003	.26		15		2.1		9.4		108		7.6	
15R	05/10/2003	.28	12	23.5	4	1.6	30	12	9	8.6	23	8.5	1
15	05/10/2003	.25		22.5		2.3		11		7		8.6	
55	03/25/2004	.24	--	38	12	4.1	**58**	14	0	15	7	18	10
55R	03/25/2004	<.2		43		2.6		14		14		20	
58	03/25/2004	.44	29	79	4	2.5	9	25	9	138	**214**	37	3
58R	03/25/2004	.34		76		2.3		23		44		36	
33	04/20/2004	<.20	--	9.8	18	5.5	2	16	**52**	4.1	8	3.6	10
33R	04/20/2004	.21		12		5.4		33		3.8		4	
88	05/06/2005	<.23	--	27	4	3.8	46	23	5	14	13	13	0
88R	05/06/2005	.36		28		2.6		22		16		13	
91	05/06/2005	<.23	--	22	4	2.4	9	17	0	14	26	9.7	3
91R	05/06/2005	.24		23		2.2		17		19		10	
62	05/06/2005	.23	26	29	0	4.2	**68**	25	19	14	7	14	0
62R	05/06/2005	.31		29		2.5		31		15		14	
107	08/23/2006	<.20	--	9.1	4	<1.2	--	7	**50**	4.5	17	4.3	2
107R	08/23/2006	<.20		9.5		<1.2		14		5.4		4.4	
99	04/29/2006	.24	**73**	13	43	2.4	14	12	33	2.3	**77**	4.6	**58**
99R	04/29/2006	.90		23		2.8		18		10		11	

Appendix 2. Quality assurance and quality control—Continued.

Appendix table 2-2. Results of replicate-sample analyses—Continued.

[mm/dd/yyyy, month/day/year; µg/L, microgram per liter; mg/L, milligram per liter; RPD, relative percent difference; %, percent; --, not applicable; values in **bold** indicate exceedance of allowable error]

Sample ID	Date (mm/dd/yyyy)	Phosphorus		Zinc		Zinc		Chloride		Ammonia-nitrogen		Nitrate plus nitrite	
		Total recoverable (mg/L)	Absolute RPD (%)	Dissolved (µg/L)	Absolute RPD (%)	Total recoverable (µg/L)	Absolute RPD (%)	Dissolved (mg/L)	Absolute RPD (%)	Flow injection (mg/L)	Absolute RPD (%)	Dissolved (mg/L)	Absolute RPD (%)
45R	09/13/2003	0.274	18	4.5	2	30	25	1.802	3	0.37	3	0.236	1
45	09/13/2003	.233		4.6		24		1.743		.38		.233	
48R	09/13/2003	.26	4	2.2	**75**	72	33	1.744	1	.27	7	.145	2
48	09/13/2003	.271		8.8		54		1.731		.29		.142	
15R	05/10/2003	.519	4	5.8	**77**	66	6	3.123	2	.43	0	.336	1
15	05/10/2003	.501		25		62		3.061		.43		.338	
55	03/25/2004	.356	8	12	45	74	4	12.3	**184**	.25	29	.438	**87**
55R	03/25/2004	.388		8.3		77		4.33		.352		.234	
58	03/25/2004	.75	16	6.1	9	158	3	4.26	1	.374	4	.232	3
58R	03/25/2004	.645		5.6		154		4.23		.359		.226	
33	04/20/2004	.452	27	12	8	54	19	2.637	2	.538	10	.373	1
33R	04/20/2004	.622		13		67		2.686		.601		.376	
88	05/06/2005	.831	1	8.6	8	99	1	3.06	1	1.08	0	.635	3
88R	05/06/2005	.840		8.0		98		3.08		1.08		.652	
91	05/06/2005	.659	3	11	21	114	3	3.04	1	1.09	0	.652	0
91R	05/06/2005	.680		14		117		3.01		1.09		.650	
62	05/06/2005	.879	1	7.8	8	122	1	2.94	1	1.22	0	.738	3
62R	05/06/2005	.891		7.2		123		2.96		1.22		.719	
107	08/23/2006	.306	3	3.2	0	28	7	1.916	1	.634	0	.405	1
107R	08/23/2006	.315		3.2		30		1.906		.633		.401	
99	04/29/2006	.644	**72**	28	8	64	**58**	2.330	1	.654	6	.536	4
99R	04/29/2006	2.30		26		151		2.296		.698		.517	

Appendix 2. Quality assurance and quality control—Continued.

Appendix table 2-2. Results of replicate-sample analyses—Continued.

[mm/dd/yyyy, month/day/year; µg/L, microgram per liter; mg/L, milligram per liter; RPD, relative percent difference; %, percent; --, not applicable; values in **bold** indicate exceedance of allowable error]

Sample ID	Date (mm/dd/yyyy)	Orthophosphorus		Total dissolved solids		Suspended sediment	
		Flow injection, dissolved (mg/L)	Absolute RPD (%)	(mg/L)	Absolute RPD (%)	(mg/L)	Absolute RPD (%)
45R	09/13/2003	0.07	0	44	10	1027	9
45	09/13/2003	.07		40		940	
48R	09/13/2003	.08	0	40	9	472	10
48	09/13/2003	.08		44		428	
15R	05/10/2003	.11	0	64	7	455	40
15	05/10/2003	.11		60		325	
55	03/25/2004	.14	**300**	106	**54**	204	**75**
55R	03/25/2004	.035		69		811	
58	03/25/2004	.034	29	72	10	1767	29
58R	03/25/2004	.048		80		1369	
33	04/20/2004	.17	5	58	4	147	22
33R	04/20/2004	.162		56		188	
88	05/06/2005	.042	11	56	7	255	1
88R	05/06/2005	.038		60		252	
91	05/06/2005	<.025	--	60	11	222	0
91R	05/06/2005	<.025		54		223	
62	05/06/2005	.065	2	58	7	327	1
62R	05/06/2005	.066		54		323	
107	08/23/2006	.13	2	58	**61**	148	6
107R	08/23/2006	.132		36		158	
99	04/29/2006	.180	3	76	0	125	9
99R	04/29/2006	.174		76		138	

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