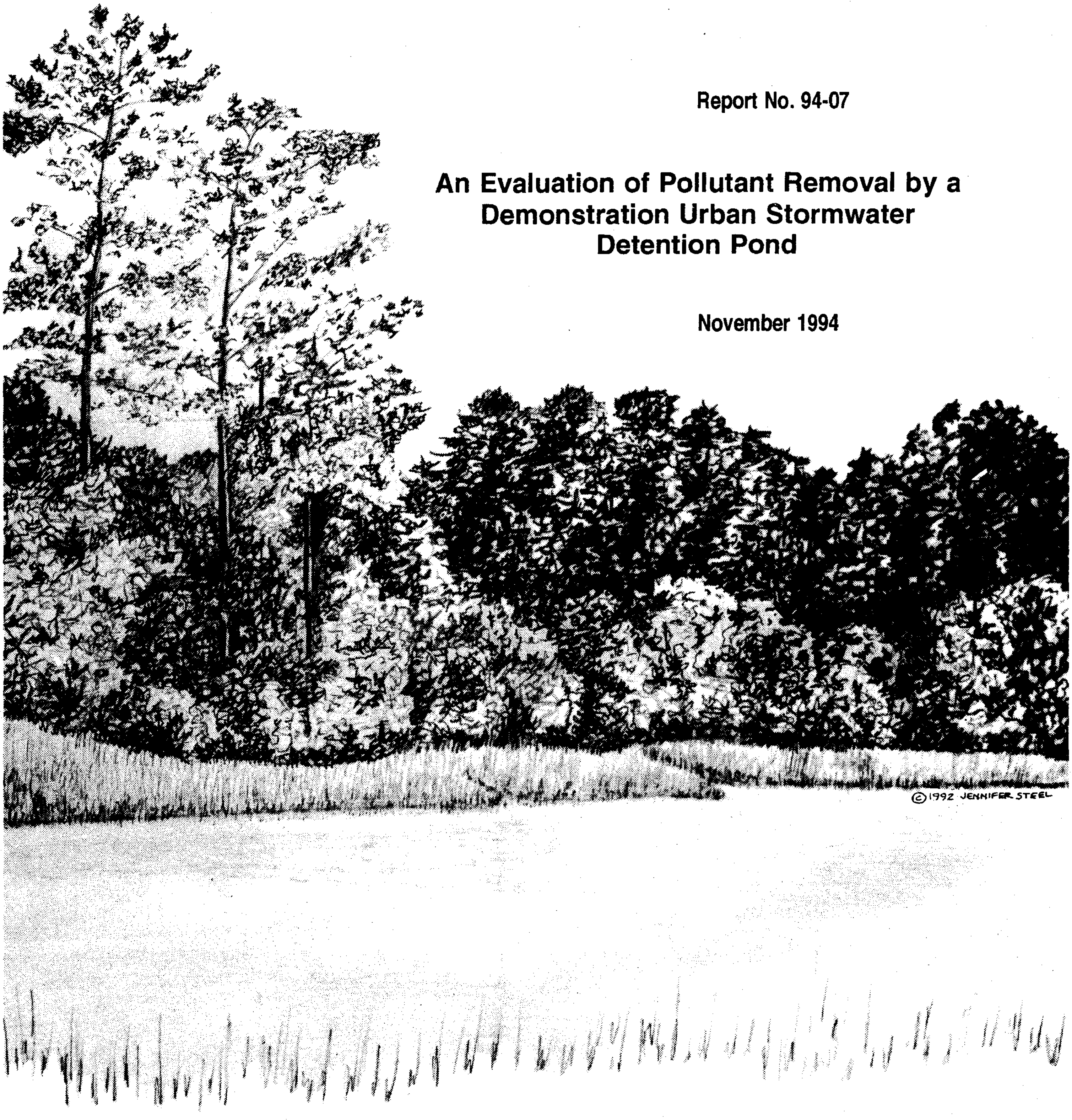
Report No. 94-07

An Evaluation of Pollutant Removal by a Demonstration Urban Stormwater Detention Pond

November 1994



ALBEMARLE-PAMLICO ESTUARINE STUDY

NC Department of
Environment, Health,
and Natural Resources

Environmental
Protection Agency
National Estuary Program

An Evaluation of Pollutant Removal by a Demonstration Urban Stormwater Detention Pond

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Summary

- **Construction of a demonstration urban stormwater detention pond in Greenville, NC in 1992 led to this study, the goal of which was to assess the effectiveness of the pond in removing urban runoff pollutants.** Specific project objectives were:
  - To perform a detailed analysis to quantify land use and other pertinent features of the detention pond drainage area.
  - To quantify the inflow and outflow hydrology for the pond and to characterize the quality of runoff from its watershed.
  - To perform settling column tests to measure the times required for maximum settling of runoff pollutants.
  - To measure the stormwater detention pond removal efficiencies for total suspended solids, nitrogen, phosphorus, organic carbon and selected metals.

- **The normally dry detention pond can hold, for up to 72 hours, the first 1.3 cm (0.5 in) of runoff from its 81-ha (200-acre) watershed.** Excess runoff from large storms bypasses the pond, flowing over a spillway near the inlet, while water detained in the pond flows out through a perforated riser.

- **The predominant land use in the pond watershed is residential (90%).** The remainder is commercial, mostly retail businesses along one major highway. The watershed is 31% impervious. Runoff is collected by a system of storm sewers which coalesce to form one inlet to the pond. There are no combined (sanitary and stormwater) sewers or any known leaking sanitary sewers contributing to the runoff.

- **The study included eight storms encompassing a wide variety of rainfall amounts and antecedent conditions.** Rainfall amounts varied from 1.2 cm (0.48 in) to 23.6 cm (9.28 in), and storm duration from 7.8 to 115 hr. On average the runoff volume was 29% of the rainfall volume. Three storms were large enough to produce some bypassing of detention (i.e., flow over the pond spillway). Seventy percent of the runoff from the largest storm bypassed the pond.

- **Pollutant concentrations in the runoff from this site are comparable to those for most other sites with similar land uses.** The median event mean concentration (EMCs, calculated by dividing the total pollutant load in runoff by runoff volume) of total suspended solids (TSS) was 98 mg/l, which is close to the average from a previous nationwide EPA survey (the NURP study). EMCs were 1.0 mg/l for total nitrogen (TN),and 0.35 mg/l for total phosphorus (TP), which are typical. Lead, zinc and other metals concentrations were also within ranges found elsewhere. Fecal coliform levels were widely variable, but highest during warm weather. BOD_5 was modest, averaging about 5 mg/l.

- **Results from four laboratory experiments indicated that after 3 days settling in a quiescent environment the maximum removals of pollutants from the runoff were 93% for TSS, and 35-75% for other particle-bound fractions.** As expected, the dissolved fractions settled poorly, but there was evidence for some biological transformation and removal of inorganic nitrogen as a result of ammonification and denitrification. However, these biological reactions are probably not important in the detention pond where mixing maintains better aeration of the water.

- **Detention pond treatment efficiencies (PTEs) were positive for particle-bound pollutants and near zero, or slightly negative, for the dissolved pollutant fractions.** PTE was calculated by comparing the load of pollutant leaving the pond through the perforated riser with the load entering the pond (minus spillway bypass). Median PTEs were 71% for TSS, about 45% for particulate organic carbon (POC) and particulate nitrogen (PN), 33% for particulate phosphorus (PP), and 26-55% for metals. Dissolved pollutant loads leaving the pond were about the same as the runoff loads, except for phosphate phosphorus (PO_4-P), which had an average PTE of about 25%. Median PTEs for dissolved nitrogen and carbon were small or slightly negative. Calculation of treatment efficiencies for BOD_5 and fecal coliforms was not possible, but there did appear to be small reductions in both resulting from detention. Differences between PTEs and storm treatment efficiencies (STEs), which take into account pond bypassing that occurs in large storms, were roughly proportional to the volumes of runoff that bypassed detention. Measured efficiencies for other dry detention ponds vary widely, but overall it appears that the Greenville pond is typical.

- **The impact of runoff treatment on Tar River water quality was estimated by comparing pollutant concentrations in untreated and treated runoff with concentrations in the river water, and with concentrations permitted by regulatory agencies.** The comparison showed that detention treatment reduces TSS to about the same level as river TSS. Concentrations of inorganic nutrient forms were not much affected by treatment, but they are no higher in untreated runoff than in the Tar River. Except for copper and zinc, the runoff metals concentrations did not exceed North Carolina state standards for freshwaters. Treatment brought the copper levels below the standard, but treated effluent zinc levels were still about two times the standard. There are no comparable Tar River metals data available. The stormwater BOD_5 was about the same as Tar River values and the State standard. Fecal coliforms in both the treated and untreated runoff were much higher than the State standard.

- **Calculations showed that total nutrient loading to the Tar River cannot be significantly reduced by urban runoff detention treatment, for two reasons.** One is that urban runoff contributes a minor part (1-4%) of the total nitrogen and phosphorus loading to the system. The second reason is that detention causes no significant removal of the dissolved inorganic nutrient fractions and only partial removal of the particulate forms.

- **Sediment accumulation is not likely to be a maintenance issue for the Greenville detention pond for many years, but other problems may develop.** Based on the rate of TSS removal by the pond, only 0.16% of the pond storage volume will be lost per year. However, the accumulated sediments may contain concentrations of metals that will cause them to be classified as hazardous wastes. A recent inspection of the site suggested that trash accumulation in the pond, accelerated by the growth of dense woody vegetation, may reduce the storage volume much more rapidly than sedimentation. It is difficult to predict how the pond's performance will be affected by these changes.

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INTRODUCTION

Urban Runoff: An Emerging Water Pollution Issue for the 1990s

The 1972 amendments to the Clean Water Act focused on controlling point source pollutants. In 1973 the Environmental Protection Agency (EPA) acknowledged that stormwater discharges fall within the Clean Water Act definition of point source. However, EPA exempted many stormwater discharges from NPDES (National Pollutant Discharge Elimination System) requirements, arguing that there were simply too many outfalls to regulate. Instead, the NPDES program focused almost entirely on the goal of reducing pollutants from municipal sanitary sewage and industrial wastewaters. Many engineers, the public, and most environmental lawmakers also dealt with stormwater runoff as though it were a lesser priority.

However, during the past decade priorities have changed considerably, partly as a result of the Nationwide Urban Runoff Program (NURP), an EPA study conducted in the early 1980s. It had been known for decades that rainfall draining off urban surfaces picks up suspended sediments and a multitude of pollutants, including oxygen-demanding substances, heavy metals, toxic organic compounds, oil and grease, bacteria, and nutrients -- and usually discharges the pollutants directly into receiving waters. The NURP study was the first large-scale effort to quantify the pollutant loads and evaluate various control measures. Today, according to EPA, urban runoff is the second most important source of water quality impairment to lakes and estuaries (U.S. EPA 1994). Studies by the Natural Resources Defense Council showed that urban runoff to streams and estuaries that are close to urban centers rivals, and in some cases surpass, loadings from factories and sewage plants (Adler et al. 1993; Cohn-Lee and Cameron 1992).

In the 1987 Clean Water Act Amendments, Congress recognized the importance of contaminated stormwater runoff by mandating new permitting controls and deadlines under the existing NPDES. Three years later EPA released final stormwater discharge rules that set in motion a complex two-part permit application process. More than 200 cities and counties with populations of 100,000 or more -- as well as about 100,000 industrial dischargers -- were required to complete a Part I application identifying pollution sources, pollutants, and impacted waterways. Part II will require cities to develop comprehensive management plans that must include a runoff quality monitoring program, an analysis of the types of controls needed, and a plan to pay for all of this. The original deadline for completing this process was May 1993.

Types of Controls Available

There are two basic controls of pollution in urban runoff. The first is source reduction, which prevents the pollutants from ever coming in contact with rainwater or runoff. When it is cost effective, source reduction is the better approach because the pollutants never get into the runoff and therefore never enter receiving waters. Source reduction practices include land-use regulations and restrictions, street sweeping, prevention and containment of spills, minimization of chemical applications, erosion control, and mitigation of illicit connections and illegal dumping. Most source reductions are useful in existing as well as in new developments.

The second type of control removes pollution from urban runoff by either reducing the amount of runoff or providing some type of treatment. Controls that reduce the amount of runoff include reducing impervious areas and increasing infiltration. Treatment controls include sedimentation and biological removal. Typical structures used to provide the treatment are grassy swales, buffer strips, infiltration devices, detention basins -- either "wet" or "dry," -- and artificial wetlands. The primary removal mechanism for pollutants in a dry detention pond is sedimentation. Wet detention, on the other hand, involves a pond that retains water permanently, so there is time for rapid sedimentation and slower biological processing to remove pollutants. Dry detention basins are one of the most common structural controls used in the United States (National Research Council 1993). They are dry except for a period ranging from hours to several days following the storm. They capture all the runoff from small storms but, depending on their size, only part of larger storms. They then release it slowly, usually through a perforated pipe incorporated in the outlet structure.

Generally, if total suspended sediment (TSS) removal in a detention basin is good, removal of other pollutants that bind to particles is good also. However, this rule of thumb does not hold true for phosphorus, nitrogen, and some other pollutants because significant fractions of them are not associated with particles. Evidence of this difference comes from laboratory settling column studies, which have shown that typical removals after 48 hr detention are 80-90% for TSS and 75% for lead, but only 20-30% for TN and TP, and 20-40% for BOD_5 (Schueler 1987; Whipple and Hunter 1981; Hartigan 1989). Although dry detention is widespread, there are only a few field studies that have quantified pollutant trapping efficiencies of operating dry detention basins (MWCOG 1983; OWML 1987; Pope and Hess 1988). A brief overview of the research literature concerning urban runoff is in Appendix B.

North Carolina Efforts

Controlling stormwater pollution in coastal North Carolina has become an important issue during recent years. The initial debate and regulations focused on impacts on estuarine shellfish waters. In 1986 the North Carolina Environmental Management Commission (EMC) required future developments within 175 m (575 feet) of shellfish waters to control stormwater. Developers could meet the requirement by either limiting density or controlling runoff from all storms smaller than 11.4 cm (4.5 in) within a 24-hr period. Effective 1 January 1988, these rules were replaced by new ones that extended protection from shellfish waters to coastal waters in general in all 20 CAMA

(Coastal Area Management Act) counties. Also, the new rules addressed the type and sizing of stormwater control structures. They prohibited detention ponds near shellfish waters, and stipulated that ponds be sized for 85% TSS removal. The new regulations were claimed to be among the most stringent in the nation (N.C. DEM 1988).

Despite this interest in controlling stormwater pollution in coastal North Carolina, no one has investigated the effectiveness of various control strategies in this region. Most previous studies were in the Piedmont, and most of these addressed the magnitude of the stormwater runoff problem rather than possible solutions (Bryan 1970; Colston 1974; TJRCOG 1976). A Nationwide Urban Runoff Program (NURP) study in Winston-Salem in the early 1980s determined that pollutant concentration in street solids is high and that street sweeping is not an effective BMP (N.C. DEM 1983). More recently, in the first study of wet detention pond effectiveness in North Carolina, Wu (1989) evaluated three basins in the City of Charlotte. He found that they significantly reduced some forms of urban runoff pollution, but cautioned that the results might not be applicable to other regions of the state.

The APES Stormwater Control Demonstration Project

In October 1989 the Albemarle-Pamlico Estuarine Study (APES) awarded a $150,000 grant to the City of Greenville, NC for a project entitled *Urban BMPs: A Stormwater Control Demonstration Project*. The project involved constructing a 0.7-ha (1.75-acre) extended dry detention pond on a 1.4-ha (3.5-acre) site that is adjacent to the Tar River and is off West Third Street, just west of Memorial Drive (U.S. 13). Groundbreaking on the project took place in late June 1991, and the City completed the construction about five months later in November 1991. Details of the project design, construction, and hydrologic characteristics are in the City of Greenville's report to APES prepared by Belk et al. (1992).

The detention pond depths range from 2.3 m (7.5 ft) in the northernmost corner to 3.3 m (11.0 ft) at the outlet structure. The bottom of the basin has an average slope towards the outlet of 1.25%. The pond's design specified that it be able to capture runoff from the first 1.3 cm (0.5 in) of rainfall on the 81-ha (200-acre) watershed and discharge it at a peak rate of 0.07 m^3/s (2.6 cfs). Runoff volume exceeding 1.3 cm (0.5 in) flows over a 13.7 m (45 ft) long trapezoidal concrete spillway. Storage capacity of the pond at the spillway elevation is 9,566 m^3 (338,026 ft^3). The maximum time for the pond to draw down after a storm event sufficient to fill it to spillway level is 74.75 hr (Belk et al. 1992).

The inlet structure for the basin consists of a 1.52 m (60 in) diameter reinforced concrete pipe with a flared end section and a 6 m (20 ft) rip-rap apron. The outlet is a perforated riser that is 1.2 m (4 ft) tall by 76 cm (30 in) in diameter. It is connected to a 61 cm (24 in) diameter horizontal barrel with a 15 cm (6 in) diameter orifice plate attached. The riser is constructed of corrugated metal pipe with 2.5 cm (1 in) diameter orifices. It has a trash rack, which quickly proved to be inadequate due to the unexpected large quantities of trash that began to enter the pond soon after it was completed. A secondary trash screen, built shortly after the study began, solved this problem. It was a length of 1.3 cm (0.5 in) mesh galvanized wire stretched from shore to shore across the corner of the pond about 1.8 m (6 ft) in front of the riser structure. This addition, along with occasional cleaning of the riser trash rack, did prevent clogging of the riser orifices. The pond has a hand operated emergency sluice gate which, if opened, will drain the pond in approximately fifteen hours. The banks and bottom of the pond are grassed and are mowed twice monthly from May through October (Belk et al. 1992).

The 81ha (200 acre) project drainage area is completely developed for urban uses. The 1990 population within the drainage area was about 2,200. Medium density residential uses predominate, with single family and duplex dwellings on lots ranging in size from 372-743 m^2 (4,000- 8,000 ft^2). In 1990, about 22,000 vehicles per day traveled on Memorial Drive (U.S. 13), a major north-south route traversing the drainage area. A variety of highway commercial uses have developed along this corridor, along with office and institutional uses.

The Goals of This Study

At about the same time Greenville submitted its construction and maintenance proposal, two companion proposals were submitted to the APES by myself and by Jared D. Bales of the U.S. Geological Survey (USGS). The overall goal of my proposed study was to determine the effectiveness of the new detention pond in removing pollutants from the urban runoff. Doing this required monitoring stormwater flows into and out of the pond, which the USGS proposed to do. Both of these study proposals were approved.

The specific objectives of this study were:

- To perform a detailed analysis to quantify land use and other pertinent features of the detention pond drainage area.
- To quantify the inflow and outflow hydrology for the pond and to characterize the quality of runoff from its watershed.
- To perform settling column tests to measure the times required for maximum settling of runoff pollutants.
- To measure the stormwater detention pond removal efficiencies for total suspended solids, nitrogen, phosphorus, organic carbon and selected metals.

Total suspended solids (TSS) is perhaps the most commonly monitored constituent of stormwater runoff. TSS is important both directly -- causing interference with sunlight penetration, increasing turbidity, and siltation of fish spawning beds -- and indirectly, as a transport mechanism for adsorbed materials including metals, nutrients, decomposable organics, and bacteria. Nutrients (N and P) are a special concern in the Tar-Pamlico watershed. The State has designated the river "Nutrient-Sensitive," and is emphasizing control of N and P loading to the river from all sources.

Trace metals have a special affinity for transport in runoff by suspended sediments and once they reach the receiving waters are often passed through food chains in increasing concentrations (bioaccumulation). Of particular interest are cadmium, chromium, copper, lead, nickel, and zinc. Three of these -- copper, lead, and zinc -- were the most frequently detected metals in the NURP study, and they were determined to be among the most important pollutants in urban runoff (U.S. EPA 1983).

The primary interest in analyzing for organic fractions is to quantify the potential for microbial respiration in the runoff water to deplete the receiving waters of dissolved oxygen. However, the choice of the appropriate indicator is problematic, because there are advantages and disadvantages to each of the commonly used measures (Wullschleger et al. 1976). Biological oxygen demand (BOD) is the most commonly used indicator, but dissolved and particulate organic carbon (DOC and POC) are also frequently measured.

Pathogenic organisms present in urban runoff are of numerous types that are difficult to isolate. Consequently, the coliform organism that is more numerous and more easily tested for is usually used as an indicator organism. Fecal coliform is that portion of the total coliform associated with the feces of warm-blooded animals (Alley 1977).

Detention basin trapping efficiencies depend, in part, on the inherent settleability of the particulate pollutant concerned. Therefore, conclusions drawn at one site will only be transferable to another site if the settleability characteristics of the pollutants reaching the two sites are similar. Also, data from settling column experiments have not supported the assumption that pollutants will settle out in amounts proportionate to their respective particulate concentrations (Whipple and Hunter 1981; Randall et al. 1982).

METHODS

Detention Pond Watershed Characteristics

Most of the information characterizing the watershed was derived from a detailed map obtained from the City of Greenville. The City Engineering and Inspections Department prepared this map, with a scale of 1 cm = 12 m (1 in = 100 ft), from aerial photographs. It depicts to scale the outlines of streets, sidewalks, and all buildings within the detention pond watershed boundaries. It also shows elevation contours at 0.6 m (2 ft) intervals, and the locations of storm drainage lines. Two land uses predominate in the drainage area; they are medium density residential and commercial. Areas (m^2) covered by buildings, paved streets, highways, sidewalks, and driveways were tallied for the two land use categories by measuring dimensions on the scaled map. Ground truthing was used to check the accuracy of the map and to update it for the Memorial Drive area where some commercial buildings were constructed recently. Information on population, income, and housing values and age came from a computerized data base maintained by the City of Greenville and derived from 1990 U.S. Census data.

Detention Pond Efficiency

The field study included eight storm events that occurred in the period 25 February - 17 August 1992. Two automated water samplers (ISCO Model 2700) equipped with water-level actuators collected stormwater samples at the detention pond inflow and outflow structures. The ISCOs were programmed to take pond inlet samples at 15-min intervals for the first 2 hr and at hourly intervals thereafter. The ISCO located at the outlet acquired samples at hourly intervals. Retrieval of the water samples within 12 hr after collection minimized chemical and biological changes. They were transported to the Central Environmental Laboratory in the Biology Department at East Carolina University, subdivided and prepared for the analyses described below. Culling some samples was necessary to keep analytical costs within budget. The criterion used was the rate of change in the TSS concentrations. Every other sample was discarded when the TSS changes were small.

Total suspended solids (TSS) were determined by filtration and gravimetric analysis. A well-mixed ISCO subsample was filtered through a glass fiber filter (Whatman 934-AH), and the residue retained on the filter was dried to constant weight at 105°C. The technique is described in detail in U.S. EPA (1979) as Method 160.2 and in APHA (1985) as Method 208D.

Four nitrogen fractions, three phosphorus fractions, and two organic carbon fractions were measured. The N and P analyses followed standard colorimetric methods adapted for use on an Orion Scientific Instruments Corporation Autoanalyzer

(U.S. EPA 1979; APHA 1985). Nitrogen fractions analyzed were nitrate (NO_3-N), ammonia (NH_4-N), particulate nitrogen, and dissolved Kjeldahl nitrogen. The phosphorus fractions analyzed were particulate (PP), total dissolved (TDP), and orthophosphate (PO_4-P). All N and P analyses were performed in the ECU Biology Department Central Environmental Laboratory. Total and dissolved organic carbon analyses involved converting the organic carbon to CO_2 by wet combustion (persulfate), followed by analysis of the CO_2 in an infrared analyzer (Oceanography International Model 524C). The procedure is modified slightly from those described in APHA (1985) and U.S. EPA (1979). All the particulate and dissolved N, P, and C fractions were separated by filtration through Whatman 934-AH filters.

John T. Bray supervised the metals analyses in his laboratory at the East Carolina University School of Medicine. The procedures followed closely EPA Method 200.7 (Inductively Coupled Plasma-Atomic Emission Spectrometric Method for Trace Element Analysis of Water and Wastes) using a simultaneous reading spectrometer. The principal difference between the procedure for aqueous samples followed in Bray's laboratory and Method 200.7 is that the analytical wavelengths available on Bray's instrument for several of the elements were different from Method 200.7. However, interelement interference and corrections on these lines have been determined in the same manner as described in Method 200.7. Both unfiltered and filtered samples were analyzed, but concentrations in the filtered samples were often below the limits of detection, indicating that most of the metals are associated with particles. Therefore, only values for the unfiltered samples, representing total metals concentrations, are included in this report.

B. Kane of the East Carolina University School of Allied Health trained project personnel to make biological oxygen demand (BOD_5) analyses using the technique described in APHA (1985) Method 507. Nitrification inhibitor was not added to the samples, which were incubated for five days at 20°C. Initial and final dissolved oxygen values were determined by the Winkler method. Kane's laboratory was also the location for fecal coliform bacteria determinations, made using the multiple tube, MPN procedure with A-1 medium, as described in APHA (1985) Method 908C. Varying concentrations of suspended solids and interfering substances expected in stormwaters affect results of this method less than they affect those from the popular membrane filter techniques. The multiple tube technique is also less subject to interfering bacterial growths or problems in estimation of confluent colony counts. This is especially important in analysis of temporal phenomena where repeat sampling is not possible. All recommended quality checks were followed.

The U.S. Geological Survey study provided inflow and outflow information for the detention pond. Under the direction of Jared D. Bales of the USGS, the City of Greenville constructed just downstream from the detention pond a small concrete-dammed pool fitted with a V-notch weir. A water level recorder was placed in the weir pool and another was located in the detention pond near the outlet. Using 2-min interval stage height readings accumulated by electronic data loggers at these two locations, USGS was able to compute 1) stormwater flow into the detention pond , 2) discharge from the pond through the perforated riser outlet, and 3) bypass flow over the spillway when the pond filled. Finally, a tipping bucket rain gage measured the rainfall rate during each storm. The instrument was a Weathermeasure Model 6010 gage with a 0.25 mm (0.01 in) sensitivity connected to a Stevens Model 6113 event recorder

For each pollutant two treatment efficiencies were determined. The first is "pond treatment efficiency" (PTE), which is the percentage of contaminant load removed from the runoff that is actually detained in the pond.

$$PTE = [((LI - SP) - PR) \times (100)] / [LI - SP],$$

where LI is the total runoff load, SP is the runoff load that bypassed treatment via discharge over the spillway, and PR is the treated load discharged through the perforated riser. The "storm treatment efficiency" (STE) is a measure of the percentage of contaminant load removed from the runoff, regardless of whether it was detained in the pond or bypassed the pond via the spillway. The STE is computed as:

$$STE = [(LI - (PR + SP)) \times (100)] / [LI].$$

Note that PTE and STE differ from one another only for storms large enough to produce spillway bypassing. In those cases, STE will be smaller than PTE.

Storm pollutant loads (kg) entering and leaving the pond were estimated by summing 2-min incremental loadings which were the products of flows (m^3/sec) and concentrations (mg/l). The flow readings were more frequent than the concentration measurements; hence linear interpolation was done to provide the missing concentrations. Losses over the spillway were based on pollutant concentrations measured at the pond inlet, since it was assumed that these losses represented a short-circuiting of the treatment process. All loading computations were made using an Excel Version 5.0 spreadsheet.

Settling Column Tests

There were four laboratory settling column experiments, using runoff water from storm events on 4 December 1991, and 19 May, 4 August, and 12 August 1992. Grab samples were collected manually at the pond inlet structure approximately when runoff peaked because this was when TSS concentrations were expected to be greatest. In the laboratory, the samples sat long enough to temperature equilibrate to 21°C before being mixed thoroughly and poured into the settling column. The column was a 30.5 cm (12 in) diameter by 142 cm (56 in) tall section of plastic pipe, closed at the bottom and open at the top. Sampling ports were built into the column at 15 cm (6 in) depth intervals. The fill line was 15 cm (6 in) above the top port, so that at the beginning of an experiment, the column water depth was 1.4 m (4.5 ft).

The procedure involved monitoring pollutant concentrations in sequential samples drawn from 0.5 ft., 2 ft, and 3.5 ft above the bottom on the column. Samplings were made at 0, 1, 3, 6, 9, 12, 24, 48, and 72 hr, except in the first test, which ended after 48 hr. Pollutants in these samples were analyzed using the same methods described above. Results for the three depths were averaged for each sampling time, and the averages were compared to the initial concentration to give a measure of removal by sedimentation and other processes in a 4-ft column of the stormwater.

RESULTS AND DISCUSSION

Detention Pond Watershed Characteristics

The detention pond is 2 miles west of downtown Greenville, NC near the western limit of the city, and just northwest of the intersection of Third Street and Memorial Drive (U.S. 13). The moderately-sloped watershed encompasses 81 ha (200 acres) with a resident population of approximately 2,213 people (1990 census). Ninety-three percent of the watershed is medium density single family and low-income multi-family residential, and the remainder is commercial (Table 1). Almost 13 km (8 miles) of streets criss-cross the watershed and it is bisected by one small, narrow commercial corridor along Memorial Drive. Businesses in this corridor include fast-food restaurants, convenience-gas markets, offices, and several industrial supply companies.

TABLE 1. *Characteristics of the Greenville detention pond watershed. Population, buildings, and households data are from the 1990 census.*

Characteristic	Land Use Category		
	Residential	Commercial	Total
Land Areas (hectares)			
Total	75.0	6.0	81.0
Pervious	53.7	2.1	55.8
Impervious	21.4	3.8	25.2
Roofs	8.9	0.8	9.6
Driveways	0.9	0.1	0.9
Sidewalks	0.2	0.0	0.2
Streets	11.5	1.1	12.6
Parking Lots	0.0	1.8	1.8
Buildings			
Commercial		16	
Median size (sq. m)		2,912	
Residential	585		
Median size (sq. m)	1,114		
Median year built	1958		
Median value ($)	$36,700		
Population	2,213		
Households	889		
Household income ($)	$10,800		
Street length (km)	11.7	0.9	12.7
Storm sewer (km)			4.1

Counting streets and roads, paved parking areas, driveways, sidewalks, and roofs, the total impervious area is 25 ha (31% of the watershed). Sixteen hectares (65% of the total impervious area) constitute the "effective" impervious area, which means that it drains to other impervious areas or directly to the storm sewer system. The remainder drains onto pervious areas such as lawns. The residential area is 28% impervious, whereas the commercial area is 64% impervious. The detention pond, located in the northwest corner of the watershed, is fed by about 4.1 km (14,000 ft) of storm sewer piping which converges to form one large inlet to the pond. Stormwater from this sewer system and direct precipitation onto the pond surface are the only known sources of water for the pond. Neither combined sewers nor any known leaking sanitary sewers contribute to the stormwater flow.

Storm Characteristics and Detention Pond Hydrology

The precipitation regime of the Greenville, NC area is characterized by intense, short duration thunderstorms during the summer and general frontal, longer duration storms during the winter and early spring. The long-term average precipitation is 122 cm (48 in) per year deposited by approximately 60 precipitation events, if the minimum dry time between storms is taken to be 8 hr (Shelly 1986). So, on average the precipitation events are about 6 days apart. Also, it has been estimated that for any given week of the year there is about a 50% chance for Greenville to receive >1.3 cm (>.5 in) of precipitation, between 25% and 45% chance for more than 2.5 cm (1 in), and 10-25% chance for more than 5.1 cm (2 in) (Imhoff and Davis 1983). The largest storms tend to occur in summer, and the smallest during the fall.

Although parts of the data for January and November 1992 are missing, the precipitation patterns for the study year appear similar to the long-term averages. Estimated total precipitation for the year was 119 cm (47 in), and there were at least 50 precipitation events (Appendix C). The most notable departure from the norm occurred in the July-August period. July precipitation was only a little more than one-half the average, whereas August was an unusually wet month, with a total rainfall over 33 cm (13 in). Much of the excess rain fell during an extended storm between 12 August and 18 August.

The eight storms monitored during this study encompassed a wide variety of rainfall characteristics and antecedent conditions (Table 2). On several occasions, an initial precipitation event produced runoff that begun to fill the previously dry pond. The precipitation stopped, but began again one or more times before all the runoff from the earlier events had drained from the pond (see Appendix D). In these situations, all the precipitation that fell until the pond finally drained constituted a single "storm". Total storm rainfalls ranged from 1.2 cm (0.48 in) for storm 5 to 23.6 cm (9.28 in) during storm 8. Duration of rainfall (continuous or intermittent) ranged between 7.8 hr and 115 hr (storms 2 and 8, respectively). In some cases, most of the rain fell during short time periods with intervening periods of several hours

Table 2. Rainfall characteristics and antecedent conditions for the monitored storms, 1992.

Storm no.	Date began	Total rainfall (inches)	Rainfall duration (hours)	No. dry days preceeding storm	Rainfall (inches)		No. days since last rainfall of			Maximum rainfall intensity (inches)		
					3 days prior to storm	14 days prior to storm	0.2-0.5 in.	0.6-1 in.	>1 in.	15-min.	1-hour	4-hour
1	25-Feb	1.21	26.0	0	0.20	0.80	10	>19	>19	0.10	0.25	0.30
2	23-Mar	0.60	7.8	3	0.00	0.60	17	4	>50	0.08	0.20	0.36
3	26-Mar	1.40	12.8	2	0.50	1.10	3	7	>53	0.09	0.34	0.68
4	21-Apr	1.98	11.5	16	0.00	0.00	29	17	26	0.45	0.85	1.08
5	7-May	0.48	35.5	7	0.00	0.10	46	50	16	0.09	0.16	0.22
6	26-May	0.54	21.0	5	0.00	0.50	8	69	35	0.37	0.41	0.44
7	21-Jun	0.64	6.3	4	0.00	1.40	23	95	12	0.42	0.45	0.45
8	12-Aug	9.28	115.0	4	0.00	0.70	6	38	24	0.55	1.27	1.44

without rainfall. Only storm 4, which occurred in April, had an extended antecedent dry period (17 days). The most intense storm (storm 8) produced the largest volume of rainfall, but there were also storms with intense 15-min downpours that produced only moderate total volumes (storms 6 and 7).

Figure 1 illustrates the rainfall-runoff pattern for storm 7 on 21 June that involved only one burst of heavy shower activity. This storm occurred about two weeks following the last significant rainfall, although there had been a brief 0.25 cm (0.1 in) shower five days before. The 21 June storm was brief, but intense, with 1.1 cm (0.42 in) falling in a 15-min period. Flow in the storm sewers responded rapidly to this downpour, peaking at the pond inlet about 20 min after the rain began. By then the rainfall had ceased, and the stormwater flow decreased rapidly also, so that within an hour almost all the runoff from this shower had reached the pond.

The 25 February event (storm 1) was more typical of the storms monitored in this study, in that it included 5 storm cells that passed through the basin in succession (Figure 2). Each of these cells produced about 0.6 cm (0.25 in) of rain falling at moderate intensity -- approximately 0.6 cm (0.25 in) per hour. The first rain began around 7:00 a.m. and lasted until about 8:00 a.m., but runoff did not begin to reach the pond until around 8 a.m. Runoff peaked at 8:45 a.m., and had ceased by 1:00 p.m. Rainfall began again at 5:00 p.m. and between then and 10:00 p.m. there were three showers, each lasting about an hour. In each case, runoff began to reach the pond 30-60 min after the rain began, and there were three runoff peaks. The final rains in this storm event fell early the following morning around 3:00 a.m. For this

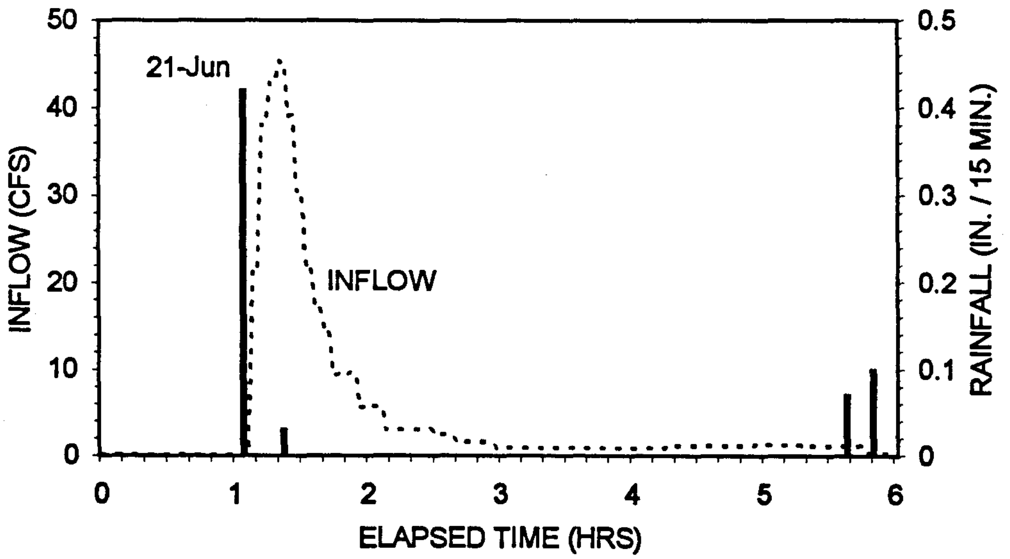


FIGURE 1. Rainfall at 15-min intervals (bars) and detention pond inflow (dashed line) during 21 June, 1992 storm.

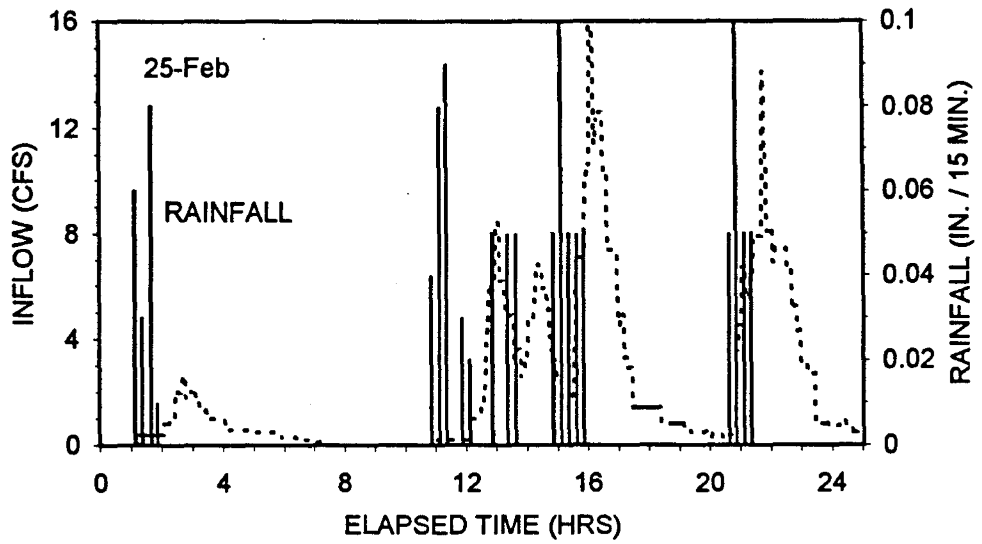


FIGURE 2. Rainfall at 15-min intervals (bars) and detention pond inflow (dashed line) during 25 February, 1992 storm.

final shower, the lag time between start of rainfall and first runoff reaching the pond was only 15 min, suggesting that the earlier showers had saturated the soil.

The runoff volumes from each of the eight monitored storm events were divided by the rainfall volumes to give information on the runoff yield for this watershed (Table 3). The yields, expressed as runoff coefficients, ranged from 0.19 to 0.44 (mean 0.29). A plot of the coefficients against total storm rainfall amounts indicated no relationship between the two, at least for the range of values associated with the eight monitored storms.

Results of previous runoff coefficient studies indicate that runoff-yield, is quite variable from one location to another. For example, the 50 NURP sites had runoff coefficients as low as 0.1 and as high as 0.9. The variability results in part from differences in soils, topography, and cover. However, the primary influence is the degree of watershed imperviousness. Driscoll (1983) and Schueler (1987) concluded from linear regression analyses that for a given site the coefficient could serve as a reliable estimator of runoff volumes, given an initial estimate of rainfall volume. Based on linear regression analyses, these two workers formulated an equation to calculate the runoff coefficient based on imperviousness of the watershed:

$$\text{Runoff Coefficient} = 0.05 + (0.009) \times (\text{Imperviousness}).$$

Table 3. Rainfall (inches), volumes of water entering and leaving the detention pond (cf), and runoff coefficients for each storm monitored in 1992.

Storm no.	Date began	Total rainfall (inches)	Watershed rainfall volume (cf)	Pond Inlet volume (cf)	Pond riser outlet volume (cf)	Pond spillway overflow volume (cf)	Runoff Coefficient
1	25-Feb	1.21	878,460	285,172	275,764	0	0.32
2	23-Mar	0.60	435,600	190,974	189,802	0	0.44
3	26-Mar	1.40	1,016,400	323,471	299,482	23,989	0.32
4	21-Apr	1.98	1,437,480	355,213	310,757	44,456	0.25
5	7-May	0.48	348,480	115,894	106,781	0	0.33
6	26-May	0.54	392,040	74,344	70,732	0	0.19
7	21-Jun	0.64	464,640	96,646	90,041	0	0.21
8	12-Aug	9.28	6,737,280	1,519,736	469,736	1,059,736	0.23
Mean		2.02	1,463,798	370,181			0.29
Median		0.93	671,550	238,073			0.28

Application of this formula to the Greenville detention watershed, which is 31% impervious, gives a predicted runoff coefficient of 0.33 -- close to the mean value based on measurements during the eight monitored storms (0.29).

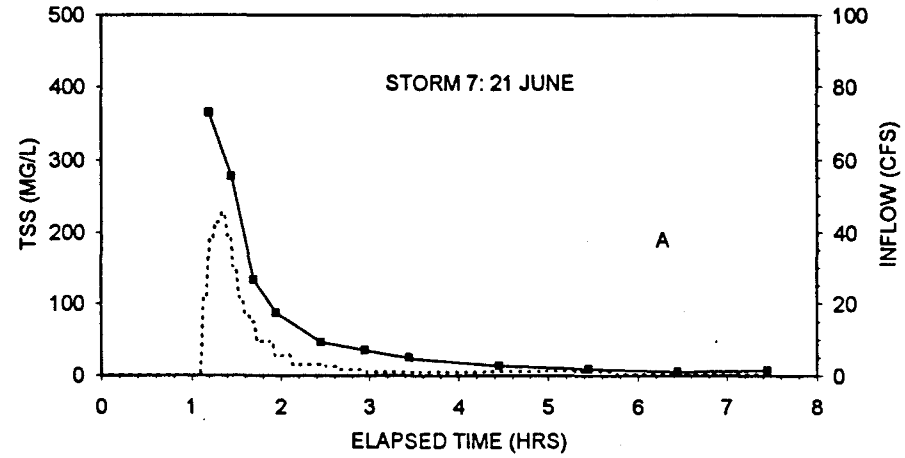
All but one of the monitored storms produced runoff volumes that either did not fill the detention pond, or just slightly exceeded its capacity (Table 3 and Appendix E). Maximum storage for the five storms that did not fill the pond ranged between 18% (7 May) and 62% (25 February), and averaged 34%. During storms three and 4 in late March and April, about 7% and 12%, respectively, of the runoff volume flowed over the spillway. This overflow represents a bypassing of the pond's treatment capability. The exceptional storm in August (storm 8) was long and had periods of relatively intense rainfall, so that 70% of the runoff from that storm went untreated over the pond spillway.

Runoff Quality

Concentration Variation Within Storms

Concentrations of total suspended solids and other pollutants associated with particles varied considerably during each storm. Typically, the concentrations were highest when the runoff rates were highest. For example, in the 21 June storm, TSS in the first inlet sample, taken about 5 min after flow began, was 364 mg/l (Figure

3A). Inlet flow increased rapidly to a peak 15 min later, and then began to fall quickly. The TSS concentrations also decreased rapidly -- to 133 mg/l about 15 min after the flow peak, and to around 50 mg/l within 1 hr after the storm began. Similarly, high flows produced high TSS during all the other storms, including the 25 February storm (Figure 3B). This event began slowly, with a small flow peak and slightly elevated TSS, which gradually decreased as the flow subsided. Nine hours later, there was a more intense shower that produced a temporary 30-fold increase in the TSS level. A third shower 3 hr later also led to a TSS spike, as did the final shower in this storm event. An examination of all the data, which is in Appendix F, shows that runoff rates affected concentrations of other particle-bound pollutants. These include particulate nitrogen, phosphorus, and organic carbon, and to some extent the metals.



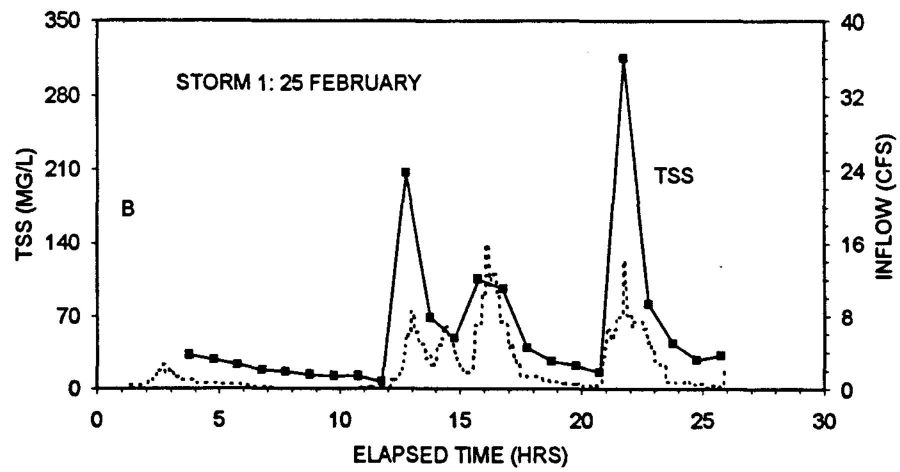


Figure 3. Concentrations of runoff TSS (solid line) in relation to pond inflow (dashed line) during 25 February and 21 June storms.

Concentrations of dissolved pollutants in runoff generally varied less than the particulate form concentrations during a given storm. Sometimes they showed little response to changes in runoff rate. At other times they decreased after the onset of runoff, and remained low for the duration of the storm, regardless of subsequent changes in the inflow. For example, in the 25 February storm NO_3-N decreased slowly from around 0.85 mg/l following the first small runoff peak, and then fell quickly by about 60% when the first major runoff occurred (Figure 4). After the second major inflow peak NO_3-N decreased again, and for the duration of the storm NO_3-N ranged between 0.15 and 0.3 mg/l. The NH_4-N concentrations also decreased by about one-half at the beginning of the first major runoff and did not respond to a later increase in runoff rates.

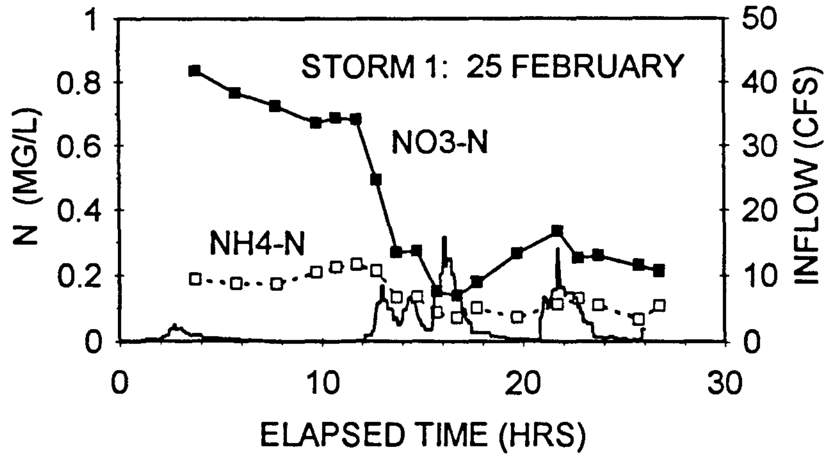


Figure 4. Changes in NH4-N and NO3-N concentrations in runoff coming into pond during storm 1. Line without symbols is inflow (cfs).

Event Mean Concentrations

Runoff event mean concentrations (EMCs), which are sometimes referred to as flow-weighted average concentrations, were computed by dividing the total load of each pollutant in the pond inflow by the total inflow volume. The results for individual storms are in Appendix G and mean, median, and ranges are in Table 4 below. Total suspended solids EMCs averaged 127 mg/l, ranged between 52 and 233 mg/l, and were noticeably higher in the last three storms than in the first five. However, the nutrient particulate fractions did not show this pattern. Particulate nitrogen EMCs were highest in storms 4, 6, and 7, and averaged 0.86 mg/l for all storms. The particulate phosphorus EMCs were not as variable as those for PN and TSS; they ranged from 0.13-0.46 mg/l (mean .25 mg/l) The particulate carbon EMCs were between 3.0

Table 4. Summary of event mean concentration data for eight monitored storms.

Pollutant EMC		Mean	Median	Range	Pollutant EMC		Mean	Median	Range
TSS	In (mg/l)	127	98	52 - 233	PP	In (mg/l)	.25	.19	.13 - .46
	Out (mg/l)	32	28	18 - 65		Out (mg/l)	.15	.13	.06 - .24
	% Reduction	72	73	57 - 83		% Reduction	40	37	30 - 58
POC	In (mg/l)	5.6	4.3	3.0 - 10.3	TDP	In (mg/l)	.16	.17	.04 - .23
	Out (mg/l)	2.9	2.8	1.2 - 5.1		Out (mg/l)	.15	.14	.08 - .25
	% Reduction	44	50	(8) - 72		% Reduction	(8)	6	(120) - 34
DOC	In (mg/l)	13.0	11.5	8.2 - 20.8	PO4	In (mg/l)	.13	.13	.06 - .23
	Out (mg/l)	13.0	11.9	7.8 - 18.9		Out (mg/l)	.10	.08	.05 - .18
	% Reduction	(1)	(3)	(15) - 22		% Reduction	27	26	11 - 46
TN	In (mg/l)	1.38	1.04	.79 - 2.31	CD	In (mg/l)	.002	.001	.000 - .009
	Out (mg/l)	.89	.86	.45 - 1.54		Out (mg/l)	.002	.001	.000 - .005
	% Reduction	32	34	(2) - 60		% Reduction	25	57	(107) - 93
PN	In (mg/l)	.86	.56	.38 - 1.84	CR	In (mg/l)	.011	.005	.003 - .032
	Out (mg/l)	.38	.37	.13 - .67		Out (mg/l)	.006	.002	.002 - .025
	% Reduction	51	49	26 - 79		% Reduction	47	49	18 - 73
DKN	In (mg/l)	.51	.50	.26 - .92	CU	In (mg/l)	.030	.014	.008 - .093
	Out (mg/l)	.51	.47	.22 - .87		Out (mg/l)	.019	.009	.004 - .054
	% Reduction	(1)	1	(61) - 31		% Reduction	36	38	16 - 55
NO3	In (mg/l)	.38	.32	.18 - .69	PB	In (mg/l)	.068	.027	.011 - .220
	Out (mg/l)	.36	.30	.19 - .64		Out (mg/l)	.035	.010	.006 - .131
	% Reduction	4	3	(9) - 21		% Reduction	50	60	6 - 80
NH4	In (mg/l)	.14	.11	.05 - .28	NI	In (mg/l)	.007	.005	.001 - .021
	Out (mg/l)	.12	.10	.06 - .28		Out (mg/l)	.003	.002	.000 - .009
	% Reduction	7	9	(62) - 45		% Reduction	46	41	19 - 90
TP	In (mg/l)	.41	.35	.21 - .64	ZN	In (mg/l)	.340	.163	.092 - 1.12
	Out (mg/l)	.30	.27	.19 - .48		Out (mg/l)	.221	.098	.059 - .612
	% Reduction	24	24	3 - 50		% Reduction	33	32	17 - 54

and 10.3 mg/l, with a mean of 5.6 mg/l. EMCs for all six of the metals analyzed were highest in the two May storms, 5 and 6. For the eight monitored storms the mean EMCs of the metals were as follows: chromium = 0.011 mg/l; copper = 0.029 mg/l; lead = 0.068 mg/l; nickel = 0.007 mg/l; and zinc = 0.340 mg/l. Dissolved nutrient EMCs were highest in storms 2, 5, and 6 (NH_4-N), storms 5,6, and 7 (NO_3-N), storms 6 and 7 (DOC), and storm 7 (PO_4-P). The NH_4-N EMC average was 0.14 mg/l (range 0.07-0.28 mg/l). The other dissolved nitrogen fraction, NO_3-N had a mean EMC of 0.38 mg/l (range 0.18-0.69 mg/l). EMCs for DOC and PO_4-P averaged 13.0 mg/l (range 8.2-20.8 mg/l) and 0.13 mg/l (range 0.06-0.23 mg/l), respectively.

Fecal Coliforms, BOD_5, and COD

There are not enough data for these three variables to justify EMC computations (see Appendix F). Measurements that were made can be summarized as follows:

- Fecal coliform levels in the runoff tended to be highest at the beginning of a storm. For example, the first sample for the 12 August storm contained 1.6 million organisms per 100 ml, but during the remainder of the lengthy runoff period the fecal coliform concentrations did not exceed 50,000/100 ml.

- Fecal coliform numbers also exhibited a seasonal pattern. In March the runoff contained 800-30,000 organisms/100 ml, compared to 70,000-230,000/100 ml in late May and up to 1.6 million/100 ml in August. This trend is probably the result of seasonal temperature change.

- BOD_5 varied between <1 mg/l and 23 mg/l, with a median of 4.9 mg/l. COD was 12-98 mg/l, with a median of 38 mg/l. There were too few data for these parameters to allow examination for trends.

Comparisons With Other Sites

Some studies show that the early part of a storm can deliver a disproportionately large load of pollutants. Presumably this "first flush" is due to the rapid runoff of accumulated pollutants (Kluesener and Lee 1974). However, at most sites studied the pollutant concentration seems to have no relation to the duration of rainfall. The EPA (1983), for example, reported finding from the extensive NURP program no statistically significant negative correlation between event mean concentrations and runoff volumes. Nevertheless, the question of first flush is an important issue since it helps define the volume of runoff that must be captured and treated to remove a given percentage of pollutant from a storm.

It has been suggested that a strong first flush is present when the first 20% of the storm runoff contains 80% or more of the total pollutant load (Stahre and Urbonas 1990). Typically, the first 20% of total storm runoff from the Greenville detention pond basin carried 24-27% of the total particulate pollutant loads and 23-37% of the total dissolved pollutant loads (Table 5). Thus, the Greenville watershed clearly does not exhibit a first flush runoff pattern, based on this criterion.

Table 5. Percent of total pollutant load in first 20% of storm runoff volume

	Storm									
Pollutant	1	2	3	4	5	6	7	8	Mean	Median
TSS	15	27	20	24	27	17	33	27	24	25
VOLS	20	31	25	24	22	30	32	28	27	26
FSOL	14	25	18	24	31	12	31	26	23	25
POC	20	24	26	32	25	27	29	24	26	26
DOC	29	32	30	24	28	30	20	17	26	29
PN	11	27	23	43	23	26	27	31	26	26
DKN	37	37	33	26	35	36	26	18	31	34
NO3-N	38	38	41	25	21	41	19	29	31	33
NH4-N	31	42	43	17	28	37	44	55	37	40
PP	23	26	21	41	19	28	25	33	27	25
TDP	23	32	24	25	10	53	17	22	26	23
PO4-P	13	33	24	25	13	32	21	20	23	23
Cd	11			10	22	13	25	49	22	17
Cr	16	28	18	33	14	37	34	32	26	30
Cu	15	31	25	19	20	33	28	39	26	27
Pb	10	27	16	25	13	29	37	36	24	26
Ni	21	14	19	14	32	32	29	36	25	25
Zn	19	34	26	21	25	30	27	20	25	25

Pollutant concentrations in the Greenville runoff are comparable to those for NURP residential sites as well as sites used in several other studies (Table 6). The median EMC of TSS at Greenville was 98 mg/l, very close to the NURP value of 101 mg/l. Nitrogen and phosphorus levels in the Greenville runoff were close to, or somewhat less than, levels measured elsewhere. Median TP and PO_4-P EMCs were similar for Greenville and the typical NURP site, but the Greenville NO_3-N and TKN median EMCs were about one-half the NURP values. Still, they were well within the ranges for all NURP sites monitored.

Federal regulations have required the use of unleaded gasoline in automobiles manufactured since the middle 1970s. This may be why lead levels in 1992 runoff from the detention watershed were much lower (median EMC 0.027 mg/l) than those

Table 6. Comparison of stormwater runoff pollutant concentrations from this study with those for other sites in the U.S. and Canada

Location	Note	TSS mg/l	TKN (mg/l)	NO3-N (mg/l)	NH4-N (mg/l)	TP (mg/l)	PO4-P (mg/l)	Cd (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)	Fecal C. MPN	BOD (mg/l)	COD (mg/l)
Greenville, NC	EMCs	98	1.06	.32	.11	.35	.19	.0010	.014	.027	.136	17,000	5	38
NURP Residential	1	101	1.90	.68		.38	.14		.033	.144	.135	10,000	10	73
Madison, WI (1971)	2	280		.60	.45	.98	.57							
Madison, WI (1991)	7	262				.66	.27	.0004	.016	.032	.203	175,106		
Roseville, MN	11	240	3.32	.66		1.44	.25			.095				185
Somerset Co, NJ	12	282	1.20			.36								32
Atlanta, GA	3	287	.57	.25	.18	.33				.015		6,300	9	40
Winston-Salem, NC	4	37	1.50	.52		.23	.18		.015	.013	.162		7	
Durham, NC	8					.58						30,000	15	179
Montgomery Co., MD	15	42	1.65	.68		.30					.075			21
Glen Ellyn, IL	10	196		.77	.18	.48	.08		.041	.224	.171		18	91
Washington, D.C. area	14	26	2.00	.48	.26	.26	.12			.018	.037		5	36
Sault Ste. Marie, MI	9					.31		.0060	.070	.097	.274			
Windsor, Canada	9					.23		.0054	.057	.154	.234			
Cincinnati, OH	13											2,500		
Cincinnati, OH	6	210		.45	.60		.80						19	99
Topeka, KS	5	395		.51	.08	.44			.022	.075	.095			64

Notes:
1. US EPA (1983). Values are median event mean concentrations for all residential sites
2. Kluesener and Lee (1974). Values are flow-weighted average concentrations for 34 storm events.
3. Holbrook et al. (1976). Values are average concentrations of 57 grab samples (not flow weighted).
4. HDR (1993). Values are average of composite values from three storms at three residential sites.
5. Pope and Bevans (1987). Study site 06889635 on Butcher Creek. Values are median EMCs.
6. Weibel et al. (1964). Values are means for an unspecified number of samples.
7. Bannerman et al. (1993). Values are geometric means for an unknown number of storms in a residential area.
8. Bryan (1970). Values are flow-weighted means.
9. Marsalek (1991)
10. Hey (1982). Flow-weighted event mean concentrations for 10-17 events
11. Oberts and Osgood (1991). Values are event mean concentrations.
12. Ferrara and Witkowski (1983). flow-weighted average concentrations for 3 storms
13. Geldreich et al. (1968)
14. Schueler (1987). Values are averages of EMCs for 298 storms.
15. Grizzard et al. (1986). Values are medians of event mean concentrations for 47 events.

for the average NURP site monitored in the late 1970s (0.144 mg/l). Greenville runoff also contained about one-half as much copper as the average NURP site, while its zinc concentrations were about the same.

Fecal coliform concentrations are highly variable in urban stormwater, but there is usually a seasonal trend in the numbers. As noted above, the Greenville site concentrations increased from 30,000/ml in March to over 1,000,000/ml in August. Similarly, fecal coliforms at the NURP sites were in the range 300-281,000/100 ml during warm weather and in the range 20-3,300/ml during cold weather (EMCs). Geldreich et al. (1968) also noted the same seasonal pattern in their study of urban-runoff fecal coliforms. At their sites in suburban Cincinnati, Ohio fecal coliform densities were lowest in winter (median 2,500) and peaked in the autumn (median 40,000).

Settling Column Tests

Initial concentrations of TSS and some other pollutants in the four test samples varied substantially (Table 7). TSS concentration ranged from 41 mg/l in test 2 sample water to 279 mg/l in the last sample tested (TSS data are not available for test 1). Concentrations of other pollutants did not necessarily increase with increasing TSS concentration. For example, TN, TOC and most of the metals -- particularly zinc -- were more concentrated in the second and third test samples than in the high-TSS fourth test sample. All concentration data from the settling column experiments are in Appendix H.

All the particle-bound pollutant fractions had a settling pattern similar to that for TSS, but the maximum percentages removed were mostly lower than for TSS. Plots like Figure 5 were prepared for all the pollutants sampled, and several are presented here as representative examples; the rest are in Appendix I. TSS removal was 85% or better in all tests after 72 hr (Figure 5). In fact, most of the settling had taken place after the first 12 hr, and after 24 hr all of the TSS concentrations were 25 mg/l or less. The volatile fraction (VSS) of the TSS varied from 10 to 50% initially. The inorganic fraction (FSOL) settled faster than the organic volatile fraction, resulting in an increasing percentage of VSS in the water column. At the end of the experiments after 72 hr the VSS ranged between 50 and 80% of the TSS.

The percentage removals for chromium, cadmium, nickel, and lead after 72 hr were all 60% or greater, and most were in the 60-75% range. Copper and zinc removals were lower, ranging between 37 and 60% for copper and 14 and 48% for zinc. Like TSS, the metals settled rapidly at first so that after 12 hr the percentage removals were almost as high as they would be after 72 hr.

Table 7. Summary of settling column results

	Test							
	1		2		3		4	
	Initial Con. (mg/l)	% Rem. (48 hrs)	Initial Con. (mg/l)	% Rem. (72 hrs)	Initial Con. (mg/l)	% Rem. (72 hrs)	Initial Con. (mg/l)	% Rem. (72 hrs)
TSS			41.00	86	71.00	94	279.00	99
NH4-N	0.11	-46	0.24	36	0.09	-141	0.26	-28
NO3-N	0.21	-57	0.78	90	0.46	94	0.55	11
PN	0.58	83	0.90	53	0.79	70	0.89	99
TN	0.81	63	2.10	40	1.80	37	1.40	60
PO4-P	0.34	43	0.31	1	0.10	-85	0.23	-5
PP	0.19	80	0.18	60	0.21	75	0.53	96
TP	0.56	51	0.50	20	0.33	49	0.76	66
DOC			24.70	25	23.60	9	12.80	34
POC			5.60	48	7.06	77	4.90	94
TOC			30.30	29	30.70	25	17.70	50
Cd	0.0008	75	0.0030	70	0.0009	71	0.0004	77
Cr	0.0040	93	0.0090	60	0.0030	67	0.0050	90
Cu	0.0100	38	0.1020	37	0.0170	47	0.0140	60
Ni	0.0040	36	0.0260	77	0.0030	63	0.0010	87
Pb	0.0080	72	0.0590	62	0.0230	88	0.0220	86
Zn	0.0800	39	0.8390	14	0.1820	38	0.0920	48

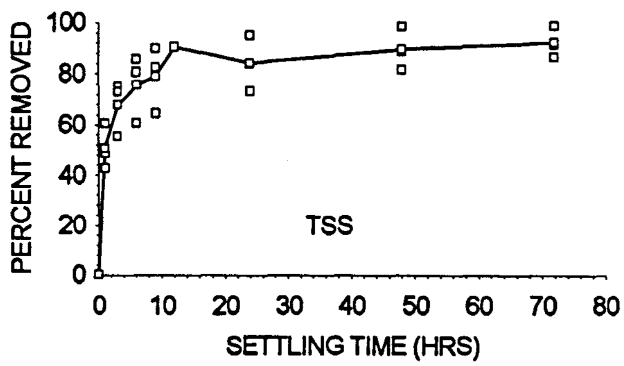


Figure 5. TSS removal in settling column during three experiments (squares), and the median values for the three experiments (line).

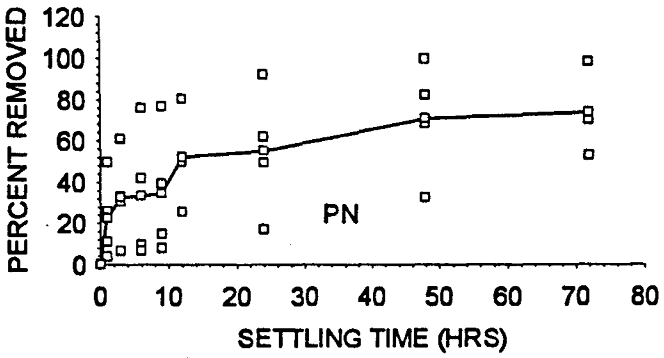


Figure 6. PN removal in settling column during four experiments (squares), and the median values for the experiments (line).

Particulate nitrogen (PN) removals after 72 hr were 53-99%, with most removal occurring early, except in test 2, which had low removal early and achieved the lowest total removal (Figure 6). The 72-hr NO_3-N removal averaged 70%, but was highly variable. Some of this removal may have been due to settling of particle sorbed NO_3-N, but the time course plots for NO_3-N and NH_4-N suggests there was also biological activity occurring in the columns (Figure 7).

In all tests there was an initial increase in NO_3-N and a decrease in NH_4-N, which indicates nitrification (biological conversion of NH_4-N to NO_3-N). Later, the nitrate began to decrease, probably due to a combination of cessation of nitrification, and the beginning of denitrification (biological reduction of NO_3-N to N_2 gas). Some biological uptake (incorporation of NO_3-N into PN) may have occurred also. Denitrification requires an oxygen-free environment, but the presence of this condition cannot be confirmed since dissolved oxygen was not monitored. However, given that the initial BOD_5 in some of the runoff samples exceeded 10 mg/l, hypoxia could have developed in the poorly aerated settling column. This would have also permitted the buildup of NH_4-N from decomposition of organic matter (ammonification). Indeed, the NH_4-N levels did begin to increase in three of the four experiments after about 24 hr. In the end, there was a net average increase in NH_4-N amounting to about 30%. Because NH_4-N is a small part of total nitrogen the TN removal pattern was not strongly affected by the increase. However, it should be noted that the maximum TN removals (37-60%) probably would have been lower had it not been for denitrification. This is an unlikely transformation in the detention pond however, because aeration there is likely much better than it is in the settling column.

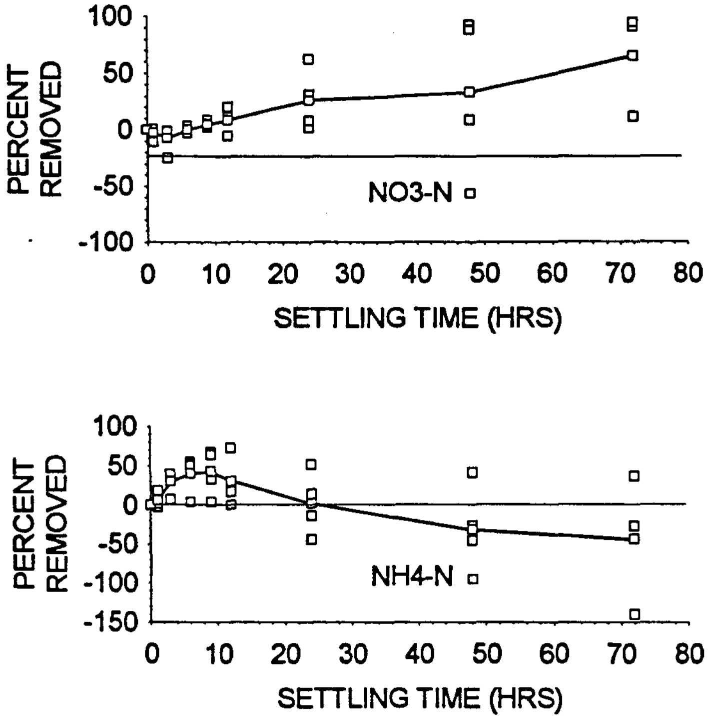


Figure 7. NO3-N and NH4-N removal in settling column during four experiments (squares), and the median values for the experiments (line).

Phosphate phosphorus (PO_4-P) is another dissolved fraction that is influenced by biological activity. There was some removal in the early hours of the tests, but after 12 hr PO_4-P tended to increase, probably from remineralization associated with organic matter decomposition. The net result was an average 30% increase in PO_4-P after 72 hr. As expected, a substantial fraction of particulate phosphorus was removed by settling. The maximum removals for total phosphorus varied from 20 to 66% (Figure 8)

Concentrations of both the particulate and dissolved organic carbon fractions (POC and DOC) decreased during the settling tests. The POC removal was 38-68% after 12 hr, and the maximum removals ranged from 48 to 94% after 72 hr (average 75%). The DOC removal was much lower, averaging 23% after 72 hr. DOC removal, and like dissolved N and P removal, was a result of a combination of physical (settling) and biological activities. BOD_5 was not monitored in these experiments. Nevertheless, assuming an initial BOD_5 of 5-20 mg/l (based on the range observed in

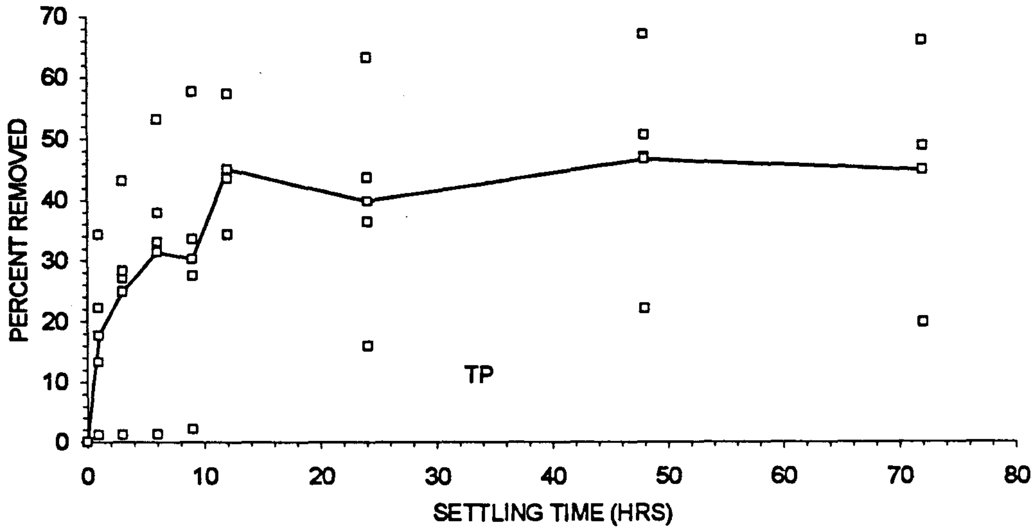


Figure 8. TP removal in settling column during four experiments (squares), and the median values for the experiments (line).

runoff samples), one can estimate that 25-100% (0.5-1.5 mg/l per day) of the settling column DOC removal could be accounted for by biological oxidation of the carbon. The 72-hr TOC removal averaged 35%.

Randall et al. (1982) noted that TSS in urban runoff behaves like a mixture of discrete and flocculant solids, with the discrete particles settling out rapidly while the flocculant solids sometimes do not settle well until after two days. Thereafter, removal of smaller diameter particles, such as fine silt and clay-sized material, occurs incrementally over a much longer period (days to weeks). Soils in Greenville, which is located in the Coastal Plain, may contain more coarse sand and less silt and fine clays than soils in Northern Virginia, a Piedmont region where settling rates have been measured in runoff from several sites (Randall et al. 1982). Thus, one might expect TSS and other particulate pollutants in the Greenville runoff to settle more rapidly than those in the Northern Virginia runoff, but comparison of settleability test results for the two areas shows little difference for most pollutants (Table 8). Randall et al. (1982) found that 48 hr of settling removed 90% of the TSS, and that concentrations leveled off between 5 and 10 mg/l, which is close to the Greenville test results.

There were other similarities between the studies:

- The percentage of TSS removed increased as the initial TSS concentration increased, which Randall and co-workers attributed to the flocculant nature of some of the particles.

- Some parameters had a tendency to increase in concentration as the TSS increased, but most were independent of TSS. Thus, generalizations relating pollutant loads to TSS loads should be avoided.
- Other pollutants showed more variability than TSS from one test to another, in terms of removal efficiencies.
- TOC and TP removal efficiencies were about 35 and 50%, respectively.
- Zinc removal efficiencies (35-44%) were lower than removals of other metals, particularly lead, which had a removal efficiency over 80%. Unlike lead, most of the zinc in urban runoff is in soluble form (Schueler 1987).

Table 8. Comparison of settleability of urban runoff pollutants

	Percent Removals		
	(This Study)	(Whipple and Hunter 1981)	(Randall et al. 1982)
Pollutant	Greenville, NC	Trenton, NJ	Northern Virginia
TSS	93	68	90
TP	46	50	56
TN	50		33
TOC	35		34
BOD5		40	64
COD			45
Cu	45	42	
Ni	66	30	
Zn	35	30	44
Pb	77	65	86

Notes:

1. No. observations: This study, 4; Whipple and Hunter, 3-4; Randall et al.
2. Duration: This study, 72 hr; Whipple and Hunter, 32 hr; Randall et al., 4
3. Settling height: This Study, 3 ft.; Whipple and Hunter, 4 ft.; Randall et a

Detention Pond Efficiencies

Pond Treatment Efficiency

Pond treatment efficiencies (PTEs) for particle-bound pollutants were normally positive and high relative to dissolved pollutants PTEs, which were low and, in some cases, negative. The PTE data are summarized in Table 9 and Figure 9, and details for individual storms are in Appendix G. Recall that pond treatment efficiency is the percentage of the (treated) runoff load removed during detention. Median PTEs were 71% for TSS, about 45% for particulate organic carbon and particulate nitrogen, 33% for particulate phosphorus, and 26-55% for metals.

Table 9. Pond treatment efficiency summary

Pollutant	Abb.	Pond Treatment Efficiency (%)		
		Mean	Median	Range
Total Suspended Solids	TSS	68	71	42 - 83
Particulate Organic Carbon	POC	39	45	(4) - 63
Particulate Nitrogen	PN	47	43	28 - 71
Particulate Phosphorus	PP	34	33	14 - 57
Cadmium (unfiltered)	Cd	24	54	(100) - 93
Chromium (unfiltered)	Cr	42	49	9 - 72
Copper (unfiltered)	Cu	29	26	11 - 54
Lead (unfiltered)	Pb	44	55	2 - 79
Nickel (unfiltered)	Ni	40	43	4 - 90
Zinc (unfiltered)	Zn	27	26	6 - 38
Dissolved Organic Carbon	DOC	(11)	(6)	(51) - 1
Dissolved Kjeldahl Nitrogen	DKN	(11)	(4)	(55) - 28
Nitrate Nitrogen	NO3-N	(8)	(2)	(52) - 21
Ammonium Nitrogen	NH4-N	(2)	9	(66) - 43
Total Dissolved Phosphorus	TDP	(16)	(9)	(113) - 19
Phosphate Phosphorus	PO4-P	19	26	(5) - 36

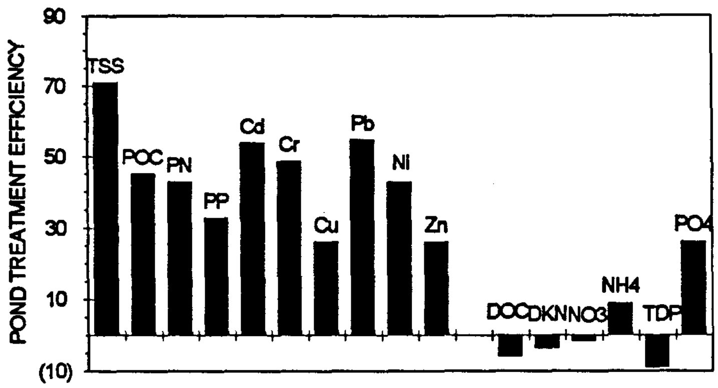


Figure 9. Median pond treatment efficiencies for eight monitored storms

Dissolved pollutant loads leaving the pond were essentially the same as the runoff loads, except for phosphate phosphorus, which had an average PTE of about 25%. Median PTEs for dissolved organic carbon and NO_3-N were small and negative (Table 9).

Storm Treatment Efficiency

Storm treatment efficiencies (STEs) were the same as the PTEs for all storms except 3, 4, and 8, portions of which bypassed detention by way of the spillway. As explained above in the Methods section, the STE is less than the PTE when there is bypass because STE is a measure of the fraction of the total storm runoff (treated plus bypass) that is removed by the detention pond. The amount of bypass during storms 3 and 4 was relatively small (7 and 13%), so that the impact on STE is not obvious, given the considerable treatment variability among those storms with no bypass (Table 10 and Appendix F). However, during storm 8 the bypass volume was large (70% of the runoff), and it clearly had an impact on the STE. As expected, only the particulate pollutant removals were affected, since removal of dissolved materials did not occur even when they were detained. The loss of efficiency was roughly proportional to the fraction of runoff that bypassed the facility. In other words, the STEs for this storm were approximately one-third the median PTEs for all storms. This is consistent with the lack of a first-flush effect in runoff pollutant concentrations noted above.

Computation of treatment efficiencies for fecal coliforms, BOD_5, and COD was not attempted since these variables were sampled relatively infrequently. However, comparison of sampling results for untreated runoff and treated pond outlet water does suggest that modest changes occurred during the detention period. The median fecal coliform density in the outlet water was 12,000 organisms per 100 ml, compared

Table 10. Storm treatment efficiency summary

Pollutant		Storm Treatment Efficiency (%) Storm 3	4	8
% of Runoff that Bypassed Pond		7	13	70
Total Suspended Solids	TSS	57	36	25
Particulate Organic Carbon	POC	13	54	19
Particulate Nitrogen	PN	31	62	22
Particulate Phosphorus	PP	13	56	17
Cadmium (unfiltered)	Cd	54	28	12
Chromium (unfiltered)	Cr	8	43	16
Copper (unfiltered)	Cu	20	9	16
Lead (unfiltered)	Pb	6	51	19
Nickel (unfiltered)	Ni	4	22	27
Zinc (unfiltered)	Zn	6	33	11
Dissolved Organic Carbon	DOC	(47)	(5)	(5)
Dissolved Kjeldahl Nitrogen	DKN	(1)	(46)	2
Nitrate Nitrogen	NO3-N	(48)	(33)	6
Ammonium Nitrogen	NH4-N	11	(32)	20
Total Dissolved Phosphorus	TDP	(15)	9	6
Phosphate Phosphorus	PO4-P	(5)	23	8

to 17,000/100 ml in the runoff. BOD_5 and COD also appear to have been somewhat lower in the outlet water than in the untreated runoff. Outlet median BOD_5 was 4.2 mg/l, which was slightly lower than the inflow median (4.9 mg/l). The outlet median COD was 23.4 mg/l, compared to 38.3 mg/l in the runoff.

Settling Column and Detention Pond Results Compared

Particulate pollutant removals were higher in the settling column than in the detention pond. Strict comparisons cannot be made since settling times in the pond were shorter for some storms than settling times in the column tests. But, recall that in the column tests, removal was rapid during the first 12 hr and much slower afterwards. Median TSS removal in the settling column was 94%, compared to 71% in the pond. Differences between column and pond removals tended to be greater than this for other pollutants. For example, the PN, PP, and POC column and pond removals were 70% vs. 33%, 60% vs. 33%, and 77% vs. 45%, respectively. Similarly, median removals for the 6 metals were 38-79% in the settling column vs. 26-55% in the pond.

This pattern of differences between settling column and pond removal can be explained if one makes two reasonable assumptions. The first is that most of the runoff pollutants are bound to particles and flocs smaller on average than the TSS particles. The second is that turbulent mixing is stronger in the pond than in the settling column. This combination would favor more rapid settling of pollutants -- other than TSS -- in the settling columns than in the pond. The only other study to date comparing dry detention pond and settling column removal of pollutants is that of Grizzard et al. (1986). They found column removal rates to be higher than pond rates for some pollutants but about the same for others.

It appears that further studies need to be made to clarify the roles of particle size, formation of flocculant suspended solids, and other factors influencing urban runoff pollutant settling rates. Ideally, physical settling and biological removal and transformation would be quantified simultaneously. Until results from such studies are available, the utility of settling column tests will be limited to providing a rough indicator of the maximum settleability of pollutants at a given site.

Comparisons With Other Detention Pond Study Results

Although dry detention ponds are in use throughout the United States, only a handful have been monitored quantitatively for treatment performance. During NURP study a dry pond in Montgomery County, Maryland (named Stedwick) was modified to achieve 6-12 hr of detention, and monitored over a 18-month period (Grizzard et al. 1986; Schueler and Helfrich 1988). Results are also available for two extended detention ponds in Northern Virginia (Lakeridge and London Commons) (MWCOG 1983; OWML 1987). These ponds also had relatively brief detention times, estimated at 1-2 hr and <10 hr, respectively. Short detention characterized at least two of the three other ponds studied. They were located in Austin TX, Baltimore MD, and Lawrence, KS (detention time information is not available for the Baltimore pond). Each study also differs with respect to pond design, number of storms monitored, pollutant removal calculation technique, and monitoring technique, so exact comparisons between sites are not appropriate.

Nevertheless, one cannot help but notice the wide variability in performance among these 7 ponds (Table 11). TSS removal ranged between 3% and 87%. Pope and Hess (1988) speculated that resuspension of previously deposited material might be the cause of unexpectedly low TSS removal in the Lawrence, Kansas pond. This problem was also cited as the reason for low TSS removal in the Lakeridge pond in Northern Virginia (MWCOG 1983). Ranges in TP, TN, and lead removal were 13-40%, 10-35%, and 29-66%, respectively.

Table 11. Summary of urban stormwater treatment efficiency studies for seven dry detention pond systems. Each study differs with rspect to pond design,number of storms monitored, pollutant removal calculation techniques, and monitoring techniques. Therefore, exact comparisons cannot be made.

	Detention Pond Name and Location						
	Lakeridge Northern VA	London Northern VA	Stedwick Montgomery Co. MD	Maple Run Austin TX	Oakhampton Baltimore MD	(none given) Lawrence KS	Greenville Greenville NC
Watershed (acres)	88	11	34	28	17	12	200
Imperviousness (%)						49	
Hours to Drain after Filing	1-2	<10	6-12	-9		6-16	75
No. Storms monitored	28	27	25	17		19	8
Removal efficiencies (%)							
TSS	14	29	70	30	87	3	71
TP	20	40	13	18	26	19	14
PO4-P	-6				-12	0	26
TN	10	25	24	35			26
NO3-N	9			52	-10	20	-2
NH4-N				55	54	69	9
BOD5				35			
COD	-1	17	27	22		16	
TOC				30		-3	10
POC							45
DOC							-6
Fecal Coliforms				78			
Copper				31			26
Lead		39	62	29		66	55
Zinc	-10	24	57	-38		65	26
Reference (see Notes)	1	2	3	4	5	6	7

Notes:
1. MWCOG (1983); 2. OWML (1987); 3. Schueler and Helfrich (1988); 4. City of Austin, 1991 personal communication, cited in Schueler et al. (1992); 5. Baltimore Department of Public Works (1989); 6. Pope and Hess (1988); 7. This study.

The Greenville pond has a substantially longer maximum detention time than the other ponds studied. Yet, it is not clear that its performance is greatly enhanced by longer detention. Its median TSS removal efficiency, for example, was 71%. That was higher than for most sites, but not better than at the Stedwick pond which had only 6-12 hr of detention. The Greenville pond's TN, TP, zinc, and lead removals were about average. Perhaps the fact that most pollutant settling in column experiments takes place in the first 12 hr explains the small difference between the Greenville results and those for the other, shorter detention ponds. Unfortunately, data for other pollutants is too limited to allow meaningful comparisons. Overall, the efficiency of the Greenville pond appears to be average, or slightly better, in comparison with other of stormwater treatment facilities of the same type.

Impact of Detention Pond Treatment on Tar River Water Quality

Runoff from the detention pond watershed and all other areas in the City of Greenville flows to the Tar River. Since the goal of stormwater management is to maintain or enhance receiving water quality, it is would be helpful to put detention pond removals into perspective relative to Tar River water quality. There are at least two approaches that can be used to do this. The first is to compare concentrations of pollutants in storm runoff with detention pond outflow concentrations, with river water concentrations, and with water quality standards criteria specified by regulatory agencies.

Table 12 summarizes the available information needed for comparing pollutant concentrations. It includes runoff EMCs, along with EMCs calculated for the treated effluent leaving the pond (see also Table 4). The third column gives data for some pollutants that have been monitored in the Tar (Stanley 1989; Harned and Davenport 1990). The last column in the table is a listing of water quality standards for freshwaters in North Carolina These standards have been assigned by the N.C. Department of Environment, Health, and Natural Resources, Division of Environmental Management (NC DEM 1989b).

Detention pond treatment reduced the runoff TSS EMC for a typical storm from 98 mg/l to 28 mg/l, which is close to the average Tar River TSS (30 mg/l). Treatment also reduced the PN and PP concentrations, from 0.56 to 0.37 mg/l and from 0.19 to 0.13 mg/l, respectively. This brought them closer to -- but still 3 times higher than -- the river PN and PP concentrations. Some of this particulate N and P may eventually remineralize to become available for algal growth, but the majority likely remains unavailable. On the other hand, inorganic nutrient forms are immediately available to stimulate algal growth; hence more attention is usually paid to their concentrations than to the particulate concentrations. Unfortunately, short-term dry detention pond treatment has little or no effect on these forms, as has been shown by this study. However, their concentrations in the untreated Greenville runoff were about the same as or (for NO_3-N) lower than concentrations in the Tar River.

Table 12. Comparison of water quality standards with pollutant concentrations in untreated stormwater runoff, treated detention pond effluent, and Tar River water. All runoff and detention pond effluent values are EMCs except those for fecal coliforms and BOD_5, which are medians.

Pollutant		Detention Pond			
		Untreated Runoff (mg/l)	Treated Effluent (mg/l)	Tar River (mg/l)	Standard (mg/l)
Total Suspended Solids	TSS	98	28	30	
Particulate Organic Carbon	POC	4.30	2.80	6.50	
Particulate Nitrogen	PN	0.56	0.37	0.12	
Particulate Phosphorus	PP	0.19	0.13	0.04	
Cadmium (unfiltered)	Cd	0.0009	0.0005		0.0020
Chromium (unfiltered)	Cr	0.005	0.002		0.050
Copper (unfiltered)	Cu	0.014	0.009		0.007
Lead (unfiltered)	Pb	0.027	0.010		0.025
Nickel (unfiltered)	Ni	0.005	0.002		0.088
Zinc (unfiltered)	Zn	0.163	0.098		0.050
Dissolved Organic Carbon	DOC	11.50	11.90	12.90	
Dissolved Kjeldahl Nitrogen	DKN	0.50	0.47	0.51	
Nitrate Nitrogen	NO3-N	0.32	0.30	0.64	
Ammonium Nitrogen	NH4-N	0.11	0.10	0.12	
Total Dissolved Phosphorus	TDP	0.17	0.14	0.13	
Phosphate Phosphorus	PO4-P	0.13	0.08	0.10	
Total Organic Carbon	TOC				
Total Phosphorus	TP	0.35	0.27	0.23	
Total Nitrogen	TN	1.04	0.86	0.63	
Fecal Coliform		17,000	12,000		200
Biological Oxygen Demand	BOD5	4.9	4.2		

Detention pond effluent had metals concentrations equal to about one-half those in the untreated runoff (Table 12). There are no comparable (infiltered) metals concentration data for the Tar River. Except for Cu and Zn, the runoff concentrations were lower than, or about the same as, maximum concentrations allowed by the State water quality standards. Untreated runoff EMCs for Cu averaged 0.014 mg/l, compared to 0.009 mg/l in the treated effluent. The State Cu standard is 0.007 mg/l. Zinc was about three times more concentrated in the runoff than permitted by the standard, and about two times higher in pond-treated effluent than the standard allows.

Fecal coliform bacteria was the pollutant with the largest discrepancy between the State standard and measured concentrations. In both runoff and treated effluent, the fecal coliform concentrations -- 17,000/100 ml and 12,000/100 ml -- were much higher than the standard of 200/100 ml. Biological oxygen Demand (BOD_5) was not affected very much by the detention treatment, but even the untreated runoff had a median BOD_5 of only 4.9 mg/l. For comparison, the State standard for High Quality Waters, is 5 mg/l BOD_5 in effluents.

A second way to relate detention pond treatment to Tar River water quality is to calculate reductions in total loadings of pollutants that result from the treatment. This approach is more feasible, and timely, for N and P than for the other runoff constituents because it relates to a new plan recently developed to manage nutrient loading in the Tar basin (Hall and Howett 1994). According to the plan, point source dischargers will be responsible for meeting a total nutrient loading limit. They may achieve this overall limit by reducing their own effluent levels, by trading individual discharge levels among themselves, or by paying a fixed cost to a fund that implements nonpoint source controls.

Establishing the total nutrient loading limits required that all point and nonpoint source loads in the basin be identified and quantified. There is some variation among available Tar basin nutrient loading budgets, but they all agree that untreated urban runoff is a minor contributor to the total basin nutrient load (N.C. DEM 1989a; Stanley 1993; R. Dodd, personal communication). Expressed as percentages of total annual loads coming from urban runoff, the ranges are 2-4% for TN and 1-3% for TP. Although detention ponds like the one in this study achieve modest N and P removals (particulate forms only), these removals would have no significant impact on the overall Tar basin loadings, even if all urban runoff in the basin were treated. Consequently, it seems unlikely that urban detention will be involved in the nutrient trading program for this system.

Sediment Accumulation and Other Maintenance Issues

A model developed by the Metropolitan Washington Council of Governments (Schueler 1987) can estimate accumulation rates of sediments in the Greenville detention basin. The model is normally used to estimate runoff loads and is known as the Simple Model. It relates annual rainfall, a runoff coefficient, watershed area, and the EMC of a given pollutant to pollutant load (L, in pounds):

$$L = [\ (P) \times (P_J) \times (R_v) / 12] \times (C) \times (A) \times (2.72),$$

where P = rainfall (inches) per year; P_J = 0.9 (assumed fraction of storms producing measurable runoff); R_v = runoff coefficient; C = event mean concentration (EMC) of pollutant; and A = watershed area.

Applying this model to data presented earlier in this report gives an estimated annual TSS runoff load equal to 25,430 kg (28 tons) for the Greenville watershed. Assuming no spillway bypass, and a 71% pond treatment efficiency, the net accumulation of sediment in the pond would be 18,055 kg/yr. Spread evenly over the pond, this would amount to a 0.4 cm (0.15 in) deep accumulation, or 0.16% of the pond storage volume, assuming that one metric ton of sediment fills a volume equivalent to 0.84 m^3 (Schueler 1987). Thus, sediment accumulation *per se* is not likely to be a maintenance issue for many years, unless the accumulation becomes focused near the outlet or something in the watershed changes to increase the runoff sediment yield.

Of course, other particulate pollutants like PN, PP and metals will accumulate in the pond. Lee and Jones-Lee (1994) contend that the metals may pose a serious disposal problem in the future. Specifically, they think it likely that soils that accumulate in detention basins will contain sufficient amounts of lead to be classified as hazardous wastes, based on EPA rules governing leachable lead allowed in contaminated soil. Therefore those responsible for maintenance of stormwater detention basins could find themselves in the position of having to manage the collected soils as hazardous wastes. This increases the cost of disposal from several tens of dollars per ton to a few hundred dollars per ton for disposal in a hazardous waste landfill.

Larger than anticipated amounts of trash in the Greenville detention pond could be more important than sediment in reducing storage capacity. Early in the study, impressive amounts of trash began to come into the pond with runoff from each storm. Between January and August 1992 project personnel attempted to collect, dry, sort and weigh trash left in the pond after each storm event. In all, 23 kg of metal, 77 kg of plastic, 45 kg of glass, and 21 kg of other kinds of trash were taken from the pond. Beverage and food containers were the most common objects, but clothing, syringes, pieces of broken furniture, and many other items were collected.

A recent visit to the Greenville detention pond, now about 2.5 years old, showed that maintaining these facilities can be problematic. The most noticeable change is that most of the pond bottom and the interior banks of the dike surrounding it are now covered with weeds and scores of sapling trees -- mostly willows in the downslope wetter areas and oaks farther back. Obviously, the pond bottom and lower interior banks have been too wet to allow regular mowing. The top of the surrounding dike appears to have been mowed. Inspection of the perforated riser showed considerable blockage of its orifices. It also appears that there is more pooling of water near the outlet between storms than earlier in the life of the pond. Overall, what began as a dry detention basin seems to be evolving towards a de facto wetlands type of facility.

It is difficult to estimate what impact, if any, these changes are having on the pond's performance. The woody vegetation, if allowed to grow and spread, might actually improve the particle trapping efficiency, and pooling could provide some nutrient removal normally associated with wet ponds. On the other hand, floatable trash will undoubtedly accumulate more rapidly, trapped in the thick willow sapling stand. Before the woody vegetation appeared, much of the trash that accumulated during smaller storms eventually floated over the spillway during large storms. If not corrected, riser orifice blockage will gradually increase the detention time for small storms, but will cause spillway bypassing of more runoff in moderate and large storms. Ultimately, the dry pond could become a wet pond, with a significant permanent storage pool.

Maintenance of control structures is a very common problem in stormwater management. Galli (1992) analyzed the performance and longevity of 11 types of urban stormwater BMPs in Prince George's County, Maryland. Twelve extended detention dry ponds were surveyed. While few of the detention ponds had totally failed (age range 0.1-3.6 years), many did not operate as designed. Some were clogged and were functioning as wet ponds, and a majority were not achieving target detention times.

In a similar study, Lindsey et al. (1992) reported on the maintenance status of more than 250 stormwater facilities in the Baltimore, MD area. Most of them were only a few years old, but only 54% of the 116 dry basin detention ponds inspected were found to be functioning as designed, and 82% needed maintenance. The performance-related problems encountered most often included excessive sediment or debris (51%), inappropriate ponding of water (36%), and clogging of the outflow structure (28%). The major maintenance problems involved growth of excessive or woody vegetation on embankments and the need to remove sediments.

Acknowledgments

This report is dedicated to the memory of my father, Jay R. Stanley (1918-1994). He was the wisest man I have known, and he was my best friend for 49 years.

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Appendices

Appendix A: GLOSSARY

- ADSORPTION - Adhesion of the molecules of a gas, liquid or dissolved substance to a surface.

- ANOXIC - Without oxygen

- BMP - Best Management Practice. A method, procedure, maintenance activity, or other management practice for reducing the amount of pollution entering a body of water.

- BOD_5 - Biological Oxygen Demand. The measurement of oxygen required by aerobic biological processes to break down organic matter in water.

- BMP - Best Management Practice. As used in the context of this report, the term refers to structural devices that temporarily store or treat urban stormwater runoff to reduce flooding, remove pollutants, and provide other amenities.

- DOC - Dissolved Organic Carbon: Organic carbon in a water sample that passes through a fine-porosity (0.5 um) filter.

- EMC - Event Mean Concentration. The flow-weighted concentration of a pollutant in the stormwater runoff or in the effluent from a detention pond. EMC is calculated as the total mass of pollutant divided by the total runoff or effluent volume.

- EXTENDED DETENTION POND - A conventional extended detention pond temporarily detains a portion of stormwater runoff for a period ranging from a few hours to several days after a storm, using an orifice that provides for the gradual release of water. Such extended detention allows pollutants to settle out. The ponds are normally dry between storm events and do not have any permanent standing water.

- FECAL COLIFORM - Bacteria from the intestinal tracts of warm-blooded animals. High numbers of fecal coliforms in a body of water may indicate a recent release of untreated wastewater. Fecal coliform is used as an indicator for managing the closure of shellfish beds in estuarine areas and for determining the safety of an aquatic environment for contact recreation.

- IMPERVIOUS SURFACE - A surface such as pavement that cannot be easily penetrated by water.

- NO_3-N - Nitrate nitrogen: A dissolved inorganic form that is readily available for plant assimilation.

- NH_4-N - Ammonium Nitrogen: A dissolved inorganic form that is readily available for plant assimilation.
- POC - Particulate Organic Carbon: All the organic carbon in a water sample that is retained on a fine-porosity filter paper (0.5 um)
- PERFORATED RISER - A vertical pipe extending from the bottom of a detention pond that is used to control the water discharge rate. Usually constructed of corrugated metal pipe, the riser perforations vary in spacing and size depending on the pond design.. In some cases, these perforations control the outflow rate, while in others, a downstream orifice plate actually controls the outflow.
- PO_4-P - Phosphate phosphorus. Inorganic, dissolved form that is readily available for plant assimilation.
- PTE - Pond Treatment Efficiency. A measure of the efficiency of a stormwater treatment pond relative to the runoff that enters the pond and undergoes treatment. In other words, any runoff that bypasses treatment is not included in the calculation of PTE (see Methods section above for method of calculation).
- STE - Storm Treatment Efficiency. A measure of the efficiency of a stormwater treatment pond relative to the total amount of runoff produced by an event (see Methods section above for method of calculation).
- DKN - Dissolved Kjeldahl Nitrogen: All nitrogen, both organic and inorganic contained in a filtered water sample.
- TN - Total Nitrogen: The sum of dissolved Kjeldahl nitrogen and particulate nitrogen
- TOC - Total Organic Carbon: The sum of POC and DOC in a water sample.
- TP - Total Phosphorus: The sum of particulate phosphorus and total dissolved phosphorus.
- TSS - Total Suspended Solids. Organic and inorganic particles, such as solids from wastewater, sand, clay, and mud, that are suspended and carried in water.

APPENDIX B: Overview of Urban Runoff Research Literature

A substantial body of literature on urban stormwater runoff has developed since the early 1970s. Much of our knowledge about stormwater in the U.S. was gained in the early 1980s during the National Urban Runoff Program (NURP), an effort by EPA and other cooperating agencies to characterize, and evaluate controls for, urban stormwater at 28 sites across the nation (U.S. EPA 1983). The NURP results were published in numerous project and data reports, and all the data were compiled into a national urban stormwater data base (Driver et al. 1985). In addition, the Urban Water Resources Council of the American Society of Civil Engineers has for more than 20 years been a leader in the transfer of urban runoff technology, through a series of conferences and proceedings reports (e.g., Urbonas and Roesner 1986; Roesner et al. 1988; Torno 1990). Finally, the Joint Committee on Urban Storm Drainage of the International Association of Hydraulic Research and the International Association of Water Quality have sponsored a series of triennial conferences on all aspects of urban storm drainage (e.g., Marsalek and Torno 1993).

Perhaps no area of the country has been studied more thoroughly in terms of urban runoff characteristics and treatment alternatives than Washington, D.C. and its suburbs. The Metropolitan Washington Council of Governments (MWCOG), a regional governmental organization, and the Occoquan Watershed Monitoring Laboratory (OWML) in Northern Virginia, have been particularly active in urban stormwater research and BMP implementation. In addition to many hundreds of project reports and journal articles on individual site studies, there are numerous "user" manuals and guides dealing with 1) the planning and design of stormwater treatment facilities (e.g., Schueler 1987; Schueler et al 1992), and 2) the collection and analysis of data needed to evaluate the effectiveness of the facilities (e.g., Alley 1977; Wullschleger et al. 1976; U.S. EPA 1980, 1986; and Geiger et al. 1987).

APPENDIX C: Daily precipitation, Greenville, NC station, 1992. Station is located at approximately 1.6 km (1 mile) NE of detention pond site. Data from NOAA (1993).

Day	Month												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1		----											
2	0.40	----											
3	----	----						0.10			1.20		
4	----	----		0.50		0.10	0.80		0.20	----	----		
5	----	----				0.10		0.20		----	----		
6	----	----	0.20					0.20	0.50		----		
7	----	0.10			[0.30]			0.10					
8	----				[0.10]								
9	----					1.30						----	
10	----											----	
11	----									0.10		----	
12	----							[1.70]			0.50	----	
13	----	0.10						[0.40]			0.70		
14	----	0.10						[1.90]					
15	----	0.20						[----]					
16	----					0.10		[----]					
17	----						0.10	[----]					
18	----	0.10			0.30		1.30	----					
19	----	0.10	0.60		0.10		0.10		0.10			0.20	
20	----				0.10			++++	0.60				
21	----			[0.30]		[0.50]		0.70			0.10		
22	----			[1.50]									
23	----	0.10	[0.50]				0.30						
24	----	0.10				0.40	0.40				0.40		
25	----	[0.60]				0.20					0.10		
26	----	[0.30]	[1.60]		[0.30]	1.60					----		
27	----						0.40				----	0.30	
28	----						0.10				----		
29	----				0.40						----		
30	----			0.10	1.30							----	
31	----						0.10			0.80		----	
TOTAL	----	1.80E	2.90	2.40	2.90	4.30	3.60	13.0E	1.40	3.30E	----	3.01E	
NORMAL	3.56	3.58	3.74	3.27	3.69	4.26	6.12	6.08	4.90	2.76	3.05	3.24	48.3

NOTES:

1. ---- Data missing for part or all of the period
2. ++++ Data distribution unknown. First hourly precipitation data value that follows is the total accumulated amount
3. NORMAL is averge monthly totals for period 1941-1970

Appendix D. Precipitation (inches) at 15-minute intervals for storm events in 1992. I-Date = date storm began; I-Time = time data began (EST). Some intervals during which there was no recorded precipitation are ommitted to save space.

		Storm No.							
Elapsed		1	2	3	4	5	6	7	8
time	I-Date:	25-Feb	23-Mar	26-Mar	21-Apr	7-May	26-May	21-Jun	12-Aug
(hrs)	I-Time:	6:00	2:00	2:00	22:00	2:00	9:00	12:00	15:00
0.25			0.03	0.02					
0.50			0.04	0.03					
0.75			0.03	0.03	0.07				0.27
1.00			0.02	0.02	0.07				0.40
1.25		0.06	0.05	0.01	0.05	0.01	0.03	0.42	0.50
1.50		0.03	0.05		0.05		0.03	0.03	0.10
1.75		0.08	0.05		0.04		0.02		0.02
2.00		0.01	0.02				0.01		0.05
2.25			0.08		0.45				0.05
2.50			0.04		0.19				0.05
2.75			0.04		0.15				0.05
3.00			0.03		0.06	0.01			0.02
3.25			0.04		0.06		0.37		0.02
3.50			0.03		0.08		0.04		0.03
3.75			0.03	0.02	0.03	0.01			0.02
4.00				0.02	0.06				0.01
4.25					0.08				
4.50					0.06				
4.75				0.02	0.05				0.01
5.00				0.04	0.06	0.01			
5.25				0.04	0.01				
5.50				0.05	0.01	0.01			
5.75				0.05	0.02			0.07	
6.00				0.05	0.04			0.10	
6.25			0.01	0.09	0.06	0.01			
6.50				0.09	0.06				0.02
6.75				0.08	0.05				
7.00				0.08	0.05				
7.25				0.08	0.03			0.02	
7.50				0.09	0.01				0.05
7.75			0.01	0.09					0.03
8.00				0.08					0.05
8.25				0.06					0.06
8.50				0.05	0.01				0.06
8.75				0.04		0.01			0.07
9.00				0.03			0.01		0.03
9.25									0.02
9.50				0.01					0.01
10.00				0.01					

Appendix D. (continued)

Elapsed time (hrs)		Storm No. 1	2	3	4	5	6	7	8
	I-Date:	25-Feb	23-Mar	26-Mar	21-Apr	7-May	26-May	21-Jun	12-Aug
	I-Time:	6:00	2:00	2:00	22:00	2:00	9:00	12:00	15:00
10.75									0.01
11.00		0.04		0.02					
11.25		0.08		0.03					
11.50		0.09		0.03	0.02				
11.75				0.03					
12.00		0.03							
12.25		0.02							
12.50									0.01
12.75				0.01					
13.50		0.05							
13.75		0.05							
14.25						0.01			
15.00		0.05							
15.25		0.10				0.01			
15.50		0.05							
15.75		0.05							
16.00		0.05							
16.75						0.01			
17.25						0.01			
17.50						0.01			
17.75						0.01			
18.00						0.09			
18.25						0.05			
18.75						0.01			
19.00						0.02	0.01		
19.25						0.01			
19.50						0.03			
20.75		0.05							
21.00		0.10							
21.25		0.05							
21.50		0.05					0.01		
22.00							0.01		
22.50						0.01			
22.75									0.05
23.00									0.07
23.25									0.10
24.25						0.01			
25.25									0.05
25.75									0.01

Appendix D. (continued)

Elapsed time (hrs)		Storm No. 1	2	3	4	5	6	7	8
	I-Date:	25-Feb	23-Mar	26-Mar	21-Apr	7-May	26-May	21-Jun	12-Aug
	I-Time:	6:00	2:00	2:00	22:00	2:00	9:00	12:00	15:00
26.75		0.07							
27.00		0.05				0.06			0.05
27.50						0.01			
27.75									0.01
29.50									0.01
30.00									0.01
30.25									0.03
30.50									0.03
32.00									0.01
34.25									0.01
35.75						0.01			
36.00						0.01			
36.25						0.01			
36.50						0.02			
37.75									0.03
38.00									0.01
38.50									0.01
41.75									0.01
42.00									0.01
42.50									0.01
42.75									0.04
43.00									0.03
43.25									0.05
43.50									0.04
43.75									0.01
44.00									0.04
44.25									0.04
44.50									0.05
44.75									0.13
45.00									0.08
45.25									0.05
45.50									0.02
45.75									0.05
46.00									0.10
46.25									0.03
46.50									0.01
47.00									0.01
47.50									0.05
48.00									0.02

Appendix D. (continued)

Elapsed time (hrs)		Storm No. 1	2	3	4	5	6	7	8
	I-Date:	25-Feb	23-Mar	26-Mar	21-Apr	7-May	26-May	21-Jun	12-Aug
	I-Time:	6:00	2:00	2:00	22:00	2:00	9:00	12:00	15:00
48.50									0.01
49.50									0.02
49.75									0.02
50.00									0.03
50.25									0.04
50.50									0.04
50.75									0.04
51.00									0.05
51.25									0.05
51.50									0.02
51.75									0.02
52.00									0.06
52.25									0.07
52.50									0.03
52.75									0.02
53.75									0.01
61.50									0.03
61.75									0.03
62.00									0.47
62.25									0.55
62.50									0.05
62.75									0.01
75.25									0.07
75.50									0.10
75.75									0.10
76.00									0.07
76.25									0.02
76.50									0.02
76.75									0.02
77.00									0.01
77.50									0.01
77.75									0.06
78.00									0.07
78.25									0.04
78.50									0.03
78.75									0.04
79.00									0.03
79.25									0.05
79.50									0.05

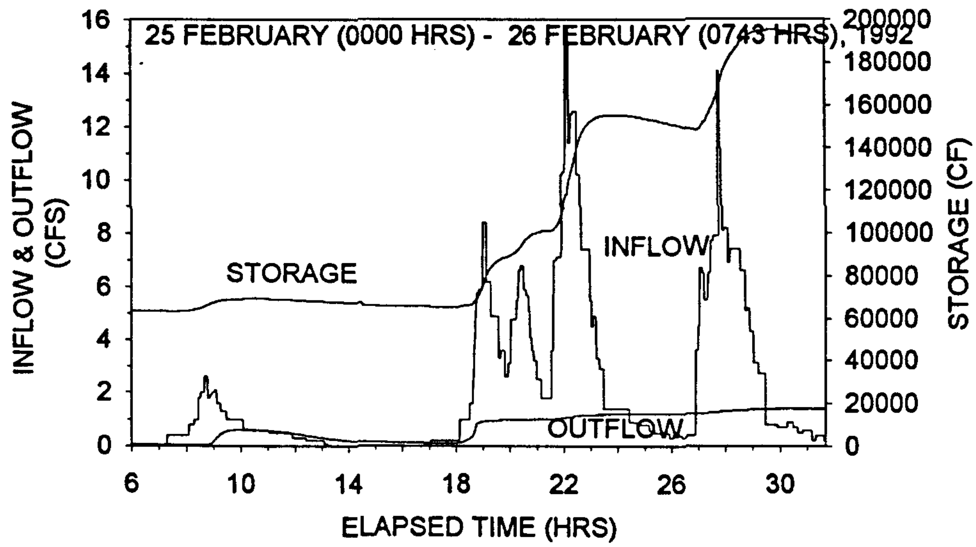
Appendix D. (continued)

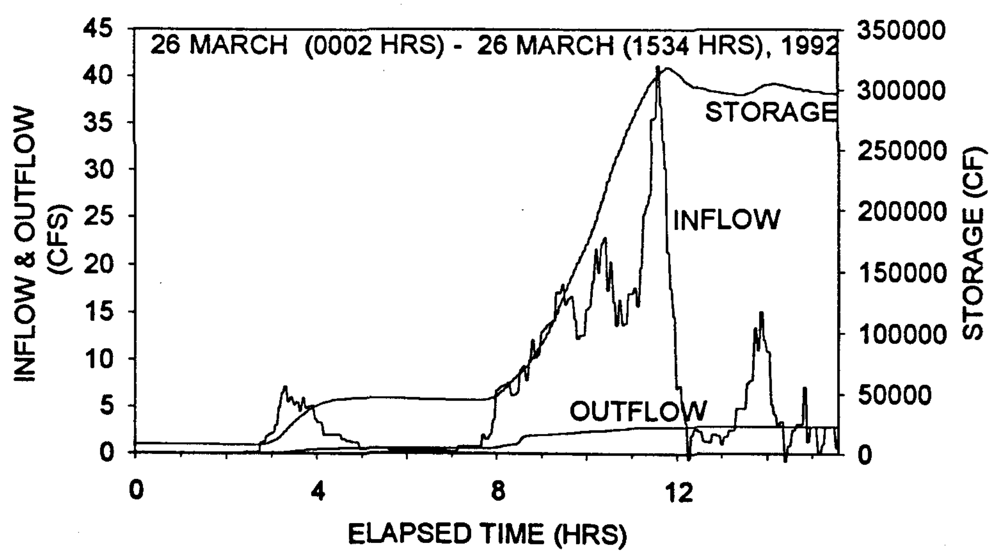
Elapsed time (hrs)		Storm No. 1	2	3	4	5	6	7	8
	I-Date:	25-Feb	23-Mar	26-Mar	21-Apr	7-May	26-May	21-Jun	12-Aug
	I-Time:	6:00	2:00	2:00	22:00	2:00	9:00	12:00	15:00
79.75									0.04
80.00									0.04
80.25									0.02
85.25									0.06
85.50									0.06
85.75									0.06
86.00									0.02
86.25									0.01
88.25									0.01
88.75									0.02
89.00									0.37
89.25									0.41
89.50									0.06
89.75									0.01
90.00									0.01
90.25									0.02
90.50									0.02
90.75									0.02
91.00									0.01
91.25									0.03
91.50									0.03
91.75									0.03
92.00									0.03
92.50									0.01
94.00									0.01
95.75									0.01
102.50									0.03
102.75									0.03
103.00									0.02
103.25									0.02
103.50									0.02
103.75									0.02
104.00									0.03
104.25									0.02
104.50									0.02
104.75									0.02
105.00									0.02
105.75									0.02
106.00									0.03

Appendix D. (continued)

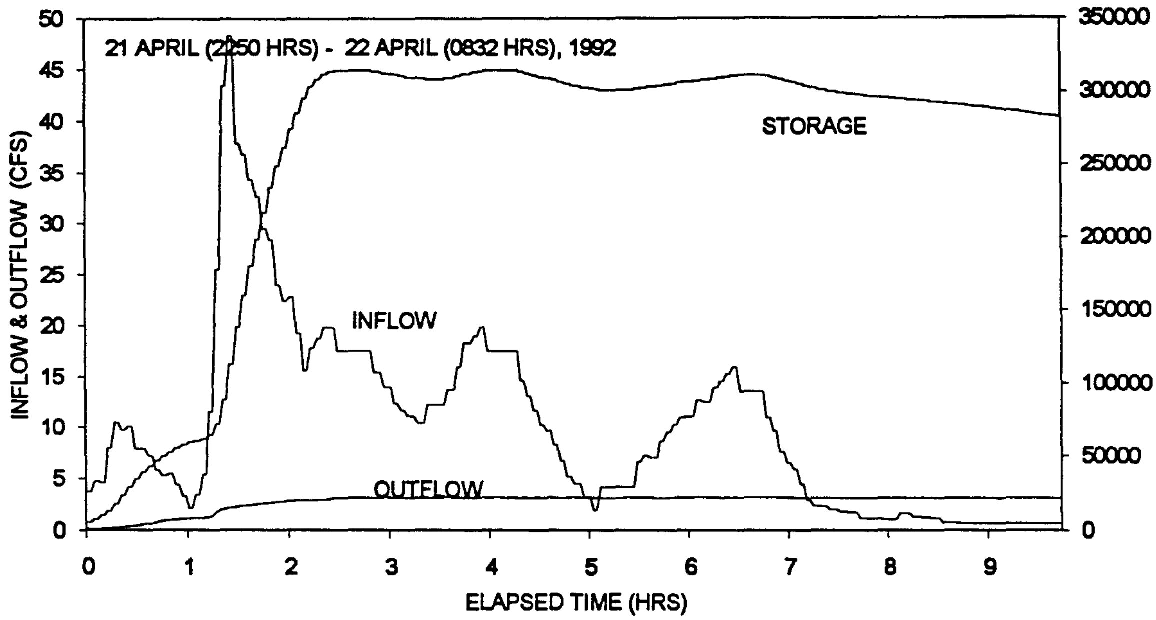
Elapsed time (hrs)	Storm No.	1	2	3	4	5	6	7	8
	I-Date:	25-Feb	23-Mar	26-Mar	21-Apr	7-May	26-May	21-Jun	12-Aug
	I-Time:	6:00	2:00	2:00	22:00	2:00	9:00	12:00	15:00
106.25									0.06
106.50									0.06
106.75									0.06
107.00									0.06
107.25									0.05
107.50									0.05
108.50									0.01
112.00									0.34
112.25									0.27
112.50									0.08
112.75									0.10
113.00									0.02
113.50									0.06
113.75									0.06
114.00									0.06
114.25									0.07
114.50									0.06
114.75									0.20
115.00									0.04

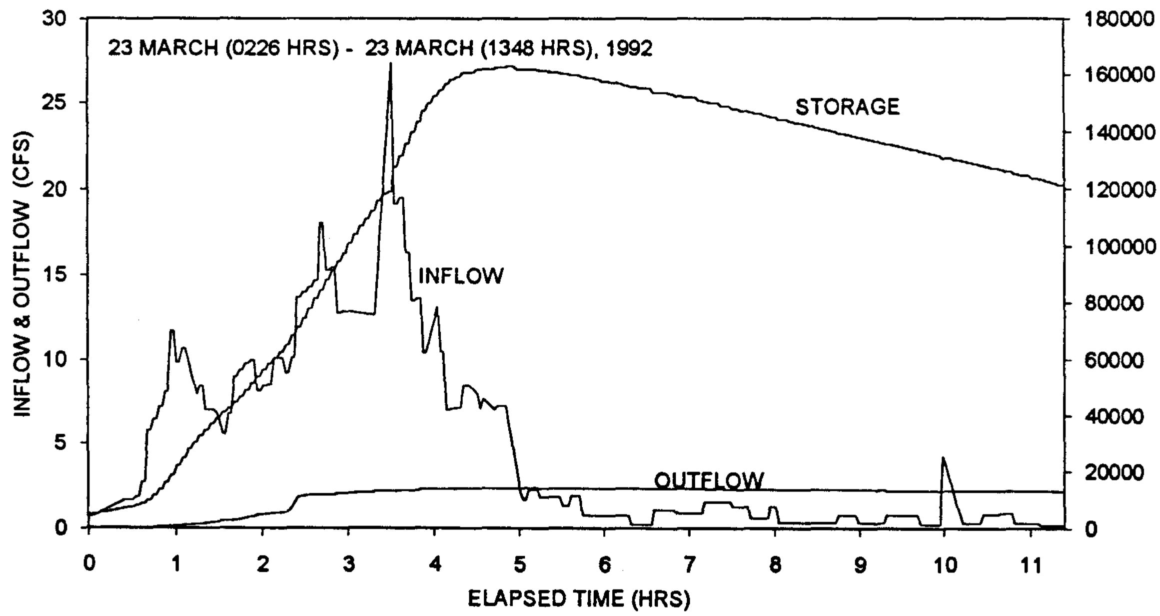
Appendix E. Inflow, outflow, and storage of runoff for eight monitored storms.



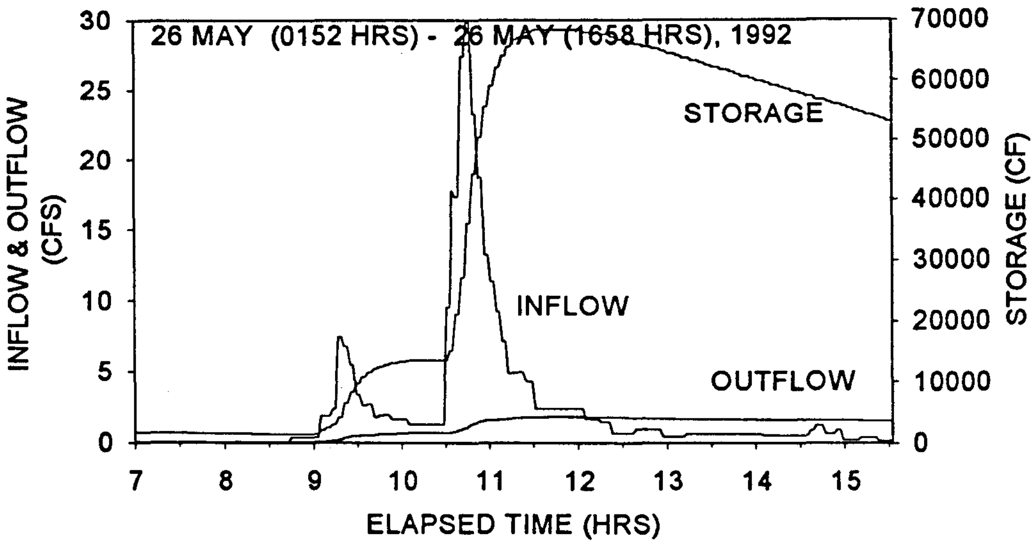


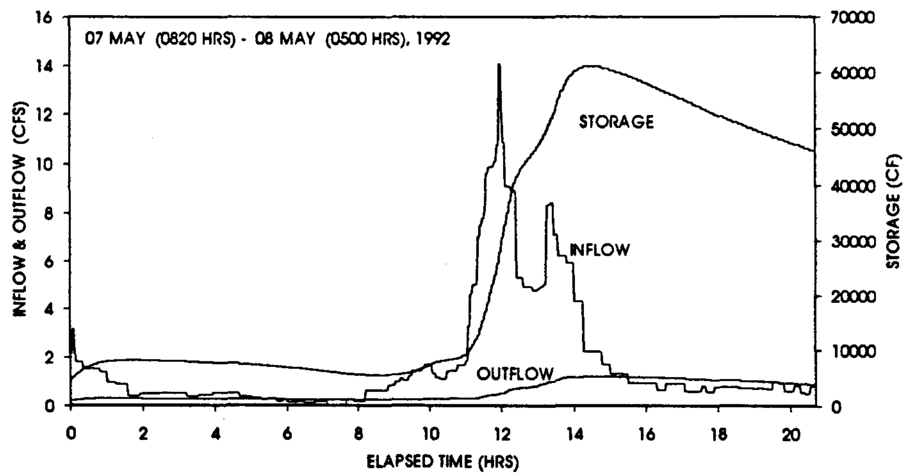
Appendix E. (continued)



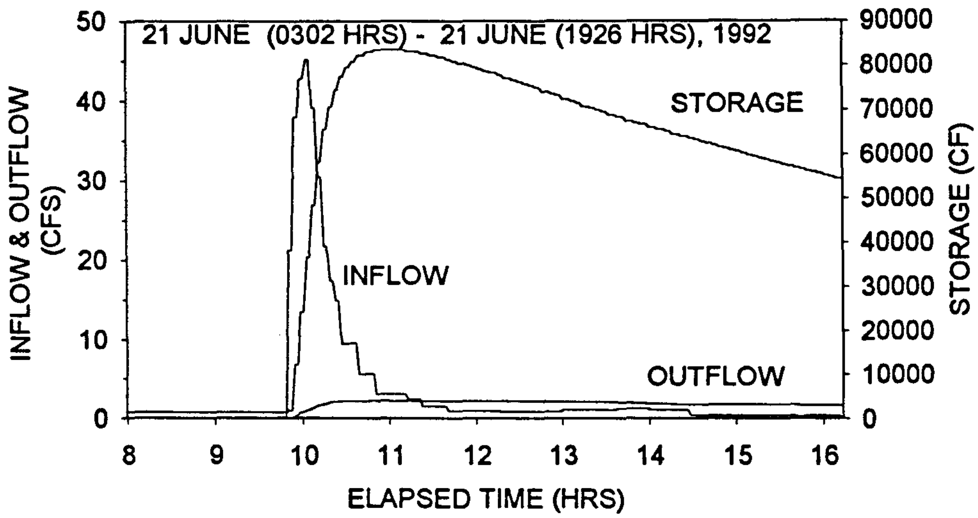


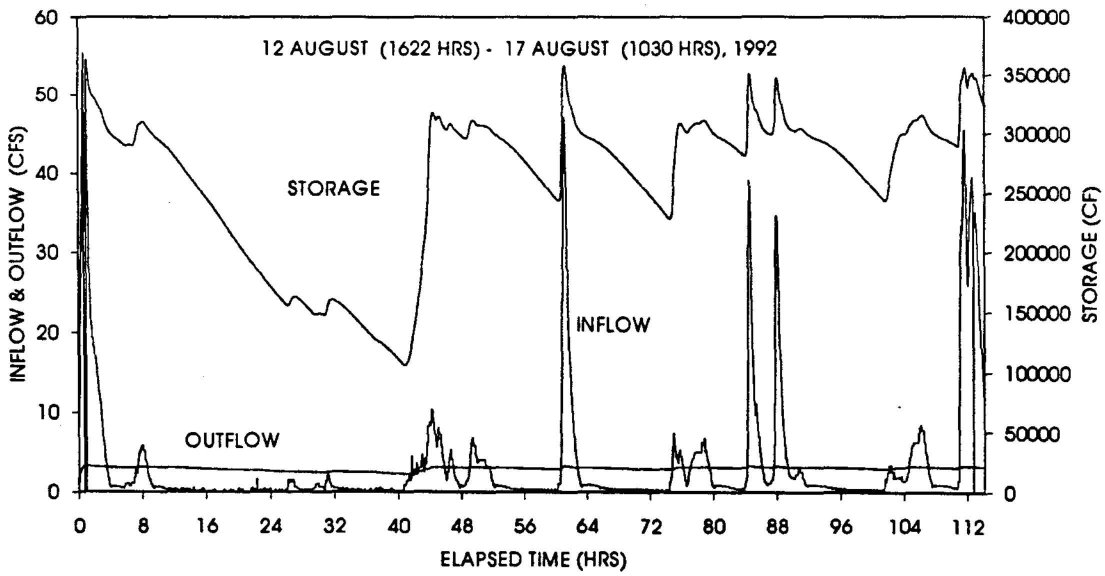
Appendix E. (continued)





Appendix E. (continued)





Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
1	25-Feb	9:45	0.0	I1	32.1	12.0	20.1	0.186	0.836	0.035	0.750	0.040	0.433	0.154	18.84	4.65
1	25-Feb	10:45	1.0	I2	27.9	10.6	17.3									
1	25-Feb	11:45	2.0	I3	22.5	8.1	14.4	0.175	0.768	0.045	0.654	0.076	0.435	0.149	17.03	3.77
1	25-Feb	12:45	0.0	I4	18.1	7.6	10.5									
1	25-Feb	13:45	4.0	I5	15.7	6.6	9.1	0.174	0.725	0.018	0.640	0.080	0.325	0.124	14.52	2.66
1	25-Feb	14:45	5.0	I6	13.2	5.2	8.0									
1	25-Feb	15:45	6.0	I7	11.9	4.4	7.5	0.208	0.670	0.009	0.501	0.048	0.213	0.101	15.52	3.09
1	25-Feb	16:45	7.0	I8	12.1	4.0	8.1	0.225	0.687	0.007	0.457	0.040	0.158	0.087	12.67	2.18
1	25-Feb	17:45	8.0	I9	6.4	2.7	3.7	0.233	0.683	0.006	0.947	0.040	0.120	0.078	12.92	1.54
1	25-Feb	18:45	9.0	I10	207.1	71.8	135.3	0.214	0.494	0.069	0.720	0.088	0.194	0.445	16.36	11.13
1	25-Feb	19:45	10.0	I11	68.5	17.8	50.7	0.133	0.271	0.060	0.325	0.036	0.525	0.197	12.13	5.59
1	25-Feb	20:45	11.0	I12	48.3	14.4	33.9	0.135	0.275	0.061	0.369	0.036	0.371	0.157	8.93	4.65
1	25-Feb	21:45	12.0	I13	105.8	27.7	78.1	0.087	0.151	0.103	0.193	0.072	0.435	0.223	8.57	5.91
1	25-Feb	22:45	13.0	I14	96.1	21.9	74.2	0.072	0.140	0.066	0.179	0.032	0.624	0.196	10.32	4.35
1	25-Feb	23:45	14.0	I15	39.3	8.3	31.0	0.100	0.179	0.136	0.245	0.040	0.321	0.140	10.34	4.09
1	26-Feb	0:45	15.0	I16	26.4	5.9	20.5									
1	26-Feb	1:45	16.0	I17	22.1	5.0	17.1	0.073	0.267	0.062	0.332	0.044	0.219	0.121	12.56	2.15
1	26-Feb	2:45	17.0	I18	15.9	3.7	12.2									
1	26-Feb	3:45	18.0	I19	315.5	76.3	239.2	0.113	0.333	0.061	0.259	0.044	1.703	0.464	9.78	11.90
1	26-Feb	4:45	19.0	I20	81.6	21.6	60.0	0.129	0.254	0.075	0.340	0.060	0.606	0.202	6.36	2.84
1	26-Feb	5:45	20.0	I21	43.8	8.9	34.9	0.111	0.260	0.082	0.354	0.064	0.329	0.132	9.45	4.06
1	26-Feb	6:45	21.0	I22	27.7	5.7	22.0									
1	26-Feb	7:45	22.0	I23	31.8	8.3	23.5	0.067	0.230	0.192	0.318	0.048	0.321	0.124	10.38	3.55
1	26-Feb	8:45	23.0	I24	254.4	60.7	193.7	0.107	0.213	0.114	0.223	0.064	1.355	0.086	10.47	13.14
1	25-Feb	9:20	0.0	O-1	27.5	11.9	15.6	0.227	0.619	0.087	0.676	0.056	0.646	0.194	15.34	5.01

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
1	25-Feb	12:20	3.0	O-2	20.5	8.5	12.0	0.100	0.691	0.118	0.486	0.060	0.479	0.153		
1	25-Feb	15:20	6.0	O-3	19.6	7.9	11.7	0.094	0.488	0.028	0.559	0.060	0.519	0.153	15.51	3.62
1	25-Feb	18:20	9.0	O-4	24.5	9.6	14.9	0.057	0.453	0.022	0.676	0.084	0.585	0.172		
1	25-Feb	21:20	12.0	O-5	43.5	14.2	29.3	0.086	0.312	0.037	0.574	0.056	0.572	0.203	11.62	4.94
1	26-Feb	0:20	15.0	O-6	44.8	12.6	32.2									
1	26-Feb	3:20	18.0	O-7	31.5	9.7	21.8	0.107	0.215	0.064	0.464	0.064	0.355	0.133	10.14	3.86
1	26-Feb	6:20	21.0	O-8	42.2	11.2	31.0									
1	26-Feb	9:20	24.0	O-9	57.2	13.1	44.1	0.127	0.226	0.057	0.530	0.092	0.450	0.159	9.33	3.96
1	26-Feb	12:20	27.0	O-10	46.8	11.3	35.5									
1	26-Feb	15:20	30.0	O-11	37.3	9.6	27.7	0.058	0.213	0.043	0.325	0.088	0.488	0.153	9.52	3.71
1	26-Feb	18:20	33.0	O-12	32.7	9.2	23.5									
1	26-Feb	21:20	36.0	O-13	27.0	7.7	19.3	0.052	0.230	0.040	0.369	0.088	0.494	0.126	10.01	3.55
1	27-Feb	0:20	39.0	O-14	21.9	6.7	15.2									
1	27-Feb	3:20	42.0	O-15	20.6	6.6	14.0	0.082	0.288	0.066	0.340	0.100	0.336	0.104	7.62	2.82
1	27-Feb	6:20	45.0	O-16	13.5	5.2	8.3									
1	27-Feb	9:20	48.0	O-17	13.4	5.1	8.3	0.059	0.243	0.038	0.303	0.096	0.317	0.096	8.05	2.53
1	27-Feb	12:20	51.0	O-18	9.8	3.9	5.9									
1	27-Feb	15:20	54.0	O-19	9.5	5.2	4.3	0.023	0.161	0.033	0.501	0.088	0.312	0.083	8.93	1.98
1	27-Feb	18:20	57.0	O-20	7.4	4.8	2.6									
1	27-Feb	21:20	60.0	O-21	7.7	5.2	2.5	0.023	0.189	0.024	0.332	0.060	0.268	0.077	8.80	
1	28-Feb	0:20	63.0	O-22	6.2	4.9	1.3	0.020	0.153	0.027	0.267	0.076	0.253	0.066		
1	28-Feb	3:20	66.0	O-23	5.2	3.6	1.6	0.019	0.142	0.028	0.267	0.100	0.241	0.058	7.94	
1	28-Feb	6:20	69.0	O-24	2.2	4.0	1.8	0.042	0.153	0.024	0.288	0.112	0.234	0.056	8.19	
2	23-Mar	3:20	0.0	I1	101.9	30.5	71.4	0.620	0.985	0.204	1.449	0.259	0.714	0.236	20.59	4.75

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
2	23-Mar	3:35	0.3	I2	67.7	20.5	47.2	0.519	0.798	0.122	0.958	0.189	0.505	0.170	13.66	4.49
2	23-Mar	3:50	0.5	I3	41.2	13.6	27.6	0.250	0.483	0.099	0.496	0.154	0.310	0.103	11.14	3.27
2	23-Mar	4:20	1.0	I4	46.7	13.3	33.4	0.164	0.273	0.084	0.569	0.131	0.308	0.104	9.65	3.54
2	23-Mar	4:50	1.5	I5	72.1	17.4	54.7	0.136	0.233	0.078	0.459	0.110	0.524	0.169	9.02	4.05
2	23-Mar	5:50	2.5	I6	51.4	12.0	39.4	0.143	0.261	0.071	0.202	0.099	0.390	0.128	8.59	3.59
2	23-Mar	6:50	3.5	I7	37.2	8.7	28.5	0.179	0.309	0.069	0.716	0.110	0.246	0.093	5.58	2.65
2	23-Mar	7:50	4.5	I8	19.8	6.1	13.7	0.170	0.378	0.075	0.400	0.136	0.169	0.070	8.05	2.25
2	23-Mar	8:50	5.5	I9	15.1	3.9	11.2	0.159	0.463	0.073	0.488	0.140	0.143	0.069	7.50	
2	23-Mar	9:50	6.5	I10	10.5	4.7	5.8	0.136	0.487	0.054	0.591	0.122	0.123	0.067	10.93	2.07
2	23-Mar	10:50	7.5	I11	10.1	5.6	4.5	0.148	0.515	0.038	0.422	0.108	0.136	0.070	10.04	0.85
2	23-Mar	11:50	8.5	I12	14.1	4.7	9.4	0.127	0.552	0.026	0.415	0.093	0.134	0.076	9.24	2.35
2	23-Mar	12:50	9.5	I13	31.2	5.7	25.5	0.124	0.588	0.016	0.400	0.084	0.182	0.113	10.24	2.69
2	23-Mar	13:50	10.5	I14	18.1	4.1	14.0	0.124	0.596	0.011	0.342	0.090	0.176	0.092	9.38	1.87
2	23-Mar	14:50	11.5	I15	13.2	4.7	8.5									
2	23-Mar	17:10	0.0	O-1	24.1	6.6	17.5	0.115	0.354	0.063	0.378	0.142	0.244	0.088	8.96	1.95
2	23-Mar	20:10	3.0	O-2	13.3	4.3	9.0	0.105	0.342	0.063	0.356	0.122	0.198	0.073	7.91	1.60
2	23-Mar	23:10	6.0	O-3	11.8	4.2	7.6	0.105	0.366	0.041	0.298	0.113	0.154	0.072	7.76	
2	24-Mar	2:10	9.0	O-4	11.1	4.8	6.3	0.106	0.334	0.057	0.276	0.125	0.178	0.068	10.11	1.55
2	24-Mar	5:10	12.0	O-5	11.1	4.0	7.1	0.101	0.342	0.056	0.349	0.134	0.176	0.069	11.14	
2	24-Mar	8:10	15.0	O-6	37.1	12.7	24.4	0.230	0.507	0.100	0.554	0.192	0.231	0.080	12.91	2.60
2	24-Mar	11:10	18.0	O-7	14.1	5.2	8.9	0.129	0.378	0.050	0.408	0.157	0.209	0.081	9.48	3.72
2	24-Mar	14:10	21.0	O-8	9.0	3.7	5.3	0.085	0.318	0.041	0.312	0.140	0.187	0.073	8.40	1.44
2	24-Mar	17:10	24.0	O-9	6.2	3.2	3.0	0.095	0.366	0.022	0.364	0.131	0.202	0.081	7.69	1.28
2	24-Mar	20:10	27.0	O-10	6.0	3.6	2.4	0.108	0.414	0.011	0.246	0.108	0.165	0.079	7.35	1.00
2	24-Mar	23:10	30.0	O-11	7.9	3.4	4.5	0.046	0.277	0.033	0.319	0.125	0.240	0.084	8.54	1.26

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
2	25-Mar	2:10	33.0	O-12	6.8	3.4	3.4	0.058	0.293	0.022	0.254	0.110	0.209	0.087	10.33	
2	25-Mar	5:10	36.0	O-13	6.2	3.2	3.0	0.070	0.378	0.017	0.305	0.102	0.213	0.091	9.06	1.61
2	25-Mar	8:10	39.0	O-14	6.7	3.2	3.5	0.061	0.305	0.013	0.254	0.110	0.233	0.102	10.00	1.31
3	26-Mar	8:03	0.0	I1	84.1	24.8	59.3	0.262	0.486	0.111	0.600	0.146	0.526	0.171	16.48	4.67
3	26-Mar	8:18	0.3	I2	96.4	26.7	69.7	0.155	0.234	0.092	0.412	0.143	0.518	0.179	11.18	4.41
3	26-Mar	8:33	0.5	I3	100.8	27.2	73.6	0.114	0.156	0.082	0.330	0.120	0.553	0.202	9.07	4.61
3	26-Mar	9:03	1.0	I4	156.6	34.7	121.9	0.091	0.113	0.084	0.354	0.131	0.690	0.274	7.61	4.20
3	26-Mar	9:33	1.5	I5	167.4	33.7	133.7	0.061	0.099	0.078	0.233	0.123	0.722	0.293	8.84	5.11
3	26-Mar	10:33	2.5	I6	123.6	24.5	99.1	0.053	0.103	0.079	0.378	0.110	0.555	0.199	6.51	3.54
3	26-Mar	11:33	3.5	I7	73.8	15.6	58.2	0.074	0.127	0.073	0.108	0.095	0.397	0.139	6.47	2.43
3	26-Mar	12:33	4.5	I8	61.5	10.2	51.3	0.073	0.165	0.090	0.320	0.140	0.289	0.135	7.87	2.48
3	26-Mar	13:33	5.5	I9	35.3	8.5	26.8	0.073	0.236	0.103	0.349	0.158	0.275	0.118	7.46	2.79
3	26-Mar	14:33	6.5	I10	32.9	8.3	24.6	0.095	0.167	0.080	0.296	0.110	0.240	0.100	15.63	2.31
3	26-Mar	15:33	7.5	I11	24.0	7.0	17.0	0.089	0.203	0.088	0.354	0.131	0.199	0.084	13.12	1.98
3	25-Mar	18:35	0.0	O-1	14.6	4.0	10.6	0.109	0.450	0.016	0.267	0.062	0.213	0.322	10.30	0.99
3	25-Mar	21:35	3.0	O-2	6.3	3.3	3.0									0.99
3	26-Mar	0:35	6.0	O-3	4.9	2.9	2.0	0.106	0.445	0.015	0.257	0.064	0.197	0.109	9.13	0.75
3	26-Mar	3:35	9.0	O-4	32.4	12.7	19.7	0.281	0.512	0.049	0.682	0.110	0.463	0.241	15.14	3.20
3	26-Mar	6:35	12.0	O-5	149.6	8.1	11.5	0.367	0.464	0.111	0.687	0.161	0.240	0.102	15.85	1.88
3	26-Mar	9:35	15.0	O-6	59.8	15.4	44.4	0.158	0.277	0.086	0.364	0.138	0.432	0.188	11.67	3.95
3	26-Mar	12:35	18.0	O-7	55.1	11.6	43.5	0.093	0.139	0.080	0.262	0.125	0.320	0.138	10.81	3.10
3	26-Mar	15:35	21.0	O-8	39.1	8.2	30.9									
3	26-Mar	18:35	24.0	O-9	34.1	8.1	26.0	0.060	0.156	0.080	0.262	0.125	0.270	0.112	10.69	2.91
3	26-Mar	21:35	27.0	O-10	29.9	8.1	21.8									

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
3	27-Mar	0:35	30.0	O-11	25.3	6.8	18.5	0.046	0.149	0.081	0.214	0.113	0.236	0.107	8.88	2.35
3	27-Mar	3:35	33.0	O-12	23.8	6.6	17.2									
3	27-Mar	6:35	36.0	O-13	21.3	5.8	15.5	0.050	0.198	0.071	0.277	0.120	0.217	0.099	11.24	2.17
3	27-Mar	9:35	39.0	O-14	19.1	5.7	13.4									
3	27-Mar	12:35	42.0	O-15	18.5	6.5	12.0	0.036	0.165	0.074	0.098	0.095	0.205	0.098	11.82	2.44
3	27-Mar	15:35	45.0	O-16	19.4	6.1	13.3									
3	27-Mar	18:35	48.0	O-17	16.0	5.2	10.8	0.024	0.215	0.050	0.203	0.090	0.232	0.187	8.14	2.18
3	27-Mar	21:35	51.0	O-18	11.0	2.0	9.0									
3	28-Mar	0:35	54.0	O-19	12.0	3.0	9.0	0.036	0.232	0.048	0.088	0.064	0.195	0.090	8.35	1.12
3	28-Mar	3:35	57.0	O-20	11.3	2.6	8.7									
3	28-Mar	6:35	60.0	O-21	10.5	2.0	8.5									
3	28-Mar	9:35	63.0	O-22	8.7	1.1	7.6									
3	28-Mar	12:35	66.0	O-23	9.4	1.3	8.1	0.046	0.265	0.031	0.243	0.077	0.215	0.108	12.99	1.83
3	28-Mar	15:35	69.0	O-25	12.3	3.9	8.4	0.054	0.308	0.025	0.277	0.090	0.230	0.111	10.53	1.47
3	28-Mar	18:35	72.0	O-26	10.1	3.2	6.9									
3	28-Mar	21:35	75.0	O-27	10.3	3.4	6.9	0.080	0.464	0.013	0.359	0.077	0.244	0.112	9.33	1.22
3	29-Mar	0:35	78.0	O-28	9.7	3.3	6.4									
3	29-Mar	3:35	81.0	O-29	8.3	3.9	4.4	0.085	0.464	0.012	0.340	0.064	0.215	0.116	10.98	0.05
3	29-Mar	6:35	84.0	O-30	8.8	3.9	4.9									
3	29-Mar	9:35	87.0	O-31	7.2	3.5	3.7	0.124	0.481	0.016	0.335	0.044	0.228	0.120	8.7	
4	22-Apr	1:02	1.0	I4	956.6	215.7	740.9	0.055	0.248	0.169	0.578	0.212	3.755	0.891	11.12	12.36
4	22-Apr	1:32	1.5	I5	349.0	57.4	291.6	0.072	0.177	0.149	0.439	0.181	1.103	0.366	8.87	5.75
4	22-Apr	2:32	2.5	I6	76.7	20.1	56.6	0.086	0.171	0.131	0.381	0.158	0.454	0.124	8.69	12.44
4	22-Apr	3:32	3.5	I7	73.6	17.5	56.1	0.077	0.164	0.109	0.332	0.140	0.365	0.090	12.75	1.45

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
4	22-Apr	4:32	4.5	I8	30.2	6.5	23.7	0.079	0.182	0.118	0.365	0.149	0.227	0.056	9.03	1.08
4	22-Apr	5:32	5.5	I9	44.5	13.6	30.9	0.080	0.190	0.117	0.430	0.153	0.286	0.085	8.16	14.03
4	22-Apr	6:32	6.5	I10	44.7	12.4	32.3									
4	22-Apr	7:32	7.5	I11	33.1	12.3	20.8	0.079	0.230	0.133	0.471	0.176	0.296	0.075	10.28	2.04
4	22-Apr	8:32	8.5	I12	16.3	4.8	11.5	0.080	0.312	0.149	0.578	0.208	0.246	0.064	11.47	1.16
4	22-Apr	9:08	0.0	O-1	77.7	26.1	51.6	0.466	0.331	0.047	1.265	0.140	1.407	0.520	16.26	7.33
4	22-Apr	10:08	1.0	*0-1	38.5	7.4	31.1	0.025	0.218	0.115	0.430	0.122	0.503	0.220	8.79	2.89
4	22-Apr	11:08	2.0	O-2	28.4	6.6	21.8									
4	22-Apr	12:08	3.0	O-3	26.1	7.1	19.0	0.020	0.228	0.109	0.406	0.004	0.400	0.121	8.63	2.84
4	22-Apr	13:08	4.0	O-4	25.1	7.6	17.5									
4	22-Apr	15:08	6.0	O-5	25.4	8.7	16.7	0.044	0.262	0.112	0.357	0.162	0.439	0.134	9.02	3.60
4	22-Apr	17:08	8.0	O-6	23.1	8.5	14.6									
4	22-Apr	19:08	10.0	O-7	21.7	7.8	13.9	0.031	0.227	0.106	0.340	0.131	0.435	0.117	8.24	3.08
4	22-Apr	22:08	12.0	O-8	18.5	6.9	11.6	0.029	0.226	0.112	0.316	0.131	0.551	0.107	8.26	2.48
4	23-Apr	1:08	15.0	O-9	16.7	6.0	10.7									
4	23-Apr	4:08	18.0	O-10	15.2	5.2	10.0	0.041	0.219	0.096	0.299	0.131	0.381	0.105	8.16	2.62
4	23-Apr	7:08	21.0	O-11	13.9	5.1	8.8	0.039	0.194	0.105	0.299	0.131	0.369	0.096	7.94	1.97
4	23-Apr	10:08	24.0	O-12	10.8	4.0	6.8									
4	23-Apr	13:08	27.0	O-13	10.9	4.4	6.5	0.101	0.193	0.115	0.349	0.140	0.265	0.087	8.43	1.53
4	23-Apr	16:08	30.0	O-14	8.0	3.3	4.7	0.107	0.157	0.121	0.398	0.140	0.227	0.084	10.58	1.61
4	23-Apr	19:08	33.0	O-15	7.6	3.5	4.1	0.115	0.140	0.115	0.414	0.162	0.269	0.089	10.42	1.60
4	23-Apr	22:08	36.0	O-16	6.1	3.8	2.3									
4	24-Apr	1:08	39.0	O-17	9.4	4.5	4.9	0.089	0.142	0.073	0.496	0.176	0.404	0.179	11.91	2.18
4	24-Apr	4:08	42.0	O-18	6.2	6.1	0.1									
4	24-Apr	7:08	45.0	O-19	6.4	5.5	0.9	0.030	0.092	0.048	0.529	0.203	0.655	0.220	10.82	2.29

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
4	24-Apr	10:08	48.0	O-20	11.5	6.9	4.6	0.170	0.041	0.094	0.701	0.217	0.679	0.269	11.69	3.06
4	24-Apr	13:08	51.0	O-21	10.4	6.4	4.0	0.186	0.185	0.052	0.611	0.226	0.645	0.254	10.66	2.76
4	24-Apr	16:08	54.0	O-22	11.0	6.4	4.6									
4	24-Apr	19:08	57.0	O-23	14.4	8.2	6.2	0.301	0.327	0.027	0.668	0.185	0.641	0.255	10.40	3.38
4	24-Apr	22:08	60.0	O-24	9.7	6.3	3.4	0.332	0.357	0.027	0.692	0.149	0.649	0.233	9.60	2.43
5	7-May	19:22	0.0	I1	132.2	68.1	64.1	0.361	0.869	0.163	1.216	0.352	1.168	0.369	21.59	9.61
5	7-May	19:37	0.3	I2	109.1	45.9	63.2	0.297	0.795	0.129	0.889	0.258	0.947	0.252	20.66	7.97
5	7-May	20:07	0.8	I4	113.5	44.9	68.6	0.255	0.587	0.115	0.594	0.190	0.891	0.303	13.20	6.54
5	7-May	21:07	1.8	I6	40.1	15.4	24.7	0.181	0.379	0.108	0.381	0.162	0.385	0.117	11.58	3.86
5	7-May	21:37	2.3	I7	34.2	14.1	20.1	0.184	0.320	0.135	0.381	0.190	0.443	0.116	10.88	
5	7-May	22:37	3.3	I8	19.3	7.3	12.0	0.157	0.256	0.112		0.081	0.200	0.069	9.32	2.58
5	7-May	23:37	4.3	I9	12.0	4.6	7.4	0.161	0.379	0.129	0.299	0.194			9.58	2.56
5	8-May	1:37	6.3	I11	9.9	3.3	6.6	0.181	0.468	0.055	0.430	0.258	0.180	0.115	12.53	2.69
5	8-May	4:37	10.3	I14	4.5	2.7	1.8	0.163	0.553	0.038	0.463	0.249	0.084	0.085	12.58	2.07
5	8-May	5:37	11.3	I15	15.4	5.2	10.2	0.248	0.449	0.102	0.619	0.249	0.219	0.079	13.87	3.62
5	9-May	14:46	0.0	I41	80.8	36.2	44.6	0.380	0.865	0.060	0.987	0.235	0.882	0.268	17.02	9.27
5	9-May	15:16	0.5	I43	93.4	39.3	54.1	0.204	0.943	0.126	0.897	0.307	1.130	0.346	19.37	10.51
5	9-May	15:31	0.8	I44	64.4	26.7	37.7	0.232	0.925	0.088	0.741	0.244	0.655	0.224	15.92	9.02
5	9-May	16:01	1.3	I45	34.2	14.3	19.9	0.240	0.847	0.079	0.709	0.235	0.412	0.139	16.54	4.95
5	7-May	17:23	0.0	O-1	16.5	9.3	7.2	0.480	0.746	0.051	1.306	0.321	0.427	0.182	22.46	4.69
5	7-May	20:47	3.4	O-4	53.5	20.4	33.1	0.314	0.572	0.103	0.774	0.276	0.674	0.252	16.83	5.57
5	7-May	22:23	5.0	O-5	21.7	7.9	13.8	0.248	0.416	0.112	0.594	0.267	0.446	0.153	14.74	4.30
5	8-May	8:23	15.0	O-9	12.5	5.4	7.1	0.226	0.372	0.105	0.553	0.267	0.257	0.087	13.53	3.42
5	8-May	19:23	26.0	O-43	20.2	10.0	10.2	0.126	0.546	0.066	0.594	0.221	0.308	0.132	13.70	3.26

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
5	8-May	22:23	29.0	O-44	15.4	7.4	8.0	0.120	0.487	0.060	0.602	0.221	0.431	0.140	13.54	2.87
5	9-May	1:23	32.0	O-45	12.2	7.3	4.9	0.093	0.457	0.061	0.561	0.203	0.385	0.134	13.74	2.75
5	9-May	13:23	44.0	O-30	11.2	5.8	5.4	0.153	0.372	0.033	0.594	0.199	0.304	0.142	13.04	2.81
5	9-May	19:23	50.0	O-32	9.5	5.9	3.6	0.191	0.320	0.033	1.053	0.235	0.290	0.140	13.29	2.23
5	9-May	22:23	53.0	O-33	10.4	5.7	4.7	0.317	0.320	0.017	0.611	0.226	0.254	0.144	11.11	2.39
5	10-May	1:23	56.0	O-34	8.0	5.1	2.9	0.348	0.301	0.020	0.709	0.208	0.099	0.154	11.05	2.07
5	10-May	10:23	65.0	O-37	8.1	5.0	3.1	0.422	0.386	0.008	0.643	0.226	0.157	0.176	8.85	1.47
6	26-May	11:35	0.0	I1	133.9	48.7	85.2	0.521	0.892	0.109	1.645	0.174	1.006	0.276	29.65	10.16
6	26-May	11:50	0.3	I2	96.1	35.3	60.8	0.475	0.894	0.108	1.474	0.163			28.20	6.94
6	26-May	12:05	0.5	I3	416.2	100.3	315.9	0.285	0.623	0.175	0.920	0.184	1.775	0.504	19.03	14.40
6	26-May	12:20	0.8	I4	316.8	85.3	231.5	0.217	0.526	0.157	0.693	0.184	1.742	0.485	20.22	12.05
6	26-May	12:50	1.3	I5	113.9	30.3	83.6	0.167	0.490	0.168	0.636	0.203	0.859	0.265	15.12	7.59
6	26-May	13:20	1.8	I6	74.7	20.7	54.0	0.180	0.546	0.157	0.622	0.193	0.591	0.197	23.95	4.14
6	26-May	13:50	2.3	I7	54.5	14.5	40.0	0.192	0.570	0.143	0.636	0.174	0.503	0.177	14.45	4.89
6	26-May	14:50	3.3	I8	41.5	10.7	30.8	0.179	0.618	0.092	0.586	0.144	0.361	0.170	13.92	4.00
6	26-May	15:50	4.3	I9	50.5	12.8	37.7	0.207	0.734	0.060	0.792	0.134	0.356	0.174	16.96	4.81
6	26-May	16:50	5.3	I10	31.0	8.4	22.6								16.06	3.61
6	26-May	11:30	0.0	O-6	240.5	78.8	161.7	0.513	0.892	0.060	1.645	0.109	1.738	0.587	45.92	10.60
6	26-May	14:30	3.4	O-7	82.4	20.9	61.5	0.256	0.647	0.152	0.821	0.148	0.743	0.250	19.04	6.01
6	26-May	17:30	5.0	O-8	48.5	14.0	34.5	0.229	0.611	0.150	0.743	0.153	0.589	0.188	19.05	4.59
6	26-May	20:30	7.0	O-9	37.5	12.6	24.9	0.230	0.618	0.144	0.785	0.163	0.474	0.153	18.61	4.01
6	26-May	23:30	9.0	O-10	35.5	12.6	22.9								20.49	3.57
6	27-May	2:30	12.0	O-11	23.8	9.4	14.4	0.264	0.540	0.153	0.679	0.124	0.456	0.135	19.01	3.65
6	27-May	5:30	15.0	O-12	17.5	8.9	8.6	0.301	0.473	0.133	0.998	0.169	0.408	0.130	19.34	

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
6	27-May	8:30	17.0	O-13	14.7	7.0	7.7	0.329	0.623	0.047	0.856	0.104	0.291	0.145	16.38	
7	21-Jun	13:12	0.0	I1	364.6	82.6	282.0	0.277	0.647	0.237	0.878	0.214	1.726	0.434	18.21	
7	21-Jun	13:27	0.3	I2	277.6	61.4	216.2	0.038	0.673	0.170	0.624	0.153	1.726	0.473	18.78	9.66
7	21-Jun	13:42	0.5	I3	132.8	31.4	101.4	0.122	0.658	0.184	0.569	0.163	1.024	0.288	15.49	6.50
7	21-Jun	13:57	0.8	I4	87.1	25.2	61.9	0.026	0.669	0.228	0.534	0.224	0.874	0.238	14.62	5.33
7	21-Jun	14:27	1.3	I5	46.4	13.1	33.3	0.043	0.706	0.306	0.541	0.301	0.575	0.185	20.33	4.31
7	21-Jun	14:57	1.8	I6	34.7	11.4	23.3									
7	21-Jun	15:27	2.3	I7	24.3	8.7	15.6	0.014	0.806	0.451	0.520	0.454	0.438	0.166	18.27	3.63
7	21-Jun	16:27	3.3	I8	13.1	6.6	6.5	0.020	0.858	0.379	0.500	0.469	0.297	0.136	16.70	3.06
7	21-Jun	17:27	4.3	I9	8.6	5.1	3.5	0.058	0.921	0.283	0.527	0.469	0.209	0.121	20.16	2.74
7	21-Jun	18:27	5.3	I10	5.1	3.6	1.5									
7	21-Jun	19:27	6.3	I11	6.8	5.0	1.8	0.103	0.917	0.093	0.507	0.326	0.176	0.114	16.92	1.99
7	21-Jun	13:07	0.0	O1	142.1	32.2	109.9	0.111	0.477	0.059	0.265	0.209	1.103	1.124	9.56	6.01
7	21-Jun	14:08	1.0	O2	116.7	26.5	90.2	0.097	0.721	0.166	0.630	0.224	1.053	0.419	16.43	5.07
7	21-Jun	15:08	2.0	O3	59.5	16.6	42.9	0.080	0.728	0.182	0.603	0.224	0.783	0.261	17.24	4.40
7	21-Jun	16:08	3.0	O4	50.3	15.7	34.6	0.088	0.743	0.187	0.603	0.219	0.642	0.206	17.28	4.25
7	21-Jun	17:08	4.0	O5	43.2	13.8	29.4	0.081	0.754	0.197	0.610	0.230	0.662	0.218	16.04	3.94
7	21-Jun	20:08	7.0	O6	32.4	11.4	21	0.075	0.743	0.205	0.630	0.235	0.604	0.187	17.04	3.57
7	21-Jun	23:08	10.0	O7	25.4	9.8	15.6	0.085	0.706	0.191	0.672	0.235	0.588	0.187	18.28	3.62
7	22-Jun	2:08	13.0	O8	18.6	21.2	-2.6									
7	22-Jun	5:08	16.0	O9	17.4	8.6	8.8	0.163	0.391	0.214	0.892	0.291	0.608	0.188		3.44
7	22-Jun	8:08	19.0	O10	20.2	10	10.2									
7	22-Jun	11:08	22.0	O11	10.5	6.3	4.2	0.243	0.310	0.111	0.940	0.270	0.351	0.191	20.80	2.69
7	22-Jun	14:08	25.0	O12	13.4	9.4	4									

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
7	22-Jun	17:08	28.0	O13	9.6	6.4	3.2	0.037	0.317	0.014	0.369	0.158	0.305	0.169	12.50	1.51
7	22-Jun	20:08	31.0	O14	4.1	3.9	0.2	0.151	0.332	0.007	0.417	0.143	0.164	0.135	10.75	1.36
7	22-Jun	23:08	34.0	O15	9.6	6.3	3.3	0.311	0.340	0.003	0.500	0.128	0.209	0.178	9.80	1.25
7	23-Jun	2:08	37.0	O16	9.1	6.1	3									
7	23-Jun	5:08	40.0	O17	7.5	6.3	1.2	0.371	0.351	-0.001	0.534	0.143	0.093	0.157	11.57	1.34
7	23-Jun	8:08	43.0	O18	4.4	3.7	0.7	0.288	0.391	0.002	0.451	0.122	0.068	0.139	11.29	0.71
7	23-Jun	11:08	46.0	O19	0.9	1.8	-0.9	0.221	0.473	0.010	0.417	0.122	0.143	0.127	8.67	1.79
8	12-Aug	16:07	0.0	I1	304.3	76.8	227.5	0.550	0.803	0.342	1.792	0.350	1.827	0.445	36.62	7.50
8	12-Aug	16:22	0.3	I2	395.2	54.7	340.5	0.298	0.671	0.166	0.667	0.184	1.751	0.493	16.04	6.61
8	12-Aug	16:37	0.5	I3/I4	271.4	33.8	237.6	0.160	0.408	0.188	0.338	0.171	1.199	0.348	15.24	5.20
8	12-Aug	17:22	0.8	I5	319.9	30.8	289.1	0.152	0.359	0.211	0.310	0.221	0.754	0.261	16.03	4.66
8	12-Aug	17:52	1.3	I6	193.7	25.3	168.4	0.188	0.408	0.157	0.513	0.184	0.568	0.128	8.43	3.78
8	12-Aug	18:22	1.8	I7	178.4	21.9	156.5	0.127	0.394	0.162	0.443	0.171	0.471	0.127	11.22	3.82
8	12-Aug	19:22	2.8	I8	117.3	18.4	98.9	0.064	0.434	0.163	0.303	0.177	0.401	0.107	8.64	3.46
8	12-Aug	20:22	3.8	I9	85.5	19.4	66.1	0.015	0.732	0.186	0.380	0.192	0.673	0.121	15.58	2.49
8	12-Aug	21:22	4.8	I10	78.3	48.7	29.6	0.074	1.066	0.217	0.583	0.208	0.256	0.076	36.44	2.71
8	12-Aug	22:22	5.8	I11	49.2	25.0	24.2	0.082	1.132	0.237	0.639	0.241	0.230	0.073	13.54	1.90
8	12-Aug	23:22	6.8	I12	39.6	13.7	25.9	0.044	0.737	0.125	0.464	0.151	0.304	0.073	38.98	3.47
8	13-Aug	00:22	7.8	I13	269.9	39.9	230.0	0.008	0.175	0.088	0.205	0.089	0.885	0.173	48.49	3.15
8	13-Aug	01:22	8.8	I14	106.2	22.8	83.4	0.012	0.280	0.141	0.359	0.178	0.234	0.105	39.23	3.67
8	13-Aug	O2:22	9.8	I15	60.3	9.6	50.7	0.017	0.465	0.184	0.569	0.241	0.340	0.071	42.83	2.27
8	13-Aug	O3:22	10.8	I16	20.7	4.6	16.1									
8	13-Aug	04:22	11.8	I17	29.0	5.6	23.4	0.037	0.816	0.145	0.576	0.201	0.116	0.032	13.14	2.29
8	13-Aug	05:22	12.8	I18	18.1	4.2	13.9									

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
8	13-Aug	06:22	13.8	I19	17.4	5.4	12.0	0.068	1.150	0.094	0.576	0.184	0.085	0.030	13.77	0.83
8	13-Aug	07:22	14.8	I20	9.0	4.5	4.5									
8	13-Aug	17:13	24.6	I21	9.4	3.9	5.5	0.087	1.167	0.023	0.492	0.094	0.151	0.039	12.34	0.78
8	13-Aug	18:13	25.6	I22	17.6	7.3	10.3	0.042	1.211	0.029	0.604	0.054	0.225	0.076	13.60	2.04
8	13-Aug	19:13	26.6	I23	216.8	67.0	149.8	0.015	0.280	0.069	0.527	0.076	0.441	0.253	15.50	6.86
8	13-Aug	20:13	27.6	I24	45.7	14.6	31.1	0.025	0.350	0.054	0.464	0.073	0.120	0.117	17.97	2.59
8	13-Aug	21:13	28.6	I25	18.6	7.0	11.6	0.011	0.447	0.037	0.387	0.073	0.007	0.067	16.03	2.58
8	13-Aug	22:13	29.6	I26	28.9	11.1	17.8									
8	13-Aug	23:13	30.6	I27	25.1	8.6	16.5	0.008	0.254	0.052	0.317	0.093	0.208	0.060	35.40	3.34
8	14-Aug	00:13	31.6	I28	458.2	124.1	334.1	0.009	0.166	0.092	0.289	0.102	0.064	0.393	11.73	9.97
8	14-Aug	01:13	32.6	I29	125.2	38.6	86.6	0.059	0.908	0.100	0.562	0.125	0.014	0.286	20.58	5.59
8	14-Aug	02:13	33.6	I30	44.1	11.9	32.2	0.030	1.044	0.087	0.520	0.140	0.146	0.045	12.98	2.35
8	14-Aug	03:13	34.6	I31	36.5	10.6	25.9	0.019	1.360	0.057	0.408	0.110	0.269	0.066	41.54	2.48
8	14-Aug	04:13	35.6	I32	25.3	5.5	19.8									
8	14-Aug	05:13	36.6	I33	16.0	4.4	11.6	0.026	1.913	0.016	0.366	0.067		0.064	10.39	2.08
8	14-Aug	06:13	37.6	I34	41.7	7.6	34.1									
8	14-Aug	07:13	38.6	I35	10.0	3.7	6.3	0.032	1.290	0.035	0.331	0.064	0.076	0.045	11.08	2.19
8	14-Aug	08:13	39.6	I36	13.3	4.5	8.8	0.074	1.531	0.024	0.429	0.064	0.054	0.041	39.47	2.46
8	14-Aug	09:13	40.6	I37	100.2	26.8	73.4	0.043	1.062	0.053	0.352	0.061	0.752	0.155	11.25	7.63
8	14-Aug	10:13	41.6	I38	260.4	36.3	224.1	0.013	0.083	0.062	0.212	0.067	0.445	0.125	6.58	5.85
8	14-Aug	11:13	42.6	I39	137.1	14.7	122.4	0.011	0.069	0.091	0.198	0.093	0.179	0.097	6.61	3.93
8	14-Aug	11:45	43.1	I40	84.7	12.5	72.2	0.006	0.061	0.107	0.261	0.128				
8	14-Aug	11:46	43.2	I41	91.5	17.1	74.4	0.007	0.091	0.140	0.233	0.164	0.247	0.082	7.32	3.35
8	14-Aug	12:01	43.4	I42	170.3	17.2	153.1	0.023	0.105	0.124	0.198	0.166	0.348	0.120	30.22	
8	14-Aug	12:13	43.6	I43	462.7	27.3	435.4	0.023	0.083	0.077	0.380	0.087	0.479	0.142	6.41	1.26

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
8	14-Aug	12:14	43.6	I44	390.6	26.0	364.6	0.024	0.087	0.072	0.324	0.082	0.590	0.197	5.58	3.11
8	14-Aug	17:15	48.6	I45	269.0	51.9	217.1	0.018	0.315	0.163	0.471	0.169	0.620	0.139	11.36	3.64
8	14-Aug	18:15	49.6	I46	183.5	34.4	149.1	0.028	0.127	0.126	0.387	0.098	0.796	0.142	9.22	3.01
8	14-Aug	19:15	50.6	I47	105.6	17.4	88.2	0.010	0.140	0.159	0.310	0.141	0.506	0.096	35.91	6.77
8	14-Aug	20:15	51.6	I48	80.7	23.0	57.7	0.019	0.197	0.169	0.422	0.167	0.265	0.071	9.78	1.49
8	14-Aug	21:15	52.6	I49	66.3	13.3	53.0	0.022	0.315	0.215	0.520	0.258	0.203	0.062	10.87	2.38
8	14-Aug	22:15	53.6	I50	36.5	12.4	24.1									
8	14-Aug	23:15	54.6	I51	31.6	5.8	25.8	0.041	0.570	0.218	0.695	0.324	0.199	0.059	13.45	1.01
8	15-Aug	OO:15	55.6	I52	32.7	8.6	24.1									
8	15-Aug	01:15	56.6	I53	28.9	5.8	23.1	0.025	0.719	0.168	0.716	0.284	0.199	0.066	12.86	1.10
8	15-Aug	02:15	57.6	I54	25.8	6.1	19.7									
8	15-Aug	03:15	58.6	I55	24.1	5.2	18.9	0.017	0.842	0.108	0.716	0.217	0.133	0.061	12.42	0.89
8	15-Aug	04:15	59.6	I56	18.2	4.3	13.9	0.008	0.926	0.106	0.576	0.172	0.217	0.048	11.42	1.13
8	15-Aug	05:15	60.6	I57	501.1	59.9	441.2	0.071	0.105	0.062	0.352	0.064	1.734	0.486	5.67	2.12
8	15-Aug	05:16	60.7	I58	473.4	43.8	429.6	0.016	0.078	0.058	0.170	0.057	1.807	0.505	10.13	7.94
8	15-Aug	06:13	61.6	I61	165.5	19.5	146.0	0.016	0.060	0.145	0.380	0.127	0.449	0.140	9.27	3.62
8	15-Aug	06:15	61.6	I62	186.1	23.9	162.2									
8	15-Aug	06:16	61.7	I63	186.9	19.1	167.8	0.022	0.069	0.149	0.338	0.160	0.515	0.149	6.73	2.69
8	15-Aug	06:17	61.7	I64	149.0	15.2	133.8									
8	15-Aug	06:18	61.7	I65	133.5	21.0	112.5	0.027	0.083	0.169	0.352	0.185	0.361	0.108	6.60	
8	15-Aug	06:20	61.7	I66	109.8	13.4	96.4									
8	15-Aug	07:15	62.6	I67	96.9	17.8	79.1	0.034	0.236	0.233	0.478	0.278	0.699	0.127	10.11	2.44
8	15-Aug	18:15	73.6	I77	4.5	3.7	0.8	0.076	1.202	0.081	0.674	0.201	0.085	0.060	10.48	0.38
8	15-Aug	19:15	74.6	I78	407.2	43.1	364.1	0.022	0.201	0.068	0.261	0.075	1.114	0.326	45.30	6.74
8	15-Aug	20:15	75.6	I79	89.0	11.5	77.5	0.011	0.135	0.149	0.310	0.140	0.274	0.058	10.63	2.52

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
8	15-Aug	21:15	76.6	I80	36.6	9.3	27.3	0.044	0.197	0.237	0.464	0.242	0.234	0.054	26.62	3.17
8	15-Aug	22:15	77.6	I81	86.5	15.8	70.7	0.018	0.091	0.179	0.338	0.199	0.291	0.069	30.99	1.85
8	15-Aug	23:15	78.6	I82	91.7	11.9	79.8									
8	16-Aug	00:15	79.6	I83	34.7	5.7	29.0	0.038	0.201	0.318	0.618	0.293	0.111	0.048	14.74	0.68
8	16-Aug	01:15	80.6	I84	16.1	4.3	11.8									
8	16-Aug	02:15	81.6	I85	16.5	2.8	13.7	0.049	0.526	0.366	0.786	0.212	0.063	0.037	21.18	1.24
8	16-Aug	03:15	82.6	I86	11.3	2.5	8.8									
8	16-Aug	04:15	83.6	I87	11.4	2.8	8.6	0.055	0.798	0.267	0.814	0.221	0.041	0.036	17.27	0.81
8	16-Aug	05:15	84.6	I91	184.0	14.0	170.0	0.031	0.105	0.188	0.289	0.251	0.375	0.092	23.70	2.38
8	16-Aug	10:15	89.6	I92	37.4	5.2	32.2	0.051	0.337	0.355	0.534	0.299	0.164	0.059	44.62	1.61
8	16-Aug	11:15	90.6	I93	72.0	10.2	61.8	0.029	0.298	0.233	0.373	0.267	0.234	0.069	27.98	2.92
8	16-Aug	12:15	91.6	I94	25.1	4.7	20.4									
8	16-Aug	13:15	92.6	I95	12.5	3.7	8.8	0.055	0.588	0.353	0.660	0.332	0.085	0.047	44.59	
8	16-Aug	14:15	93.6	I96	8.7	2.5	6.2									
8	16-Aug	15:15	94.6	I97	8.1	2.9	5.2	0.078	0.833	0.534	0.660	0.577	0.041	0.029	41.49	0.82
8	16-Aug	21:15	100.6	I103	9.9	6.3		0.014	1.062	0.151	0.674	0.323	0.059	0.038	12.64	1.06
8	16-Aug	22:15	101.6	I104	129.4	20.9	108.5	0.009	0.671	0.095	0.401	0.128	0.506	0.122	11.49	3.85
8	16-Aug	23:15	102.6	I105	85.5	12.7	72.8	0.007	0.175	0.143	0.338	0.101	0.239	0.081	9.11	4.55
8	17-Aug	00:15	103.6	I106	52.4	3.7	48.7									
8	17-Aug	01:15	104.6	I107	99.5	12.9	86.6	0.021	0.131	0.184	0.408	0.136	0.274	0.078		
8	17-Aug	02:15	105.6	I108	144.2	13.6	130.6									
8	17-Aug	03:15	106.6	I109	110.0	5.8	104.2									
8	17-Aug	04:15	107.6	I110	96.9	7.0	89.9									
8	17-Aug	05:15	108.6	I111	26.4	3.2	23.2									
8	17-Aug	06:15	109.6	I112	22.4	2.0	20.4									

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
8	17-Aug	07:15	110.6	I113	32.1	3.2	28.9									
8	17-Aug	08:15	111.6	I114	234.6	14.2	220.4									
8	17-Aug	09:15	112.6	I115	151.4	10.3	141.1									
8	17-Aug	10:15	113.6	I116	68.1	7.8	60.3									
8	17-Aug	11:15	114.6	I117	98.5	10.0	88.5									
8	17-Aug	12:15	115.6	I118	92.5	8.1	84.4									
8	17-Aug	13:15	116.6	I119	72.2	6.6	65.6									
8	17-Aug	14:15	117.6	I120	57.3	5.0	52.3									
8	17-Aug	15:15	118.6	I121	45.2	4.6	40.6									
8	17-Aug	16:15	119.6	I122	34.0	4.0	30.0									
8	12-Aug	16:12	0.0	O1	251.9	57.4	194.5	0.179	0.649	0.119	0.814	0.166	1.677	1.820	16.20	6.28
8	12-Aug	17:13	1.0	O2	200.3	21.9	178.4	0.183	0.412	0.220	0.373	0.204	0.718	0.493	40.69	4.28
8	12-Aug	18:13	2.0	O3	137.0	17.0	120.0	0.187	0.394	0.198	0.450	0.214	0.336	0.206	44.16	3.40
8	12-Aug	19:13	3.0	O4	88.1	11.5	76.6	0.145	0.394	0.192	0.394	0.195	0.344	0.142	50.04	3.15
8	12-Aug	20:13	4.0	O5	74.2	15.3	58.9	0.148	0.394	0.181	0.499	0.155	0.315	0.134	14.63	2.56
8	12-Aug	23:13	7.0	O6	49.2	8.0	41.2	0.150	0.465	0.217	0.415	0.140	0.255	0.072	11.42	1.99
8	13-Aug	02:13	10.0	O7	41.0	9.0	32.0	0.098	0.359	0.181	0.436	0.168	0.081	0.073	46.40	2.03
8	13-Aug	05:13	13.0	O8	29.2	7.0	22.2	0.094	0.377	0.185	0.450	0.179	0.060	0.066	18.73	2.10
8	13-Aug	08:13	16.0	09	21.8		171.5	0.110	0.487	0.176	0.380	0.115	0.094	0.060	13.13	1.40
8	13-Aug	11:13	19.0	O10	18.0	4.0	14.0	0.083	0.469	0.148	0.408	0.157	0.133	0.059		
8	13-Aug	14:13	16.0	O11	17.0	4.0	13.0	0.092	0.469	0.140	0.380	0.169	0.203	0.067	31.59	1.28
8	13-Aug	17:13	19.0	O12	16.6	4.0	12.6	0.099	0.447	0.158	0.380	0.146	0.155	0.061		
8	13-Aug	20:13	22.0	O13	18.9	6.1	12.8	0.070	0.424	0.132	0.450	0.172	0.208	0.065	45.66	3.45
8	13-Aug	23:13	25.0	O14	17.8	6.5	11.3	0.053	0.342	0.139	0.422	0.139	0.085	0.073		
8	14-Aug	02:13	28.0	O15	17.2	5.9	11.3	0.023	0.276	0.109	0.443	0.167	0.326	0.072	46.19	1.97

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
8	14-Aug	05:13	31.0	O16	13.3	4.7	8.6	0.075	0.197	0.104	0.450	0.132	0.212	0.041	27.23	1.21
8	14-Aug	08:13	34.0	O17	7.6	5.1	2.5	0.058	0.320	0.110	0.751	0.172	0.085	0.045	43.05	1.31
8	14-Aug	11:13	37.0	O18	36.7	7.3	29.4	0.053	0.153	0.095	0.324	0.104	0.094	0.065	8.97	2.08
8	14-Aug	14:13	40.0	O19	58.0	7.4	50.6	0.038	0.105	0.117	0.408	0.079	0.111	0.064	9.17	1.16
8	14-Aug	17:13	43.0	O20	32.9	5.4	27.5	0.040	0.118	0.128	0.338	0.127	0.160	0.053	9.71	1.11
8	14-Aug	20:13	46.0	O21	28.5	5.0	23.5	0.027	0.131	0.132	0.352	0.156	0.190	0.048	24.28	1.18
8	14-Aug	23:13	49.0	O22	21.0	5.0	16.0	0.032	0.157	0.151	0.380	0.153	0.160	0.042	9.42	0.66
8	15-Aug	02:13	52.0	O23	15.6	3.8	11.8	0.215	0.184	0.161	0.590	0.194	0.133	0.035	10.26	0.52
8	15-Aug	05:13	55.0	O24	13.8	3.8	10.0	0.034	0.223	0.145	0.352	0.170	0.076	0.028	9.26	0.43
8	15-Aug	08:13	58.0	O25	64.0	6.4	57.6	0.032	0.171	0.169	0.380	0.191	0.252	0.067	8.67	1.13
8	15-Aug	11:13	61.0	O26	37.3	5.4	31.9	0.048	0.162	0.149	0.303	0.163	0.190	0.050	20.07	1.60
8	15-Aug	14:13	64.0	O27	43.8	5.9	37.9	0.064	0.047	0.134	0.436	0.161	0.181	0.054	33.35	1.48
8	15-Aug	17:13	67.0	O28	27.1	4.2	22.9	0.189	0.210	0.139	0.940	0.160	0.010	0.051	40.21	2.15
8	15-Aug	20:13	70.0	O29	44.7	8.4	36.3	0.183	0.210	0.111	0.590	0.101	0.217	0.065	21.48	1.76
8	15-Aug	23:13	73.0	O30	34.4	8.2	26.2	0.099	0.179	0.150	0.632	0.146	0.173	0.057	8.50	1.22
8	16-Aug	02:13	76.0	O31	20.5	8.5	12.0	0.151	0.192	0.210	0.520	0.198	0.124	0.043	20.97	1.35
8	16-Aug	05:13	79.0	O32	127.5	14.5	113.0	0.160	0.184	0.139	0.310	0.157	0.322	0.100	40.40	2.62
8	16-Aug	08:13	82.0	O33	75.2	9.1	66.1	0.159	0.192	0.210	0.422	0.227	0.199	0.076	34.29	1.76
8	16-Aug	17:15	91.0	O36	1.1	4.0	24.1	0.149	0.184	0.180	0.597	0.216	0.072	0.054		
8	16-Aug	20:15	94.0	O37	1.1	4.0	20.8	0.085	0.201	0.183	0.394	0.215	0.133	0.051	7.93	0.68
8	16-Aug	23:15	97.0	O38	22.0	2.5	19.5	0.194	0.263	0.164	0.583	0.199	0.142	0.051	9.02	0.75
8	17-Aug	02:15	100.0	O39	24.0	3.7	20.3	0.137	0.219	0.190	0.394	0.202	0.102	0.043		
8	17-Aug	05:14	103.0	O40	21.0	3.3	17.7									
8	17-Aug	08:15	106.0	O41	86.2	10.7	75.5									
8	17-Aug	09:15	107.1	O42	83.6	8.9	74.7									

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)
8	17-Aug	12:15	110.1	O43	41.2	5.5	35.7									
8	17-Aug	15:15	113.1	O44	29.7	4.3	25.4									

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
1	25-Feb	9:45	0.0	I1	0.0041		0.0007	0.0073	0.0094	0.1219			
1	25-Feb	10:45	1.0	I2									
1	25-Feb	11:45	2.0	I3	0.0037	0.0008	0.0017	0.0111	0.0103	0.1248			
1	25-Feb	12:45	0.0	I4									
1	25-Feb	13:45	4.0	I5	0.0026	0.0001	0.0002	0.0056	0.0080	0.1111			
1	25-Feb	14:45	5.0	I6									
1	25-Feb	15:45	6.0	I7	0.0026	0.0004	-0.0008	0.0099	0.0066	0.1021			
1	25-Feb	16:45	7.0	I8									
1	25-Feb	17:45	8.0	I9	0.0023	0.0005	0.0017	0.0057	0.0050	0.1119			
1	25-Feb	18:45	9.0	I10									
1	25-Feb	19:45	10.0	I11	0.0070	0.0006	0.0046	0.0228	0.0109	0.1217			
1	25-Feb	20:45	11.0	I12									
1	25-Feb	21:45	12.0	I13	0.0043	0.0006	0.0047	0.0241	0.0139	0.1249			
1	25-Feb	22:45	13.0	I14									
1	25-Feb	23:45	14.0	I15	0.0044		-0.0010	0.0116	0.0075	0.0844			
1	26-Feb	0:45	15.0	I16									
1	26-Feb	1:45	16.0	I17	0.0048	0.0010	0.0032	0.0217	0.0059	0.0814			
1	26-Feb	2:45	17.0	I18									
1	26-Feb	3:45	18.0	I19	0.0131	0.0009	0.0036	0.0733	0.0235	0.2143			
1	26-Feb	4:45	19.0	I20									
1	26-Feb	5:45	20.0	I21	0.0054	0.0002	0.0002	0.0108	0.0097	0.0997			
1	26-Feb	6:45	21.0	I22									
1	26-Feb	7:45	22.0	I23	0.0043	0.0002	0.0006	0.0135	0.0075	0.1014			
1	26-Feb	8:45	23.0	I24									
1	25-Feb	9:20	0.0	O-1	0.0040		0.0041	0.0089	0.0064	0.1013			

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
1	25-Feb	12:20	3.0	O-2									
1	25-Feb	15:20	6.0	O-3	0.0023	0.0003	0.0037	0.0001	0.0075	0.3130			
1	25-Feb	18:20	9.0	O-4									
1	25-Feb	21:20	12.0	O-5	0.0044	0.0000	0.0021	0.0151	0.0092	0.1076			
1	26-Feb	0:20	15.0	O-6									
1	26-Feb	3:20	18.0	O-7	0.0052		-0.0011	0.0026	0.0063	0.0793			
1	26-Feb	6:20	21.0	O-8									
1	26-Feb	9:20	24.0	O-9	0.0027	0.0011	0.0007	0.0210	0.0100	0.0767			
1	26-Feb	12:20	27.0	O-10									
1	26-Feb	15:20	30.0	O-11	0.0025	0.0003	0.0014	0.0062	0.0080	0.0736			
1	26-Feb	18:20	33.0	O-12									
1	26-Feb	21:20	36.0	O-13	0.0021	0.0014	0.0037	0.0021	0.0069	0.0702			
1	27-Feb	0:20	39.0	O-14									
1	27-Feb	3:20	42.0	O-15	0.0021	0.0005	0.0025	0.0025	0.0063	0.0779			
1	27-Feb	6:20	45.0	O-16									
1	27-Feb	9:20	48.0	O-17	0.0028	0.0001	0.0001	0.0147	0.0054	0.0605			
1	27-Feb	12:20	51.0	O-18									
1	27-Feb	15:20	54.0	O-19	0.0020	0.0018	0.0009	0.0086	0.0087	0.0653			
1	27-Feb	18:20	57.0	O-20									
1	27-Feb	21:20	60.0	O-21	0.0008	0.0023	0.0022	0.0110	0.0194	0.0678			
1	28-Feb	0:20	63.0	O-22									
1	28-Feb	3:20	66.0	O-23	0.0016	0.0009	0.0025	0.0024	0.0045	0.0613			
1	28-Feb	6:20	69.0	O-24									
2	23-Mar	3:20	0.0	I1	0.0050		0.0003	0.0229	0.0180	0.2836	30000		

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
2	23-Mar	3:35	0.3	I2									
2	23-Mar	3:50	0.5	I3	0.0033		0.0011	0.0051	0.0062	0.1083			
2	23-Mar	4:20	1.0	I4									
2	23-Mar	4:50	1.5	I5	0.0027		-0.0004	0.0147	0.0090	0.1065			
2	23-Mar	5:50	2.5	I6									
2	23-Mar	6:50	3.5	I7	0.0030		0.0023	0.0076	0.0042	0.0801	3000		
2	23-Mar	7:50	4.5	I8									
2	23-Mar	8:50	5.5	I9	0.0010		0.0019		0.0062	0.0818			
2	23-Mar	9:50	6.5	I10									
2	23-Mar	10:50	7.5	I11	0.0019	-0.0003	0.0019	0.0110	0.0063	0.1229			
2	23-Mar	11:50	8.5	I12									
2	23-Mar	12:50	9.5	I13	0.0036		0.0023	0.0088	0.0065	0.1359	8000		
2	23-Mar	13:50	10.5	I14									
2	23-Mar	14:50	11.5	I15	0.0022		0.0014	0.0086	0.0039	0.1263			
2	23-Mar	17:10	0.0	O-1	0.0021		0.0016	0.0140	0.0058	0.0829	1300		
2	23-Mar	20:10	3.0	O-2									
2	23-Mar	23:10	6.0	O-3	0.0036		0.0028	0.0003	0.0091	0.0733			
2	24-Mar	2:10	9.0	O-4									
2	24-Mar	5:10	12.0	O-5	0.0019		0.0014	0.0111	0.0048	0.0661			
2	24-Mar	8:10	15.0	O-6									
2	24-Mar	11:10	18.0	O-7	0.0013		0.0007	0.0076	0.0038	0.0681	300		
2	24-Mar	14:10	21.0	O-8									
2	24-Mar	17:10	24.0	O-9	0.0008		0.0010	0.0112	0.0029	0.0683			
2	24-Mar	20:10	27.0	O-10									
2	24-Mar	23:10	30.0	O-11	0.0006		0.0011	0.0048	0.0040	0.0813			

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
2	25-Mar	2:10	33.0	O-12									
2	25-Mar	5:10	36.0	O-13	-0.0004		0.0008	0.0076	0.0027	0.0702	220		
2	25-Mar	8:10	39.0	O-14									
3	26-Mar	8:03	0.0	I1	0.0034	0.0012	0.0034	0.0132	0.0142	0.1413	800	3.9	
3	26-Mar	8:18	0.3	I2									
3	26-Mar	8:33	0.5	I3	0.0019	0.0011	0.0014	0.0060	0.0082	0.0639			
3	26-Mar	9:03	1.0	I4									
3	26-Mar	9:33	1.5	I5	0.0057	0.0002	0.0032	0.0284	0.0141	0.1186			
3	26-Mar	10:33	2.5	I6									
3	26-Mar	11:33	3.5	I7	0.0017	0.0008	0.0028	0.0091	0.0067	0.0660	1700	4.5	
3	26-Mar	12:33	4.5	I8									
3	26-Mar	13:33	5.5	I9	0.0051	0.0005	0.0037	0.0126	0.0079	0.0852			
3	26-Mar	14:33	6.5	I10									
3	26-Mar	15:33	7.5	I11	0.0036	0.0011	0.0035	0.0083	0.0058	0.0711	8000	5.1	
3	25-Mar	18:35	0.0	O-1	0.0009	0.0005	0.0013	0.0060	0.0029	0.0702	70	3	
3	25-Mar	21:35	3.0	O-2									
3	26-Mar	0:35	6.0	O-3	0.0017	0.0009	0.0042	-0.0003	-0.0005	0.0669			
3	26-Mar	3:35	9.0	O-4									
3	26-Mar	6:35	12.0	O-5	0.0029	0.0002	0.0033	0.0089	0.0079	0.1149			
3	26-Mar	9:35	15.0	O-6									
3	26-Mar	12:35	18.0	O-7	0.0052	0.0003	0.0026	0.0185	0.0077	0.0654	5000	4.2	
3	26-Mar	15:35	21.0	O-8									
3	26-Mar	18:35	24.0	O-9	0.0038		0.0027	0.0059	0.0069	0.0647			
3	26-Mar	21:35	27.0	O-10									

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
3	27-Mar	0:35	30.0	O-11	0.0037	0.0007	0.0035	0.0144	0.0061	0.0628			
3	27-Mar	3:35	33.0	O-12									
3	27-Mar	6:35	36.0	O-13	0.0028	0.0004	0.0035	0.0149	0.0069	0.0656			
3	27-Mar	9:35	39.0	O-14									
3	27-Mar	12:35	42.0	O-15	0.0031	0.0012	0.0040	0.0100	0.0048	0.0542	2200	4.5	
3	27-Mar	15:35	45.0	O-16									
3	27-Mar	18:35	48.0	O-17	0.0033	0.0002	0.0015	0.0113	0.0058	0.0663			
3	27-Mar	21:35	51.0	O-18									
3	28-Mar	0:35	54.0	O-19	0.0034	0.0003	0.0016	0.0031	0.0044	0.0591			
3	28-Mar	3:35	57.0	O-20									
3	28-Mar	6:35	60.0	O-21									
3	28-Mar	9:35	63.0	O-22									
3	28-Mar	12:35	66.0	O-23	0.0026	0.0005	0.0026	0.0036	0.0042	0.0663	110	5.1	
3	28-Mar	15:35	69.0	O-25	0.0025		0.0034	0.0056	0.0027	0.0715			
3	28-Mar	18:35	72.0	O-26									
3	28-Mar	21:35	75.0	O-27	0.0014		0.0000		0.0012	0.0848			
3	29-Mar	0:35	78.0	O-28									
3	29-Mar	3:35	81.0	O-29	0.0006		-0.0010	0.0055	0.0022	0.0826			
3	29-Mar	6:35	84.0	O-30									
3	29-Mar	9:35	87.0	O-31	0.0006		0.0002	0.0030	0.0007	0.0853			
4	22-Apr	1:02	1.0	I4									
4	22-Apr	1:32	1.5	I5	0.0078	0.0005	0.0035	0.0399	0.0188	0.1573	50000	4.6	66.1
4	22-Apr	2:32	2.5	I6									
4	22-Apr	3:32	3.5	I7	-0.0003	0.0037	0.0134	0.0339	0.0429	0.2540			

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
4	22-Apr	4:32	4.5	I8									
4	22-Apr	5:32	5.5	I9	0.0015		0.0019	0.0103	0.0056	0.0504			
4	22-Apr	6:32	6.5	I10									
4	22-Apr	7:32	7.5	I11	0.0023		0.0000	0.0099	0.0044	0.0566	50000	2.9	16.6
4	22-Apr	8:32	8.5	I12									
4	22-Apr	9:08	0.0	O-1	0.0029	0.0003	0.0044	0.0097	0.0120	0.1325	23000	3.4	12.6
4	22-Apr	10:08	1.0	*0-1	0.0013	0.0002	0.0005	0.0054	0.0055	0.0832			
4	22-Apr	11:08	2.0	O-2									
4	22-Apr	12:08	3.0	O-3	0.0006	0.0004	-0.0001	0.0040	0.0047	0.0615			
4	22-Apr	13:08	4.0	O-4									
4	22-Apr	15:08	6.0	O-5	0.0029	0.0012	0.0017	0.0237	0.0333	0.2696			
4	22-Apr	17:08	8.0	O-6									
4	22-Apr	19:08	10.0	O-7	-0.0007	0.0019	0.0020	0.0067	0.0379	0.3180			
4	22-Apr	22:08	12.0	O-8									
4	23-Apr	1:08	15.0	O-9									
4	23-Apr	4:08	18.0	O-10									
4	23-Apr	7:08	21.0	O-11	0.0008		0.0003	0.0102	0.0039	0.0461	17000	3.4	15.6
4	23-Apr	10:08	24.0	O-12									
4	23-Apr	13:08	27.0	O-13	0.0040	0.0030	0.0016	0.0068	0.0344	0.3875			
4	23-Apr	16:08	30.0	O-14									
4	23-Apr	19:08	33.0	O-15	0.0049	0.0021	-0.0008	0.0236	0.0351	0.4160			
4	23-Apr	22:08	36.0	O-16									
4	24-Apr	1:08	39.0	O-17	0.0004	0.0073	0.0006	0.0013	0.0263	0.4618	1300	4.4	21.3
4	24-Apr	4:08	42.0	O-18									
4	24-Apr	7:08	45.0	O-19	0.0035	0.0035	0.0003	0.0172	0.0306	0.3565			

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
4	24-Apr	10:08	48.0	O-20									
4	24-Apr	13:08	51.0	O-21	0.0019	0.0011	0.0034	-0.0040	0.0172	0.3666			
4	24-Apr	16:08	54.0	O-22									
4	24-Apr	19:08	57.0	O-23	0.0313	0.0024	0.0102	0.1698	0.0177	0.4341	2200	5.8	22.9
4	24-Apr	22:08	60.0	O-24									
5	7-May	19:22	0.0	I1	0.0392	0.0035	0.0220	0.2056	0.1024	1.1257	17000	26	
5	7-May	19:37	0.3	I2									
5	7-May	20:07	0.8	I4									
5	7-May	21:07	1.8	I6									
5	7-May	21:37	2.3	I7	0.0278	0.0039	0.0019	0.1833	0.0369	0.4455			
5	7-May	22:37	3.3	I8									
5	7-May	23:37	4.3	I9	0.0092	0.0047	0.0114	0.0821	0.0492	0.4990			
5	8-May	1:37	6.3	I11	0.0281	0.0042	0.0074	0.1590	0.0559	0.7887	8000	5.3	25.6
5	8-May	4:37	10.3	I14									
5	8-May	5:37	11.3	I15	0.0211	0.0020	0.0022	0.1582	0.0364	0.5175			
5	9-May	14:46	0.0	I41	0.0597	0.0032	0.0200	0.2735	0.0859	1.1708			
5	9-May	15:16	0.5	I43	0.0265	0.0064	0.0129	0.1341	0.1034	1.0736	90000	18.6	
5	9-May	15:31	0.8	I44									
5	9-May	16:01	1.3	I45	0.0135	0.0058	0.0141	0.0294	0.0740	0.9774			
5	7-May	17:23	0.0	O-1	0.0090	0.0061	0.0221	0.0891	0.0682	1.0104			
5	7-May	20:47	3.4	O-4									
5	7-May	22:23	5.0	O-5	0.0157	0.0031	0.0082	0.0684	0.0596	0.5771	50000	6.3	53.2
5	8-May	8:23	15.0	O-9	-0.0004	0.0009	0.0016	0.0556	0.0392	0.4571			
5	8-May	19:23	26.0	O-43	0.0507	0.0024	0.0091	0.2266	0.0536	0.8018	17000	8.4	40.9

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
5	8-May	22:23	29.0	O-44									
5	9-May	1:23	32.0	O-45	0.0707	0.0049	0.0095	0.3205	0.0497	0.6846			
5	9-May	13:23	44.0	O-30							4000	3.3	39.9
5	9-May	19:23	50.0	O-32									
5	9-May	22:23	53.0	O-33	0.0071	0.0014	0.0099	0.0402	0.0299	0.5302			
5	10-May	1:23	56.0	O-34									
5	10-May	10:23	65.0	O-37	0.0281	0.0007	0.0046	0.0887	0.0104	0.3833	2000	3.9	15.6
6	26-May	11:35	0.0	I1	0.0322	0.0058	0.0273	0.1627	0.0978	1.4667	230000	28	
6	26-May	11:50	0.3	I2									
6	26-May	12:05	0.5	I3	0.0407	0.0134	0.0240	0.3239	0.1135	1.2136			
6	26-May	12:20	0.8	I4									
6	26-May	12:50	1.3	I5	0.0244	0.0056	0.0174	0.1563	0.0745	0.8680			
6	26-May	13:20	1.8	I6									
6	26-May	13:50	2.3	I7	0.0156	0.0035	0.0097	0.0972	0.0538	0.7503			
6	26-May	14:50	3.3	I8									
6	26-May	15:50	4.3	I9	0.0196	0.0032	0.0106	0.0590	0.0559	0.8430	70000	10.8	51
6	26-May	16:50	5.3	I10									
6	26-May	11:30	0.0	O-6									
6	26-May	14:30	3.4	O-7	0.0157	0.0027	0.0123	0.1293	0.0668	0.6751	220000	13.8	98.2
6	26-May	17:30	5.0	O-8									
6	26-May	20:30	7.0	O-9	0.0121	0.0049	0.0047	0.0843	0.0506	0.5639			
6	26-May	23:30	9.0	O-10									
6	27-May	2:30	12.0	O-11	0.0084	0.0032	0.0059	0.0523	0.0416	0.4846			
6	27-May	5:30	15.0	O-12									

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
6	27-May	8:30	17.0	O-13	0.0061	0.0057	0.0181	0.0323	0.0293	0.5726	50000	10.5	29.9
7	21-Jun	13:12	0.0	I1	0.0112	0.0010	0.0071	0.0901	0.0261	0.2953			
7	21-Jun	13:27	0.3	I2									
7	21-Jun	13:42	0.5	I3	0.0034	0.0006	0.0035	0.0193	0.0131	0.1488			
7	21-Jun	13:57	0.8	I4									
7	21-Jun	14:27	1.3	I5	0.0031	0.0003	0.0034	0.0057	0.0095	0.1466			
7	21-Jun	14:57	1.8	I6									
7	21-Jun	15:27	2.3	I7	0.0024	0.0003	0.0015	0.0015	0.0112	0.1394			
7	21-Jun	16:27	3.3	I8									
7	21-Jun	17:27	4.3	I9	0.0017	0.0006	0.0025	0.0068	0.0111	0.1399			
7	21-Jun	18:27	5.3	I10									
7	21-Jun	19:27	6.3	I11	0.0011	0.0001	0.0022	0.0015	0.0114	0.1720			
7	21-Jun	13:07	0.0	O1	0.0053	0.0013	0.0040	0.0167	0.0137	0.2103			
7	21-Jun	14:08	1.0	O2									
7	21-Jun	15:08	2.0	O3	0.0028	0.0006	0.0021	0.0179	0.0133	0.1354			
7	21-Jun	16:08	3.0	O4									
7	21-Jun	17:08	4.0	O5	0.0015	0.0001	0.0026	0.0086	0.0103	0.2907			
7	21-Jun	20:08	7.0	O6									
7	21-Jun	23:08	10.0	O7	0.0011	0.0004	0.0021	0.0073	0.0090	0.1026			
7	22-Jun	2:08	13.0	O8									
7	22-Jun	5:08	16.0	O9	0.0014	0.0000	0.0018	0.0050	0.0093	0.1087			
7	22-Jun	8:08	19.0	O10									
7	22-Jun	11:08	22.0	O11	0.0007	0.0003	0.0034	0.0033	0.0071	0.1029	50000	17.5	63.5
7	22-Jun	14:08	25.0	O12									

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
7	22-Jun	17:08	28.0	O13	-0.0003		0.0026	0.0011	0.0076	0.0610			
7	22-Jun	20:08	31.0	O14									
7	22-Jun	23:08	34.0	O15	0.0010	0.0008	0.0014		0.0026	0.0656	11000	4.5	23.4
7	23-Jun	2:08	37.0	O16									
7	23-Jun	5:08	40.0	O17	0.0007	0.0007	0.0019		0.0042	0.0600			
7	23-Jun	8:08	43.0	O18									
7	23-Jun	11:08	46.0	O19	0.0019	0.0010	0.0055	0.0044	0.0031	0.0788	13000	3.4	17.8
8	12-Aug	16:07	0.0	I1	0.0071	0.0004	0.0053	0.0556	0.0267	0.2823	1600000	23	
8	12-Aug	16:22	0.3	I2									
8	12-Aug	16:37	0.5	I3/I4	0.0075	0.0007	0.0449	0.0359	0.0256	0.1154			
8	12-Aug	17:22	0.8	I5	0.0080	0.0010	0.0082	0.0323	0.0182	0.1037			
8	12-Aug	17:52	1.3	I6									
8	12-Aug	18:22	1.8	I7	0.0036	0.0005	0.0167	0.0195	0.0167	0.0871			
8	12-Aug	19:22	2.8	I8									
8	12-Aug	20:22	3.8	I9	0.0025	0.0003	0.0033	0.0078	0.0083	0.1057			
8	12-Aug	21:22	4.8	I10									
8	12-Aug	22:22	5.8	I11	0.0023	0.0003	0.0089	0.0099	0.0225	0.1470	50000	4.7	
8	12-Aug	23:22	6.8	I12									
8	13-Aug	00:22	7.8	I13	0.0059	0.0003	0.0064	0.0140	0.0102	0.0796			
8	13-Aug	01:22	8.8	I14									
8	13-Aug	O2:22	9.8	I15	0.0014		0.0058	0.0040	0.0065	0.0917			
8	13-Aug	O3:22	10.8	I16									
8	13-Aug	04:22	11.8	I17	0.0019	0.0003	0.0215	0.0066	0.0076	0.1463			
8	13-Aug	05:22	12.8	I18									

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
8	13-Aug	06:22	13.8	I19	0.0009	0.0003	0.0274	0.0066	0.0091	0.1900	8000	2.6	
8	13-Aug	07:22	14.8	I20									
8	13-Aug	17:13	24.6	I21	0.0009	0.0004	0.0024	0.0060	0.0041	0.1766			
8	13-Aug	18:13	25.6	I22									
8	13-Aug	19:13	26.6	I23	0.0057	0.0002	0.0024	0.0313	0.0185	0.1676			
8	13-Aug	20:13	27.6	I24									
8	13-Aug	21:13	28.6	I25	0.0019	0.0001	0.0000	0.0066	0.0065	0.1327			
8	13-Aug	22:13	29.6	I26									
8	13-Aug	23:13	30.6	I27	0.0017	0.0003	0.0008	0.0061	0.0067	0.0878			
8	14-Aug	00:13	31.6	I28									
8	14-Aug	01:13	32.6	I29	0.0030	0.0003	0.0004	0.0157	0.0084	0.1247	30000	5.2	
8	14-Aug	02:13	33.6	I30									
8	14-Aug	03:13	34.6	I31	0.0010	0.0004	0.0005	0.0032	0.0056	0.1362			
8	14-Aug	04:13	35.6	I32									
8	14-Aug	05:13	36.6	I33	0.0010	0.0002	0.0003	0.0045	0.0039	0.1887			
8	14-Aug	06:13	37.6	I34									
8	14-Aug	07:13	38.6	I35	0.0013			0.0056	0.0053	0.1379			
8	14-Aug	08:13	39.6	I36									
8	14-Aug	09:13	40.6	I37	0.0031		0.0014	0.0194	0.0091	0.1262	50000	6	
8	14-Aug	10:13	41.6	I38									
8	14-Aug	11:13	42.6	I39	0.0028	0.0002	0.0008	0.0125	0.0054	0.0551			
8	14-Aug	11:45	43.1	I40									
8	14-Aug	11:46	43.2	I41	0.0027	0.0000	0.0002	0.0099	0.0063	0.0651			
8	14-Aug	12:01	43.4	I42									
8	14-Aug	12:13	43.6	I43	0.0067		0.0011	0.0207	0.0091	0.0614			

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
8	14-Aug	12:14	43.6	I44									
8	14-Aug	17:15	48.6	I45	0.0032	0.0002	0.0000	0.0109	0.0088	0.0913			
8	14-Aug	18:15	49.6	I46									
8	14-Aug	19:15	50.6	I47	0.0015		0.0008	0.0099	0.0046	0.0552			
8	14-Aug	20:15	51.6	I48									
8	14-Aug	21:15	52.6	I49	0.0023	0.0005	0.0009	0.0072	0.0050	0.1000			
8	14-Aug	22:15	53.6	I50									
8	14-Aug	23:15	54.6	I51	0.0016		0.0004	0.0062	0.0050	0.1589			
8	15-Aug	OO:15	55.6	I52									
8	15-Aug	01:15	56.6	I53	0.0014		0.0001	0.0016	0.0045	0.2452			
8	15-Aug	02:15	57.6	I54									
8	15-Aug	03:15	58.6	I55	0.0019	0.0003	0.0007	0.0050	0.0047	0.2945			
8	15-Aug	04:15	59.6	I56									
8	15-Aug	05:15	60.6	I57	0.0120	0.0007	0.0026	0.0446	0.0198	0.1177	17000	0.4	
8	15-Aug	05:16	60.7	I58									
8	15-Aug	06:13	61.6	I61	0.0031			0.0132	0.0048	0.0496			
8	15-Aug	06:15	61.6	I62									
8	15-Aug	06:16	61.7	I63	0.0026	0.0002	0.0016	0.0081	0.0050	0.0562			
8	15-Aug	06:17	61.7	I64									
8	15-Aug	06:18	61.7	I65	0.0028	0.0002		0.0089	0.0045	0.0576			
8	15-Aug	06:20	61.7	I66									
8	15-Aug	07:15	62.6	I67	0.0020			0.0037	0.0045	0.0626			
8	15-Aug	18:15	73.6	I77	0.0013	0.0007	0.0024	0.0035	0.0067	0.2554			
8	15-Aug	19:15	74.6	I78									
8	15-Aug	20:15	75.6	I79	0.0022	0.0003	0.0012	0.0102	0.0065	0.0881			

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
8	15-Aug	21:15	76.6	I80									
8	15-Aug	22:15	77.6	I81	0.0021	0.0000	0.0015	0.0097	0.0057	0.0907			
8	15-Aug	23:15	78.6	I82									
8	16-Aug	00:15	79.6	I83	0.0006	0.0002	0.0014	0.0056	0.0052	0.1010			
8	16-Aug	01:15	80.6	I84									
8	16-Aug	02:15	81.6	I85	0.0015		0.0019	0.0005	0.0077	0.1304	8000	0.6	
8	16-Aug	03:15	82.6	I86									
8	16-Aug	04:15	83.6	I87	0.0018	0.0000	0.0008	0.0041	0.0072	0.1978			
8	16-Aug	05:15	84.6	I91	0.0034	0.0006	0.0023	0.0145	0.0082	0.2159			
8	16-Aug	10:15	89.6	I92									
8	16-Aug	11:15	90.6	I93	0.0018		0.0005	0.0059	0.0057	0.1009			
8	16-Aug	12:15	91.6	I94									
8	16-Aug	13:15	92.6	I95	0.0015			0.0037	0.0048	0.0973			
8	16-Aug	14:15	93.6	I96									
8	16-Aug	15:15	94.6	I97	0.0011	0.0003	0.0003	0.0037	0.0063	0.2160			
8	16-Aug	21:15	100.6	I103									
8	16-Aug	22:15	101.6	I104									
8	16-Aug	23:15	102.6	I105									
8	17-Aug	00:15	103.6	I106									
8	17-Aug	01:15	104.6	I107	0.0027	0.0001	0.0003	0.0098	0.0053	0.0546			
8	17-Aug	02:15	105.6	I108									
8	17-Aug	03:15	106.6	I109									
8	17-Aug	04:15	107.6	I110									
8	17-Aug	05:15	108.6	I111									
8	17-Aug	06:15	109.6	I112									

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
8	17-Aug	07:15	110.6	I113							17000	0.2	
8	17-Aug	08:15	111.6	I114									
8	17-Aug	09:15	112.6	I115									
8	17-Aug	10:15	113.6	I116									
8	17-Aug	11:15	114.6	I117									
8	17-Aug	12:15	115.6	I118									
8	17-Aug	13:15	116.6	I119									
8	17-Aug	14:15	117.6	I120									
8	17-Aug	15:15	118.6	I121									
8	17-Aug	16:15	119.6	I122									
8	12-Aug	16:12	0.0	O1	0.0086	0.0006	0.0032	0.0408	0.0164	0.2430	500000	8.1	
8	12-Aug	17:13	1.0	O2									
8	12-Aug	18:13	2.0	O3	0.0052	0.0002	0.0007	0.0246	0.0128	0.0827			
8	12-Aug	19:13	3.0	O4									
8	12-Aug	20:13	4.0	O5	0.0033	-0.0001	-0.0008	0.0101	0.0085	0.0800			
8	12-Aug	23:13	7.0	O6									
8	13-Aug	02:13	10.0	O7	0.0030	0.0010	0.0004	0.0080	0.0060	0.0698			
8	13-Aug	05:13	13.0	O8									
8	13-Aug	08:13	16.0	09	0.0015	0.0000	0.0016	0.0065	0.0057	0.0756			
8	13-Aug	11:13	19.0	O10									
8	13-Aug	14:13	16.0	O11	0.0019	0.0002	-0.0005	0.0049	0.0041	0.0738	130000	3.7	
8	13-Aug	17:13	19.0	O12									
8	13-Aug	20:13	22.0	O13	0.0013	0.0000	0.0005	0.0017	0.0052	0.0738			
8	13-Aug	23:13	25.0	O14									
8	14-Aug	02:13	28.0	O15	0.0028	0.0000	0.0008	0.0158	0.0058	0.0684			

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
8	14-Aug	05:13	31.0	O16									
8	14-Aug	08:13	34.0	O17	0.0015	0.0003	0.0003	0.0082	0.0055	0.0707			
8	14-Aug	11:13	37.0	O18									
8	14-Aug	14:13	40.0	O19	0.0035	0.0000	0.0002	0.0092	0.0065	0.0486	30000	0.3	
8	14-Aug	17:13	43.0	O20									
8	14-Aug	20:13	46.0	O21	0.0025	-0.0001	0.0006	0.0058	0.0059	0.0590			
8	14-Aug	23:13	49.0	O22									
8	15-Aug	02:13	52.0	O23	0.0013	0.0001	-0.0005	0.0027	0.0040	0.0515			
8	15-Aug	05:13	55.0	O24									
8	15-Aug	08:13	58.0	O25	0.0030	0.0000	0.0012	0.0081	0.0055	0.0599	5000	0.4	
8	15-Aug	11:13	61.0	O26									
8	15-Aug	14:13	64.0	O27	0.0041	0.0002	0.0011	0.0056	0.0103	0.1111			
8	15-Aug	17:13	67.0	O28									
8	15-Aug	20:13	70.0	O29	0.0024	0.0000	0.0001	0.0130	0.0048	0.0989			
8	15-Aug	23:13	73.0	O30									
8	16-Aug	02:13	76.0	O31	0.0012	0.0004	0.0006	0.0023	0.0035	0.0807			
8	16-Aug	05:13	79.0	O32									
8	16-Aug	08:13	82.0	O33	0.0021	0.0001	0.0008	0.0101	0.0051	0.1134	28000	0.2	
8	16-Aug	17:15	91.0	O36									
8	16-Aug	20:15	94.0	O37	0.0018	0.0002	0.0006	0.0049	0.0023	0.0567			
8	16-Aug	23:15	97.0	O38									
8	17-Aug	02:15	100.0	O39	0.0011	-0.0004	0.0000	0.0002	0.0021	0.0431			
8	17-Aug	05:14	103.0	O40									
8	17-Aug	08:15	106.0	O41							50000	0.2	
8	17-Aug	09:15	107.1	O42									

Appendix F Concentration data for monitored storm events, 1992.

Evnt.	Date	Time	Elapsed time (hr.)	Samp. #	CR (ug/l)	CD (ug/l)	NI (ug/l)	PB (ug/l)	CU (ug/l)	ZN (ug/l)	Fecal coliform (MPN)	BOD (mg/l)	COD (mg/l)
8	17-Aug	12:15	110.1	O43									
8	17-Aug	15:15	113.1	O44									

Appendix G. Event mean concentrations and treatment efficiency summary

	Variable	Storm 1	2	3	4	5	6	7	8	Mean	Median	Min.	Max.
TSS	Runoff EMC (mg/l)	98	52	99	67	67	233	216	184	127	98	52	233
	Treated EMC (mg/l)	26	19	27	29	18	65	41	30	32	28	18	65
	Runoff Load (kg)	789	283	909	677	219	490	592	7920	1485	634	219	7920
	Treated Load Out (kg)	202	109	319	345	54	159	117	405	214	181	54	405
	Pond Bypass (kg)	0	0	67	85	0	0	0	5523	709	0	0	5523
	Pond T. Efficiency (%)	74	61	62	42	75	68	80	83	68	71	42	83
	Storm T. Efficiency (%	74	61	57	36	75	68	80	25	60	65	25	80
VOLS	Runoff EMC (mg/l)	25	14	22	18	29	62	50	20	30	23	14	62
	Treated EMC (mg/l)	8	6	6	10	8	20	14	5	10	8	5	20
	Runoff Load (kg)	204	73	199	177	94	131	136	843	232	157	73	843
	Treated Load Out (kg)	64	33	76	118	24	50	41	72	60	57	24	118
	Pond Bypass (kg)	0	0	15	22	0	0	0	588	78	0	0	588
	Pond T. Efficiency (%)	69	55	59	24	74	62	70	72	60	65	24	74
	Storm T. Efficiency (%	69	55	54	21	74	62	70	22	53	59	21	74
FSOL	Runoff EMC (mg/l)	72	39	77	50	38	170	167	165	97	75	38	170
	Treated EMC (mg/l)	18	13	18	19	10	45	27	27	22	19	10	45
	Runoff Load (kg)	585	210	709	498	125	358	456	7090	1254	477	125	7090
	Treated Load Out (kg)	140	76	217	227	30	109	76	356	154	125	30	356
	Pond Bypass (kg)	0	0	53	62	0	0	0	4944	632	0	0	4944
	Pond T. Efficiency (%)	76	64	67	48	76	69	83	83	71	73	48	83
	Storm T. Efficiency (%	76	64	62	42	76	69	83	25	62	67	25	83
TOC	Runoff EMC (mg/l)	11.2	13.0	12.6	18.1	18.0	31.1	26.2	18.8	18.6	18.1	11.2	31.1

Appendix G. Event mean concentrations and treatment efficiency summary

		Storm											
	Variable	1	2	3	4	5	6	7	8	Mean	Median	Min.	Max.
	Treated EMC (mg/l)	12.7	10.8	11.9	10.1	17.7	24.0	21.3	18.9	15.9	15.2	10.1	24.0
	Runoff Load (kg)	91	71	115	182	59	65	72	807	183	81	59	807
	Treated Load Out (kg)	100	61	141	121	54	58	60	251	106	80	54	251
	Pond Bypass (kg)	0	0	9	23	0	0	0	563	74	0	0	563
	Pond T. Efficiency (%)	-10	13	-32	24	9	11	16	-3	4	10	-32	24
	Storm T. Efficiency (%	-10	13	-30	21	9	11	16	-1	4	10	-30	21
POC	Runoff EMC (mg/l)	3.0	3.5	3.5	8.1	5.0	10.3	8.3	3.4	5.6	4.3	3.0	10.3
	Treated EMC (mg/l)	3.2	1.7	2.2	2.3	3.5	5.1	3.8	1.2	2.9	2.8	1.2	5.1
	Runoff Load (kg)	24	19	32	81	16	22	23	147	46	23	16	147
	Treated Load Out (kg)	25	10	26	27	11	12	11	16	17	14	10	27
	Pond Bypass (kg)	0	0	2	10	0	0	0	103	14	0	0	103
	Pond T. Efficiency (%)	-4	48	14	61	35	42	52	63	39	45	-4	63
	Storm T. Efficiency (%	-4	48	13	54	35	42	52	19	32	39	-4	54
DOC	Runoff EMC (mg/l)	8.2	9.6	9.0	10.0	13.0	20.8	17.9	15.3	13.0	11.5	8.2	20.8
	Treated EMC (mg/l)	9.5	9.1	9.7	7.8	14.2	18.9	17.5	17.7	13.0	11.9	7.8	18.9
	Runoff Load (kg)	67	52	83	101	43	44	49	660	137	59	43	660
	Treated Load Out (kg)	74	51	115	94	43	46	50	235	88	63	43	235
	Pond Bypass (kg)	0	0	6	13	0	0	0	460	60	0	0	460
	Pond T. Efficiency (%)	-12	1	-51	-6	0	-5	-1	-18	-11	-6	-51	1
	Storm T. Efficiency (%	-12	1	-47	-5	0	-5	-1	-5	-9	-5	-47	1
TN	Runoff EMC (mg/l)	0.79	0.91	0.80	2.31	1.16	2.21	1.96	0.87	1.38	1.04	0.79	2.31
	Treated EMC (mg/l)	0.81	0.59	0.45	0.91	0.98	1.54	1.33	0.50	0.89	0.86	0.45	1.54

Appendix G. Event mean concentrations and treatment efficiency summary

	Variable	Storm 1	Storm 2	Storm 3	Storm 4	Storm 5	Storm 6	Storm 7	Storm 8	Mean	Median	Min.	Max.
	Runoff Load (kg)	6.36	4.93	7.34	23.27	3.82	4.66	5.35	37.36	11.64	5.86	3.82	37.36
	Treated Load Out (kg)	6.29	3.31	5.41	10.96	2.95	3.75	3.78	6.60	5.38	4.59	2.95	10.96
	Pond Bypass (kg)	0.00	0.00	0.54	2.91	0.00	0.00	0.00	26.05	3.69	0.00	0.00	26.05
	Pond T. Efficiency (%)	1	33	20	46	23	20	29	42	27	26	1	46
	Storm T. Efficiency (%	1	33	19	40	23	20	29	13	22	21	1	40
PN	Runoff EMC (mg/l)	0.53	0.38	0.49	1.84	0.59	1.29	1.29	0.47	0.86	0.56	0.38	1.84
	Treated EMC (mg/l)	0.40	0.22	0.23	0.39	0.35	0.67	0.65	0.13	0.38	0.37	0.13	0.67
	Runoff Load (kg)	4.30	2.06	4.52	18.55	1.94	2.72	3.54	20.30	7.24	3.92	1.94	20.30
	Treated Load Out (kg)	3.09	1.25	2.78	4.64	1.07	1.62	1.85	1.76	2.26	1.81	1.07	4.64
	Pond Bypass (kg)	0.00	0.00	0.34	2.32	0.00	0.00	0.00	14	2.10	0.00	0.00	14.16
	Pond T. Efficiency (%)	28	39	34	71	45	40	48	71	47	43	28	71
	Storm T. Efficiency (%	28	39	31	62	45	40	48	22	39	40	22	62
DKN	Runoff EMC (mg/l)	0.26	0.53	0.31	0.47	0.57	0.92	0.66	0.40	0.51	0.50	0.26	0.92
	Treated EMC (mg/l)	0.41	0.36	0.22	0.53	0.62	0.87	0.68	0.36	0.51	0.47	0.22	0.87
	Runoff Load (kg)	2.06	2.87	2.82	4.72	1.88	1.94	1.81	17.06	4.40	2.44	1.81	17.06
	Treated Load Out (kg)	3.20	2.06	2.63	6.32	1.88	2.13	1.93	4.84	3.12	2.38	1.88	6.32
	Pond Bypass (kg)	0.00	0.00	0.21	0.59	0.00	0.00	0.00	12	1.59	0.00	0.00	11.90
	Pond T. Efficiency (%)	-55	28	-1	-53	0	-10	-7	6	-11	-4	-55	28
	Storm T. Efficiency (%	-55	28	-1	-46	0	-10	-7	2	-11	-4	-55	28
NO3	Runoff EMC (mg/l)	0.22	0.38	0.18	0.21	0.51	0.63	0.69	0.26	0.38	0.32	0.18	0.69
	Treated EMC (mg/l)	0.24	0.36	0.19	0.21	0.44	0.63	0.64	0.20	0.36	0.30	0.19	0.64
	Runoff Load (kg)	1.81	2.05	1.61	2.08	1.68	1.33	1.90	11.01	2.93	1.86	1.33	11.01

Appendix G. Event mean concentrations and treatment efficiency summary

	Variable	Storm 1	2	3	4	5	6	7	8	Mean	Median	Min.	Max.
	Treated Load Out (kg)	1.90	2.02	2.27	2.50	1.33	1.54	1.82	2.69	2.01	1.96	1.33	2.69
	Pond Bypass (kg)	0.00	0.00	0.12	0.26	0.00	0.00	0.00	8	1.01	0.00	0.00	7.68
	Pond T. Efficiency (%)	-5	1	-52	-38	21	-16	4	19	-8	-2	-52	21
	Storm T. Efficiency (%	-5	1	-48	-33	21	-16	4	6	-9	-2	-48	21
NH4	Runoff EMC (mg/l)	0.09	0.21	0.10	0.07	0.23	0.28	0.12	0.05	0.14	0.11	0.05	0.28
	Treated EMC (mg/l)	0.07	0.11	0.06	0.07	0.21	0.28	0.11	0.09	0.12	0.10	0.06	0.28
	Runoff Load (kg)	0.72	1.12	0.88	0.69	0.74	0.59	0.32	2.26	0.92	0.73	0.32	2.26
	Treated Load Out (kg)	0.55	0.64	0.72	0.82	0.63	0.68	0.30	1.13	0.68	0.66	0.30	1.13
	Pond Bypass (kg)	0.00	0.00	0.07	0.09	0.00	0.00	0.00	2	0.22	0.00	0.00	1.58
	Pond T. Efficiency (%)	24	43	11	-36	15	-15	6	-66	-2	9	-66	43
	Storm T. Efficiency (%	24	43	11	-32	15	-15	6	-20	4	8	-32	43
TP	Runoff EMC (mg/l)	0.21	0.26	0.30	0.64	0.40	0.56	0.58	0.30	0.41	0.35	0.21	0.64
	Treated EMC (mg/l)	0.21	0.22	0.21	0.32	0.38	0.37	0.48	0.19	0.30	0.27	0.19	0.48
	Runoff Load (kg)	1.73	1.38	2.79	6.39	1.31	1.17	1.60	13.12	3.69	1.67	1.17	13.12
	Treated Load Out (kg)	1.62	1.25	2.53	3.82	1.15	0.89	1.36	2.55	1.90	1.49	0.89	3.82
	Pond Bypass (kg)	0.00	0.00	0.21	0.80	0.00	0.00	0.00	9.15	1.27	0.00	0.00	9.15
	Pond T. Efficiency (%)	6	9	2	32	12	24	15	36	17	14	2	36
	Storm T. Efficiency (%	6	9	2	28	12	24	15	11	13	12	2	28
PP	Runoff EMC (mg/l)	0.18	0.13	0.18	0.46	0.19	0.38	0.35	0.14	0.25	0.19	0.13	0.46
	Treated EMC (mg/l)	0.12	0.08	0.11	0.20	0.13	0.22	0.24	0.06	0.15	0.13	0.06	0.24
	Runoff Load (kg)	1.42	0.70	1.69	4.58	0.63	0.79	0.97	5.81	2.07	1.20	0.63	5.81
	Treated Load Out (kg)	0.96	0.47	1.34	2.40	0.40	0.54	0.68	0.75	0.94	0.72	0.40	2.40

Appendix G. Event mean concentrations and treatment efficiency summary

	Variable	Storm 1	2	3	4	5	6	7	8	Mean	Median	Min.	Max.
	Pond Bypass (kg)	0.00	0.00	0.13	0.57	0.00	0.00	0.00	4	0.59	0.00	0.00	4.05
	Pond T. Efficiency (%)	32	33	14	40	37	32	30	57	34	33	14	57
	Storm T. Efficiency (%	32	33	13	35	37	32	30	17	29	32	13	37
TDP	Runoff EMC (mg/l)	0.04	0.13	0.12	0.18	0.21	0.18	0.23	0.17	0.16	0.17	0.04	0.23
	Treated EMC (mg/l)	0.08	0.14	0.10	0.12	0.25	0.14	0.24	0.14	0.15	0.14	0.08	0.25
	Runoff Load (kg)	0.31	0.68	1.10	1.81	0.68	0.38	0.63	7.31	1.61	0.68	0.31	7.31
	Treated Load Out (kg)	0.66	0.78	1.19	1.43	0.75	0.35	0.68	1.80	0.95	0.77	0.35	1.80
	Pond Bypass (kg)	0.00	0.00	0.08	0.23	0.00	0.00	0.00	5	0.68	0.00	0.00	5.10
	Pond T. Efficiency (%)	-113	-15	-16	10	-10	8	-8	19	-16	-9	-113	19
	Storm T. Efficiency (%	-113	-15	-15	9	-10	8	-8	6	-17	-9	-113	9
PO4	Runoff EMC (mg/l)	0.06	0.09	0.08	0.14	0.12	0.15	0.23	0.18	0.13	0.13	0.06	0.23
	Treated EMC (mg/l)	0.05	0.06	0.06	0.08	0.08	0.13	0.18	0.13	0.10	0.08	0.05	0.18
	Runoff Load (kg)	0.49	0.46	0.77	1.44	0.39	0.31	0.62	7.59	1.51	0.56	0.31	7.59
	Treated Load Out (kg)	0.36	0.33	0.75	0.93	0.25	0.32	0.52	1.70	0.64	0.44	0.25	1.70
	Pond Bypass (kg)	0.00	0.00	0.06	0.18	0.00	0.00	0.00	5	0.69	0.00	0.00	5.29
	Pond T. Efficiency (%)	27	28	-5	26	36	-3	16	26	19	26	-5	36
	Storm T. Efficiency (%	27	28	-5	23	36	-3	16	8	16	20	-5	36
Cd	Runoff EMC (mg/l)	0.000			0.001	0.004	0.009	0.001	0.000	0.002	0.001	0.000	0.009
	Treated EMC (mg/l)	0.001			0.000	0.005	0.003	0.000	0.000	0.002	0.001	0.000	0.005
	Runoff Load (kg)	0.003			0.011	0.012	0.018	0.002	0.014	0.010	0.011	0.002	0.018
	Treated Load Out (kg)	0.005			0.004	0.014	0.008	0.001	0.000	0.005	0.004	0.000	0.014
	Pond Bypass (kg)	0.000			0.001	0.000	0.000	0.000	0.010	0.002	0.000	0.000	0.010

Appendix G. Event mean concentrations and treatment efficiency summary

	Variable	Storm 1	2	3	4	5	6	7	8	Mean	Median	Min.	Max.
	Pond T. Efficiency (%)	-100			61	-16	57	50	93	24	54	-100	93
	Storm T. Efficiency (%	-100			54	-16	57	50	28	12	39	-100	57
Cr	Runoff EMC (mg/l)	0.005	0.003	0.005	0.005	0.030	0.032	0.006	0.004	0.011	0.005	0.003	0.032
	Treated EMC (mg/l)	0.003	0.002	0.003	0.002	0.025	0.012	0.002	0.002	0.006	0.002	0.002	0.025
	Runoff Load (kg)	0.040	0.016	0.045	0.050	0.099	0.067	0.018	0.167	0.063	0.047	0.016	0.167
	Treated Load Out (kg)	0.021	0.012	0.038	0.022	0.075	0.030	0.005	0.024	0.028	0.023	0.005	0.075
	Pond Bypass (kg)	0.000	0.000	0.003	0.006	0.000	0.000	0.000	0.117	0.016	0.000	0.000	0.117
	Pond T. Efficiency (%)	47	25	9	50	24	55	72	52	42	49	9	72
	Storm T. Efficiency (%	47	25	8	43	24	55	72	16	36	34	8	72
Cu	Runoff EMC (mg/l)	0.010	0.008	0.010	0.027	0.064	0.093	0.018	0.009	0.030	0.014	0.008	0.093
	Treated EMC (mg/l)	0.008	0.006	0.006	0.018	0.049	0.054	0.010	0.004	0.019	0.009	0.004	0.054
	Runoff Load (kg)	0.078	0.042	0.091	0.270	0.210	0.196	0.049	0.399	0.167	0.143	0.042	0.399
	Treated Load Out (kg)	0.064	0.033	0.066	0.211	0.147	0.131	0.029	0.056	0.092	0.065	0.029	0.211
	Pond Bypass (kg)	0.000	0.000	0.007	0.034	0.000	0.000	0.000	0	0.040	0.000	0.000	0.278
	Pond T. Efficiency (%)	18	21	22	11	30	33	41	54	29	26	11	54
	Storm T. Efficiency (%	18	21	20	9	30	33	41	16	24	21	9	41
Pb	Runoff EMC (mg/l)	0.021	0.011	0.015	0.033	0.180	0.220	0.046	0.015	0.068	0.027	0.011	0.220
	Treated EMC (mg/l)	0.008	0.010	0.010	0.010	0.131	0.092	0.009	0.006	0.035	0.010	0.006	0.131
	Runoff Load (kg)	0.172	0.060	0.137	0.332	0.590	0.463	0.126	0.658	0.317	0.252	0.060	0.658
	Treated Load Out (kg)	0.065	0.059	0.119	0.123	0.395	0.225	0.026	0.075	0.136	0.097	0.026	0.395
	Pond Bypass (kg)	0.000	0.000	0.010	0.042	0.000	0.000	0.000	0	0.064	0.000	0.000	0.459
	Pond T. Efficiency (%)	63	2	7	58	33	52	79	62	44	55	2	79

Appendix G. Event mean concentrations and treatment efficiency summary

	Variable	Storm 1	2	3	4	5	6	7	8	Mean	Median	Min.	Max.
	Storm T. Efficiency (%	63	2	6	51	33	52	79	19	38	42	2	79
Ni	Runoff EMC (mg/l)	0.002	0.001	0.003	0.005	0.011	0.021	0.005	0.005	0.007	0.005	0.001	0.021
	Treated EMC (mg/l)	0.002	0.001	0.002	0.002	0.007	0.009	0.002	0.000	0.003	0.002	0.000	0.009
	Runoff Load (kg)	0.016	0.005	0.027	0.052	0.035	0.044	0.013	0.195	0.049	0.031	0.005	0.195
	Treated Load Out (kg)	0.013	0.004	0.024	0.024	0.022	0.023	0.007	0.006	0.015	0.017	0.004	0.024
	Pond Bypass (kg)	0.000	0.000	0.002	0.007	0.000	0.000	0.000	0.136	0.018	0.000	0.000	0.136
	Pond T. Efficiency (%)	22	20	4	48	37	49	48	90	40	43	4	90
	Storm T. Efficiency (%	22	20	4	42	37	49	48	27	31	32	4	49
Zn	Runoff EMC (mg/l)	0.100	0.115	0.092	0.253	0.737	1.119	0.210	0.096	0.340	0.163	0.092	1.119
	Treated EMC (mg/l)	0.080	0.078	0.062	0.115	0.612	0.596	0.165	0.059	0.221	0.098	0.059	0.612
	Runoff Load (kg)	0.805	0.624	0.844	2.540	2.418	2.355	0.575	4.137	1.787	1.600	0.575	4.137
	Treated Load Out (kg)	0.626	0.444	0.734	1.383	1.852	1.452	0.467	0.780	0.967	0.757	0.444	1.852
	Pond Bypass (kg)	0.000	0.000	0.063	0.318	0.000	0.000	0.000	2.885	0.408	0.000	0.000	2.885
	Pond T. Efficiency (%)	22	29	6	38	23	38	19	38	27	26	6	38
	Storm T. Efficiency (%	22	29	6	33	23	38	19	11	23	23	6	38

Appendix H. Settling column data. ET = elapsed time.

Date	Time	ET (hr.)	Port #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)	TN (mg/l)	TP (mg/l)	TOC (mg/l)
12/4/91	9:00	0	5				0.11	0.21	0.34	0.23	0.38	0.58	0.19			0.8	0.6	
12/4/91	10:00	1	2				0.10	0.19	0.27	0.23	0.35	0.55	0.18			0.8	0.5	
12/4/91	10:00	1	5				0.10	0.22	0.21	0.22	0.29	0.55	0.18			0.8	0.5	
12/4/91	10:00	1	8				0.10	0.23	0.21	0.20	0.28	0.57	0.18			0.8	0.5	
12/4/91	12:00	3	2				0.08	0.27	0.19	0.21	0.27	0.56	0.16			0.8	0.4	
12/4/91	12:00	3	5				0.07	0.26	0.20	0.16	0.25	0.55	0.17			0.7	0.4	
12/4/91	12:00	3	8				0.07	0.27	0.20	0.19	0.24	0.51	0.14			0.7	0.4	
12/4/91	15:00	6	2				0.05	0.24	0.19	0.19	0.23	0.52	0.14			0.7	0.4	
12/4/91	15:00	6	5				0.05	0.23	0.18	0.19	0.24	0.55	0.16			0.7	0.4	
12/4/91	15:00	6	8				0.05	0.18	0.18	0.14	0.23	0.50	0.14			0.6	0.4	
12/4/91	18:00	9	2				0.04	0.21	0.17	0.15	0.32	0.49	0.14			0.6	0.5	
12/4/91	18:00	9	5				0.03	0.18	0.17	0.14	0.26	0.48	0.14			0.6	0.4	
12/4/91	18:00	9	8				0.04	0.19	0.18	0.13	0.24	0.51	0.14			0.6	0.4	
12/4/91	21:00	12	2				0.03	0.21	0.18	0.15	0.26	0.44	0.12			0.6	0.4	
12/4/91	21:00	12	5				0.03	0.24	0.17	0.19	0.24	0.44	0.12			0.6	0.4	
12/4/91	21:00	12	8				0.04	0.22	0.22	0.17	0.26	0.42	0.12			0.6	0.4	
12/5/91	9:00	24	2				0.09	0.20	0.24	0.20	0.29	0.20	0.07			0.4	0.4	
12/5/91	9:00	24	5				0.09	0.17	0.23	0.19	0.29	0.31	0.09			0.5	0.4	
12/5/91	9:00	24	8				0.10	0.26	0.19	0.18	0.25	0.36	0.09			0.5	0.3	
12/6/91	9:00	48	2				0.16	0.30	0.19	0.23	0.24	0.13	0.04			0.4	0.3	
12/6/91	9:00	48	5				0.16	0.38	0.19	0.18	0.24	0.09	0.04			0.3	0.3	
12/6/91	9:00	48	8				0.16	0.33	0.19	0.18	0.24	0.09	0.04			0.3	0.3	
5/19/92	8:30	0		41.5	20.9	20.6	0.24	0.78	0.31	1.22	0.36	0.90	0.18	24.7	5.6	2.1	0.5	30.3
5/19/92	9:30	1	2	22.8	11.0	11.8	0.18	0.79	0.31	1.19	0.37	0.79	0.16	22.9	5.0	2.0	0.5	27.9

Appendix H. Settling column data. ET = elapsed time.

Date	Time	ET (hr.)	Port #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)	TN (mg/l)	TP (mg/l)	TOC (mg/l)
5/19/92	9:30	1	4	22.7	11.6	11.1								24.4	4.6			29.0
5/19/92	9:30	1	8	25.9	13.9	12.0	0.20	0.79	0.31	1.25	0.37	0.81	0.16	24.7	5.7	2.1	0.5	30.4
5/19/92	11:30	3	2	17.3	9.2	8.1	0.15	0.79	0.30	1.28	0.37	0.57	0.16	22.7	4.2	1.8	0.5	27.0
5/19/92	11:30	3	4	17.5	10.8	6.7								25.0	4.3			29.3
5/19/92	11:30	3	8	20.7	10.9	9.8	0.15	0.79	0.30	1.24	0.39	0.68	0.15	23.7	4.8	1.9	0.5	28.5
5/19/92	14:30	6	2	16.2	9.8	6.4	0.12	0.77	0.29	1.01	0.37	0.84	0.16	22.2	3.7	1.8	0.5	25.9
5/19/92	14:30	6	4	16.1	10.3	5.8								21.5	3.6			25.1
5/19/92	14:30	6	8	16.8	9.6	7.2	0.11	0.77	0.30	1.05	0.38	0.85	0.16	23.8	4.3	1.9	0.5	28.1
5/19/92	17:30	9	2	12.8	8.4	4.4	0.08	0.76	0.30	0.96	0.38	0.80	0.14	21.5	3.1	1.8	0.5	24.6
5/19/92	17:30	9	4	15.3	9.7	5.6								20.6	3.4			24.0
5/19/92	17:30	9	8	16.1	11.0	5.1	0.09	0.78	0.30	1.04	0.37	0.86	0.16	21.0	4.3	1.9	0.5	25.3
5/20/92	8:30	24	2	12.0	8.4	3.6	0.12	0.56	0.30	1.25	0.36	0.78	0.13	20.7	3.7	2.0	0.5	24.4
5/20/92	8:30	24	4	11.0	8.0	3.0								21.0	3.5			24.5
5/20/92	8:30	24	8	10.0	7.8	2.2	0.12	0.52	0.30	0.83	0.29	0.72	0.12	20.3	3.0	1.5	0.4	23.3
5/21/92	8:30	48	2	8.4	7.3	1.1	0.14	0.08	0.33	0.95	0.35	0.63	0.10	19.9	2.2	1.6	0.4	22.1
5/21/92	8:30	48	4	7.0	6.0	1.0								19.2	1.9			21.1
5/21/92	8:30	48	8	7.3	5.7	1.6	0.14	0.05	0.32	0.65	0.30	0.59	0.10	19.3	3.2	1.2	0.4	22.6
5/22/92	8:30	72	2	5.7	4.5	1.2	0.16	0.00	0.33	0.93	0.37	0.42	0.08	19.1	3.2	1.3	0.4	22.3
5/22/92	8:30	72	4	5.6	5.2	0.4								18.2	2.7			20.9
5/22/92	8:30	72	8	5.6	4.7	0.9	0.14	0.16	0.28	0.79	0.35	0.42	0.07	18.2	2.8	1.2	0.4	21.1
8/4/92	7:35	0		71.2	24.4	46.8	0.09	0.46	0.10	0.98	0.14	0.79	0.21	23.6	7.1	1.8	0.3	30.7
8/4/92	8:35	1	2	19.9	10.0	9.9	0.09	0.53	0.10	0.97	0.14	0.58	0.15	23.0	4.8	1.5	0.3	27.8
8/4/92	8:35	1	5	21.6	12.0	11.4								21.6	4.0			25.6
8/4/92	8:35	1	8	42.6	19.9	22.7	0.09	0.50	0.09	0.95	0.11	0.59	0.15	21.0	3.9	1.5	0.3	25.0
8/4/92	10:35	3	2	16.3	7.7	8.6	0.05	0.48	0.09	0.77	0.11	0.51	0.12	21.7	3.5	1.3	0.2	25.2

Appendix H. Settling column data. ET = elapsed time.

Date	Time	ET (hr.)	Port #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)	TN (mg/l)	TP (mg/l)	TOC (mg/l)
8/4/92	10:35	3	5	18.2	8.4	9.8								21.2	3.3			24.5
8/4/92	10:35	3	8	18.7	8.7	10.0	0.05	0.48	0.08	0.84	0.14	0.55	0.13	21.4	2.7	1.4	0.3	24.1
8/4/92	13:35	6	2	11.8	7.3	4.5	0.04	0.49	0.08	0.78	0.11	0.48	0.11	25.0	1.5	1.3	0.2	26.5
8/4/92	13:35	6	5	13.2	7.8	5.4								22.3	1.9			24.2
8/4/92	13:35	6	8	16.5	9.4	7.1	0.04	0.47	0.08	0.76	0.11	0.44	0.10	21.1	3.2	1.2	0.2	24.3
8/4/92	16:35	9	2	11.5	7.8	3.7	0.06	0.45	0.09	0.83	0.11	0.51	0.12	23.0	3.0	1.3	0.2	26.0
8/4/92	16:35	9	5	12.6	7.9	4.7								19.8	2.6			22.4
8/4/92	16:35	9	8	13.2	8.1	5.1	0.06	0.44	0.08	0.88	0.13	0.45	0.10	21.7	3.0	1.3	0.2	24.7
8/4/92	19:35	12	2	10.4	7.5	2.9	0.07	0.35	0.09	0.92	0.13	0.38	0.07	19.7	1.9	1.3	0.2	21.5
8/4/92	19:35	12	5	11.8	8.5	3.3								21.9	3.5			25.4
8/4/92	19:35	12	8	11.6	7.4	4.2	0.07	0.39	0.09	0.81	0.11	0.41	0.08	20.6	2.9	1.2	0.2	23.6
8/5/94	7:35	24	2	7.4	6.0	1.4	0.12	0.19	0.09	0.88	0.13	0.30	0.07	19.0	0.1	1.2	0.2	19.1
8/5/94	7:35	24	5	7.4	5.5	1.9								21.1	0.4			21.5
8/5/94	7:35	24	8	9.0	6.0	3.0	0.13	0.16	0.10	0.91	0.13	0.30	0.07	23.6	2.4	1.2	0.2	26.0
8/6/92	7:35	48	2	5.7	5.9	-0.2	0.17	0.09	0.10	0.82	0.12	0.26	0.06	20.6	2.1	1.1	0.2	22.7
8/6/92	7:35	48	5	5.4	5.3	0.1								18.8	1.9			20.7
8/6/92	7:35	48	8	6.9	6.2	0.7	0.17	0.03	0.11	0.98	0.13	0.24	0.05	23.1	1.6	1.2	0.2	24.7
8/7/92	7:35	72	2	4.3	3.0	1.3	0.20	0.02	0.12	0.83	0.12	0.23	0.05	18.7	1.6	1.1	0.2	20.2
8/7/92	7:35	72	5	4.4	2.0	2.4								22.7	1.7			24.4
8/7/92	7:35	72	8	3.8	1.8	2.0	0.21	0.04	0.25	0.93	0.13	0.24	0.05	23.2	1.6	1.2	0.2	24.8
8/13/92	7:10	0		279.1	31.5	247.6	0.26	0.55	0.23	0.55	0.24	0.89	0.53	12.9	4.9	1.4	0.8	17.7
8/13/92	8:10	1	2	98.8	10.2	88.6	0.25	0.54	0.23	0.56	0.24	0.43	0.22	12.8	4.1	1.0	0.5	16.9
8/13/92	8:10	1	5	153.6	14.7	138.9								11.2	4.3			15.5
8/13/92	8:10	1	8	177.2	17.3	159.9	0.26	0.55	0.24	0.55	0.25	0.47	0.29	12.1	4.5	1.0	0.5	16.6
8/13/92	10:10	3	2	63.7	7.9	55.8	0.23	0.57	0.23	0.53	0.24	0.34	0.19	10.1		0.9	0.4	13

Appendix H. Settling column data. ET = elapsed time.

Date	Time	ET (hr.)	Port #	TSS (mg/l)	VSOL (mg/l)	FSOL (mg/l)	NH4-N (mg/l)	NO3-N (mg/l)	PO4-P (mg/l)	DKN (mg/l)	TDP (mg/l)	PN (mg/l)	PP (mg/l)	DOC (mg/l)	POC (mg/l)	TN (mg/l)	TP (mg/l)	TOC (mg/l)
8/13/92	10:10	3	5	75.7	8.5	67.2								9.9	2.3			12.2
8/13/92	10:10	3	8	86.0	10.1	75.9	0.25	0.55	0.23	0.54	0.23	0.35	0.21	11.1	2.7	0.9	0.4	13.8
8/13/92	13:10	6	2	36.2	4.6	31.6	0.24	0.53	0.23	0.49	0.23	0.18	0.12	8.6	1.7	0.7	0.4	10.3
8/13/92	13:10	6	5	34.1	4.6	29.5								8.0	0.8			8.8
8/13/92	13:10	6	8	49.7	5.5	44.2	0.26	0.53	0.24	0.47	0.22	0.24	0.15	9.5	2.1	0.7	0.4	11.6
8/13/92	16:10	9	2	24.7	3.5	21.2	0.24	0.52	0.22	0.45	0.20	0.21	0.12	8.7	1.7	0.7	0.3	10.5
8/13/92	16:10	9	5	25.3	3.3	22.0								8.8	1.7			10.5
8/13/92	16:10	9	8	35.0	6.4	28.6	0.26	0.52	0.23	0.43	0.21	0.21	0.12	8.6		0.6	0.3	10.4
8/13/92	19:10	12	2	25.9	6.2	19.7	0.25	0.49	0.23	0.47	0.22	0.20	0.11	8.2	1.9	0.7	0.3	10.1
8/13/92	19:10	12	5	26.4	6.3	20.1								9.2				
8/13/92	19:10	12	8	26.9	6.0	20.9	0.27	0.49	0.23	0.46	0.23	0.15	0.09	9.5	1.9	0.6	0.3	11.4
8/14/94	7:10	24	2	14.3	3.5	10.8	0.30	0.51	0.23	0.51	0.23	0.08	0.04	10.9	0.9	0.6	0.3	11.8
8/14/94	7:10	24	5	13.2	3.3	9.9								10.7				
8/14/94	7:10	24	8	12.8	3.4	9.4	0.29	0.50	0.24	0.54	0.24	0.06	0.05	8.6	0.7	0.6	0.3	9.3
8/15/92	7:10	48	2	3.0	1.5	1.5	0.32	0.50	0.24	0.53	0.23	0.01	0.02	9.3	0.4	0.5	0.3	9.6
8/15/92	7:10	48	5	5.9	2.4	3.5								8.6	0.3			8.9
8/15/92	7:10	48	8	4.2	1.6	2.6	0.33	0.50	0.25	0.55	0.22	-0.01	0.02	7.9	0.3	0.5	0.2	8.2
8/16/92	7:10	72	2	3.7	1.7	2.0	0.31	0.50	0.24	0.52	0.24	0.01	0.02	8.7	0.1	0.5	0.3	8.8
8/16/92	7:10	72	5	2.3	1.1	1.2								8.5				
8/16/92	7:10	72	8	3.2	3.2	0.0	0.35	0.48	0.25	0.62	0.24	0.01	0.02	8.4	0.5	0.6	0.3	8.9

Appendix I Settling column data. ET = elapsed time.

Date	Elapsed ET (hr.)	Port #	Cr (ug/l)	Cd (ug/l)	Ni (ug/l)	Fe (ug/l)	Pb (ug/l)	Cu (ug/l)	Zn (ug/l)
12/4/91	0	5	0.0040	0.0008	0.0040	0.9481	0.0079	0.0100	0.0800
12/4/91	1	2	0.0039	0.0005	0.0029	0.6727	0.0064	0.0085	0.0702
12/4/91	1	5	0.0022	0.0006	0.0028	0.5519	0.0054	0.0069	0.0699
12/4/91	1	8	0.0038	0.0005	0.0039	0.7416	0.0066	0.0078	0.0630
12/4/91	3	2	0.0020	0.0004	0.0034	0.6808	0.0069	0.0097	0.0585
12/4/91	3	5	0.0017	0.0004	0.0012	0.6112	0.0047	0.0099	0.0550
12/4/91	3	8	0.0034	0.0004	0.0023	0.7118	0.0046	0.0085	0.0646
12/4/91	6	2	0.0002	0.0001	0.0030	0.6045	0.0015	0.0087	0.0554
12/4/91	6	5	0.0003	0.0001	0.0027	0.5843	0.0020	0.0060	0.0716
12/4/91	6	8	0.0021	0.0002	0.0006	0.6419	0.0022	0.0045	0.0605
12/4/91	9	2	0.0016	0.0005	0.0029	0.7014	0.0025	0.0052	0.0570
12/4/91	9	5	0.0024	0.0001	0.0028	0.7272	0.0023	0.0099	0.0490
12/4/91	9	8	0.0019	0.0001	0.0027	0.7547	0.0016	0.0052	0.0594
12/4/91	12	2	0.0011	0.0001	0.0029	0.5485	0.0010	0.0049	0.0590
12/4/91	12	5	0.0006	0.0002	0.0032	0.5039	0.0017	0.0056	0.0701
12/4/91	12	8	0.0019	0.0001	0.0033	0.6502	0.0033	0.0064	0.0587
12/5/91	24	2	0.0003	0.0003	0.0024	0.4081	0.0051	0.0082	0.0574
12/5/91	24	5	0.0005	0.0001	0.0026	0.4665	0.0027	0.0077	0.0400
12/5/91	24	8	0.0010	0.0002	0.0034	0.3422	0.0001	0.0030	0.0638
12/6/91	48	2	0.0005	0.0004	0.0025	0.2255	0.0027	0.0067	0.0602
12/6/91	48	5	0.0002	0.0001	0.0031	0.3370	0.0027	0.0088	0.0360
12/6/91	48	8	0.0001	0.0001	0.0020	0.2610	0.0012	0.0031	0.0495
5/19/92	0	2	0.0087	0.0025	0.0258	3.8915	0.0591	0.1016	0.8391
5/19/92	1	2	0.0074	0.0023	0.0124	2.1529	0.0301	0.0730	0.7091
5/19/92	1	8	0.0069	0.0022	0.0131	2.7189	0.0115	0.0783	0.8277

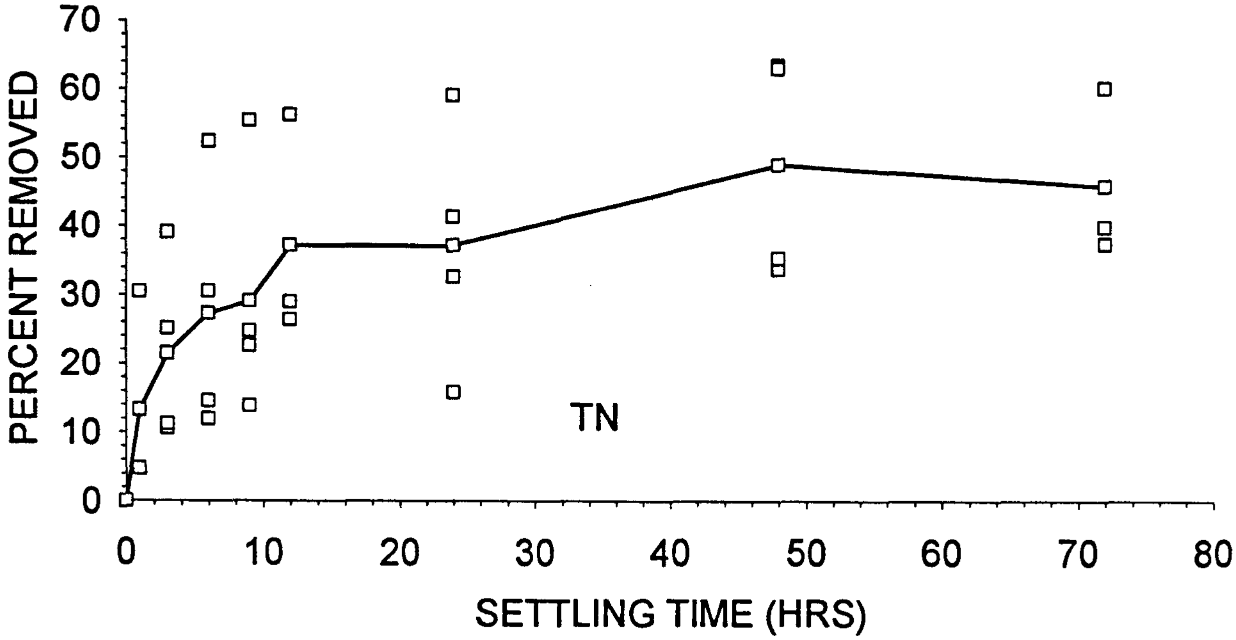
Appendix I Settling column data. ET = elapsed time.

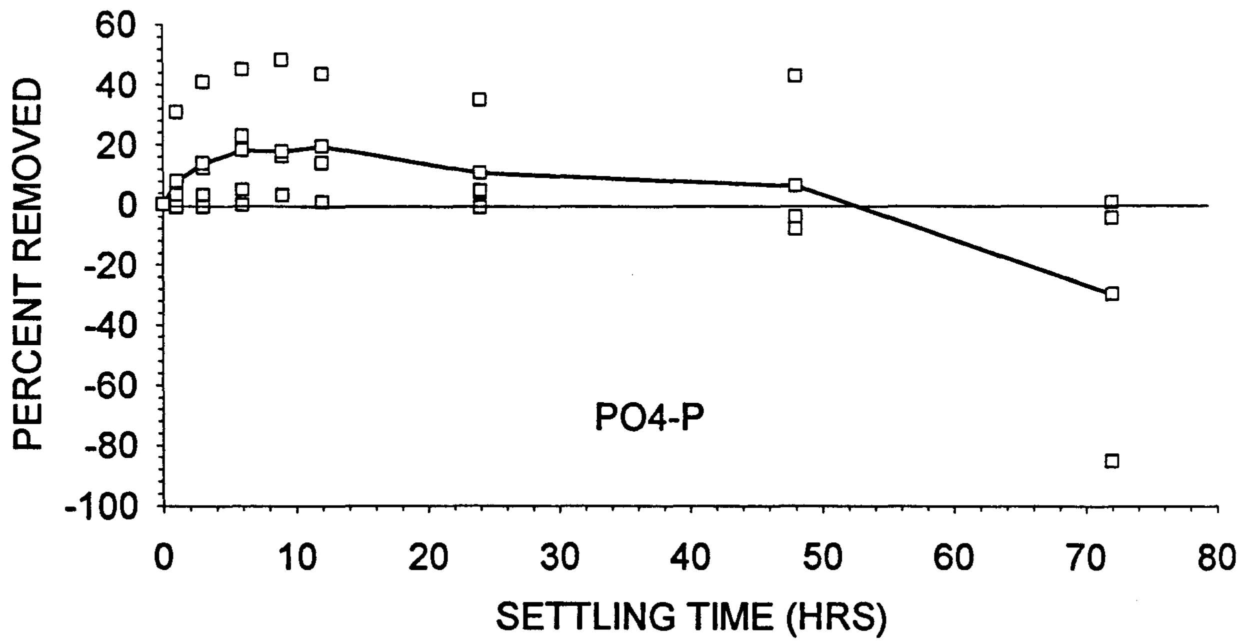
Date	Elapsed ET (hr.)	Port #	Cr (ug/l)	Cd (ug/l)	Ni (ug/l)	Fe (ug/l)	Pb (ug/l)	Cu (ug/l)	Zn (ug/l)
5/19/92	3	2	0.0057	0.0015	0.0072	1.8558	0.0193	0.0541	0.5840
5/19/92	3	8	0.0057	0.0014	0.0072	2.3223	0.0258	0.0662	0.7129
5/19/92	6	2	0.0066	0.0022	0.0063	1.9226	0.0256	0.0718	0.7164
5/19/92	6	8	0.0047	0.0016	0.0073	2.0105	0.0338	0.0691	0.7720
5/19/92	9	2	0.0047	0.0014	0.0066	1.5352	0.0148	0.0636	0.7239
5/19/92	9	8	0.0046	0.0018	0.0067	1.6000	0.0257	0.0723	0.8068
5/20/92	24	2	0.0035	0.0015	0.0056	1.8647	0.0435	0.0784	0.7594
5/20/92	24	8	0.0037	0.0019	0.0146	2.1450	0.0341	0.0750	0.7661
5/21/92	48	2	0.0048	0.0013	0.0080	1.9131	0.0198	0.0786	0.8081
5/21/92	48	8	0.0042	0.0009	0.0078	1.5000	0.0456	0.0738	0.7707
5/22/92	72	2	0.0042	0.0008	0.0049	1.5545	0.0283	0.0648	0.6801
5/22/92	72	8	0.0027	0.0007	0.0068	1.6014	0.0165	0.0628	0.7685
8/4/92	0	2	0.0025	0.0009	0.0033	1.4454	0.0234	0.0167	0.1824
8/4/92	1	2	0.0016	0.0005	0.0030	0.7973	0.0167	0.0126	0.1491
8/4/92	1	8	0.0020	0.0002	0.0019	0.8604	0.0129	0.0137	0.1540
8/4/92	3	2	0.0013	0.0003	0.0024	0.5117	0.0107	0.0101	0.1290
8/4/92	3	8	0.0011	0.0003	0.0024	0.6061	0.0045	0.0102	0.1378
8/4/92	6	2	0.0015	0.0000	0.0027	0.4942	0.0060	0.0116	0.1308
8/4/92	6	8	0.0012	0.0002	0.0030	0.6078	0.0050	0.0108	0.1329
8/4/92	9	2	0.0007	0.0003	0.0024	0.2720	0.0105	0.0109	0.1265
8/4/92	9	8	0.0007	0.0001	0.0023	0.3168	0.0011	0.0096	0.1286
8/4/92	12	2	0.0006	0.0003	0.0032	0.2634	0.0096	0.0109	0.1259
8/4/92	12	8	0.0007	0.0002	0.0024	0.3350	0.0069	0.0108	0.1286
8/5/94	24	2	0.0008	0.0002	0.0020	0.1685	0.0020	0.0079	0.1187
8/5/94	24	8	0.0005	0.0003	0.0018	0.3229	0.0041	0.0098	0.1471

Appendix I Settling column data. ET = elapsed time.

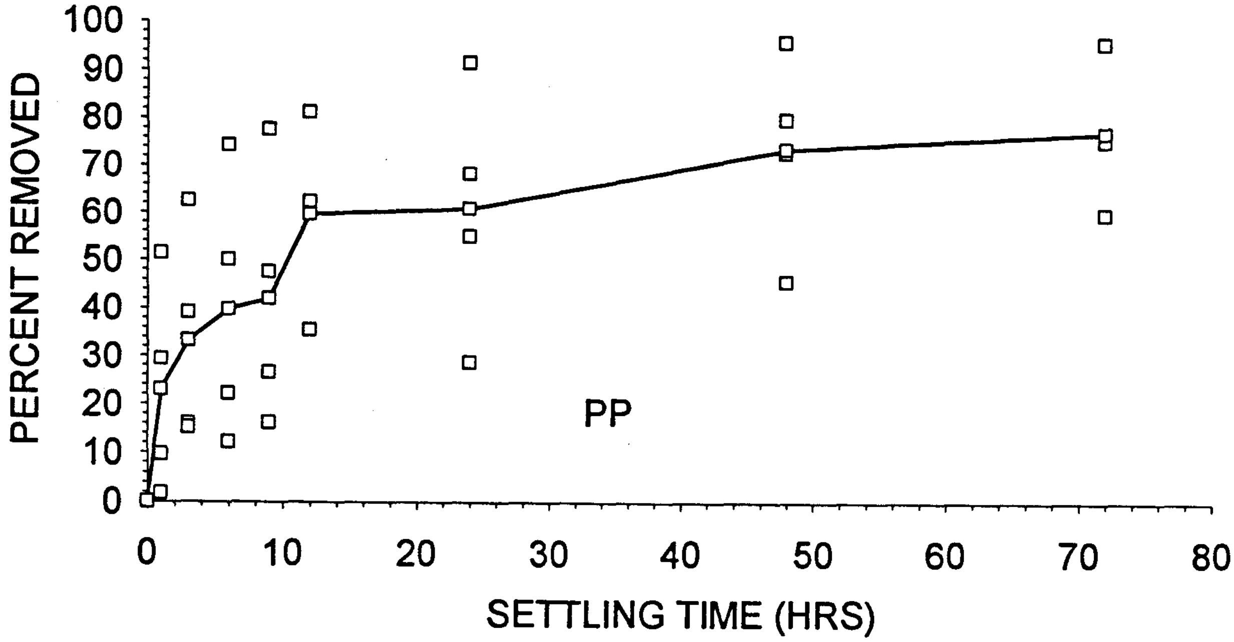
Date	Elapsed ET (hr.)	Port #	Cr (ug/l)	Cd (ug/l)	Ni (ug/l)	Fe (ug/l)	Pb (ug/l)	Cu (ug/l)	Zn (ug/l)
8/6/92	48	2	0.0013	0.0000	0.0015	0.6886	0.0055	0.0112	0.1369
8/6/92	48	8	0.0004	0.0001	0.0014	0.3058	0.0070	0.0091	0.1303
8/7/92	72	2	0.0011	0.0003	0.0013	0.3241	0.0034	0.0083	0.1165
8/7/92	72	8	0.0006	0.0002	0.0012	0.2698	0.0021	0.0094	0.1088
8/13/92	0	2	0.0050	0.0004	0.0011	3.0020	0.0216	0.0144	0.0916
8/13/92	1	2	0.0040	0.0004	0.0009	2.2131	0.0124	0.0112	0.0808
8/13/92	1	8	0.0036	0.0004	0.0008	2.0874	0.0134	0.0105	0.0792
8/13/92	3	2	0.0014	0.0003	0.0003	1.5548	0.0093	0.0090	0.0628
8/13/92	3	8	0.0037	0.0003	0.0004	1.7877	0.0187	0.0097	0.0670
8/13/92	6	2	0.0027	0.0003	0.0001	1.1445	0.0115	0.0094	0.0600
8/13/92	6	8	0.0024	0.0003	0.0001	1.2596	0.0067	0.0096	0.0600
8/13/92	9	2	0.0022	0.0002	0.0004	1.0120	0.0051	0.0067	0.0613
8/13/92	9	8	0.0018	0.0001	0.0003	1.1995	0.0083	0.0083	0.0731
8/13/92	12	2	0.0016	0.0001	0.0006	0.7815	0.0055	0.0065	0.0544
8/13/92	12	8	0.0014	0.0001	0.0003	0.7811	0.0105	0.0085	0.0566
8/14/94	24	2	0.0016	0.0001	0.0002	0.5028	0.0074	0.0053	0.0465
8/14/94	24	8	0.0018	0.0001	0.0001	0.6711	0.0051	0.0070	0.0489
8/15/92	48	2	0.0006	0.0001	0.0001	0.3766	0.0031	0.0057	0.0477
8/15/92	48	8	0.0018	0.0001	0.0001	0.4095	0.0015	0.0054	0.0511
8/16/92	72	2	0.0002	0.0001	0.0001	0.2337	0.0027	0.0047	0.0464
8/16/92	72	8	0.0009	0.0001	0.0002	0.4117	0.0034	0.0067	0.0490

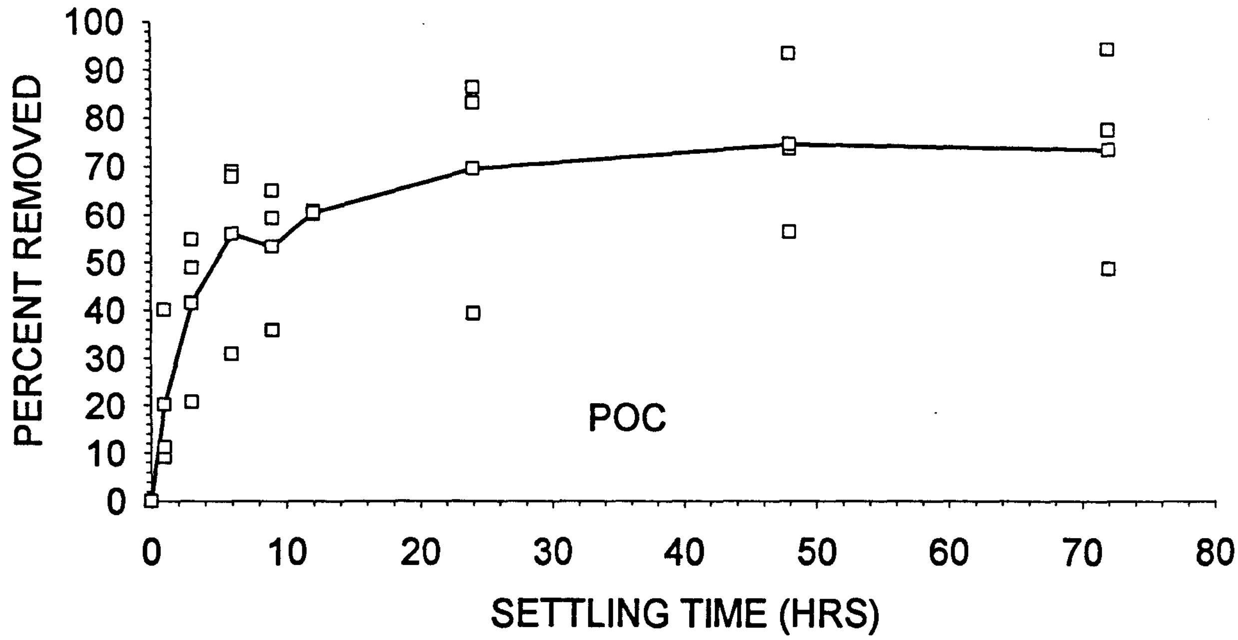
Appendix I. Plots of Percent of Pollutant Removed vs. Settling Time.



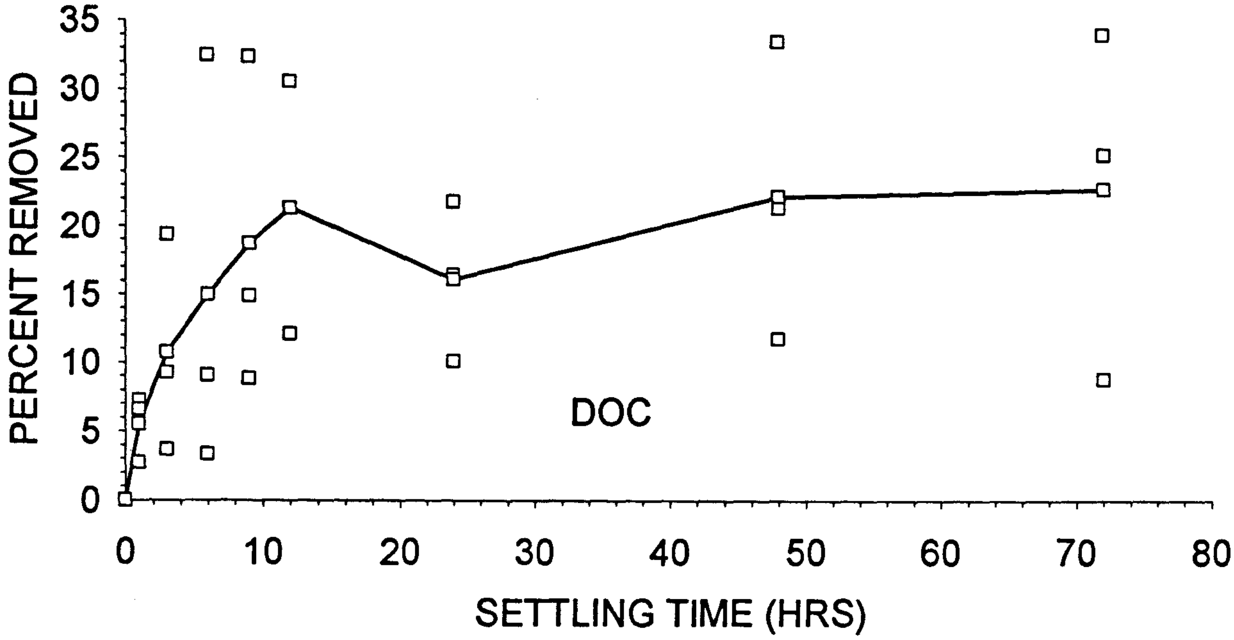


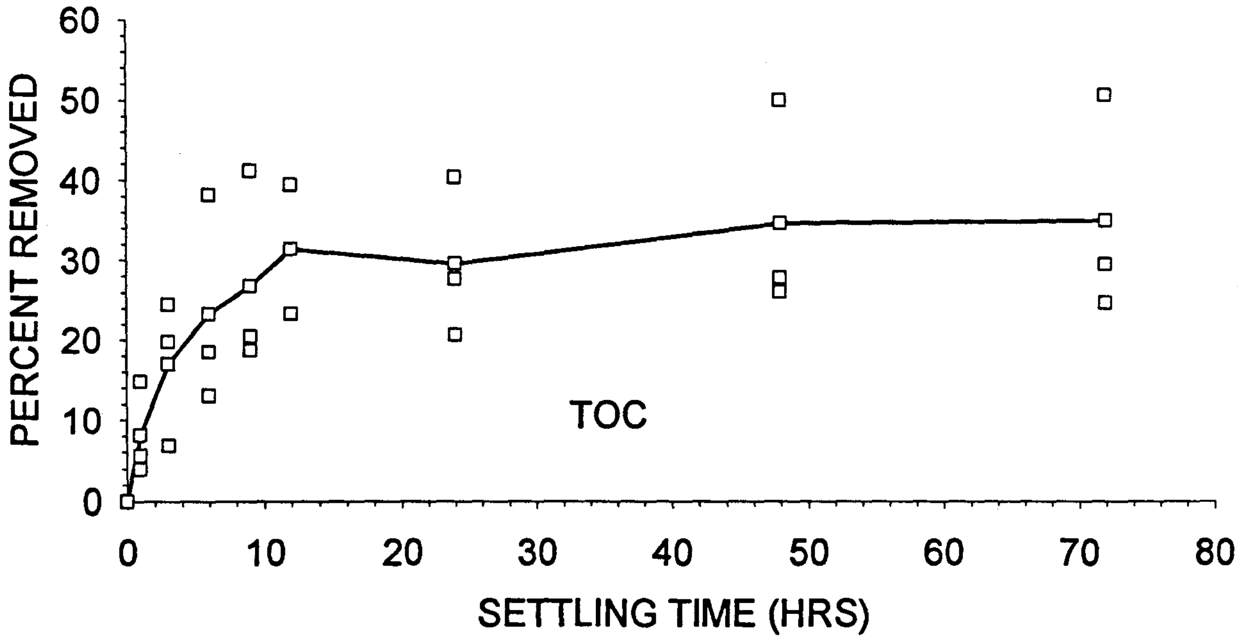
Appendix I. (continued).



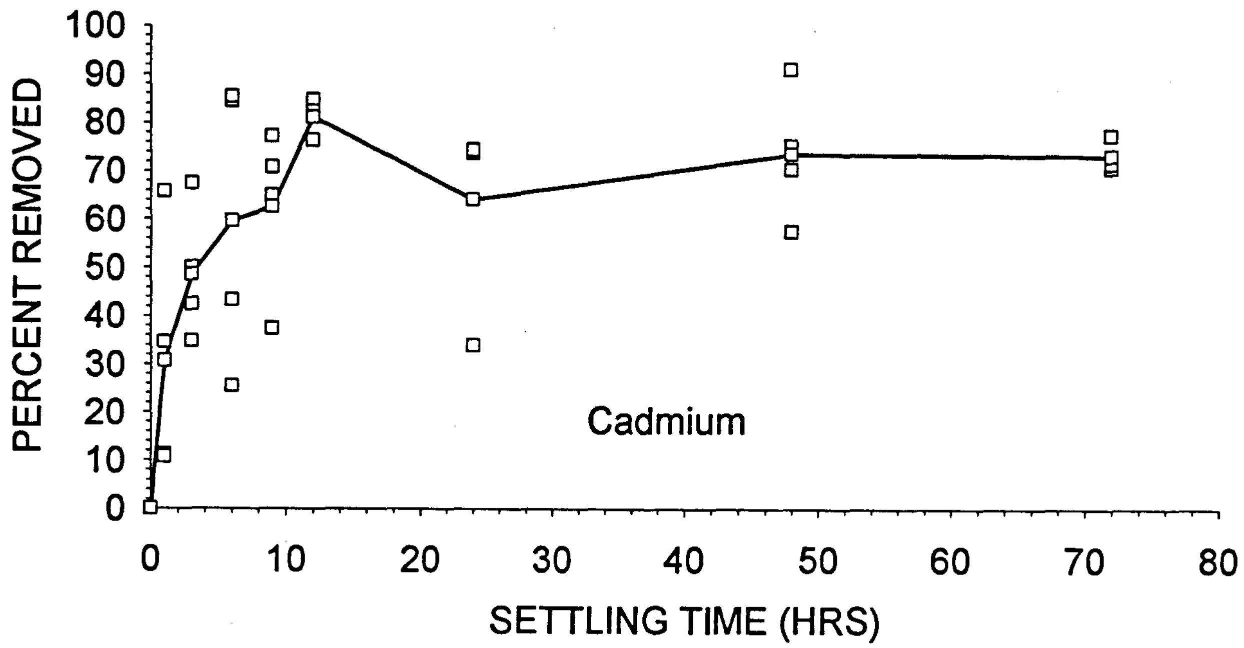


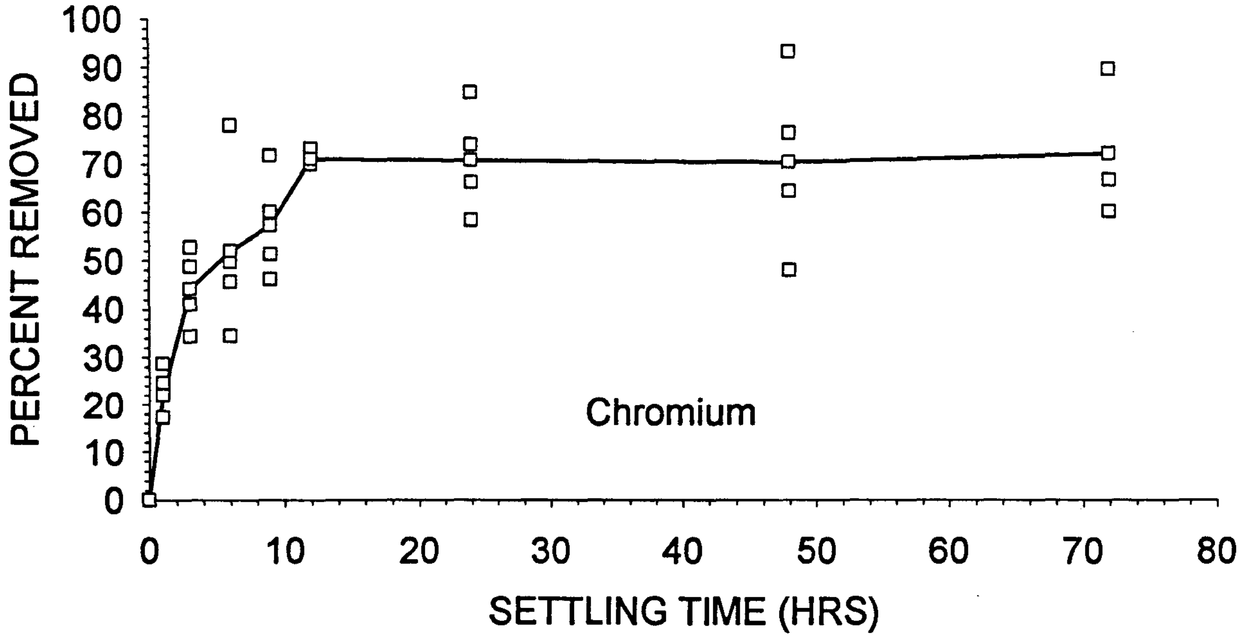
Appendix I. (continued).



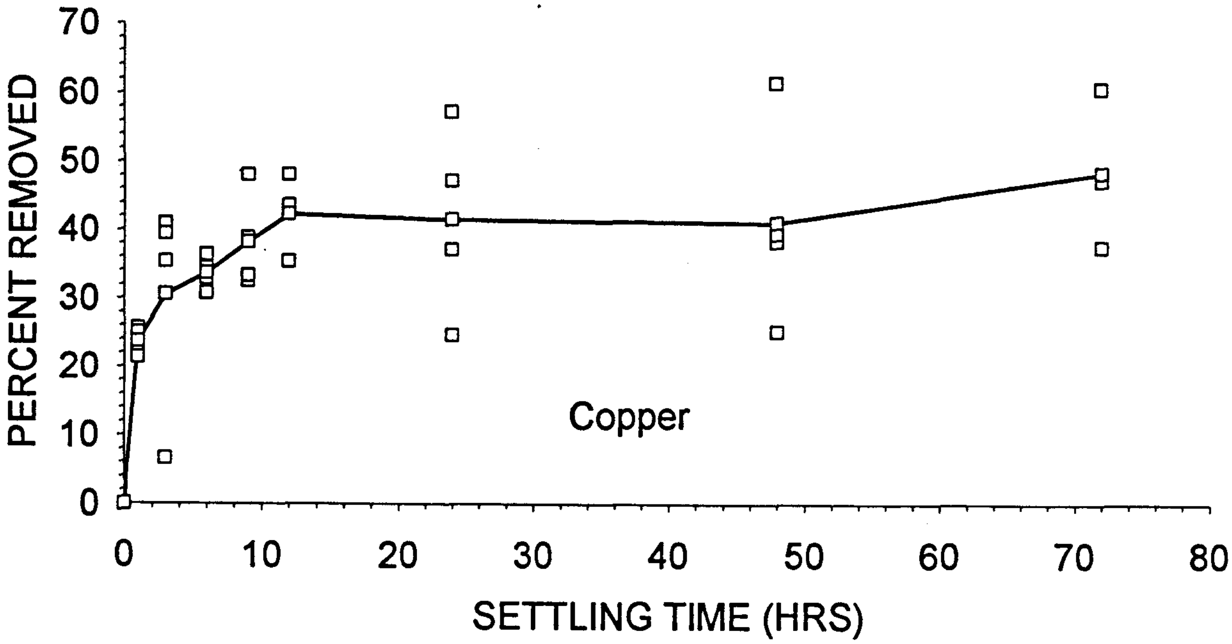


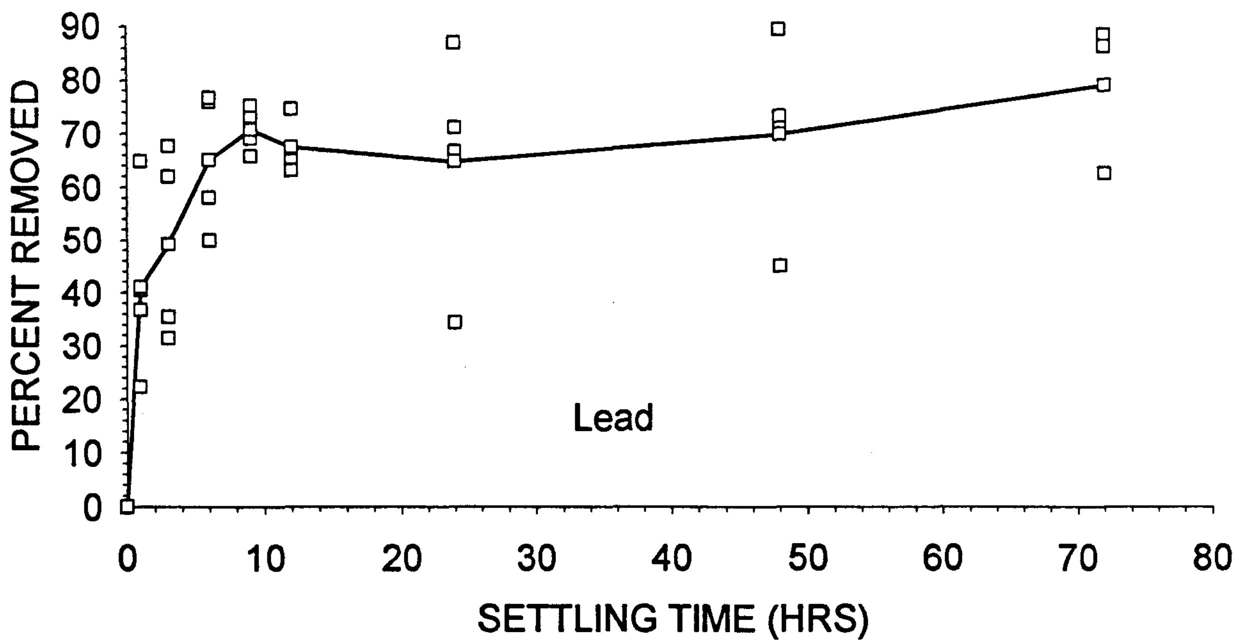
Appendix I. (continued).





Appendix I. (continued).





Appendix I. (continued).