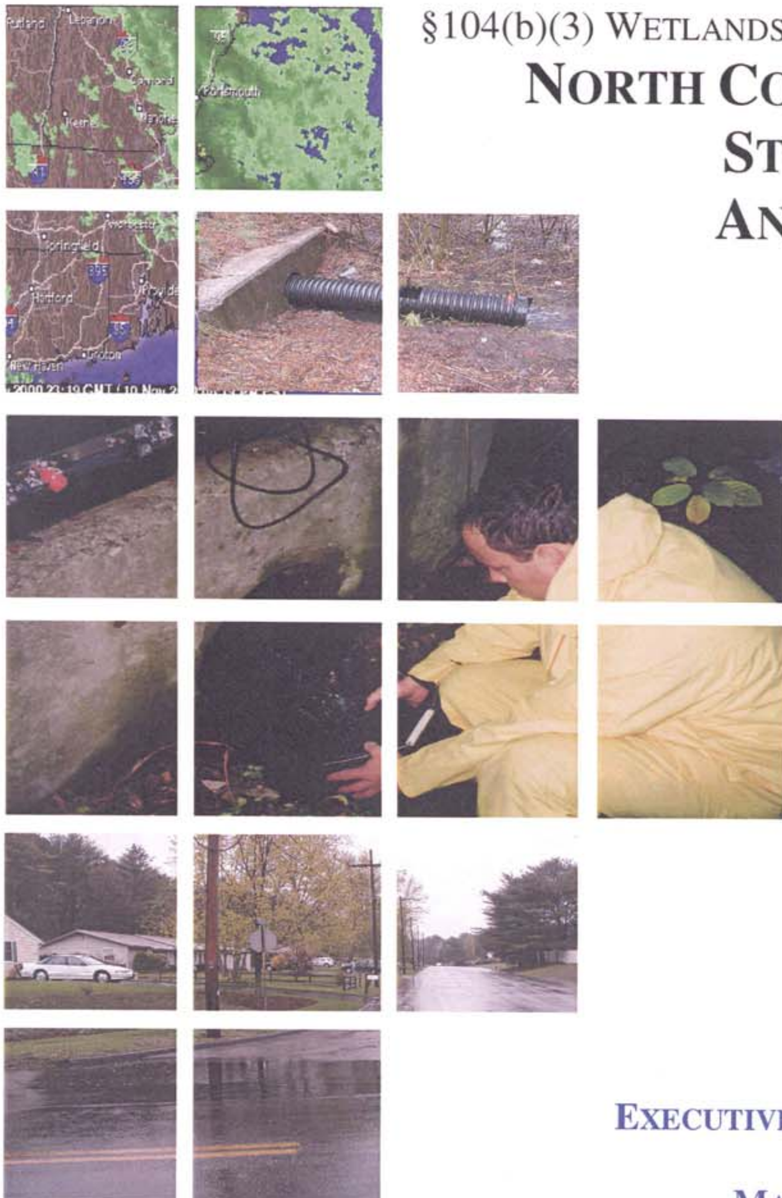

§104(b)(3) WETLANDS ECOLOGICAL ASSESSMENT PROJECT

NORTH COASTAL IPSWICH BASINS STORMWATER SAMPLING, ANALYSIS, & ASSESSMENT ASSISTANCE

FINAL REPORT

Prepared for:
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
MASSACHUSETTS COASTAL ZONE MANAGEMENT

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Executive Summary

- **Objective**

The primary objective of this project was to assist the Massachusetts Coastal Zone Management (MCZM) Office in the collection, analysis, and evaluation of stormwater inputs to two wetland sites. This project was part of the Wetlands Ecological Assessment Project, funded by the MDEP and the USEPA through the Clean Water Act §104(b)(3) Wetland Grants Program.

- **Study Sites**

Of the 14 wetland study sites for the Wetland Ecological Assessment Project, 8 sites have direct and unmitigated stormwater discharges. Therefore, the evaluation of stormwater discharges from differing neighboring land-uses on the integrity of receiving wetlands was one of the specific goals of the Project.

The two wetland/stormdrain sites selected for assessment were the Pinefield site at Ipswich Willowdale North and the Cherry Hill site on the Danvers/Beverly town line. The Pinefield site's contributing land use is characterized by medium density residential development, while the contributing land use at the Cherry Hill site is characterized by industrial/commercial (office park and interior processing/shipping). Both sites had defined contributing areas and discharge points which allowed sampling of flow and constituent loads.

- **Methodology**

The rainfall volumes that fell during the three storms at the three sites represented approximately 5% of the annual rainfall at the sites. Stormwater samples were collected at both sites during three storms in years 2000 and 2002. Samples were collected throughout the storm and analyzed for fecal coliform, nutrients, total suspended solids, and total petroleum hydrocarbons. Flow measurements were used to calculate constituent loads. Loads were then converted into weight per square meter of the impervious and the total (impervious and pervious) drainage area for each site.

- **Findings**

The stormwater investigation of the Pinefield and Cherry Hill discharge sites supports the contention that process level studies are required in order to develop loading coefficients for general application over larger areas. The difference between the Pinefield and Cherry Hill sites is significant when trying to extrapolate from site specific drainage basins to whole watersheds. The Pinefield Site is primarily residential with significant vegetation and access for both wild and domestic animals. The Cherry Hill Site is primarily a parking lot with little bordering vegetation. This difference in basin structure appears to be the dominant underlying cause of the differences in fecal coliform patterns between the sites. Fecal coliform concentrations at the Cherry Hill site were high at the beginning of the storm (first flush); at the Pinefield site the concentrations were high through the storm (possibly a result of wash-off and flushing of the storm drains).

In fact, the difference in basin structure is central to the pattern of discharge of each of the major stormwater contaminants assayed. However, even with the observed relatively large differences between the two sites, there were common trends in contaminant discharge. In fact, the major difference in nitrogen discharge was in the nitrogen forms rather than in the total nitrogen mass released per square meter of impermeable surface. The major contamination difference between the sites appears to be in bacterial loads with much higher loading from the residential watershed.

1.0 Introduction

1.1 Objective

The primary objective of this project was to assist the Massachusetts Coastal Zone Management (MCZM) Office in the collection, analysis, and evaluation of the stormwater inputs to two wetland sites, one within the North Coastal Basin and one within the Ipswich Basin. This project was part of the Wetlands Ecological Assessment Project, funded by the MDEP and the USEPA through the Clean Water Act §104(b)(3) Wetland Grants Program.

1.2 Background

Continuously increasing nutrient and bacteria inputs, primarily the result of increased point and non-point source inputs via increasing coastal development, are of growing concern to coastal communities. Apparently declining coastal water quality over recent decades is generally attributed to the increased loads from these sources. Point source nutrient and bacteria inputs tend to be discrete and easily quantifiable. However, non-point sources, which are small and widespread, are more difficult to identify and measure. Therefore, point sources have historically been regulated and quantified while non-point sources have a larger error associated with their estimates. The primary non-point sources are from residential waste disposal, fertilizer use (agricultural and residential), dairy and cattle farming, direct precipitation and surface water runoff. The last, surface water runoff, is of concern in that with increased development comes increased paving of surfaces and subsequent increases of nutrient and pollutant loading via this pathway.

Our understanding of nutrient inputs to coastal waters via stormwater runoff, however, is limited and little quantitative data exists to evaluate various management options to remediate or limit inputs from this source. This is unfortunate since proper management, either for remediation or conservation, requires quantitative data to make informed decisions on potential management options for watershed development and remediation.

The Wetland Ecological Assessment approach is a multi-component method for wetland assessment developed by Massachusetts Coastal Zone Management in conjunction with UMass Amherst and the Waquoit Bay National Estuarine Research Reserve. The approach combines rapid assessment methods with measurements of biota and physical and chemical properties to produce a comprehensive evaluation of the ecological health of a wetland. Metrics and indices are employed in data analysis and reporting. A cumulative Wetland Ecological Condition score is the final assessment output, combining the above variables into one single score or rank. Statistical approaches are employed to examine data patterns, significance, and use for predictive inquiry.

In this project, MCZM requested specific assistance related to the stormwater sampling, analysis, and assessment components of the current Wetland Ecological Assessment Project. The technical team, headed by the Louis Berger Group, Inc., in collaboration with the School for Marine Science and Technology (SMAST) of the University of Massachusetts (Dartmouth), was working with MCZM, EOEA Basin Team Leaders, and other project partners to sample rain generated stormwater discharges through storm drains at two selected wetland study sites. Measurements of flow and appropriate physical parameters were conducted in the field with parallel samples of stormwater collected for laboratory chemical analysis. Information generated will help to characterize types, concentrations and loading rates of pollutants entering wetlands through stormwater discharges and will help to diagnose potential resulting ecological disruptions as detected by the results of the multi-metric utilized in the Wetland Ecological Assessment approach.

1.3 Selection of Sites

Of the 14 wetland study sites for the Wetland Ecological Assessment Project, 8 sites have direct and unmitigated stormwater discharges. Therefore, the evaluation of stormwater discharges from differing neighboring land-uses on the integrity of receiving wetlands was one of the specific goals of the Project. Due to the cost and complexity of stormwater sampling, lab analysis, and assessment, it was decided by MCZM to select two sites for stormwater assessment work. The objective of selecting two sites was to try to identify sites with storm drainage basins containing different land use types and characteristics. Secondarily, site selection focused on areas compatible with the logistics of wet weather sampling (i.e., parking, access to stormdrain, stormdrain not crushed or buried, etc.).

The two wetland/stormdrain sites selected for assessment were the Pinefield site at Ipswich Willowdale North and the Cherry Hill site on the Danvers/Beverly town line. The Pinefield site's contributing land use is characterized by medium density residential development, while the contributing land use at the Cherry Hill site is characterized by industrial/commercial (office park and interior processing/shipping). Both sites had defined contributing areas and discharge points which allowed sampling of flow and constituent load. These physical features helped to constrain the storm water loading estimates derived from the field program.

1.4 Project Tasks

The project consisted of four tasks as follows:

- *Task 1 - Startup Activities and Quality Assurance Project Plan:* The goal of this task was to perform the activities needed in preparation for stormwater sampling. Specific activities consisted of the following:
  - Kickoff meeting with MCZM
  - Site selection: Several wetland locations were visited with the MCZM Project Officer to select the most suitable sites for this study.
  - Preparation of the Quality Assurance Project Plan (QAPP)

- *Task 2 - Stormwater Sampling:* Collection of stormwater samples during three storms per site following the methodology specified in the QAPP.

- *Task 3 - Preparation of Loading Estimates for Each Sites:* Based on the data collected in the field, loading estimates of the analyzed constituents were prepared. Loads were calculated for each event and averaged on an annual basis.

- *Task 4 -Final Report and Presentation*

2.0 Description of Sites

As previously stated, two sites were selected for this study:

- Pinefield site Town of Ipswich Runoff from residential neighborhood
- Cherry Hill site Town of Beverly Runoff from parking lot of industrial buildings

2.1 Pinefield Site

The site was located in Ipswich at the southern end of the Pinefield development and in the northern part of the Willowdale State Forest (Figures 2-1 and 2-2). The development consists entirely of single family homes (Figure 2-3). The stormwater sampling location was located at the southern end of two parallel pipes (diameter 12") underneath Linebrook Road (Figure 2-4).

Stormwater that exits the pipe flows within a partially vegetated drainage channel into the wetland (Figures 2-5 and 2-6). The drainage channel is roughly 15 m long.

The approximate drainage area for the sampling location was estimated during a site visit during a rainstorm in April 2002. The size of the area was 76,922 square meters (Figure 2-2). The estimated total impermeable surface area was 19,775 square meters (or 26% of the total drainage area), consisting of the following components:

- Road surface 11,165 square meters
- Roof surface 6,150 square meters (using 150 sq. meters per building)
- Driveway surface 2,460 square meters (using 60 sq. meters per building)

2.2 Cherry Hill Site

The site was located in Danvers just to the south of the Beverly Municipal Airport (Figure 2-7). Specifically, the wetland was within the Cherry Hill Industrial Development area (Figure 2-8). The sampling location was located at the edge of the parking lot of 35 Cherry Hill Drive. The wetland receives runoff from the parking lot of the development at mainly three discharge locations. In addition, the wetland receives runoff from adjacent industrial developments.

The sampling location was one of the three stormwater pipes that drain the parking lot from the 35 Cherry Hill Drive development (Figures 2-9 and 2-10). The selected pipe was located at the eastern end of the parking lot. The stormwater enters two manholes just above the wetland. The water is first contained in a catchbasin. The overflow of the catchbasin is discharged through a 12" diameter pipe into the wetland (Figure 2-11 and 2-12).

The approximate drainage area was also determined during a site visit during a rainstorm in April 2002. The estimated drainage area for the sampling location was 5,490 square meters, as marked on Figure 2-8. The estimated total impermeable surface area was 5,290 square meters (or 96% of the total drainage area).

Figure 2-1: USGS map of the Pinefield site. The stormwater sampling location is marked with a red arrow. (Scale: 1 inch = 2000 feet)

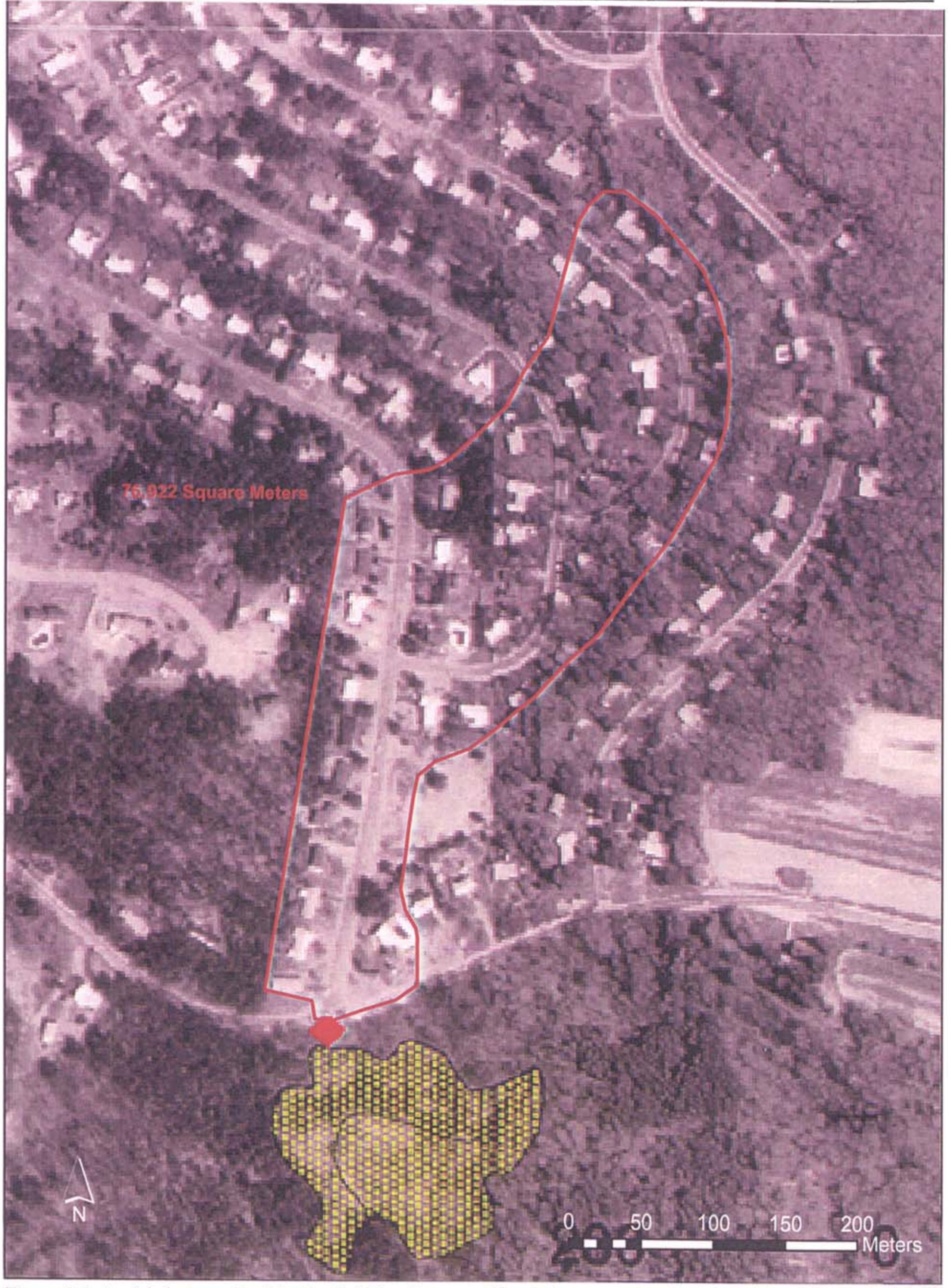


Figure 2-2: Aerial photograph of the Pinefield development. The drainage area (outlined in red) is entirely residential. The wetland is marked in yellow; the sampling station is marked with a red dot.

Figure 2-3: Pinefield development, looking north from Linebrook Road (foreground). The sampling location is approximately 15 m below the bottom of the photograph. The area consists of single residential homes.

Figure 2-4: Sampling location at the Pinefield site. The location consists of two parallel, partially submerged 12" diameter drainage pipes.

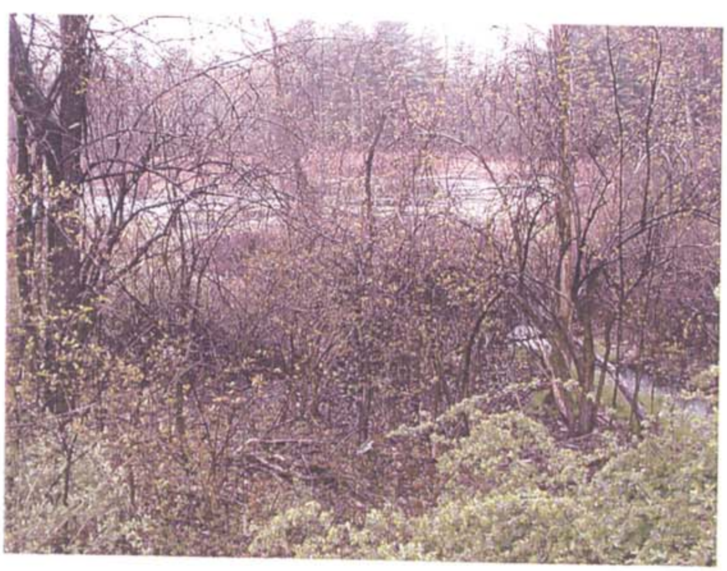


Figure 2-5: The stormwater drainage channel (lower right corner) enters the wetland (in the background) approximately 15 m from the sampling location.

Figure 2-6: Wetland receiving the stormwater discharge from the Pinefield development. The photograph is looking to the south.

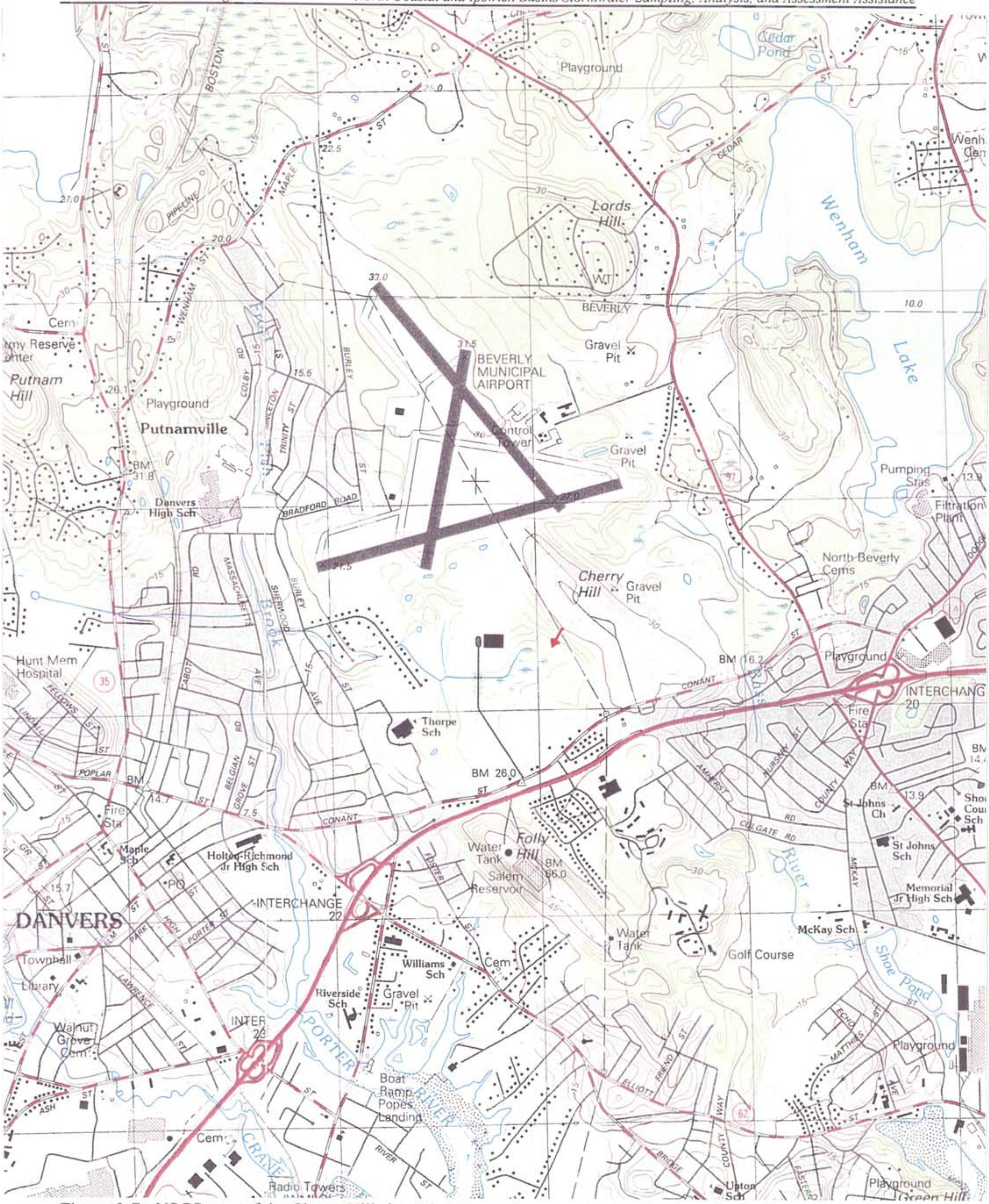


Figure 2-7: USGS map of the Cherry Hill site. The stormwater sampling location is marked with a red arrow. (Scale: 1 inch = 2000 feet)

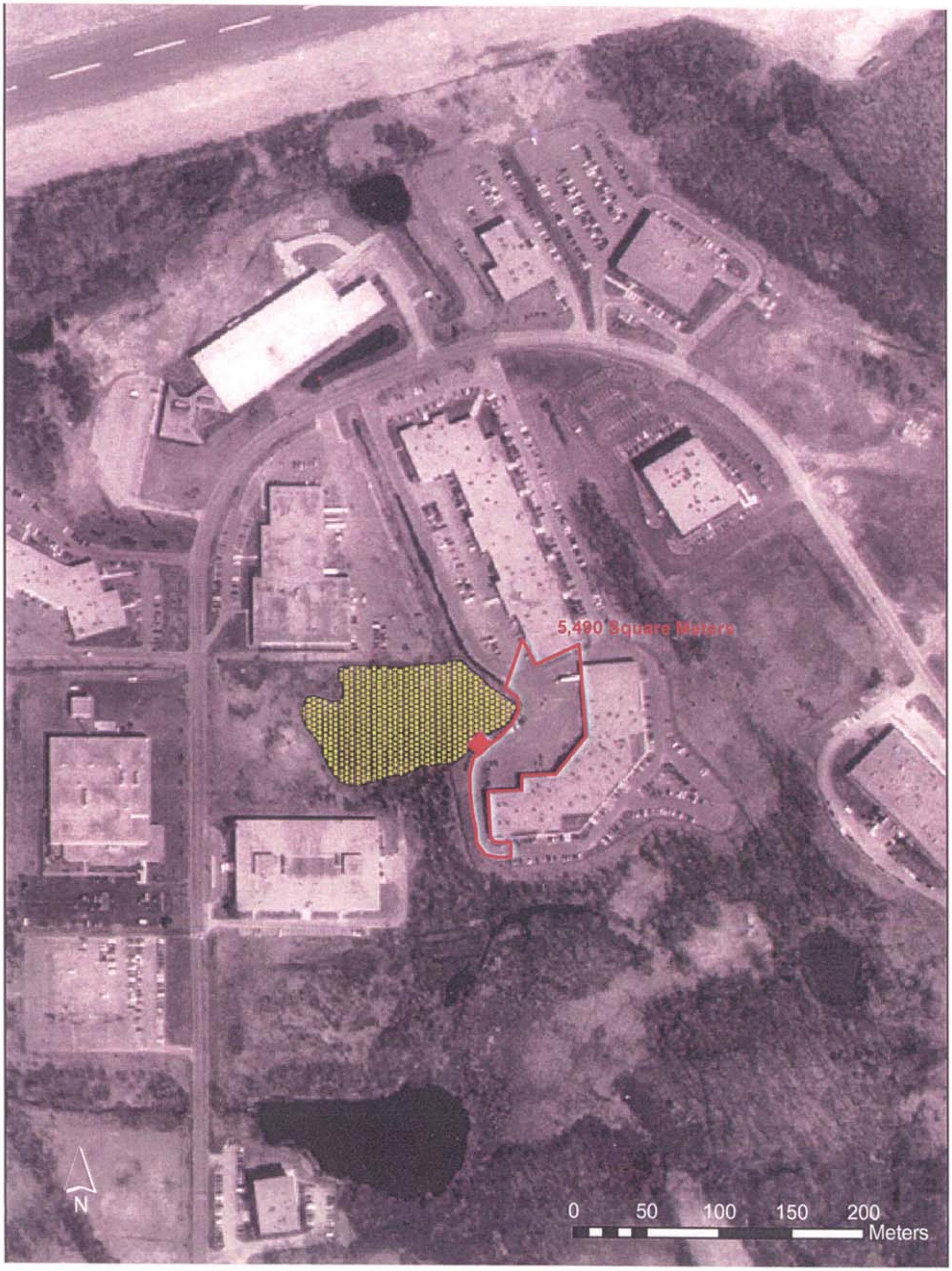


Figure 2-8: Aerial photograph of the Cherry Hill site. The drainage area (outlined in red) is essentially a parking lot and a loading zone. The wetland is marked in yellow; the sampling station is marked with a red dot.

Figure 2-9: Part of the parking lot draining into the wetland.

Figure 2-10: Manhole cover for catchbasin at parking lot at Cherry Hill site. The catchbasin overflows into the wetland.

Figure 2-11: Discharge from catchbasin into the wetland at Cherry Hill site.

Figure 2-12: Wetland at Cherry Hill site. The sampled discharge pipe is located behind the small bush on the left side of the photograph.

3.0 Methodology

3.1 Overview

Sampling was conducted during three storms at each site. The samples were subsequently transported to the UMass Coastal Systems Laboratory at SMAST for nutrient and TSS analyses. Samples for fecal coliform analyses were delivered to Toxikon (Storms A to D), and to the Barnstable County Laboratory (Storms E and F).

3.2 Site Preparations

Each of the two storm drainage sites required some preparations prior to the start of the first sampling event:

- **Pinefield site:** The end of the pipe at the southern side of Linebrook Road (sampling location) drains directly into a small channel. The low elevation of the pipe did not allow for the installation of a weir. Instead, flow was measured by channeling the flow from the pipe into a 3-feet long flume (described further below). At the end of the flume, the ground was excavated to allow for graduated bucket volume determinations during low flow conditions. Site preparation activities consisted of constructing the flume and preparing the channel for the placement of the flume and bucket.

- **Cherry Hill site:** The end of the 12" diameter pipe from a catch basin at the lowest point of the 35 Cherry Hill Development sampling location drains directly into the wetland. The open wetland immediately beyond the pipe does not allow for the installation of a weir. Instead, flow was measured by channeling the flow from the pipe into a 6-foot long pipe extension. Site preparation activities consisted of preparing the ground for the placement of the extension pipe.

3.3 Sampling

3.3.1 Selection of Storm

Storms to be sampled required the following criteria:

- Dry period prior to the storm: at least 36 hours
- Rainfall amount: 0.33" of rain per storm

Weather patterns were followed closely in search of appropriate storms for sampling. All equipment was assembled in a manner that allowed for rapid mobilization once a suitable storm was identified.

3.3.2 Water Sample Collection

The protocol for field sampling is attached in Section 7.

The sampling staff arrived at least one hour before the beginning of the storm. Basic information was recorded in the field notebook. The dissolved oxygen (DO) and pH meter calibrations were checked. The site was prepared for flow measurements.

- **Dry weather samples:** A dry weather sample was collected from the Pinefield site pipe, if flow existed. A dry weather sample was also collected from the manhole at the Cherry Hill site.

- **Wet Weather samples:** The goal of the sampling effort was to capture the load of constituents that enter the wetland at the two study locations for a specific storm. To meet this goal, samples were collected during the first flush with more frequent sampling at the beginning of the storm. Sampling intervals become longer toward the end of the storm. The last sample was reserved for the end of the flow period. Given that all storms are different, we maintained flexibility in setting the sampling interval to assure that the sampling goal was met.

A total of at least 10 samples from each site per sampling event were analyzed. This number of samples included one duplicate sample. For the single sample collected from the catch basin of the Cherry Hill site before the storm starts, the water was collected with a sterile-clean groundwater well bailer. All other samples at the Cherry Hill site were collected directly from the end of the stormwater pipe without the use of a dipper or other water sampler (Figure 3-1). At the Pinefield site, all samples were collected directly from the end of the pipe without the use of a sampler.

Prior to collecting each sample, the sample labels were filled out completely. Samples were placed into a cooler on ice immediately after sampling.

3.3.3 In situ Water Quality Measurements

The pH was measured with the calibrated pH meter. Conductivity, dissolved oxygen, and temperature were measured with a YSI meters, Models 33 and 55. The meters were calibrated before and after each sampling events.

Figure 3-1: Stormwater sampling at the Cherry Hill site during Storm C. Water samples were collected by filling bottles without the use of a bailor.

3.3.4 Flow Measurements

The flow was measured at each site in two ways, depending on the rate of discharge.

3.3.4.1 High Flow Conditions

Each site had a flow structure for high flow measurements. The flow was measured in the structure with a handheld flow meter (manufacturer: *Global Water*; model: *Flow Probe*; range: 0-25 ft/sec; accuracy: average velocity +/-0.1 ft/sec; flow averaging capability).

- **Pinefield site**: A structure was constructed that constricted the flow in the channel. The structure had vertical walls and was 3 feet long (Figure 3-2). The base of the channel was graded to a flat surface which included the removal of rocks. Flow measurements were made with the Global Water flow meter in the center of the flow structure. The height of the flow in the structure was measured with a ruler. The flow rate was determined as follows:

  Flow rate *(cubic feet per second)* = Width of flume *(feet)* * Elevation of water in the flume *(feet)* * Velocity (from flow meter; *feet/second)*

- **Cherry Hill site**: The stormwater drainage pipe was extended with a 6-feet long stormwater pipe with a diameter of 12" (Figure 3-3). The inside of the pipe was smooth (i.e., not ribbed). The pipe could be fitted easily to the lip of discharge point, thereby avoiding spillage. A hole was cut into the center of the pipe to allow for the insertion of the Global Water flow meter. The height of the flow in the pipe was measured with a ruler. The calculation of the flow rate considered the arc-shaped crossection of the pipe. The flow rate was determined as follows:

  Flow rate *(cubic feet per second)* = Cross-sectional area of the flow (based on depth of flow and diameter of pipe) *(square feet)* * Velocity (from flow meter; *feet/second)*

3.3.4.2 Low Flow Conditions

For low flow conditions, the flow in the flow structures was too low to obtain an accurate flow rate. Therefore, a graduated bucket was used. At the Pinefield site, the bucket was positioned behind a constructed weir (Figure 3-4). At the Cherry Hill site, the bucket was positioned behind the discharge pipe; a flexible plastic insert was used to create a lip in the pipe under which the bucket was placed (Figure 3-5). Measurements were made at a minimum in duplicate. The flow rate was determined as follows:

Flow rate *(cubic feet per second)* = Volume of water in the bucket *(cubic feet)* / Time to fill bucket *(seconds)*

Flow measurement were made at each site immediately after the collection of each water sample. In addition, the flow was measured between water samples.

The factory-calibration of the flow meter (Global Water - Flow Probe) was verified in the field with the graduated bucket at times when stormwater flows were suitable for measurements with both methods (bucket and flow meter).

Figure 3-2: Flow structure at the Pinefield site for high flow conditions. The structure funneled the flow through a confined channel of uniform width. The natural base of the channel was flattened which included removal of rocks. The flow was measured by placing the Global Water flow probe into the middle of the channel.

Figure 3-3: Flow structure at the Cherry Hill site for high flow conditions. The existing drainage pipe at the site was "extended" with a ribbed pipe. Walls within the pipe extension were smooth (i.e., not ribbed). Flow was measured by placing the Global Water flow probe into the center hole, that was cut into the pipe extension.

Figure 3-4: Flow structure at the Pinefield site for low flow conditions. The structure funneled the flow through a confined opening. The channel was excavated behind the opening to allow for the placement of a graduated bucket. Flow was measured by recording the time needed to fill the bucket.

Figure 3-5: Flow measurements at the Cherry Hill site during low flow conditions. A flexible plastic sheet was placed into the existing pipe to create a lip. A graduated bucket was placed under the lip for flow measurements.

3.3.5 Rainfall Measurements

At each location, at least one raingage was deployed. The gage consisted of graduated cylinder with an accuracy of 0.01" of rain. The gage was deployed prior to the start of rainfall at an appropriate unobstructed location near the sampling location. Raingage readings were taken with each flow measurement. Additional readings were taken between water samples in order to understand the dynamics of the storm.

Rainfall information is recorded also by the Beverly Municipal Airport. The airport is located approximately 8 miles from the Pinefield site and approximately 0.5 miles from the Cherry Hill site. The readings are published on the NOAA National Weather Service website.

Rainfall data were compared also to measurements collected by the following sources:

- **Pinefield site:** Rainfall information is collected daily at 7:00am at the Ipswich Wastewater Treatment Plant. The raingage used in Ipswich is a graduated cylinder model with an accuracy of 0.01". The treatment plant is approximately 3.3 miles east of the Pinefield sampling site.

- **Cherry Hill site:** Rainfall information is collected daily at 8:00am at the laboratory of the Beverly Salem Water Supply Board. Data are collected with a standard USGS raingage which is a graduated cylinder model with an accuracy of 0.01". The laboratory is located just to the south of Wenham Lake, approximately 1.3 miles ENE of the Cherry Hill sampling site.

3.3.6 Sample Analysis

MCZM did not find any previous sampling data for these sites. Other storm water studies indicate that concentrations of contaminants can range over several orders of magnitude both within a single event (first flush versus final levels) and between events depending on the volume and frequency of rainfall. As a result, we chose methods with low detection levels to ensure quantitative results. The methods employed in the nutrient assays were the standard methods of research level environmental laboratories. Since the study was more a research than a "regulatory-type" investigation, the higher quality methods were selected to ensure that storm water loads (i.e., flow times concentration) could be determined.

Monitoring parameters, sample volumes, containers, sample processing and storage for this project are listed in 3-1. Analytical methods and associated references are listed in Table 3-2. Analyses were conducted within the recommended holding times specified in Table 3-3. Analytical detection limits, accuracy and precision for laboratory analyses are listed in Table 3-4.

3.3.7 Field Quality Control / Quality Assurance

- **Preparation of Sampling Containers:** Sample containers were pre-cleaned by the laboratories for the respective constituents that were analyzed by the lab (Table 3-1). All nutrient sample containers were leached for 24 hours in 10% HCl, rinsed with triple-distilled water, and dried at 60 degrees C. The containers for the TPH sample were cleaned with hydrochloric acid to pH <2. The clean containers were delivered to our team in coolers which were also used for transfer of the samples back to the respective labs. A sufficient number of coolers were available to allow for ice (double-bagged and sealed) during storage of samples at each of the two sites and for transport to the labs.

- **Sample Identification:** All sample bottles were labeled with the date, time, site identification, storm event number and parameter to be analyzed.

Table 3-1
Monitoring Parameters

Parameter	Volume	Container (*)	Processing & Storage
Nitrate + Nitrite	60 ml	polyethylene (HCl leached)	0.45 um membrane field filtration stored on ice (dark)
Dissolved ammonium ($NH_3 + NH_4^+$)	60 ml	polyethylene (HCl leached)	0.45 um membrane field filtration stored on ice (dark)
Total Dissolved Nitrogen	60 ml	polyethylene (HCl leached)	0.45 um membrane field filtration stored on ice (dark)
Particulate Carbon/Nitrogen	1000 ml	polyethylene or solids	stored on ice (dark) (acid washed) combusted GFF, dried
Ortho-Phosphate	60 ml	polyethylene (HCl leached)	0.45 um membrane field filtration stored on ice (dark)
Total Phosphorus	1000 ml	polyethylene (HCl leached)	stored on ice (dark)
Total Suspended Solids	1000 ml	polyethylene	stored on ice (dark)
Specific Conductance	60-125 ml	polyethylene	no headspace in bottle stored on ice (dark)
Fecal Coliform	100 ml	polyethylene (sterilized)	stored on ice (dark)
TPH	1000 ml	amber/glass bottle (bottles are acidified with HCl to pH < 2)	stored on ice (dark)

(*) The acid used for acid-washed bottles was 10% hydrochloric acid.

Table 3-2
Laboratory Analyses [k]

Parameter	Matrix	Units	Method	Reference
Nitrate + Nitrite	water	ug/L	Autoanalyzer	a
Dissolved Ammonium ($NH_3 + NH_4^+$)	water	ug/L	Indophenol	b
Total Dissolved water Nitrogen		ug/L	Persulfate Digest	c
Particulate Carbon/Nitrogen	water	ug/L	Elemental analysis	d
Ortho-Phosphate	water	ug/L	Molybdenum Blue	e
Total Phosphorus	water	ug/L	Persulfate Digest Molybdenum Blue	f
Total Suspended Solids	water	mg/L	Filtration/Drying	g
Specific Conductance	water	mS/m	Meter and Probe	h
Fecal Coliform	water	CFU/100mL	Membrane Filtration	i
TPH	water	mg/L	IR	j

a Lachat Autoanalysis procedures based upon the following techniques
- Wood, E., F. Armstrong and F. Richards. 1967. Determination of nitrate in sea water by cadmium copper reduction to nitrite. J. Mar. Biol. Ass. U.K. 47:23-31.
- Bendschneider, K. and R. Robinson. 1952. A new spectrophotometric method for the determination of nitrite in sea water. J. Mar. Res. 11: 87-96.

b Scheiner, D. 1976. Determination of ammonia and Kjeldahl nitrogen by indophenol method. Water Resources 10: 31-36.

c D'Elia, C.F., P.A. Stuedler and N. Corwin. 1977. Determination of total nitrogen in aqueous samples using persulfate digestion. Limnol. Oceanogr. 22: 760-764.

d Perkin-Elmer Model 2400 CHN Elemental Analyzer Technical Manual.

e Murphy, J. and J. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta 27: 31-36.

f Persulfate Digestion Method for Total Phosphorus; Standard Methods 4500-P B.5 (18th ed.)

g Total Suspended Solids dried at 103-105°C, Standard Methods 2540 D (18th ed.)

h Conductivity, Standard Methods 2510 B. (18th ed.), Fisher Temp. Compensated Conductivity Meter

i Fecal coliform, Standard Methods 9221 E. (18th edition)

j TPH, Standard Methods 418.1 .

k The techniques used by the SMAST laboratory were methods generally used by state-of-the-art research laboratories. All of the methods and QA/QC are routinely performed by the SMAST laboratory have been accepted by EPA, USGS, MCZM, DEP, NSF and NOAA as part of previous studies conducted by the SMAST lab under their review.

Table 3-3
Standard Sample Holding Times

Assay	**Project Team Holding Time (*)**	**Laboratory**
Nitrate +Nitrite	48 hrs	SMAST
Dissolved Ammonia ($NH_3 + NH_4^+$)	12-24 hrs	SMAST
Total Dissolved Nitrogen	12-24 hrs	SMAST
Partic. Org. Carbon/Nitrogen	24 hrs	SMAST
Ortho-Phosphate	12-24 hrs	SMAST
Total Phosphorus	24 hrs	SMAST
Total Suspended Solids	24 hrs	SMAST
Fecal Coliform	24 hrs	Toxikon/BCL(***)
TPH	28 days**	Toxikon

(*) Samples were kept between 0 and 4 degrees C during storage in the field.
(**) Acidified
(***) BCL = Barnstable County Laboratory

Table 3-4
Detection Limits and Accuracy for Laboratory Measurements

Variable (Lab)	Matrix	Units	Lower Detection Limits	Accuracy and Precision* *(Better than)*
Nitrate +Nitrite	water	mg/l	0.001	5%
Dissolved Ammonia	water	mg/l	0.001	5%
Total Diss. Nitrogen	water	mg/l	0.003	5%
Partic. Org. Carbon/Nitrogen	water	mg/l	0.006	5%
Ortho-Phosphate	water	mg/l	0.003	5%
Total Phosphorus	water	mg/l	0.006	5%
Fecal Coliform	water	CFU	1 **	--
TPH (***)	water	mg/l	0.001	20%

* Accuracy based on results of laboratory control standards and spiked samples; however, no spikes are available for POC/PON analysis; precision based on relative %difference of duplicate samples.

** The dynamic range provided by the laboratory was 10 to 100,000 CFU.

*** The laboratory control standard (LCS) for TPH 418.1 used by Toxikon is composed of a 50/50 mix of Pennzoil 10W30 motor oil and Wesson corn oil. For this method, Toxikon performs an LCS with every batch of 20 or fewer (5% or higher) samples, and performs either a sample duplicate and matrix spike at a frequency of at least 5% if the client provides the appropriate number of samples 2 or 3 separate containers), or an LCS and LCS duplicate to demonstrate precision and accuracy.

- **Sample Handling and Delivery:** Samples for dissolved nutrient analysis were filtered (0.45 um) in the field upon collection using 10% HCl, leached-triple-distilled water rinsed in-line polycarbonate syringe filter housings. All samples were collected in appropriate sample containers with appropriate pre-cleaning. Samples collected for laboratory analysis were placed in coolers with ice sufficient to maintain a 4°C temperature. No preservatives are required beyond temperature regulation with the exception of the sample for TPH analysis which must be acidified with HCL to pH<2. Samples were delivered to the two laboratories in accordance with holding time requirements.

- **Field QA/QC**: All samples were collected using appropriate field techniques to minimize contamination and cross-contamination of samples. For example, field personnel did not contact the inside of any sample containers.

- **Duplicate Samples/Trip Blanks:** For each storm, between 10 and 12 samples were analyzed in the laboratory. One of these samples was a field duplicate sample. Field duplicates were collected by simultaneous holding the sampling bottle for the original and duplicate sample for a specific analyte(s) into the flowing water, i.e., the bottles were filled at the same time. Duplicates were not collected from the first flush, because the variability of constituent concentrations in the water was expected to be highest at that time. As discussed during the kickoff meeting, there were no trip blanks.

- **Transfer of Samples to Laboratories:** The coolers with the samples were taped and sealed and transported by car to the laboratories within the specified holding times specified in the QAPP.

- **Chain of Custody**: A triplicate chain of custody (COC) form was included with all sample coolers. The COC included all sample IDs, the date and time of sample collection, and the parameters to be analyzed.

- **Post-event Calibration:** After a storm, the calibration of the field monitoring equipment was checked. Calibration information was entered into the field notebooks.

- **Post-sampling Activities:** The data from the deployed raingages was compared to rainfall from permanent precipitation measurement locations owned by adjacent towns.

3.4 Pollutant Load Calculations

The instantaneous mass flux (discharge * concentration) of the reported analytical data for composited samples were calculated by integrating the flux of a specific constituent in relation to its discharge to determine the pollutant load.

Discharge volumes were calculated from the flow rates. Flow rates were verified by the rainfall volume (rainfall rate times drainage area). The instantaneous mass discharge was calculated by multiplying the concentration data by the flow rate at each sampling time. The mass load for the entire storm was then estimated by integrating under the Mass x Time curve developed for each constituent from the sampling time-course over the entire storm period.

Average annual discharge rates per square meter were calculated for each site for both the total and the impervious areas.

4.0 Storm Data

Stormwater sampling was conducted on the following dates:

Storm A: August 23, 2000	Cherry Hill site	Rainfall Amount: 0.32"
Storm B: September 15, 2000	Pinefield site	Rainfall Amount: 1.23"
Storm C: November 10, 2000	Cherry Hill site	Rainfall Amount: 1.12"
Storm D: September 21, 2001	Pinefield site	Rainfall Amount: 0.30"
Storm E: September 25, 2001	Pinefield site	Rainfall Amount: 0.60"
Storm F: April 25, 2002	Cherry Hill site	Rainfall Amount: 0.93"

Following is a detailed description of the stormwater sampling events. Rainfall and discharge rates data are presented in Tables 4-1 and 4-2.

4.1 Storm A: Cherry Hill Site - August 23, 2000

The relevant information describing the characteristics of the sampling event is listed below:

- Arrival on site: 15:30h
- Parking lot occupancy: The parking lot adjacent to the site was approximately 90% filled with cars. This parking lot covers a large part of the drainage area for the discharge location that was sampled.
- Catchbasin: The runoff from the parking lot first enters a catchbasin before draining through a short pipe to the wetland. The water level in the catchbasin was 8" below the lowest part of the overflow pipe that drains into the wetland. The water depth to the bottom of the catchbasin was 11" on the left side (facing the wetland) and 3.5" on the right side of the basin. Using an average depth of the entire basin of 7.25" and given the diameter of the basin of 4 feet, the volume of water in the basin was 0.22 cubic meter prior to Storm A.
- Pre-storm Activities: The dissolved oxygen and pH meters were calibrated. Two raingages were deployed at unobstructed locations, approximately 200 meters apart from each other. A water sample (CH-A-1) was collected from the catchbasin at 17:30h using a sterile bailer. The bailer allowed sampling through the grate in the basin cover, thereby avoiding the need to remove the cover.
- Rainfall during Storm A: Rain started falling at 18:01h. The rain stopped falling at 22:30h. The total amount of rainfall for the entire storm was 0.315" in Raingage 1 and 0.325" in Raingage 2. The rainfall data are presented in Table 4-1 and Figure 4-1. The total amount of rainfall measured at the Beverly Municipal Airport was 0.26". The total amount of rainfall recorded by the Salem and Beverly Water Supply Board station was 0.28". The total amount of rainfall recorded at the National Weather Station in Boston was 0.37". The storm followed a dry period of 4 days. A total of 0.25" of rain fell on August 18 and 19 at the Beverly Municipal Airport; the amount measured by the Salem and Beverly Water Supply Board station during the same period was 0.22".

Table 4-1

Rainfall (cumulative) Storms A-C

Date	Time	Rainfall
	h	inch
STORM A: Cherry Hill Site		
8/23/00	18:01	0.000
	18:31	0.012
	19:05	0.055
	19:35	0.074
	20:04	0.117
	21:07	0.215
	21:51	0.302
	22:17	0.314
	23:26	0.320
STORM B: Pinefield Site		
9/15/00	6:00	0.000
	7:00	0.055
	7:45	0.110
	7:52	0.150
	8:17	0.220
	8:23	0.270
	9:00	0.510
	9:29	0.730
	9:48	0.900
	9:57	0.975
	10:21	1.100
	10:30	1.135
	10:38	1.175
	11:15	1.225
	11:39	1.230
	12:18	1.230
	13:00	1.230
	14:15	1.230
STORM C: Cherry Hill Site		
10-Nov	2:00	0.000
	2:30	0.015
	2:54	0.025
	3:26	0.035
	3:36	0.040
	4:35	0.055
	5:00	0.055
	5:30	0.055
	6:00	0.060
	6:40	0.100
	7:04	0.110
	7:28	0.140
	7:37	0.170
	8:11	0.235
	8:37	0.280
	9:02	0.305
	9:20	0.320
	9:34	0.340
	9:57	0.365
	10:14	0.405
	10:22	0.430
	10:32	0.470
	10:39	0.510
	11:02	0.620
	11:30	0.655
	12:05	0.690
	12:42	0.705
	13:05	0.715
	13:33	0.870
	14:02	0.955
	14:13	0.980
	14:32	1.025
	15:02	1.050
	15:30	1.060
	16:02	1.115
	16:15	1.120

Rainfall (cumulative) Storms D-F

Date	Time	Rainfall
	h	inch
STORM D: Pinefield Site		
9/20/01	20:15	0.011
	21:26	0.011
	22:47	0.043
9/21/01	0:00	0.070
	2:03	0.070
	2:45	0.123
	3:11	0.139
	3:39	0.161
	4:04	0.204
	4:16	0.214
	4:46	0.246
	5:17	0.257
	5:46	0.284
	6:17	0.300
	6:45	0.300
STORM E: Pinefield Site		
9/25/01	13:10	0.000
	14:00	0.010
	14:23	0.190
	14:36	0.210
	14:48	0.370
	15:06	0.460
	15:33	0.570
	16:52	0.585
	17:22	0.600
	17:55	0.600
	18:25	0.600
	18:50	0.600
STORM F: Cherry Hill Site		
4/25/02	14:50	
	16:41	0.000
	17:46	0.100
	18:20	0.150
	19:55	0.360
	20:50	0.430
	21:43	0.570
	22:31	0.730
	23:00	0.730
	23:38	0.760
4/25/02	0:35	0.850
	1:03	0.890
	1:30	0.930

Table 4-2

Discharge Rates Storms A-C

Date	Time (h)	Discharge Rate (cfs)	Bucket	Flow Meter
STORM A: Cherry Hill Site				
8/23/00	18:01			
	18:31			
	18:48	0.000		
	18:58	0.053	●	
	19:14	0.029	●	
	19:40	0.025	●	
	20:20	0.302		●
	20:50	0.099		●
	21:30	0.070	●	
	21:53	0.080	Estimate	
	22:33	0.006	●	
	23:49	0.001	●	
STORM B: Pinefield Site				
9/15/00	5:55			
	6:19	0.000		
	6:20	0.009	●	
	7:11	0.009	●	
	7:40	0.044	●	
	7:58	0.163	●	
	8:12	1.094		●
	8:30	1.531		●
	8:45	1.313		●
	9:15	1.969		●
	9:40	2.297		●
	10:12	1.467		●
	10:43	0.984		●
	11:01	0.592		●
	11:12	0.410		●
	11:44	0.109		●
	11:58	0.050	●	
	12:15	0.050	●	
	13:17	0.032	●	
	14:10	0.039	●	
STORM C: Cherry Hill Site				
11/10/00	2:50	0.000		
	2:57	0.015	●	
	3:31	0.021	●	
	3:59	0.021	●	
	4:30	0.021	●	
	5:00	0.009	●	
	5:30	0.009	●	
	6:00	0.014	●	
	6:40	0.056	●	
	7:04	0.042	●	
	7:37	0.121	●	
	8:02	0.111	●	
	9:02	0.111	●	
	9:20	0.046	●	
	10:07	0.169	●	
	10:36	0.406		●
	11:02	0.424		●
	11:30	0.051	●	
	12:08	0.056	●	
	12:45	0.021	●	
	13:05	0.028	●	
	13:33	0.876		●
	14:02	0.198		●
	14:32	0.106	●	
	15:02	0.097	●	
	15:30	0.035	●	
	15:55	0.106	●	

Discharge Rates Storms D-F

Date	Time (h)	Discharge Rate (cfs)	Bucket	Flow Meter
STORM D: Pinefield Site				
9/20/01	20:15			
	21:26			
	22:47			
9/21/01	0:00			
	2:03			
	2:45	0.000	●	
	3:11	0.009	●	
	3:31	0.008	●	
	3:51	0.070	●	
	4:11	0.023	●	
	4:41	0.050	●	
	5:11	0.070	●	
	5:41	0.023	●	
	6:11	0.023	●	
	6:45	0.010	●	
STORM E: Pinefield Site				
9/25/01	14:11	0.000		
	14:34	1.628		●
	14:45	3.197		●
	15:03	1.776		●
	15:30	2.279		●
	16:00	0.010	●	
	17:22	0.002	●	
	17:45	0.006	●	
	18:17	0.004	●	
	18:45	0.001	●	
STORM F: Cherry Hill Site				
4/25/01	17:26	0.000		
	17:40	0.316	●	
	18:10	0.257	●	
	19:22	0.550	●	
	19:45	0.319	●	
	20:41	0.269	●	
	21:34	0.324	●	
	22:24	0.674	●	
	23:00	0.009		●
	23:29	0.886	●	
4/26/02	0:25	0.379	●	
	1:00	0.313	●	
	1:50	0.009		●

Figure 4-1
Storm A - Cherry Hill Site: RAINFALL

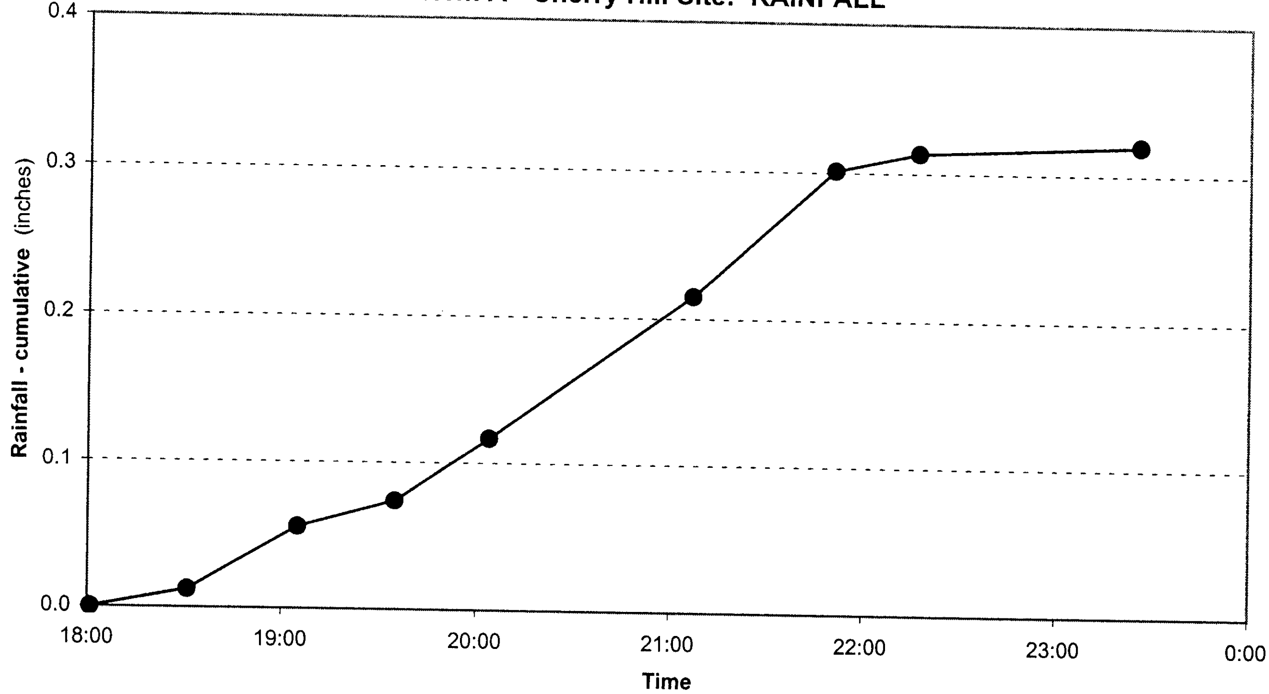
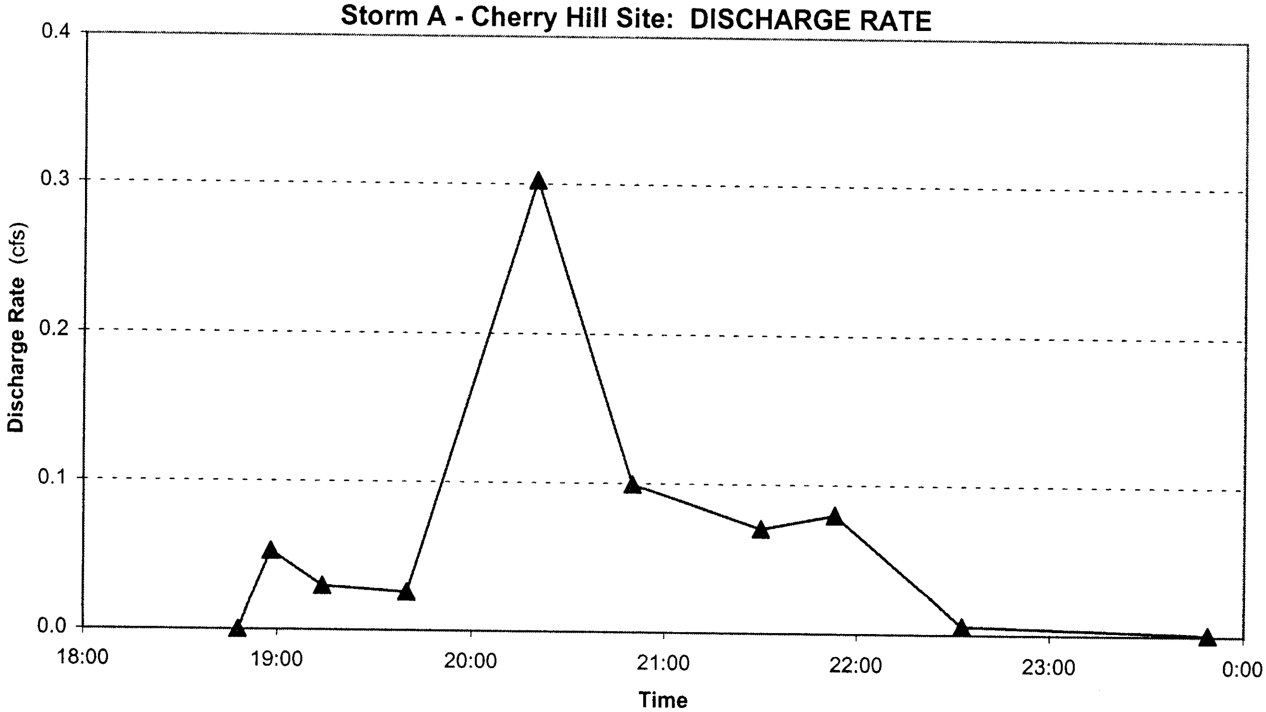


Figure 4-2
Storm A - Cherry Hill Site: DISCHARGE RATE



- Stormwater Sampling: Runoff started to enter the catchbasin at 18:25h, 24 minutes after the start of the rainfall. Some of the shallow puddles on the parking lot had a light sheen of oil. Water started to flow out of the catchbasin through the overflow pipe at 18:48h, or 47 minutes after rainfall began. Stormwater samples were collected from the end of the catchment's discharge pipe at the following times:

18:53h	CH-A-2	5 minutes after start of discharge	
19:17h	CH-A-3	29 minutes	(")
19:47h	CH-A-4	59 minutes (1h)	(")
20:35h	CH-A-5	107 minutes (1.75h)	(")
20:35h	CH-A-6	*(Field QA Duplicate of CH-A-5)*	
20:52h	CH-A-7	124 minutes (2h)	(")
21:25h	CH-A-8	157 minutes (2.5h)	(")
21:53h	CH-A-9	185 minutes (3h)	(")
23:49h	CH-A-10	241 minutes (4h)	(")

Samples were collected by holding the individual sampling bottles directly under the end of the drainage pipe; a water sampler was not needed.

- Discharge Rates: The discharge rates were determined by timing the filling of a bucket for low flow rates, and a Global Water Flow Probe for higher flow rates. The graduated bucket was filled with water by holding it under the lip of the drainage pipe. The flow meter measurements were collected by extending the existing catchment overflow pipe with a six foot long 12" diameter plastic drain pipe. Discharge rates were determined by measuring the cross-section of the pipe (which was filled with water) and the flow velocity measured by inserting the Flow Probe through a hole in the top of the pipe into the center of the discharging water. The discharge rates throughout the rain event are presented in Table 4-2 and Figure 4-2.

- Completion of Sampling: Rain stopped falling at approximately 22:30h, at which time it changed into a very light drizzle without appreciable accumulation. The runoff volume from the site decreased rapidly due to the small size of the drainage areas. Approximately one hour after the storm, the flow from the drainage pipe was only 2 liters per minute (i.e., 0.001 cfs). The departure from the site occurred at 00:41h on August 24, 2000. At this time, the flow entering the wetland consisted of merely a trickle (less than 0.2 liters per minute).

- Water Samples: The water samples were stored on site in the dark and on ice, and delivered to the two laboratories for analyses on August 24, 2000 (i.e., within holding times). Samples for fecal coliform and total petroleum hydrocarbon analyses were delivered to Toxikon at 10:45h; samples for nutrient and total suspended solids analyses were delivered to the SMAST Laboratory of the University of Massachusetts in New Bedford at 12:56h. Compositing of the samples was not needed since only a total of 10 samples were collected.

- Post-sampling Calibration: The calibration of the dissolved oxygen meter and the pH probe was checked on August 24, 2000 at 10:00h.

4.2 Storm B: Pinefield Site - September 15, 2000

The relevant information describing the characteristics of the sampling event is listed below:

- Arrival on site: 5:30h
- Drainage Channel: There was standing water in the drainage channel.
- Pre-storm Activities: The dissolved oxygen and pH meters had been calibrated on the evening before the event. Two raingages were deployed at unobstructed locations, approximately 10 meters apart from each other; the distance to the sampling location was approximately 50 meters. A sample of the standing water in the drainage channel (PF-B-1) was collected at 5:55h, 5 minutes prior to the start of the rainfall.
- Rainfall during Storm B: A radar map of the storm is shown in Figure 4-3. Rain started falling at 6:00h. The rain stopped falling at 11:15h, at which time it decreased to a light drizzle for two more hours without appreciable accumulation. The total amount of rainfall for the entire storm was 1.25" in Raingage 1 and 1.23" in Raingage 2. The total amount of rainfall measured at the Beverly Municipal Airport was 1.28". The total amount of rainfall recorded by the Salem and Beverly Water Supply Board station was 1.26". The total amount of rainfall recorded at the National Weather Station in Boston was 0.94". The rainfall data are presented in Table 4-1 and Figure 4-4.

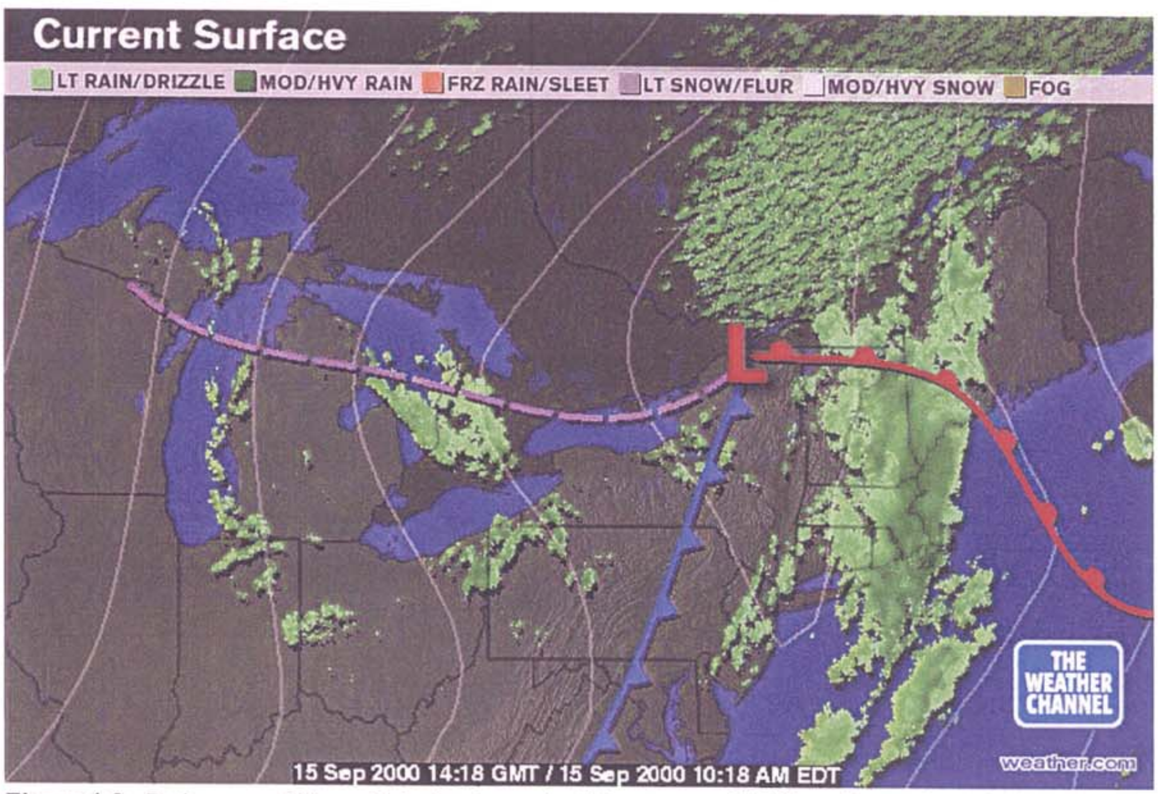


Figure 4-3: Radar map of Storm B during the peak of the storm at 10:18h on September 15, 2000 (Source: The Weather Channel).

Figure 4-4
Storm B - Pinefield Site: RAINFALL

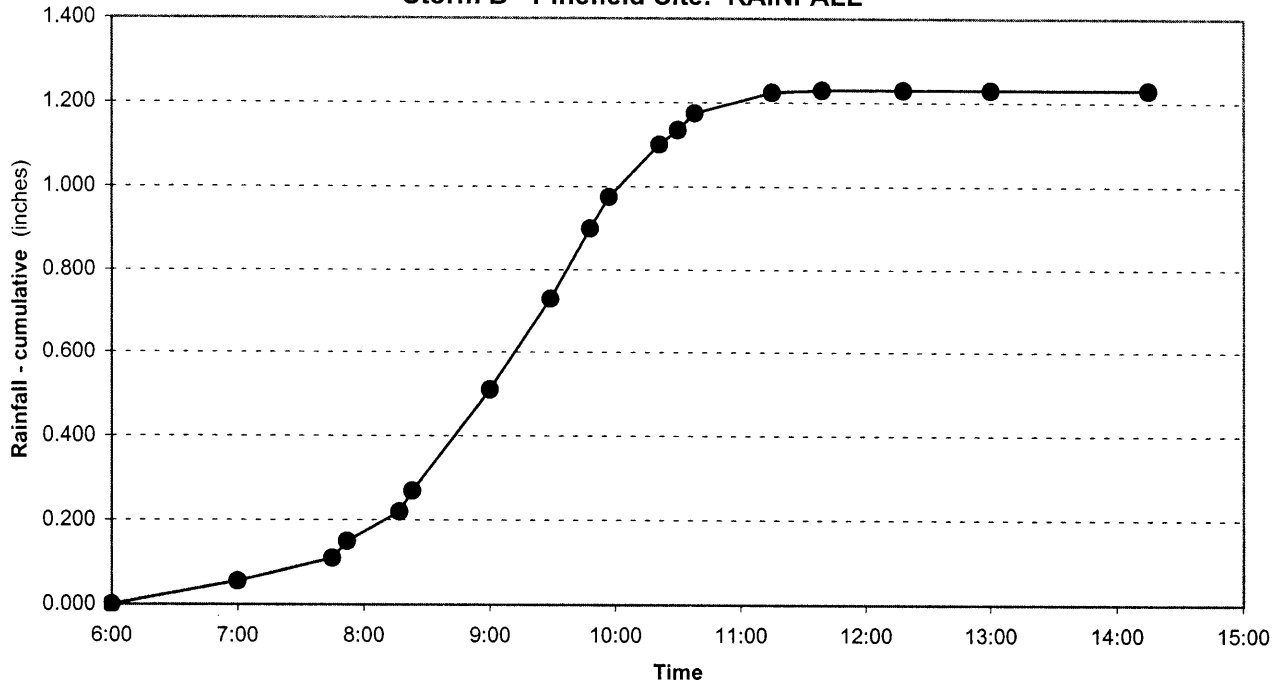
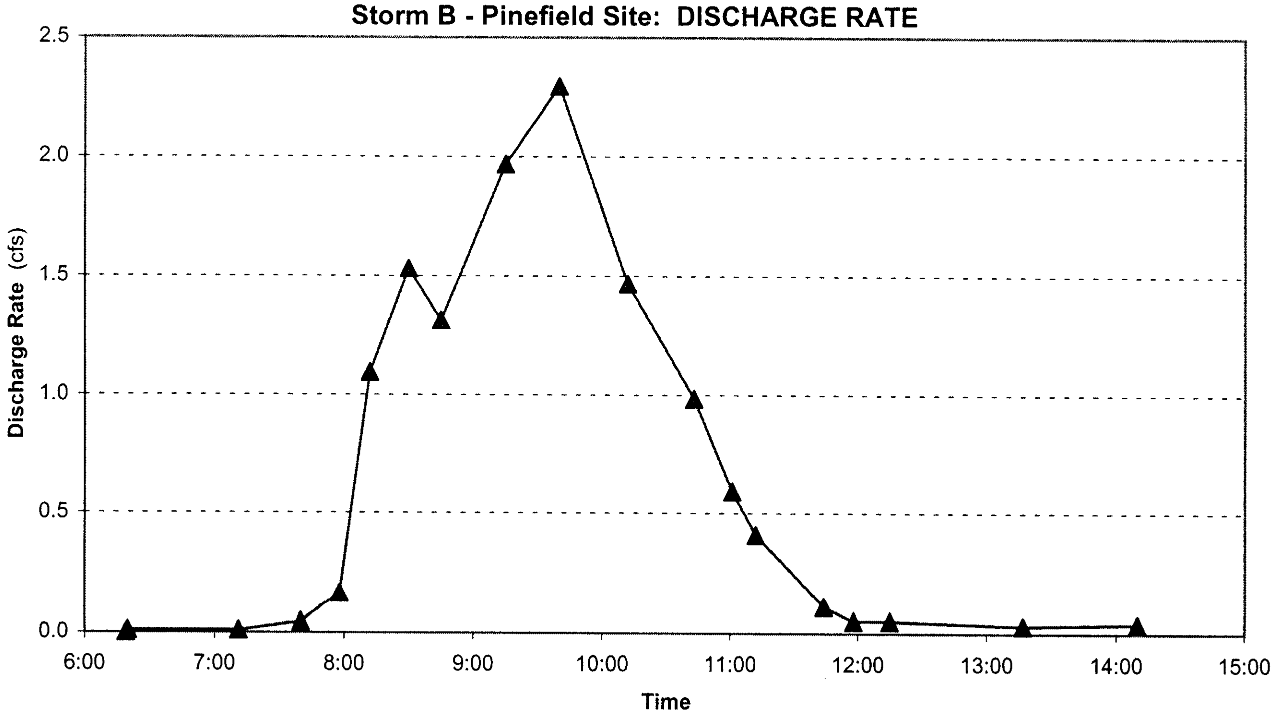


Figure 4-5
Storm B - Pinefield Site: DISCHARGE RATE



The storm followed a dry period of almost two days (44 hours). A total of 0.27" of rain fell on September 13 at the Beverly Municipal Airport between 3:00h and 10:00h; the amount measured by the Salem and Beverly Water Supply Board station during the same period was 0.23".

- Stormwater Sampling: Runoff started in the drainage channel at 6:20h, or 20 minutes after the rainfall ended. Rainfall and thus runoff during the first two hours of the storm were comparatively low. The peak of the storm occurred between 8:00h and 10:00h. The first storm sample (PF-B-2) was collected 50 minutes after the start of runoff; there was a lot of standing water in the drainage channel that first needed to be replaced by the runoff. There was no distinct first flush sample; Sample PF-B-2 is considered the sample closest to the first flush sample. Specifically, stormwater samples were collected from the end of the drainage channel at the following times:

7:10h	PF-B-2	50 minutes after start of runoff entering the drainage channel	
7:40h	PF-B-3	80 minutes (1.25h)	(")
7:58h	PF-B-4	98 minutes (1.75h)	(")
8:35h	PF-B-5	135 minutes (2.25h)	(")
8:35h	PF-B-6	*(Field QA Duplicate of PF-B-5)*	
9:07h	PF-B-7	167 minutes (2.75h)	(")
9:35h	PF-B-8	195 minutes (3.25h)	(")
10:10h	PF-B-9	230 minutes (3.75h)	(")
11:08h	PF-B-10	288 minutes (4.75h)	(")
12:11h	PF-B-11	351 minutes (5.75h)	(")
14:07h	PF-B-12	467 minutes (7.75h)	(")

Samples were collected by holding the individual sampling bottles directly into the flowing water; a water sampler was not needed.

- Discharge Rates: The discharge rates were determined by timing the filling of a bucket for low flow rates, and a Global Water Flow Probe for higher flow rates. For each method, a temporary structure was constructed to capture the flow given the low gradient in the drainage channel. A weir was constructed for the bucket method. The weir had an opening of 8 inches with an 8 inch long lip that allowed for the capture of the water by the bucket. For the flow meter method, a flume was constructed with vertical walls. The flume was 2.5 feet long and 21 inches wide with a flat bottom. Both structures were located downstream of the water sampling location to avoid any changes in the stormwater constituents resulting from the flow sampling process. The flow velocities are presented in Table 4-2 and Figure 4-5.

- Completion of Sampling: Rain stopped falling approximately at 11:15h or 5.25 hours after rainfall started; at this time only very light drizzle remained, without appreciable accumulation. One hour after the rain stopped, the runoff had decreased to only 0.05 cfs or about 2% of the peak discharge rate. A residual flow of less than 0.05 cfs persisted at 12:00h. It is conceivable that a low discharge rates may have continued for several more hours to days after rain event. Low discharge rates had been observed during previous visits to the site even after several days without rainfall. The source of the residual flow was considered to be infiltration of groundwater. The departure from the site was at 14:30h, or 10.5 hours after rainfall began; the final water sample was collected at 14:07h, shortly before departure (PF-B-12).

- Water Samples: The water samples were stored on site in the dark and on ice, and delivered to the two laboratories for analyses on the same day (September 15, 2000) within holding times. Samples for fecal coliform and total petroleum hydrocarbon analyses were delivered to Toxikon at 10:19h; samples for nutrient and total suspended solids analyses were delivered to the SMAST Laboratory of the University of Massachusetts in New Bedford at 17:14h. Compositing of the samples was not performed; instead we analyzed all twelve samples with the exception of TPH; only the first 10 samples were analyzed for TPH.

- Post-sampling Calibration: The calibration of the dissolved oxygen meter and the pH probe was checked on September 15, 2000 at 20:30h.

4.3 Storm C: Cherry Hill Site - November 10, 2000

The relevant information describing the characteristics of the sampling event is listed below:

- Arrival on site: 1:30h

- Parking lot occupancy: The parking lot adjacent to the site was empty.

- Catchbasin: The water level in the catchbasin was 8" below the lowest part of the overflow pipe that drains into the wetland. The water depth to the bottom of the catchbasin was 11" on the left side (facing the wetland) and 3.5" on the right side of the basin. Using an average depth of the entire basin of 7.25" and given the diameter of the basin of 4 feet, the volume of water in the basin was 0.22 cubic meters prior to Storm C.

- Pre-storm Activities: The dissolved oxygen and pH meters were calibrated on the day prior to the storm. A raingage was deployed at an unobstructed location, approximately 20 meter from the sampling point. A water sample (CH-C-1) was collected from the catchbasin at 1:50h using a sterile bailer.

- Rainfall during Storm C: A radar map of the storm is shown in Figure 4-6. Rain started falling at 2:00h on September 10. The rain stopped falling at approximately 11:00h on September 11 after a period of 33 hours. The total amount of rainfall for this storm measured at the Beverly Municipal Airport was 1.92". The total amount of rainfall recorded by the Salem and Beverly Water Supply Board station was 2.10". The total amount of rainfall recorded at the National Weather Station in Boston was 1.72".

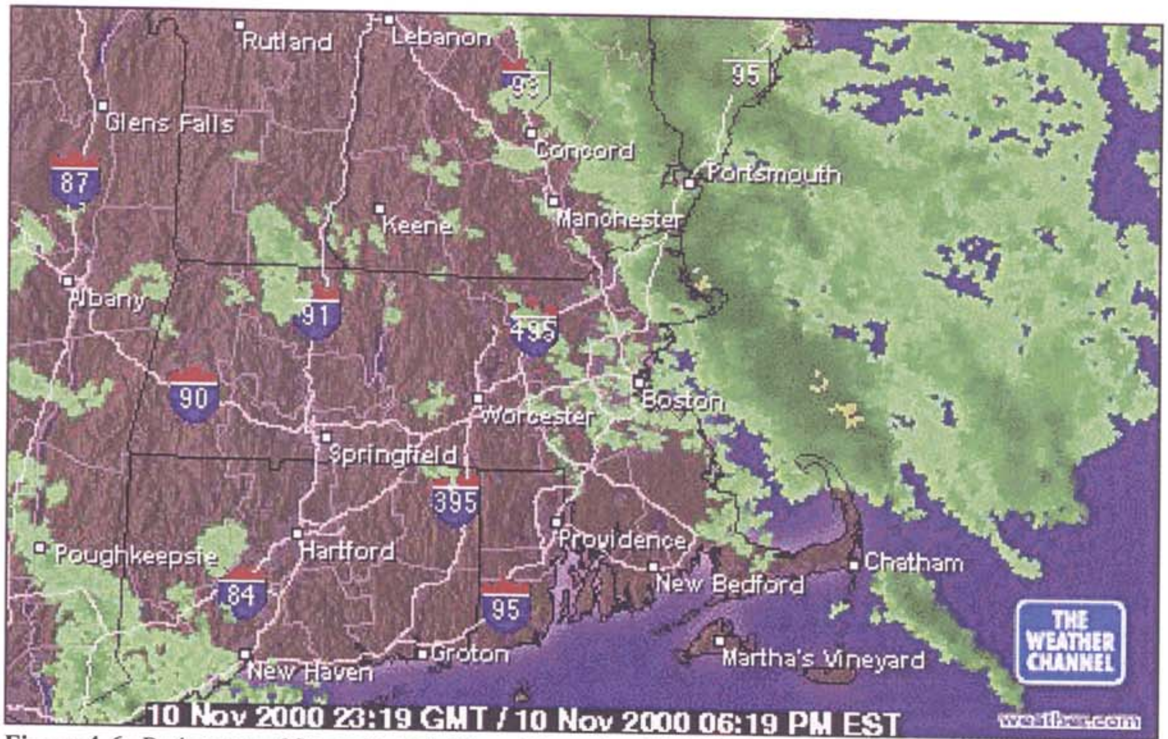


Figure 4-6: Radar map of Storm C at 18:19h on November 10, 2000 after the storm had passed (Source: The Weather Channel).

Rainfall during this storm was sporadic; there were several downpours interspersed with no or little rain. The rain had declined to a light rain and sampling stopped at 16:15h or 14.25 hrs after the start of the rainfall. At that time, the rainfall amount was 1.12". The rainfall data are presented in Table 4-1 and Figure 4-7. The storm continued with later accumulations. Sampling was discontinued at that time because the water level in the wetland had risen to the base of the end of the drainage pipe. The increasing level prevented any further water flow measurements from this point on. Without flow measurements, contaminant loads cannot be determined.

Nevertheless, we consider this sampling event acceptable for the purpose of this study for the following reason: The drainage area for the sampling point is comparatively small. In addition, the area is almost entirely paved with asphalt. Therefore, rain that falls on the area, runs off comparatively rapidly. During the previous sampling event at this site (Storm A), the flow decreased sharply in less than 30 minutes after the end of the storm. This information allowed us to determine the contaminant load for a "complete" 1.12" storm.

The storm followed a dry period of 5 days. A total of 1.01" of rain fell on November 5 at the Beverly Municipal Airport. The amount measured by the Salem and Beverly Water Supply Board station during the same period was 0.92".

Figure 4-7
Storm C - Cherry Hill: RAINFALL

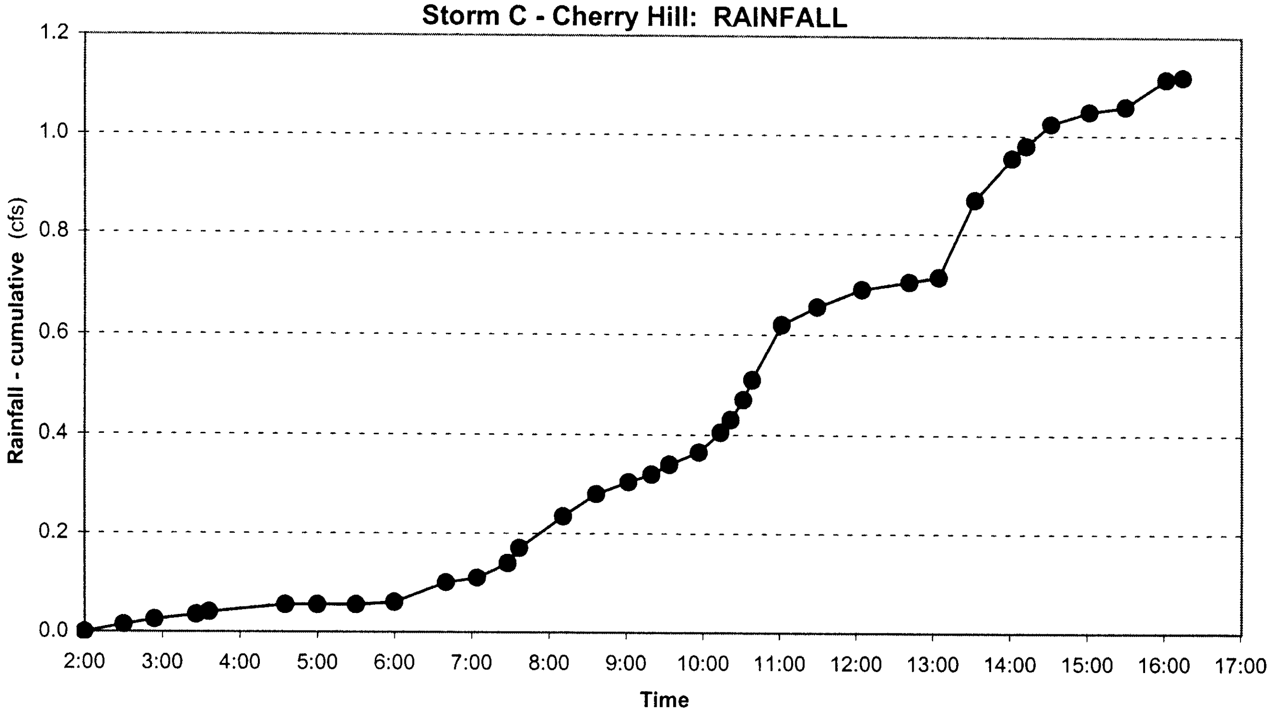
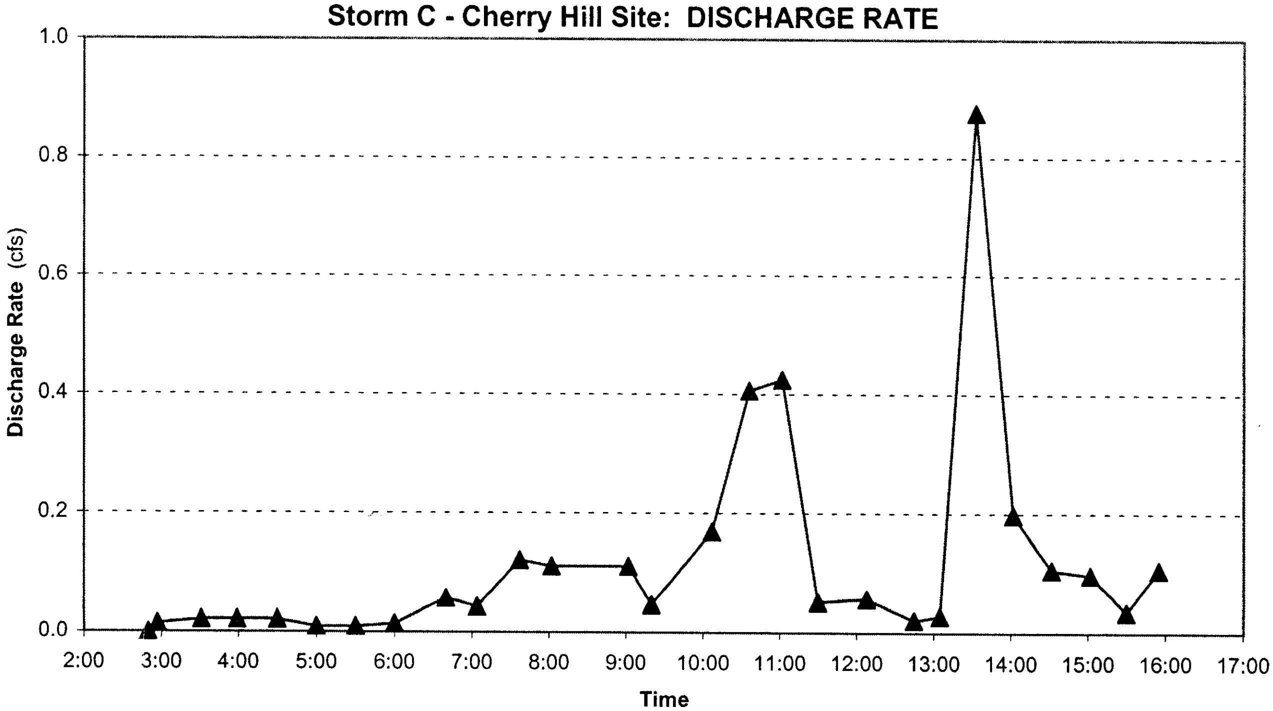


Figure 4-8
Storm C - Cherry Hill Site: DISCHARGE RATE



- Stormwater Sampling: Runoff started to enter the catchbasin at 2:30h, 30 minutes after the start of the rainfall. Water started to flow out of the catchbasin through the overflow pipe at 2:50h, or 50 minutes after rainfall started. Stormwater samples were collected from the end of this pipe at the following times:

2:57h	CH-C-2	7 minutes after start of discharge	
3:27h	CH-C-3	37 minutes	(")
3:57h	CH-C-4	67 minutes (1h)	(")
6:00h	CH-C-5	190 minutes (3h)	(")
8:02h	CH-C-6	312 minutes (5h)	(")
8:02h	CH-C-7	*(Duplicate of CH-A-5)*	
10:02h	CH-C-8	432 minutes (7h)	(")
12:08h	CH-C-9	558 minutes (9h)	(")
14:05h	CH-C-10	675 minutes (11h)	(")
16:00h	CH-C-11	790 minutes (13h)	(")

Samples were collected by holding the individual sampling bottles directly under the end of the drainage pipe.

- Discharge Rates: The discharge rates were determined by timing the filling of a graduated bucket for low flow rates, and by a Global Water Flow Probe for higher flow rates. Discharge rates throughout the rain event are presented in Table 4-2 and Figure 4-8.

- Completion of Sampling: Sampling was discontinued at 16:15h. The departure from the site occurred at 16:30h on November 10, 2000.

- Water Samples: The water samples were stored on site in the dark and on ice, and delivered to Toxikon laboratories for analyses for fecal coliform and total petroleum hydrocarbon analyses (at 17:20h); samples for nutrient and total suspended solids analyses were delivered to the SMAST Laboratory of the University of Massachusetts in New Bedford on the following day at 12:56h. Compositing of the samples was not performed; instead, we analyzed all 11 samples with the exception of TPH; only the first 7 samples were analyzed for TPH.

- Post-sampling Calibration: The calibration of the dissolved oxygen meter and the pH probe was checked on November 11, 2000 at 10:00h.

4.4 Storm D: Pinefield Site - September 20/21, 2001

The relevant information describing the characteristics of the sampling event is listed below:

- Arrival on site: 16:00h, 9/20/01

- Drainage Channel: The drainage channel was dry.

- Pre-storm Activities: The dissolved oxygen and pH meters were calibrated on site. Two raingages were deployed at unobstructed locations. One was located in the wetland, approximately 20 m from the sampling location. The second raingage was located in the residential area, approximately 300 m from the first rain gage.

raingage was located in the residential area, approximately 300 m from the first rain gage.

- Rainfall during Storm D: A radar map of the storm is shown in Figure 4-9. Rain started falling at 20:15h on 9/20/01 as drizzle. The drizzle continued on and off until 2:45h on 9/21/01 when runoff started to appear at the sampling location. At that time, 0.115" of rain had fallen. The rain stopped falling at 6:00h. The total amount of rainfall for the entire storm was 0.28" in Raingage 1 and 0.32" in Raingage 2. The cumulative rainfall rate of Raingage 1 is presented in Figure 4-10, adjusted for the average rainfall of 0.30". The total amount of rainfall measured at the Beverly Municipal Airport was 0.35" for the two days.

  The storm followed a dry period of six days. A total of 0.30" of rain fell on September 14 at the Beverly Municipal Airport. On September 15 and 18, 0.01" of rain fell as well which would not have resulted in runoff at the Pinefield sampling location.

- Stormwater Sampling: Runoff started in the drainage channel at 2:45h on 9/21/01, or 6.5 hours after the rainfall started. Rainfall and thus runoff were comparatively steady. The peak of the storm occurred between 2:00h and 6:00h. The first storm sample (PF-D-1) was collected 26 minutes after the start of runoff, since runoff started very slowly. Specifically, stormwater samples were collected at the following times:

Figure 4-9: Radar map of Storm D at 09:04h on September 20, 2001 before arrival of the storm. Rain started falling at 20:15h (Source: The Weather Channel).

Figure 4-10

Storm D - Pinefield Site: RAINFALL

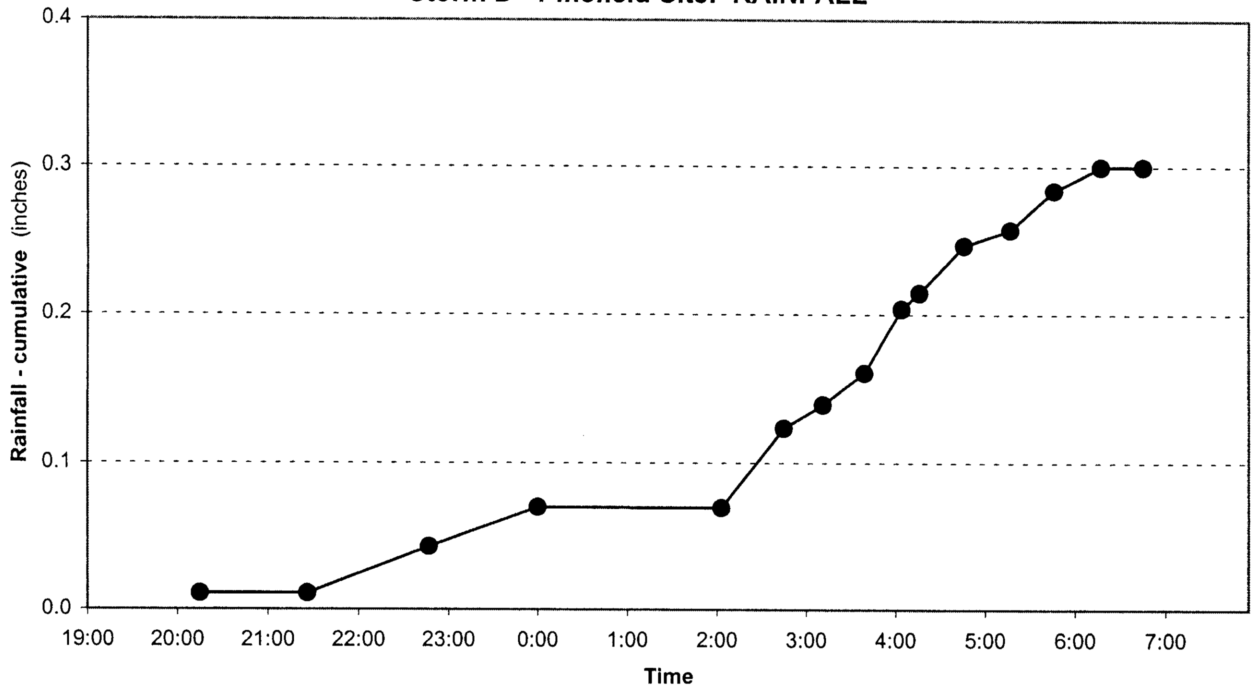
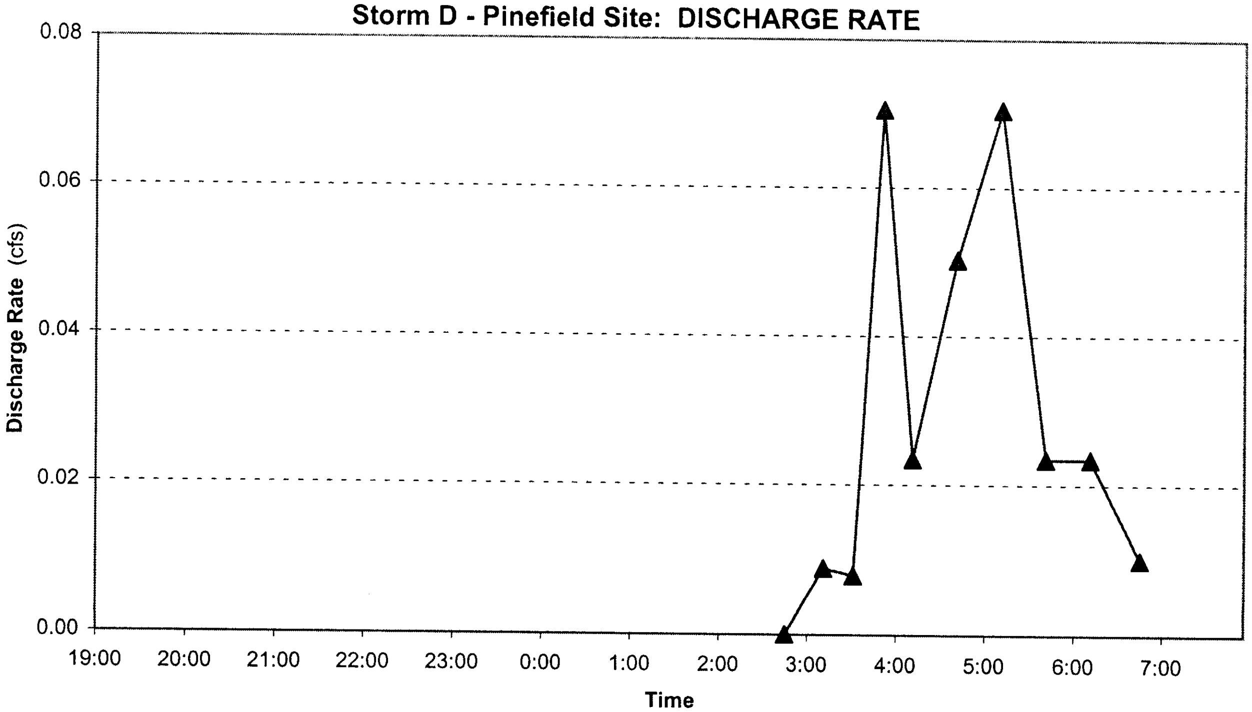


Figure 4-11

Storm D - Pinefield Site: DISCHARGE RATE



3:11h	PF-D-1	26 minutes after start of runoff	
3:31h	PF-D-2	46 minutes	(")
3:51h	PF-D-3	66 minutes	(")
4:11h	PF-D-4	86 minutes (1.43h)	(")
4:41h	PF-D-5	116 minutes (1.93h)	(")
4:41h	PF-D-6	*(Field QA Duplicate of PF-D-5)*	
5:11h	PF-D-7	146 minutes (2.43h)	(")
5:41h	PF-D-8	176 minutes (2.93h)	(")
6:11h	PF-D-9	206 minutes (3.43h)	(")
6:45h	PF-D-10	240 minutes (4.00h)	(")

Samples were collected by holding the individual sampling bottles directly into the flowing water.

- Discharge Rates: The discharge rates were determined by timing the filling of a bucket for low flow rates, and a Global Water Flow Probe for higher flow rates. For each method, a temporary structure was constructed to capture the flow given the low gradient in the drainage channel. A weir was constructed for the bucket method. The weir had an opening of 8 inches with an 8 inch long lip that allowed for the capture of the water by the bucket. For the flow meter method, a flume was constructed with vertical walls. The flume was 2.5 feet long and 21 inches wide with a flat bottom. Both structures were located downstream of the water sampling location to avoid any changes in the stormwater constituents resulting from the flow sampling process. The flow velocities are presented in Figure 4-11.

- Completion of Sampling: Rain stopped falling approximately at 6:00h or 9.75 hours after rainfall started. One hour after the rain stopped, the runoff had decreased to only 0.01 cfs. The departure from the site was at 7:10h, or 10 hours after rainfall began; the final water sample was collected at 6:45h, shortly before departure (PF-D-10).

- Water Samples: The water samples were stored on site in the dark and on ice, and delivered to the two laboratories for analyses on the same day (September 21, 2001) within holding times. Samples for fecal coliform analyses were delivered to Toxikon; samples for nutrient and total suspended solids analyses were delivered to the SMAST Laboratory of the University of Massachusetts in New Bedford. Compositing of the samples was not performed; instead we analyzed all 10 samples.

- Post-sampling Calibration: The calibration of the dissolved oxygen meter and the pH probe was checked on September 21, 2001 in the afternoon.

4.5 Storm E: Pinefield Site - September 25, 2001

The relevant information describing the characteristics of the sampling event is listed below:

- Arrival on site: 10:00h, 9/25/01

- Drainage Channel: The drainage channel was dry.

- Pre-storm Activities: The dissolved oxygen and pH meters were calibrated on site. One raingage was deployed in the wetland, about 20 m from the sampling location.

- Rainfall during Storm E: Rain started falling at 13:10h as drizzle. The drizzle continued until 14:05h when rain started falling heavily for approximately 1.5 hours (Figure 4-12). Runoff started to appear at 14:11h. The rain stopped falling at 17:45h. The total amount of rainfall for the entire storm was 0.60". The total amount of rainfall measured at the Beverly Municipal Airport was 0.72".The storm followed a dry period of 2.5 days. A total of 0.58" of rain fell on September 22 at the Beverly Municipal Airport. On September 23 and 24, 0.01" of rain fell each day as well which would not have resulted in runoff at the Pinefield sampling location.

- Stormwater Sampling: Runoff started in the drainage channel at 14:11h, or one hour after the rainfall started. Rainfall and thus runoff was comparatively high during the peak storm period between 14:00h and 15:30h. The first storm sample (PF-E-1) was collected 5 minutes after the start of runoff. Specifically, stormwater samples were collected at the following times:

14:16h	PF-E-1	5 minutes after start of runoff	
14:38h	PF-E-2	27 minutes	(“)
15:00h	PF-E-3	49 minutes	(“)
15:25h	PF-E-4	74 minutes (1.23h)	(“)
16:35h	PF-E-5	144 minutes (2.40h)	(“)
17:13h	PF-E-6	182 minutes (3.03h)	(“)
17:13h	PF-E-7	*(Field QA Duplicate of PF-E-6)*	
17:45h	PF-E-8	214 minutes (3.57h)	(“)
18:17h	PF-E-9	247 minutes (4.12h)	(“)
18:45h	PF-E-10	274 minutes (4.57h)	(“)

Samples were collected by holding the individual sampling bottles directly into the flowing water.

- Discharge Rates: The discharge rates were determined by timing the filling of a bucket for low flow rates, and a Global Water Flow Probe for higher flow rates. For each method, a temporary structure was constructed to capture the flow given the low gradient in the drainage channel. A weir was constructed for the bucket method. The weir had an opening of 8 inches with an 8 inch long lip that allowed for the capture of the water by the bucket. For the flow meter method, a flume was constructed with vertical walls. The flume was 2.5 feet long and 21 inches wide with a flat bottom. Both structures were located downstream of the water sampling location to avoid any changes in the stormwater constituents resulting from the flow sampling process. The flow velocities are presented in Figure 4-13.

- Completion of Sampling: Rain stopped falling approximately at 17:45h or 4.58 hours after rainfall started. One hour after the rain stopped, the runoff had decreased to only 0.001 cfs. The departure from the site was at 19:10h, or 6 hours after rainfall began; the final water sample was collected at 18:45h, shortly before departure (PF-E-10).

Figure 4-12
Storm E - Pinefield Site: RAINFALL

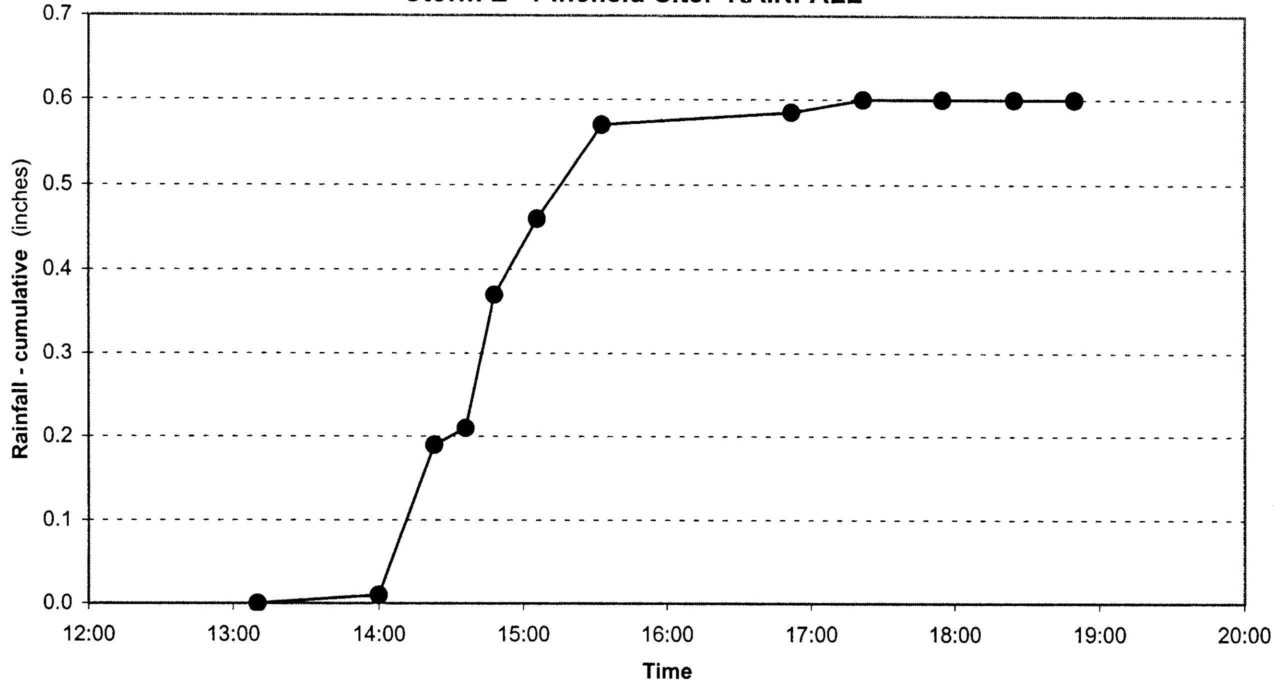
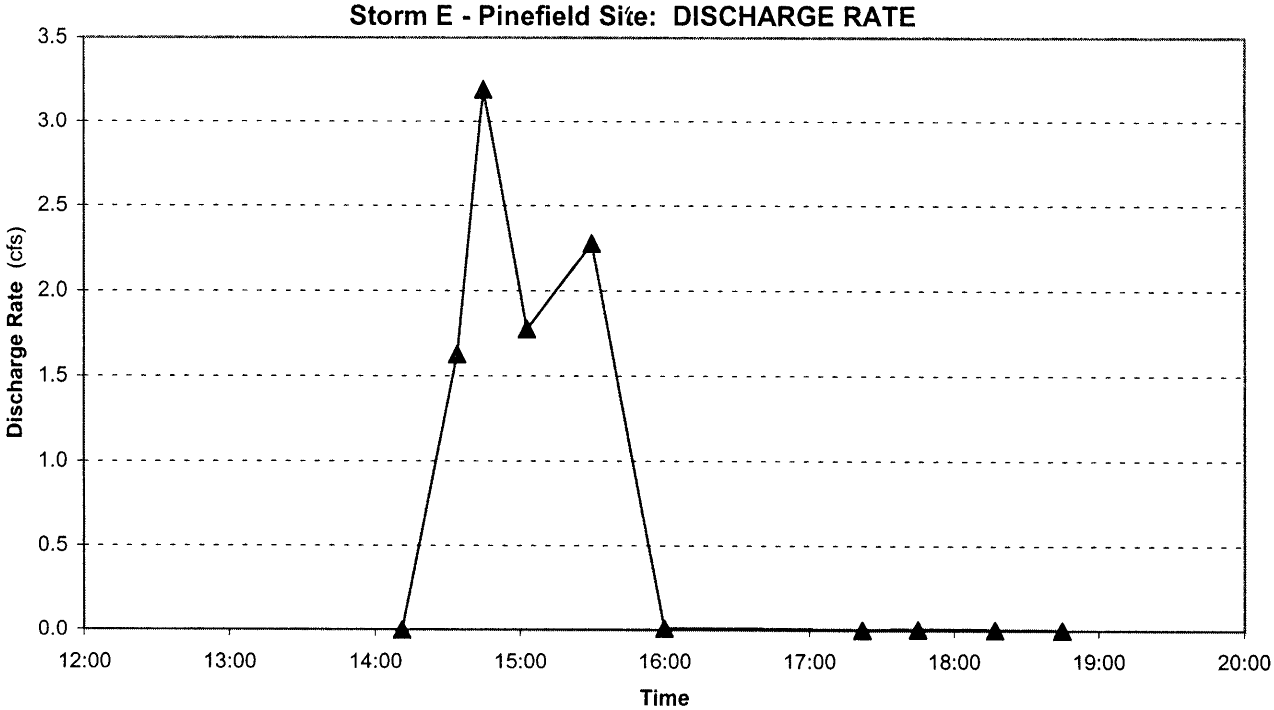


Figure 4-13
Storm E - Pinefield Site: DISCHARGE RATE



Water Samples: The water samples were stored on site in the dark and on ice, and delivered to the two laboratories for analyses on the next morning (September 26, 2001) within the required holding times. Samples for fecal coliform analyses were delivered to the Barnstable County Laboratory; samples for nutrient and total suspended solids analyses were delivered to the SMAST Laboratory of the University of Massachusetts in New Bedford. Compositing of the samples was not performed; instead we analyzed all 10 samples.

- Post-sampling Calibration: The calibration of the dissolved oxygen meter and the pH probe was checked on September 26, 2001 in the morning.

4.6 Storm F: Cherry Hill Site - April 25, 2002

The relevant information describing the characteristics of the sampling event is listed below:

- Arrival on site: 14:40h
- Parking lot occupancy: The parking lot adjacent to the site was almost full.
- Catchbasin: The water depth to the bottom of the catchbasin was 22.75" on the left side (facing the wetland) and 20" on the right side of the basin. Using an average depth of the entire basin of 21.4" and given the diameter of the basin 48", the volume of water in the basin was 0.62 cubic meters prior to Storm F.
- Pre-storm Activities: Both the pH meter and the dissolved oxygen meter was not functioning properly; therefore, data are not available. A raingage was deployed at an unobstructed location approximately 20 meter from the sampling point. A water sample (CH-F-1) was collected from the catchbasin at 14:50h using a sterile bailer.
- Rainfall during Storm F: A radar map of the storm is shown in Figure 4-14. Rain started falling at 16:41h on April 25. The rain stopped falling at approximately 1:30h on April 26 after a period of 9 hours. The total amount of rainfall for this storm measured was:

- On-site raingage:	0.93"
- Beverly Municipal Airport:	1.09"
- Salem and Beverly Water Supply Board station:	1.12"

Rainfall during this storm was continuous. The rainfall data are presented in Table 4-1 and Figure 4-15. Snow mixed with rain fell between 22:35h and midnight. Some accumulation occurred in the form of slush. However, the precipitation changed again to rain after midnight, melting the accumulated snow. At the time of departure from the site at 2:00h on 4/26/02, the accumulated was gone. Therefore, the storm event is considered completely sampled.

Figure 4-14: Radar map of Storm F at 08:22h on April 25, 2002 during the peak of the storm. The snow band seen in the north as white and pink areas covered the sampling site briefly later before midnight (Source: The Weather Channel).

The storm followed a dry period of 2.75 days. A total of 0.14" of rain fell on April 22 at the Beverly Municipal Airport. The amount measured by the Salem and Beverly Water Supply Board station during the same period was 0.20". A small amount of rain (0.01") was also recorded at the airport on 0.01" on also fell on April 22. However, this amount would not have produced runoff at the site.

- Stormwater Sampling:

Water started to flow out of the catchbasin through the overflow pipe at 17:26h, or 45 minutes after rainfall started. Stormwater samples were collected from the end of this pipe at the following times:

17:40h	CH-F-2	14 minutes after start of discharge	
18:13h	CH-F-3	47 minutes	(")
19:22h	CH-F-4	116 minutes (1.5 h)	(")
19:45h	CH-F-10	139 minutes (2h)	(")
20:41h	CH-F-5	195 minutes (3h)	(")
21:34h	CH-F-6	248 minutes (4h)	(")
22:24h	CH-F-7	298 minutes (5h)	(")
23:29h	CH-F-8	363 minutes (6h)	(")
00:25h	CH-F-9	419 minutes (7h)	(")

Samples were collected by holding the individual sampling bottles directly under the end of the drainage pipe; a water sampler was not needed.

Figure 4-15

Storm F - Cherry Hill: RAINFALL

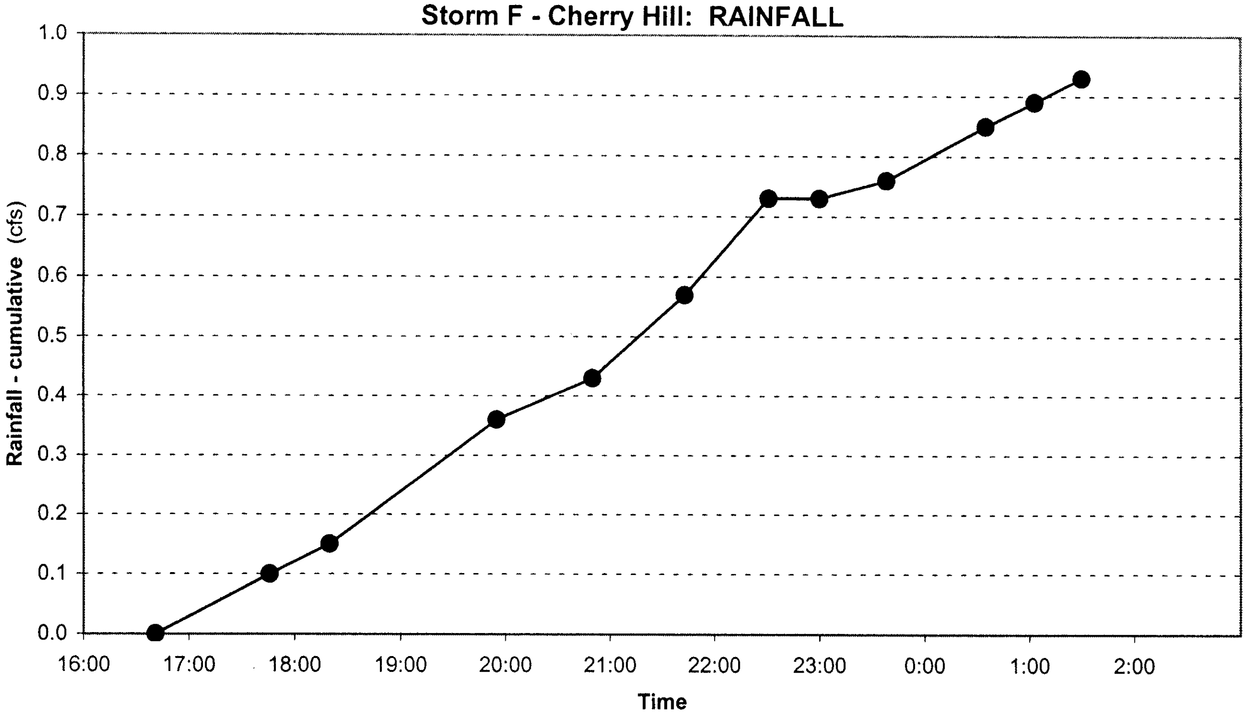
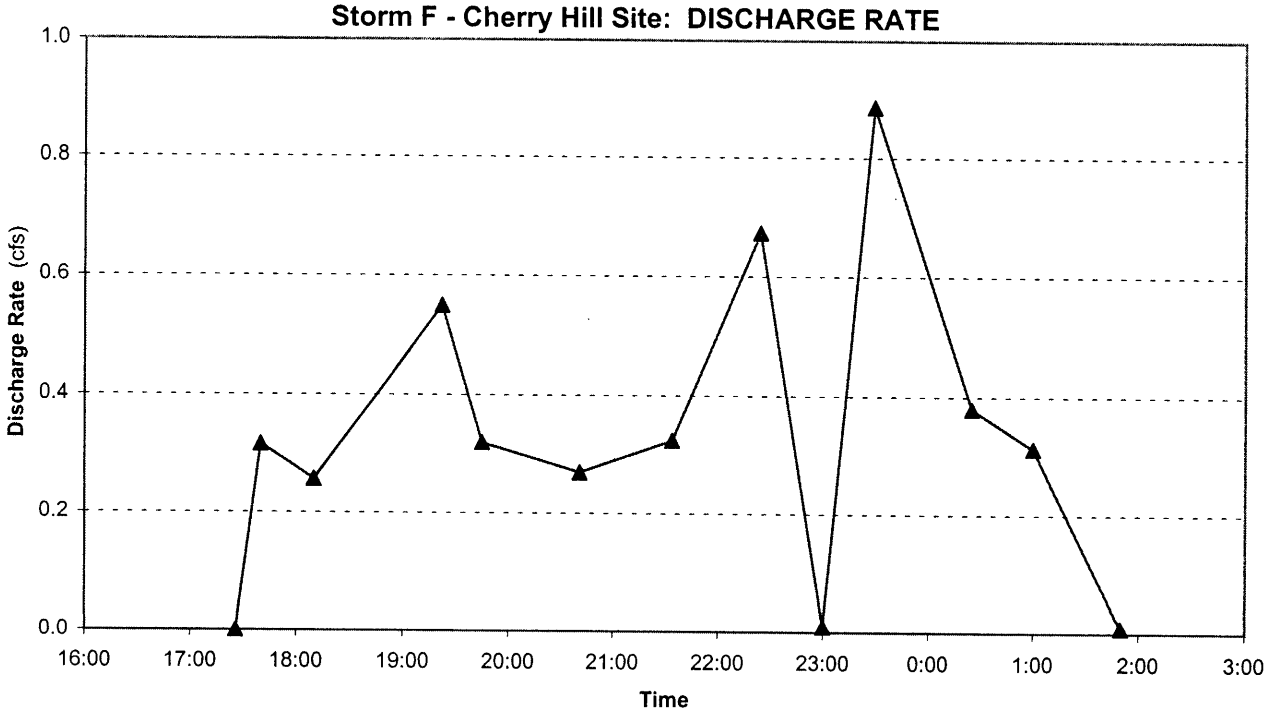


Figure 4-16

Storm F - Cherry Hill Site: DISCHARGE RATE



- Discharge Rates: The discharge rates were determined by timing the filling of a graduated bucket for low flow rates, and by a Global Water Flow Probe for higher flow rates. Discharge rates throughout the rain event are presented in Table 4-2 and Figure 4-16.

- Completion of Sampling: Sampling was discontinued at 1:30h. The departure from the site occurred at 2:00h on April 26, 2002.

- Water Samples: The water samples were stored on site in the dark and on ice, and delivered to the laboratories for analyses on April 26 (Barnstable County Laboratory for fecal coliform analyses at 10:05h; SMAST laboratory of the University of Massachusetts in New Bedford at noon for nutrient and total suspended solids analyses). Compositing of the samples was not performed.

5.0 Stormwater Quality

Stormwater data are presented in the following tables and figures:

All tables and figures are attached at the end of Section 5. Laboratory data are attached in Section 9.

5.1 Rainfall and Flow

The average annual rainfall rate measured by the Salem Beverly Water Supply Board from the years 1950 to 2002 was 43.2 inches (Table 5-1). The annual rainfall rate increased slightly over the 52 year long period (Figure 5-1). The average monthly variability was very low, ranging between 3.1 inches in June to 4.4 inches in November. All monthly data for the period between 1950 to 2002 are presented in Table 8-1 in Section 8.

Daily rainfall data from 1987 to 2002 are presented in Tables 8-2 to 8-17 in Section 8. The average annual rate for this period was 46.5 inches (Table 5-2). Most of the rainfall was delivered by larger storms. A total of 40% of the storms exceeded 0.3 inches, contributing 85% of the total annual rainfall (Table 5-2; Figure 5-3). Since the rain events captured in the present study ranged from 0.30 to 1.23 inches over two sites, it increases confidence that they are representative of most of the rainfall at these sites, at least on a volumetric basis.

5.1.1 Pinefield Site

The estimated total discharge area for the site is 76,922 m^2; the estimated impervious discharge area is 19,775 m^2 (or 26% of the total area). Much of the pervious drainage area consists of lawns which should allow infiltration of rainwater from less intense storms.

- **Storm B:** The rainfall rate was 1.23 inches. Therefore, the total volume that fell on the drainage area was 2,403 m^3; the volume that fell on the impervious area was 618 m^3 (Table 5-5). The total discharge volume measured with the flow meter at the drainage pipe was 497 m^3 (or 21% and 80% of the volume that fell on the total and impervious drainage areas, respectively). The peak flow measured was 2.3 cfs (Figure 4-5). Over 90% of the rainfall fell steadily over a period of 4 hours. Storm B exhibited a rainfall rate in the 8th percentile; i.e., 8% of the storms exceed the rate of Storm B (Figure 5-3).

- **Storm D:** The rainfall rate was 0.30 inches. Therefore, the total volume that fell on the drainage area was 586 m^3; the volume that fell on the impervious area was 151 m^3 (Table 5-5). However, the total discharge volume measured with the flow meter at the drainage pipe was only 13 m^3 (or 2% and 9% of the volume that fell on the total and impervious drainage areas, respectively). The peak flow measured was only 0.07 cfs (Figure 4-11). Rain fell slowly for a period of approximately 10 hours. Discharge at the pipe did not start until 0.12 inches of light rain had fallen over a period of approximately 6 hours (or 40% of the total rain volume for the storm). Reasons for the discrepancies between measured flow and rain volume include the following:

- *Measurement error*: Flow measurement were all conducted with the graduated bucket, given the low flow conditions. This method is considered very accurate. The variability in flow between measurements was also small. Therefore, a measurement error that would explain the discrepancy is considered unlikely.

- *Rainfall variability:* Two raingages were deployed for this storm, approximately 200 m apart. Readings were 0.28 and 0.32 inches suggesting local variability (we used an average of 0.30 inches for our calculations). The Beverly Salem Water Board gage recorded 0.27 inches; the Beverly Municipal Airport gage recorded 0.35 inches. The variability, however, does not account for the discrepancy between the rain volume and measured flow volume.

- *Catchbasins:* The drainage system contains a number of catchbasins. Rain had not fallen for a period of 5 days. Some of the initial rainfall volume could have been captured by these basins.

- *Cracks in the drainage pipes:* The drainage pipes may have some cracks that allow flow to escape into the ground. The percentage of flow disappearing into the ground would be greater during low flow conditions (as existed during this storm).

- *Evaporation of impervious surface:* Due to the slow rainfall rate, some of the rainfall likely evaporated from the impervious surface. The average air temperature on this day was 65°F.

Storm D exhibited a rainfall rate in the 40^{th} percentile; i.e., 40% of the storms exceed the rate of Storm D (Figure 5-3).

- **Storm E:** The rainfall rate was 0.60 inches. Therefore, the total volume that fell on the drainage area was 1,172 m^3; the volume that fell on the impervious area was 301 m^3 (Table 5-5). The total discharge volume measured with the flow meter at the drainage pipe was 337 m^3 (or 29% and 112% of the volume that fell on the total and impervious drainage areas, respectively). The peak flow measured was 3.2 cfs (Figure 4-13). Over 90% of the rainfall fell steadily over a short period of 2 hours. The shorter rainfall period and higher flow rate explains why a greater percentage of the rainfall volume that fell on the drainage area was discharged. Storm E exhibited a rainfall rate in the 22^{th} percentile; i.e., 22% of the storms exceed the rate of Storm E (Figure 5-3).

The total rainfall volume measured during the three storms at the Pinefield Site was 2.13 inches. This rate corresponds to 4.6% of the average annual rate of 46.5 inches that fell between 1987 and 2001 and 4.9% of the rate of 43.2 inches between 1950 and 2002.

5.1.2 Cherry Hill Site

- **Storm A:** The rainfall rate was 0.32 inches. Therefore, the total volume that fell on the drainage area was 45 m^3; the volume that fell on the impervious area was 43 m^3 (Table 5-5). The total discharge volume measured with the flow meter at the drainage pipe was 37 m^3 (or 82% and 86% of the volume that fell on the total and impervious drainage areas, respectively). The peak flow measured was 0.3 cfs (Figure 4-2). Over 90% of the rainfall fell slowly but steadily over a period of 4 hours. Storm A exhibited a rainfall rate in the 37^{th} percentile; i.e., 37% of the storms exceed the rate of Storm A (Figure 5-3).

- **Storm C:** The rainfall rate was 1.12 inches during the period of discharge monitoring. Therefore, the total volume that fell on the drainage area was 156 m^3; the volume that fell on the impervious area was

150 m^3 (Table 5-5). The total discharge volume measured with the flow meter at the drainage pipe was 152 m^3 (or 97% and 101% of the volume that fell on the total and impervious drainage areas, respectively). In other words, approximately the entire rain volume that fell on the drainage area was discharged at the pipe. The peak flow measured was 0.9 cfs (Figure 4-8). Over 90% of the rainfall fell with varying intensity over a period of approximately 10 hours. Storm C exhibited a rainfall rate in the 10^{th} percentile; i.e., 10% of the storms exceed the rate of Storm C (Figure 5-3).

- **Storm F:** The rainfall rate was 0.93 inches. Therefore, the total volume that fell on the drainage area was 130 m^3; the volume that fell on the impervious area was 125 m^3 (Table 5-5). The total discharge volume measured with the flow meter at the drainage pipe was 326 m^3 (or 251% and 261% of the volume that fell on the total and impervious drainage areas, respectively). Reasons for the discrepancy are as follows:

  - *Measurement error:* The flow meter may have provided inaccurate measurements.

  - *Drainage area:* The drainage area is part of a significantly larger parking lot, drained by several manholes. There are two manholes upgradient of the drainage area that was studied. There is a possibility that during high flows, rainwater bypasses these upgradient manholes and flows into the studied drainage area. This was deemed unlikely, as Storm C had an even higher rainfall, 1.12 inches , and showed good agreement between the discharge estimated from the rainfall and drainage area versus the discharge measured at the outlet pipe. Rainwater would bypass, however, if the manholes were blocked by debris.

  Since the stormwater discharge cannot exceed the rainfall volume, the discharge volume was adjusted in our load calculations to a flow rate of 125 m^3 (i.e., the rainfall volume that fell on the impervious surface of the studied area). The peak flow measured was 0.9 cfs (Figure 4-16). Over 90% of the rainfall fell fairly steadily over a period of 8 hours. Storm F exhibited a rainfall rate in the 13^{th} percentile; i.e., 13% of the storms exceed the rate of Storm F (Figure 5-3).

The total rainfall volume measured during the three storms at the Cherry Hill Site was 2.37 inches. This rate corresponds to 5.1% of the average annual rate of 46.5 inches that fell between 1987 and 2001 and 5.6% of the rate of 43.2 inches between 1950 and 2002 (Tables 5-1 and 5-2).

5.2 Fecal Coliform

5.2.1 Pinefield Site

- **Concentrations:** The fecal coliform (FC) concentrations were generally high throughout the three storms, reaching 29,000 col/100 ml during Storm C (Table 5-3a; Figures 5-4, 5-6, 5-8). There was a clear pulse of fecal coliform in the initial phases of each storm; however, there was no distinct spike in concentrations during the first flush. The most likely reason for the broad initial concentration peak is the long drainage system with several man-holes and catchbasins. This results in longer travel times for the more distant input points and a mixing of this water with "cleaner" water from the already flushed lower part of the system. The contribution of septic systems from the residential area is not known. However, the results do not require septic system inputs, as surface water inflow from runoff sources would also produce the observed pattern. Functioning septic systems are an unlikely source of coliforms, since transport of fecal coliforms in soil is very low. The primary mechanism for septic system fecal coliforms to enter the stormwater system is via direct hook-ups or effluent "breakout". If direct discharges of septic wastewater to the stormwater system were occurring, there would be large changes in concentration from dilution, but the load per unit time would be relatively constant. Instead, the concentration and the load of fecal coliforms follows a pattern of initial wash-off from a surface source, consistent with washoff from impermeable surfaces (most likely from animal deposition). This conclusion is supported by the much lower rates of fecal coliform discharge from the Cherry Hill location, which would be assumed to have much less animal activity (see Section 5.2.2 below). However, without a septic system survey, it is not possible to eliminate septic systems as a potential source.

- **Loads per Storm:** The fecal coliform loads during the storms (Table 5-4a; Figure 5-5, 5-7, 5-9) reflect the respective discharge pattern (Figures 4-5, 4-11, 4-13). The total fecal coliform load contributed by the three storms was 118,000 million colonies (Table 5-5). The highest load was contributed by Storm E (76,000 million col) which was almost twice as high as the FC load contributed by Storm B, even though the rainfall rate of Storm E was only half of the rate of Storm B. At the same time, Storm E had the highest flow rate and percent discharge rate from the total drainage area. These observations suggest that the contribution may be higher due to wash-off and possibly flushing of the storm sewers, during intense downpours with high flow rates. This is consistent with the nearly double TSS values during Storm E versus Storms B and D (see Section 5.3.1 below). The contribution of Storm D was very small with 951 million colonies, largely a result of the low flow rate.

- **Annual Load:** Clearly, the calculation of annual loads depends on many factors and can therefore only be roughly estimated at best. However, given that the concentrations were generally high throughout the storms, it appears reasonable as a first order approximation to extrapolate the annual load based on rainfall volume. Therefore, given that the measured storms contributed 4.9% of the total rainfall volume between 1950 and 2002, the annual fecal coliform load at this site is estimated as 2.4×10^{12} col (Table 5-5).

  Accordingly, the average annual load per square meter of the total drainage area is estimated as 31 million colonies. The annual load per square meter of the impervious drainage area is estimated as 122 million colonies.

5.2.2 Cherry Hill Site

- **Concentrations:** In contrast to the Pinefield site, the fecal coliform concentrations showed a sharp first flush spike in concentration at the beginning of each storm (Table 5-3b; Figures 5-10, 5-12, 5-14). The first flush sample contained 3,600 col/100 ml of fecal coliform during Storm A and 1,000 col/100 ml during Storm F (Table 5-3b). During Storm C, the highest concentration was measured after 1 hour from the start of runoff (the rainfall rate at that time was 0.04 inches) which is consistent with the very slow start of the storm (Figure 4-8). Concentrations during the remainder of the storm were low, and in many samples below the detection limit. This concentration pattern is expected due to (a) the impermeable nature of the watershed and (b) the short storm sewer "system" (only a single man-hole and short pipe).

- **Loads per Storm:** The loads contributed to the wetland during these storms (Table 5-4b; Figures 5-11, 5-13, 5-15) reflect the concentration patterns (Figures 4-2, 4-8, 4-16). The total fecal coliform load contributed by the three storms was 264 million colonies (Table 5-5). The highest load was contributed by Storm F even after adjusting the discharge rate. The lowest load was contributed by Storm C, even though the storm had the highest discharge rate.

  The contribution of the catchbasin at the site is considered insignificant, due to the comparatively low FC concentrations and the small volume of water in the basin compared to the total discharged volume. The basin contained 0.22 m^3 of water during Storms A and C and 0.62 m^3 during Storm F. The average FC load from the catchbasin during the three storms was less than 1% of the total load.

- **Annual Load:** Extrapolating the FC annual load from the relative rainfall rate of the three storms, the annual fecal coliform load at this site is estimated as 4.7×10^9 colonies (Table 5-5). This calculation may not be adequate at this site as a first approximation since the FC concentration was generally only high at the beginning of the storms. Therefore, as a second approach, the annual load was calculated based on the number of storms. During Storm C, the highest FC load was measured at a rainfall rate of 0.04

inches. The average number of storms per year between 1987 and 2001 was 112. The average number of storms with 0.04 inches of rainfall or more was 94. Using the value of 94 storms, the total annual FC load would be 8.3 x 10^9 colonies.

Accordingly, the average annual load per square meter of the total drainage area is estimated as 1.50 million colonies (using the number of storm approach). The annual load per square meter of the impervious drainage area is estimated as 1.56 million colonies.

5.2.3 Discussion

The difference between the Pinefield and Cherry Hill sites is significant when trying to extrapolate from site-specific drainage basins to whole watersheds. The Pinefield site is primarily residential with significant vegetation and access for both wild and domestic animals. The Cherry Hill site is primarily a parking lot with little bordering vegetation. This difference in basin structure appears to be the dominant underlying cause of the differences in fecal coliform loads between the sites. Similarly, as discussed below, it is central to the pattern of discharge of each of the major stormwater contaminants assayed.

5.3 Total Suspended Solids and Particulate Organic Carbon

5.3.1 Pinefield Site

- **Concentrations:** The total suspended solids (TSS) concentrations were high during the first half of the two larger storms (Storms B and E) and decreased toward the end (Figures 5-16, 5-18, 5-20). Generally, the concentrations were higher with higher discharge rates. During Storm D with its comparatively low flow rate, the TSS concentrations remained high throughout the storm (Figure 5-18).

  The particulate organic carbon (POC) concentrations followed the TSS concentrations closely. POC concentrations for all three storms consisted on average of 15% of the TSS concentration in the individual samples, ranging from on average 6% in Storm D to 21% in Storm B.

- **Loads per Storm:** TSS and POC loads generally followed the discharge volume (Figures 5-17, 5-19, 5-21). The total TSS loads for the three storms was 20.5 kg (Table 5-5). The total POC load was 3.0 kg, which represents 15% of the total TSS load. The highest loads were contributed by Storm E.

- **Annual Loads:** The annual TSS and POC loads are estimated as 418 kg and 62.2 kg, respectively (Table 5-5).

  The average annual TSS and POC loads per square meter of the total drainage area are estimated as 5.44 grams and 0.81 grams, respectively. The average annual loads per square meter of the impervious drainage area are estimated as 21.15 grams and 3.15 grams, respectively.

5.3.2 Cherry Hill Site

- **Concentrations:** Highest TSS and POC concentrations were measured at the beginning of the storms (Figures 5-22, 5-24, 5-26). POC concentrations followed the TSS concentration patterns closely. The average POC concentration for the three storms was 25%, ranging from an average of 15% during Storm F to 32% during Storm A.

- **Loads during Storms:** The total TSS loads for the three storms was 4.9 kg (Table 5-5). The total POC load was 0.81 kg, which represents 17% of the total TSS load. The highest loads were contributed by Storm F.

- **Annual Loads:** The annual TSS and POC loads are estimated as 87 kg and 15 kg, respectively, extrapolating by rainfall volume (Table 5-5). The loads are estimated as 153 kg and 15 kg, respectively, extrapolating by the annual number of storms with rainfall of 0.04 inches or more. Unlike for fecal coliform, the data suggest that the rainfall volume approach is the more appropriate method as a first approximation for calculating annual TSS and POC loads.

  The average annual TSS and POC loads per square meter of the total drainage area were 15.85 grams and 2.64 grams, respectively (rainfall rate approach). The average loads per square meter of the impervious drainage area were 16.45 grams and 2.74 grams, respectively.

5.3.3 Discussion

As for the other stormwater contaminants, the basin structure between the two sites is consistent with the pattern of their contaminant discharges. The Pinefield Site had lower particulate loads per square meter of total drainage are than the Cherry Hill Site. However, when only the impermeable area is considered, the rates were very similar for both sites (Table 5-5). It may be concluded that the TSS and POC loads are predominantly associated with the impervious area within a drainage basin, rather than the total area.

5.4 Phosphorus

5.4.1 Pinefield Site

- **Concentrations:** Phosphorus concentrations were typically highest at the beginning of the storms (Figures 5-28, 5-30, 5-32). The maximum total phosphorus concentration measured was 0.84 mg/l; the maximum ortho-phosphate concentration was 0.79 mg/l P. The average concentrations of ortho-phosphate relative to total phosphorus were 82% (Storm B), 71% (Storm D), and 54% (Storm E).

- **Loads per Storm:** The total phosphorus and ortho-phosphate loads follow the discharge pattern (i.e., peak loads were discharged during peak flows) (Figures 5-29, 5-31, 5-33). The combined total phosphorus load for the three storms was 186 grams. The combined ortho-phosphate load for the three storms was 92 grams (or 49% of the total phosphorus load).

- **Annual Loads:** The annual total phosphorus and ortho-phosphate loads are estimated as 3.79 kg and 1.88 kg, respectively (Table 5-5).

  The average annual total phosphorus and ortho-phosphate loads per square meter of the total drainage area are estimated as 0.049 grams and 0.024 grams, respectively (rainfall rate approach). The average loads per square meter of the impervious drainage area are estimated as 0.192 grams and 0.095 grams, respectively.

5.4.2 Cherry Hill Site

- **Concentrations:** As for the Pinefield site, phosphorus concentrations were typically highest at the beginning of the storms (Figures 5-34, 5-36, 5-21). The maximum total phosphorus concentration measured was 1.06 mg/l; the maximum ortho-phosphate concentration was 1.04 mg/l P. The average concentrations of phosphate relative to total phosphorus were 80% (Storm A), 58% (Storm C), and 17% (Storm F). Except for Storm F, the proportion of the total phosphorus attributable to ortho-phosphate is similar to the Pinefield Site. At present there is no indication why Storm F would differ in phosphorus speciation compared to Storms A to E. Other storms had similar or lower total phosphorus discharges and there was no similar difference in dissolved inorganic nitrogen versus total nitrogen (see Section 5.5 below).

- **Loads per Storm:** The total phosphorus and ortho-phosphate loads generally follow the discharge pattern. The combined total phosphorus load for the three storms was 27 grams. The combined ortho-phosphate load for the three storms was 18 grams (or 68% of the total phosphorus load).

- **Annual Loads:** The annual total phosphorus and ortho-phosphate loads are estimated as 0.48 kg and 0.33 kg, respectively, extrapolating by rainfall volume (Table 5-5). The loads are estimated as 0.84 kg and 0.57 kg, respectively, extrapolating by the annual number of storms with rainfall of 0.04inches or more. The data indicate that the rainfall volume approach is the more appropriate method as a first approximation for calculating annual phosphorus.

  The average annual total phosphorus and ortho-phosphate loads per square meter of the total drainage area are estimated as 0.087 grams and 0.059 grams, respectively (rainfall rate approach). The average loads per square meter of the impervious drainage area are estimated as 0.090 grams and 0.062 grams, respectively. These values are lower than the values from the Pinefield site.

5.4.3 Discussion

Except for Storm F, the two sites appear to yield similar total phosphorus and ortho-phosphate ratios, although the absolute amount of organic and inorganic phosphorus differed between the sites. There was clearly a higher total phosphorus loss (2x) from the impermeable area of the Pinefield Site. This may reflect the greater potential for plant matter to be washed into the storm drains at this site. This higher total phosphorus discharge per area of impermeable surface suggests a difference in organic matter composition, since the TSS and POC discharges are relatively similar at both sites. This conclusion is supported by the ratio of particulate C/N, which also suggests different organic matter sources between the sites (see Section 5.5.3 below).

5.5 Nitrogen

5.5.1 Pinefield Site

- **Concentrations:** As for phosphorus, nitrogen concentrations were typically highest at the beginning of the storms (Figure 5-40, 5-42, 5-44). Nitrate was the largest nitrogen component, with the exception of 3 samples during Storm B where dissolved organic nitrogen was highest. Nitrate is a dominant nitrogen form in rainwater. However, the levels observed at the Pinefield site are several fold higher than typical of rainfall and therefore indicate the pick-up of additional nitrate from the drainage basin prior to discharge. Nitrate could arise from the oxidation of organic nitrogen or urea from animal deposits or runoff of lawn fertilizers and even processed organic matter. About half of the total nitrogen discharge was found to be dissolved inorganic nitrogen, the combination of ammonium, nitrate and nitrite. The sources of the DIN are generally the same. The contribution of organic nitrogen, although of a similar magnitude to the DIN, is likely to have less of an immediate impact on the receiving system, as it is not readily available for plant uptake and may be relatively refractory.

- **Loads per Storm:** The nitrogen loads generally followed the discharge pattern; peak loads were discharged during peak flows (Figure 5-41, 5-43, 5-45). The combined total phosphorus load for the three storms were as follows:
  - Nitrate and Nitrite: 460 grams
  - Ammonia: 150 grams
  - Dissolved Organic Nitrogen: 374 grams
  - Particulate Organic Nitrogen: 321 grams

- **Annual Loads:** The estimated annual nitrogen loads are as follows:
  - Nitrate and Nitrite: 9.40 kg
  - Ammonia: 3.07 kg
  - Dissolved Organic Nitrogen: 7.64 kg
  - Particulate Organic Nitrogen: 6.55 kg

  The average annual nitrogen loads per square meter of the total drainage area are estimated as follows (rainfall rate approach):
  - Nitrate and Nitrite: 0.122 grams
  - Ammonia: 0.040 grams
  - Dissolved Organic Nitrogen: 0.099 grams
  - Particulate Organic Nitrogen: 0.085 grams

  The average annual nitrogen loads per square meter of the impervious drainage area are estimated as follows (rainfall rate approach):
  - Nitrate and Nitrite: 0.475 grams
  - Ammonia: 0.155 grams
  - Dissolved Organic Nitrogen: 0.386 grams
  - Particulate Organic Nitrogen: 0.331 grams

5.5.2 Cherry Hill Site

- **Concentrations:** As for phosphorus, nitrogen concentrations were typically highest at the beginning of the storms (Figure 5-46, 5-50, 5-52) Dissolved organic nitrogen was the largest nitrogen component in Storms A and C. Nitrate was the largest component in Storm F. The Cherry Hill Site was similar to the Pinefield site in its predominant nitrate flux. However, nitrate was a smaller contributor to the total flux than at Pinefield and was a smaller fraction of the DIN. This may result from a difference in nitrogen sources between the two sites and to a smaller amount of oxidation of the available ammonium at the Cherry Hill site. Some support for the latter process is seen in that the DIN fluxes at the two sites are more similar than the nitrate fluxes. The total nitrogen fluxes from the two sites are relatively similar and the differences in the inorganic nitrogen constituents may merely represent a difference in the amount of diagenesis that may be able to occur at each site prior to discharge.

  TKN was assayed in parallel by both analytical laboratories for Storm A (Figure 5-48, 5-49). There was excellent agreement between the two methods (Toxikon=TKN, SMAST=PON+DON+NH4) indicating that the results from this study are directly comparable to previous efforts employing TKN assays.

- **Loads per Storm:** The nitrogen loads are vary variable. The combined total nitrogen load for the three storms were as follows:
  - Nitrate and Nitrite: 72 grams
  - Ammonia: 52 grams
  - Dissolved Organic Nitrogen: 201 grams
  - Particulate Organic Nitrogen: 32 grams

- **Annual Loads:** The estimated annual nitrogen loads are as follows:
  - Nitrate and Nitrite: 1.28 kg
  - Ammonia: 0.93 kg
  - Dissolved Organic Nitrogen: 3.59 kg
  - Particulate Organic Nitrogen: 0.56 kg

The average annual nitrogen loads per square meter of the total drainage area were as follows (rainfall rate approach):

- Nitrate and Nitrite:	0.233 grams
- Ammonia:	0.169 grams
- Dissolved Organic Nitrogen:	0.654 grams
- Particulate Organic Nitrogen:	0.103 grams

The average annual nitrogen loads per square meter of the impervious drainage area were as follows (rainfall rate approach):

- Nitrate and Nitrite:	0.242 grams
- Ammonia:	0.175 grams
- Dissolved Organic Nitrogen:	0.679 grams
- Particulate Organic Nitrogen:	0.107 grams

5.5.3 Discussion

The predominance of nitrate (56% and 38% of the total nitrogen fluxes at the Pinefield and Cherry Hill Sites, respectively) likely reflects the mobility of nitrate in soil and surface water systems. Nitrate also results from organic decay after microbial oxidation of released ammonium (i.e., nitrification). This nitrogen source is readily taken up by terrestrial and microbial autotrophs and is a major nitrogen form underlying the eutrophication of coastal waters. The high concentrations of nitrate suggest that runoff from the drainage area is the predominant source, since the nitrate concentrations were several times rainfall concentrations. The maximum concentrations at each site were higher at Pinefield, generally by a factor of 2. This may indicate a fertilizer source or another source associated with runoff from vegetated areas. This inter-site difference is also seen in the amount of ammonium relative to nitrate. The Pinefield site had little ammonium flux relative to nitrate (about 30%); at the Cherry Hill site, ammonium was about 70% of the nitrate flux. This is further support for a difference in nitrogen source at the two sites and is consistent with runoff from vegetation at the Pinefield versus Cherry Hill sites. Further supporting evidence for a difference in sources comes from the POC/PON ratios (Figures 5-54 to 5-59). The much higher ratios at the Cherry Hill site (10 to 35) versus Pinefield site (6 to 10) clearly indicates that the particulate matter is of different quality, if not different source. Lower C/N ratios may indicate animal waste or fertilized plants (or even algae). The higher ratios can be from a variety of sources, including higher plants. Ratios of C/N are not conclusive and may result from the mixing of different particulate sources.

5.6 Dissolved Oxygen

No specific trend was observed in the dissolved oxygen concentrations throughout the storm at either site. The stormwater was generally well oxygenated, except at the end of Storm E at the Pinefield site (Table 5-3). The lowest concentration measured was 4.9 mg/l.

Dissolved oxygen concentrations were low in the catchbasin at the Cherry Hill site, as expected. Prior to Storm A, the concentration was 0.9 mg/l; prior to Storm C, the concentration was 5.0 mg/l.

It appears that anaerobic conditions in the stormwater are not the cause of the ammonium levels observed in discharges. It may be that the ammonium merely represents nitrogen which has been mineralized and not yet nitrified to nitrate. It is also likely that a significant part of the ammonium may result from animal wastes deposited on the impermeable surfaces and then washed into the storm sewers. The role of groundwater in the measured DIN levels in the discharge waters is likely to be small. Groundwater nitrogen is predominantly as nitrate and little ortho-phosphate was observed. If the nitrogen an phosphorus was resulting from infiltration of groundwater, then the high ammonium and ortho-phosphate levels would not have been observed. All physical and biogeochemical factors indicate two systems dominated by surface water runoff, but with potentially different nutrient sources.

5.7 Conductivity

Conductivity was highest during all storms at the beginning of all storms (Figures 5-60 to 5-65). Values measured in the field and in the laboratory were very similar. While conductivity appears to be a good indicator of first flush, there was not consistent agreement between contaminant levels and measured conductivity. This results from the fact that conductivity is dominated by dissolved constituents other than those measured as contaminants.

5.8 Total Petroleum Hydrocarbons

Total Petroleum Hydrocarbons (TPH) were measured during the first three storms. None of the samples contained TPH above the detection limit. However, a small oil sheen was observed near the manhole at the Cherry Hill site at the beginning of storms.

5.9 Quality Control

5.9.1 In situ instruments

The dissolved oxygen meter and the pH meter were calibrated before each event and checked again after each event:

- **Dissolved Oxygen Meter**

Storm No.	*Should read*	*Actually read*	*Data adjusted*
A	8.6 mg/l	8.4 mg/l	No
B	8.8 mg/l	8.7 mg/l	No
C	10.8 mg/l	10.7 mg/l	No
D	8.9 mg/l	8.8 mg/l	No
E	8.6 mg/l	8.5 mg/l	No
F	(meter not operational)		

- **pH Meter**

Storm No.	*Should read*	*Actually read*	*Data adjusted*
A	7.0	6.9	No
B	7.0	6.9	No
C	7.0	6.9	No
D	7.0	6.9	No
E	7.0	6.9	No
F	(meter not operational)		

5.9.2 Flow Meter

The measurements obtained by the bucket method were compared at four occasions. The R^2 between the two methods was 0.67 (Figure 5-66). Individual comparisons were as follows:

Storm No.	*Time*	*Flow (Bucket)*	*Flow (Meter)*
A	18:58h	0.053 cfs	0.056 cfs
A	21:30h	0.070 cfs	0.092 cfs
C	7:37h	0.121 cfs	0.075 cfs
C	10:07h	0.169 cfs	0.135 cfs

5.9.3 Chemical Data

- **Duplicates:** The QAPP specified one duplicate per 20 samples, but the QAPP was based on the assumption that both sites could be sampled at the same time during a storm. As it turned out, it was better logistically to sample the two sites at different times. A duplicate sample was analyzed for each storm event (i.e., approximately 1 duplicate per 10 samples). The exception was Storm F; two duplicate samples were collected, but only for TSS, TP, POC, and PON.

  The concentrations of the duplicate samples are presented in Table 5-3c. The fecal coliform concentrations of the duplicates were within 10% of the original concentration with the exception of Storm D (46%). The SMAST nutrient assays also generally met the QA requirements as set forth in the QAPP. There were no samples collected which were below detection. Equally significant is that we conducted a laboratory and technique-blind intercalibration using the samples from Storm A. The data quality of the nutrients were tested during the first sampling event by analyzing for Total Kjeldahl Nitrogen (TKN) in addition to the equivalent analysis by the SMAST laboratory. TKN consists of the sum of ammonia, dissolved organic nitrogen (DON) and particulate organic nitrogen (PON). The data are presented in Figure 5-67. The R^2 between TKN analyzed by Toxikon and TKN (as the sum of ammonia, DON and PON) analyzed by SMAST was 0.99, in general good agreement. These results not only increase the confidence in the nutrient results, but also indicate that the results from the present study are directly comparable to those from previous efforts where only TKN was assayed.

- **Fecal coliform:** An analytical problem for fecal coliform existed during Storm D. Presumptive coliform concentration could not be confirmed by the laboratory (Toxikon). However, data from Storm E collected only 4 days after Storm D from the same site demonstrated that the presumptive concentrations appeared to be the correct data. (Samples from Storm E were analyzed by the Barnstable County Laboratory.) In addition, a similar confirmation could not be performed by Toxikon as reflected in the email from the laboratory:

  From: . "Sharon Lefebvre" <sharon.lefebvre@toxikon.com>
  To: <bhay@louisberger.com>
  Date: 2/1/02 3:22PM
  Subject: fecal coliform update

  I am writing up a formal letter to send you on Monday. Basically, as we discussed in our meeting, there is no error in the paperwork or in the way in which the test was performed. However, the results you got would be consistent with a problem having occurred with the confirmation portion of the test. We can't say this is what happened for certain based on the data which we have. However, when we examined other tests performed during the same time period, using the same media preparations for the presumptive test, we did find another case similar to yours in which high presumptive values were not confirmed in the EC-MUG test but were confirmed in the lauryl tryptose broth test. Based on the results of our investigation, we would recommend that you use your presumptive values.

  Therefore, we used the presumptive fecal coliform data for Storm D that we consider correct.

- **Compositing:** The number of samples collected during the first three events consisted of 10 samples during Storm A, 12 samples during Storm B, and 11 samples during Storm C. Rather than compositing some of the samples to reduce the number of samples to 10 (as planned in the QAPP), we decided to run all samples in order to obtain higher resolution in the data. Knowledge about the expected storm patterns through radar information available in the field allowed us to schedule the individual samples in a representative manner as outlined in the QAPP. This approach was discussed with and approved by the MCZM Project Officer, Mr. Carlisle.

Table 5-1

Rainfall Data Summary, 1950 - 2002

Salem Beverly Water Supply Board

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum (per year)
Mean rainfall (inch/month)	**3.68**	**3.36**	**3.93**	**3.78**	**3.39**	**3.12**	**3.17**	**3.29**	**3.36**	**3.85**	**4.39**	**3.93**	**43.20**
Minimum rainfall (inch/month)	0.37	0.36	0.67	0.49	0.63	0.00	0.31	0.78	0.40	0.30	0.46	0.86	*26.47*
Maximum rainfall (inch/month)	11.07	7.30	12.27	13.17	9.73	11.70	7.53	10.63	9.15	14.11	10.08	9.30	*58.16*

Table 5-2

Rainfall Data Summary, 1987 - 2001

Salem Beverly Water Supply Board

All Data

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean No. of rain (days/month)	9.6	7.5	9.4	10.7	11.3	9.1	9.5	9.0	9.3	8.4	9.9	8.6	112.1
Mean rainfall (inch/month)	**4.01**	**3.08**	**4.32**	**4.58**	**3.21**	**3.16**	**3.61**	**3.56**	**4.46**	**4.49**	**4.25**	**3.73**	**46.47**
Minimum rainfall (inch/day)	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Maximum rainfall (inch/day)	3.26	2.82	2.80	3.77	1.71	5.98	2.81	2.78	4.37	9.44	4.20	2.40	9.44

ONLY Rainfall days with 0.3 inches or more

Mean No. of rain (days/month)	4.3	3.2	4.5	3.7	3.8	2.6	4.1	3.3	3.8	3.7	4.2	3.7	44.9
% of Total rainfall days	*44%*	*42%*	*48%*	*34%*	*34%*	*29%*	*43%*	*37%*	*41%*	*44%*	*43%*	*43%*	***40%***
Mean rainfall (inch/month)	**3.44**	**2.59**	**3.68**	**3.84**	**2.40**	**2.54**	**3.11**	**3.03**	**3.91**	**4.05**	**3.63**	**3.21**	**39.43**
% of Total Rainfall	*86%*	*84%*	*85%*	*84%*	*75%*	*81%*	*86%*	*85%*	*88%*	*90%*	*85%*	*86%*	***85%***

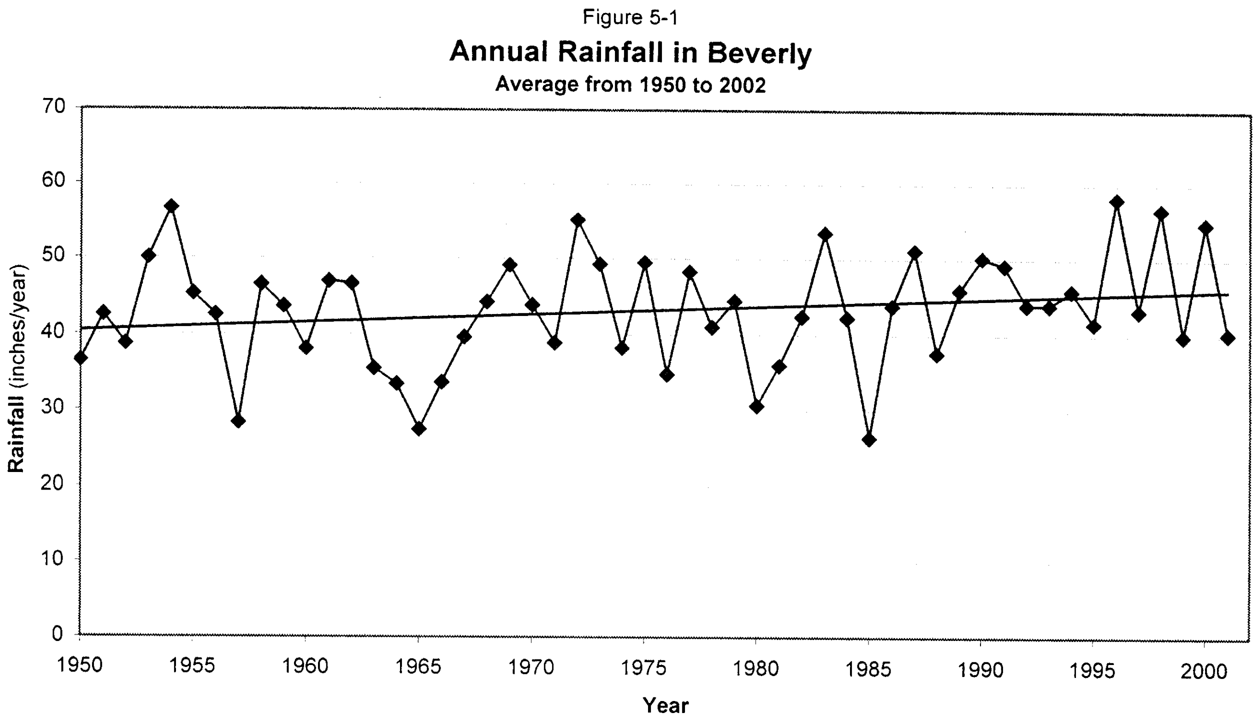


Figure 5-1
Annual Rainfall in Beverly
Average from 1950 to 2002
Rainfall (inches/year)
70
60
50
40
30
20
10
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Year

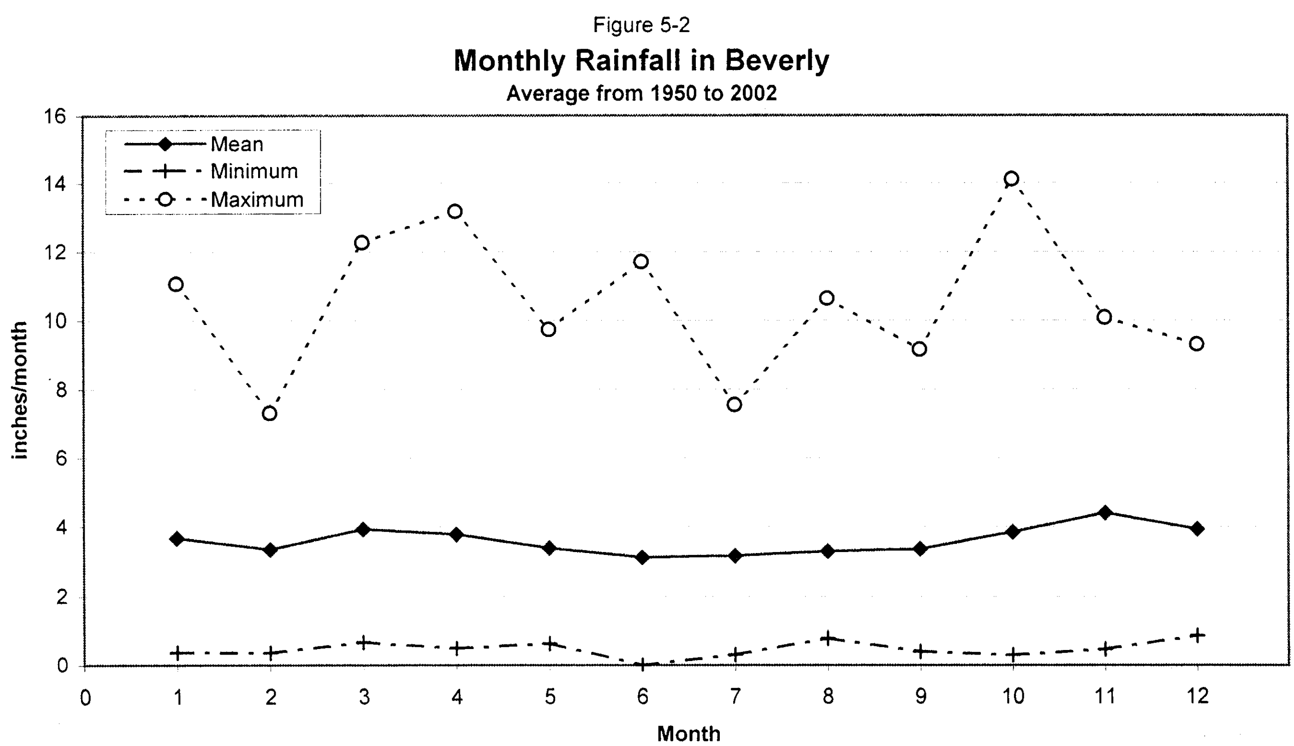


Figure 5-2
Monthly Rainfall in Beverly
Average from 1950 to 2002
Mean
Minimum
Maximum
inches/month
16
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
8
9
10
11
12
Month

Figure 5-3

Percentile of Rainfall per Day, 1987-2001

(based on rainfall record from Beverly Salem Water Board)

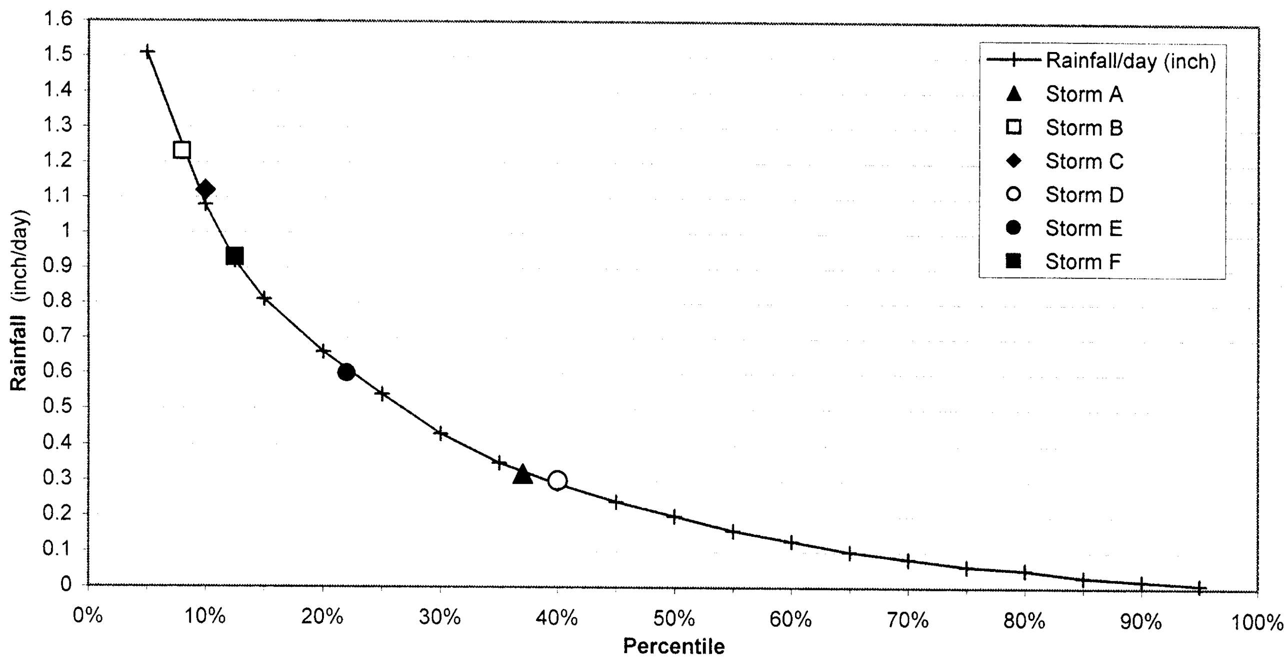


Table 5-3a

Stormwater Quality - Pinefield Site - Concentrations (Storms A, C, F)

Sample ID	Date	Time	Flow (1)	Temperature	Dissolved Oxygen	pH	Conductivity (field)	Conductivity (lab)	Fecal Coliform	Total Petroleum Hydrocarbon	TSS	Total Kjeldahl Nitrogen (2)	Total Kjeldahl Nitrogen (3)	PO4	TP	NH4	NO3+NO2	DIN	DON	POC	PON	C/N (i.e., POC/PON)
		h	cfs	deg. C	mg/l		uS/cm	uS/cm	col/100 ml	mg/l	mg/l	mg/l N	mg/l N	mg/l P	mg/l P	mg/l N	mg/l N	mg/l N	mg/l N	mg/l	mg/l N	
Storm B: Pinefield, September 15, 2000																						
PF-B-1	9/15/00	5:55	0.000	17.4	8.7	7.7	30	294	250	nd	0.34	--	--	0.218	0.277	0.027	6.256	6.282	0.357	0.25	0.07	3.77
PF-B-2	9/15/00	7:10	0.009	17.9	8.7	7.4	270	331	300	nd	2.60	--	--	0.792	0.844	1.011	5.857	6.869	10.696	0.67	0.10	6.93
PF-B-3	9/15/00	7:40	0.044	18.0	8.7	7.2	237	326	300	nd	2.67	--	--	0.775	0.797	0.903	5.830	6.733	9.912	0.61	0.10	6.35
PF-B-4	9/15/00	7:58	0.163	18.1	8.7	6.9	199	124	6,400	nd	15.85	--	--	0.136	0.192	0.478	2.105	2.583	0.330	3.73	0.40	9.27
PF-B-5	9/15/00	8:35	0.146	18.1	9.3	6.9	36	25	12,000	nd	27.95	--	--	0.137	0.192	0.345	0.785	1.129	0.396	4.53	0.51	8.91
PF-B-6 (Dupl.)	9/15/00	8:35	--	--	--	--	--	30	11,000	nd	25.15	--	--	0.138	0.182	0.346	0.787	1.133	0.290	4.14	0.48	8.59
PF-B-7	9/15/00	9:07	1.800	18.6	9.3	6.0	27	19	12,000	nd	20.20	--	--	0.125	0.172	0.209	0.461	0.670	0.226	3.09	0.41	7.58
PF-B-8	9/15/00	9:35	2.230	18.5	9.5	5.8	15	15	3,700	nd	23.85	--	--	0.103	0.136	0.119	0.265	0.384	1.403	3.47	0.42	8.18
PF-B-9	9/15/00	10:10	1.520	18.5	9.5	6.2	16	14	12,000	nd	11.47	--	--	0.107	0.145	0.107	0.278	0.384	0.157	2.07	0.30	6.79
PF-B-10	9/15/00	11:08	0.470	18.7	9.5		29	24	<1	nd	4.80	--	--	0.127	0.145	0.119	0.519	0.638	0.187	1.04	0.22	4.83
PF-B-11	9/15/00	12:11	0.050	18.7	8.7	6.9	45	38	4,000	--	3.00	--	--	0.157	0.175	0.121	0.842	0.963	0.328	0.82	0.11	7.51
PF-B-12	9/15/00	14:07	0.038	18.5	8.5	6.9	104	86	3,100	--	2.77	--	--	0.274	0.290	0.117	2.173	2.290	0.368	0.69	0.11	6.09
Storm D: Pinefield, September 21, 2001																						
PF-D-1	9/21/01	3:11	0.009	17.0	7.8	7.4	110	81	2,400	--	21.81	--	--	0.213	0.289	0.567	0.998	1.565	0.410	1.522	0.23	6.58
PF-D-2	9/21/01	3:31	0.008	17.5	7.3	7.5	199	192	17,000	--	24.12	--	--	0.177	0.243	0.661	3.750	4.411	0.410	1.662	0.28	5.98
PF-D-3	9/21/01	3:51	0.070	17.7	7.6	7.6	150	177	2,600	--	20.01	--	--	0.165	0.212	0.613	2.932	3.545	0.303	1.458	0.23	6.40
PF-D-4	9/21/01	4:11	0.023	18.1	8.1	7.8	156	173	1,200	--	23.62	--	--	0.120	0.179	0.391	1.599	1.991	0.364	1.215	0.20	6.09
PF-D-5	9/21/01	4:41	0.050	18.1	8.0	7.8	122	141	11,100	--	24.87	--	--	0.115	0.170	0.335	1.208	1.542	0.405	1.177	0.22	5.36
PF-D-6 (Dupl.)	9/21/01	4:41	--	--	--	--	--	141	7,600	--	24.47	--	--	0.115	0.168	0.332	1.230	1.561	0.248	1.233	0.21	5.82
PF-D-7	9/21/01	5:11	0.070	18.2	7.8	7.8	96	110	9,300	--	24.62	--	--	0.130	0.187	0.296	0.978	1.275	0.422	1.461	0.25	5.88
PF-D-8	9/21/01	5:41	0.023	18.2	8.0	7.7	92	100	2,900	--	23.77	--	--	0.136	0.186	0.294	0.959	1.253	0.428	1.248	0.21	5.95
PF-D-9	9/21/01	6:11	0.023	18.1	7.9	7.7	110	99	2,900	--	22.67	--	--	0.137	0.198	0.279	0.861	1.139	0.427	1.303	0.21	6.12
PF-D-10	9/21/01	6:45	0.010	18.2	7.9	7.7	99	94	7,200	--	23.42	--	--	0.140	0.191	0.263	0.914	1.178	0.391	1.203	0.21	5.73
Storm E: Pinefield, September 25, 2001																						
PF-E-1	9/25/01	14:16	1.628	20.0	7.7	7.7	122	79	33	--	12.75	--	--	0.091	0.154	0.193	1.480	1.673	0.233	2.96	0.22	13.27
PF-E-2	9/25/01	14:38	2.350	20.4	8.0	7.6	50	71	9,000	--	52.85	--	--	0.129	0.359	0.459	0.777	1.237	0.371	7.72	0.60	12.88
PF-E-3	9/25/01	15:00	2.000	20.8	8.1	7.7	15	22	27,000	--	28.30	--	--	0.078	0.438	0.117	0.328	0.445	0.222	3.61	0.34	10.72
PF-E-4	9/25/01	15:25	2.200	20.7	8.0	7.5	16	21	29,000	--	40.25	--	--	0.078	0.180	0.075	0.238	0.313	0.241	5.56	0.45	12.45
PF-E-5	9/25/01	16:35	0.010	20.4	7.0	7.6	22	33	12,000	--	17.00	--	--	0.092	0.186	0.115	0.368	0.483	0.230	2.72	0.22	12.36
PF-E-6	9/25/01	17:13	0.002	20.3	6.7	7.7	23	32	8,000	--	13.35	--	--	0.093	0.173	0.115	0.395	0.510	0.233	2.14	0.17	12.51
PF-E-7 (Dupl.)	9/25/01	17:13	--	--	--	--	--	36	8,000	--	12.25	--	--	0.094	0.191	0.118	0.388	0.506	0.203	1.85	0.15	12.27
PF-E-8	9/25/01	17:45	0.006	20.2	4.9	7.7	24	27	11,000	--	7.65	--	--	0.096	0.142	0.107	0.425	0.532	0.177	1.72	0.18	9.44
PF-E-9	9/25/01	18:17	0.004	20.1	5.7	7.8	26	35	21,000	--	12.67	--	--	0.097	0.114	0.110	0.444	0.554	0.218	2.07	0.24	8.51
PF-E-10	9/25/01	18:45	0.001	20.0	5.0	7.7	25	37	14,000	--	16.87	--	--	0.097	0.124	0.109	0.468	0.577	0.257	2.61	0.26	9.88

Table 5-3b

Stormwater Quality - Cherry Hill Site - Concentrations (Storms A, C, F)

Sample ID	Date	Time	Flow (1)	Temperature	Dissolved Oxygen	pH	Conductivity (field)	Conductivity (lab)	Fecal Coliform	Total Petroleum Hydrocarbon	TSS	Total Kjeldahl Nitrogen (2)	Total Kjeldahl Nitrogen (3)	PO4	TP	NH4	NO3+NO2	DIN	DON	POC	PON	C/N (i.e., POC/PON)
		h	cfs	deg. C	mg/l		uS/cm	uS/cm	col/100 ml	mg/l	mg/l	mg/l N	mg/l N	mg/l P	mg/l P	mg/l N	mg/l N	mg/l N	mg/l N	mg/l	mg/l N	
Storm A: Cherry Hill, August 23, 2000																						
CH-A-1	8/23/00	17:30	0.000	17.5	0.9	7.2	95	86	80	nd	11.33	0.94	3.85	0.006	0.033	0.965	0.255	1.220	0.050	2.84	0.36	7.97
CH-A-2	8/23/00	18:53	0.053	20.7	7.7	7.1	226	277	3,600	nd	26.70	24.00	24.96	0.807	0.817	1.486	1.887	3.373	17.682	5.79	0.55	10.57
CH-A-3	8/23/00	19:17	0.029	19.7	7.6	7.2	66	148	<10	nd	12.50	15.00	15.42	1.043	1.057	1.429	1.615	3.044	10.987	3.00	0.26	11.35
CH-A-4	8/23/00	19:47	0.070	20.5	7.6	7.5	14	112	340	nd	10.52	13.00	12.57	0.608	0.631	1.207	1.407	2.614	8.444	2.92	0.24	12.21
CH-A-5	8/23/00	20:35	0.182	20.0	7.8	7.8	30	48	<10	nd	5.38	2.50	4.89	0.333	0.347	0.840	0.787	1.627	2.472	1.58	0.13	12.18
CH-A-6 (Dupl.)	8/23/00	20:35	--	--	--	--	--	47	<10	nd	5.20	2.80	4.97	0.334	0.361	0.841	0.787	1.628	2.606	1.52	0.11	14.15
CH-A-7	8/23/00	20:52	0.098	19.6	7.8	7.8	25	23	<10	nd	3.65	1.00	1.77	0.126	0.148	0.376	0.335	0.711	0.506	0.89	0.06	13.99
CH-A-8	8/23/00	21:25	0.074	19.7	7.8	7.8	25	23	160	nd	5.64	1.10	2.05	0.076	0.108	0.339	0.390	0.728	0.304	1.40	0.08	17.09
CH-A-9	8/23/00	21:53	0.080	19.6	8.2	7.1	29	26	<10	nd	1.18	0.63	1.30	0.059	0.077	0.416	0.588	1.004	0.337	0.55	0.05	10.33
CH-A-10	8/23/00	23:49	0.001	19.8	8.1	7.3	32	48	<10	nd	2.30	0.85	2.41	0.050	0.074	0.422	0.986	1.408	0.331	1.65	0.08	20.59
Storm C: Cherry Hill, November 10, 2000																						
CH-C-1	11/10/00	1:50	0.000	10.3	5.0	8.7	64	59	10	nd	2.25	--	--	0.010	0.154	0.360	0.301	0.661	0.268	1.07	0.08	12.71
CH-C-2	11/10/00	2:57	0.015	9.8	9.0	7.7	73	60	26	nd	14.52	--	--	0.022	0.054	0.311	0.816	1.128	0.675	3.34	0.17	20.22
CH-C-3	11/10/00	3:27	0.021	9.6	10.2	7.4	57	54	17	nd	14.11	--	--	0.024	0.069	0.262	0.963	1.225	1.366	2.96	0.12	24.91
CH-C-4	11/10/00	3:57	0.021	9.5	11.2	7.9	38	45	230	nd	15.01	--	--	0.030	0.079	0.198	0.819	1.017	1.343	3.37	0.12	28.63
CH-C-5	11/10/00	6:00	0.014	9.4	11.2	7.1	27	25	45	nd	2.87	--	--	0.031	0.039	0.114	0.525	0.639	0.471	1.19	0.04	28.37
CH-C-6	11/10/00	8:02	0.111	9.4	11.4	6.9	9	15	<1	nd	12.78	--	--	0.030	0.058	0.057	0.114	0.171	0.837	2.87	0.08	34.79
CH-C-7 (Dupl.)	11/10/00	8:02	--	--	--	--	--	15	<1	nd	9.81	--	--	0.037	0.041	0.057	0.081	0.138	0.194	2.63	0.08	34.79
CH-C-8	11/10/00	10:02	0.155	10.2	11.2	6.4	9	14	<1	--	8.04	--	--	0.041	0.061	0.054	0.036	0.089	0.069	2.37	0.07	32.55
CH-C-9	11/10/00	12:08	0.056	10.2	10.8	8.6	18	15	6	--	4.25	--	--	0.026	0.029	0.081	0.111	0.192	0.170	1.08	0.03	32.14
CH-C-10	11/10/00	14:05	0.190	9.9	11.8	7.0	10	15	<1	--	6.28	--	--	0.026	0.031	0.097	0.111	0.207	0.236	1.25	0.03	40.44
CH-C-11	11/10/00	16:00	0.106	9.9	11.8	--	15	15	<1	--	10.47	--	--	0.017	0.031	0.083	0.086	0.168	0.096	2.09	0.04	46.69
Storm F: Cherry Hill, April 25, 2002																						
CH-F-1	4/25/02	14:50	0.000	7.8	--	--	110	98	250	--	5.00	--	--	0.006	0.042	0.201	1.056	1.257	0.317	1.253	0.127	9.83
CH-F-2	4/25/02	17:40	0.316	8.7	--	--	150	150	1,000	--	106.90	--	--	0.019	0.177	0.332	1.200	1.532	0.801	11.768	0.499	23.58
CH-F-3	4/25/02	18:13	0.257	10.7	--	--	36	33	90	--	29.40	--	--	0.014	0.079	0.221	0.435	0.657	0.238	4.627	0.187	24.79
CH-F-4	4/25/02	19:22	0.550	8.5	--	--	25	22	80	--	65.20	--	--	0.008	0.095	0.133	0.206	0.338	0.154	8.413	0.316	26.63
CH-F-10	4/25/02	19:45	0.319	8.7	--	--	21	13	20	--	26.30	--	--	0.009	0.072	0.086	0.138	0.224	0.081	3.467	0.122	28.48
CH-F-5	4/25/02	20:41	0.269	8.7	--	--	26	20	560	--	7.40	--	--	0.009	0.022	0.093	0.143	0.236	0.118	1.262	0.056	22.59
CH-F-6	4/25/02	21:34	0.324	7.6	--	--	16	11	20	--	19.10	--	--	0.005	0.059	0.052	0.055	0.107	0.073	2.673	0.110	24.32
CH-F-7	4/25/02	22:24	0.674	6.1	--	--	10	7	30	--	30.40	--	--	0.005	0.059	0.029	0.028	0.057	0.047	4.332	0.162	26.73
CH-F-8A	4/25/02	23:29	0.886	1.4	--	--	--	8	20	--	4.50	--	--	0.003	0.012	0.016	0.040	0.055	0.071	0.691	0.031	22.57
CH-F-8B	4/25/02	23:29	0.886	--	--	--	--	--	--	--	3.80	--	--	--	0.009	--	--	--	--	0.645	0.032	19.91
CH-F-9A	4/26/02	0:25	0.379	2.2	--	--	11	7	70	--	8.70	--	--	0.003	0.012	0.014	0.040	0.055	0.037	1.240	0.047	26.27
CH-F-9B	4/26/02	0:25	0.379	--	--	--	--	--	--	--	5.90	--	--	--	0.020	--	--	--	--	0.946	0.033	28.56

Table 5-3c

Stormwater Quality - Quality Control (Storms A - F)

Sample ID	Date	Time	Flow *(1)*	Temperature	Dissolved Oxygen	pH	Conductivity *(field)*	Conductivity *(lab)*	Fecal Coliform	Total Petroleum Hydrocarbon	TSS	Total Kjeldahl Nitrogen *(2)*	Total Kjeldahl Nitrogen *(3)*	PO4	TP	NH4	NO3+NO2	DIN	DON	POC	PON	C/N (i.e., POC/PON)
		h	cfs	deg. C	mg/l		uS/cm	uS/cm	col/100 ml	mg/l	mg/l	mg/l N	mg/l N	mg/l P	mg/l P	mg/l N	mg/l N	mg/l N	mg/l N	mg/l	mg/l N	
QC/QC Comparison (comparison of "original" samples with duplicates)																						
Storm A: Cherry Hill, August 23, 2000								102%	100%	nd	103%	89%	98%	100%	96%	100%	100%	100%	95%	103%	120%	86%
Storm B: Pinefield, September 15, 2000								84%	109%	nd	111%	--	--	99%	106%	100%	100%	100%	136%	109%	105%	104%
Storm C: Cherry Hill, November 10, 2000								103%	100%	nd	130%	--	--	83%	141%	100%	140%	124%	431%	109%	109%	100%
Storm D: Pinefield, September 21, 2001								100%	146%	--	102%	--	--	100%	101%	101%	98%	99%	164%	95%	104%	92%
Storm E: Pinefield, September 25, 2001								90%	100%	--	109%	--	--	99%	91%	98%	102%	101%	114%	116%	114%	102%
Storm F: Cherry Hill, April 25, 2002 *CH-F-8A vs B*								--	--	--	118%	--	--	--	137%	--	--	--	--	107%	95%	113%
CH-F-9A vs B								--	--	--	147%	--	--	--	60%	--	--	--	--	131%	143%	92%

nd = Not detected.

-- No data obtained.

(1) Flow rates were integrated from measurements before and after water sampling time.

(2) Total Kjeldahl Nitrogen determined by Toxikon.

(3) Total Kjeldahl Nitrogen, as calculated from data by SMAST by adding ammonia, DON and PON.

Table 5-4a

Stormwater Quality - Pinefield Site- Loads (Storms B, E, D)

Sample ID	Date	Time	Flow (1)	Fecal Coliform (4)	TSS	Total Kjeldahl Nitrogen (2)	Total Kjeldahl Nitrogen (3)	PO4	TP	NH4	NO3+NO2	DIN	DON	POC	PON
		h	cfs	col/h x 10^6	g/h	g/h	g/h	g/h P	g/h P	g/h N	g/h N	g/h N	g/h N	g/h	g/h N
Storm B: Pinefield, September 15, 2000															
PF-B-2	9/15/00	7:10	0.009	2.76	2.4	--	--	0.73	0.78	0.93	5.38	6.31	9.83	0.62	0.09
PF-B-3	9/15/00	7:40	0.044	13.48	12.0	--	--	3.48	3.58	4.06	26.20	30.26	44.55	2.73	0.43
PF-B-4	9/15/00	7:58	0.163	1,065.54	263.9	--	--	2.27	3.20	7.95	35.05	43.00	5.50	62.12	6.70
PF-B-5	9/15/00	8:35	0.146	1,789.52	416.8	--	--	2.05	2.87	5.14	11.70	16.84	5.90	67.49	7.57
PF-B-6 (Dupl.)	9/15/00	8:35	0.146	1,640.39	375.1	--	--	2.06	2.71	5.16	11.73	16.89	4.33	61.72	7.18
PF-B-7	9/15/00	9:07	1.800	22,062.55	3,713.9	--	--	22.91	31.60	38.50	84.74	123.24	41.61	568.04	74.92
PF-B-8	9/15/00	9:35	2.230	8,427.69	5,432.4	--	--	23.39	31.07	27.01	60.39	87.40	319.51	790.87	96.63
PF-B-9	9/15/00	10:10	1.520	18,630.60	1,780.3	--	--	16.60	22.49	16.56	43.12	59.68	24.42	320.64	47.22
PF-B-10	9/15/00	11:08	0.470	*0.24*	230.4	--	--	6.10	6.95	5.69	24.92	30.61	9.00	50.16	10.38
PF-B-11	9/15/00	12:11	0.050	204.28	15.3	--	--	0.80	0.90	0.62	4.30	4.92	1.68	4.19	0.56
PF-B-12	9/15/00	14:07	0.038	120.32	10.8	--	--	1.06	1.13	0.46	8.43	8.89	1.43	2.69	0.44
Storm D: Pinefield, September 21, 2001															
PF-D-1	9/21/01	3:11	0.009	22.06	20.1	--	--	0.20	0.27	0.52	0.92	1.44	0.38	1.40	0.21
PF-D-2	9/21/01	3:31	0.008	136.00	19.3	--	--	0.14	0.19	0.53	3.00	3.53	0.33	1.33	0.22
PF-D-3	9/21/01	3:51	0.070	187.20	144.1	--	--	1.19	1.53	4.41	21.11	25.52	2.18	10.50	1.64
PF-D-4	9/21/01	4:11	0.023	28.80	56.7	--	--	0.29	0.43	0.94	3.84	4.78	0.87	2.92	0.48
PF-D-5	9/21/01	4:41	0.050	570.86	127.9	--	--	0.59	0.87	1.72	6.21	7.93	2.08	6.05	1.13
PF-D-6 (Dupl.)	9/21/01	4:41	0.050	388.14	125.0	--	--	0.59	0.86	1.69	6.28	7.97	1.26	6.30	1.08
PF-D-7	9/21/01	5:11	0.070	669.60	177.2	--	--	0.94	1.35	2.13	7.04	9.18	3.04	10.52	1.79
PF-D-8	9/21/01	5:41	0.023	69.60	57.0	--	--	0.33	0.45	0.71	2.30	3.01	1.03	3.00	0.50
PF-D-9	9/21/01	6:11	0.023	69.60	54.4	--	--	0.33	0.47	0.67	2.07	2.73	1.02	3.13	0.51
PF-D-10	9/21/01	6:45	0.010	74.06	24.1	--	--	0.14	0.20	0.27	0.94	1.21	0.40	1.24	0.22
Storm E: Pinefield, September 25, 2001															
PF-E-1	9/25/01	14:16	1.628	54.88	2,120.2	--	--	15.08	25.63	32.12	246.06	278.19	38.70	492.61	37.11
PF-E-2	9/25/01	14:38	2.350	21,602.92	12,685.7	--	--	30.93	86.16	110.25	186.56	296.81	89.10	1,853.03	143.90
PF-E-3	9/25/01	15:00	2.000	55,156.38	5,781.2	--	--	15.92	89.42	23.80	67.03	90.83	45.33	736.73	68.71
PF-E-4	9/25/01	15:25	2.200	65,166.25	9,044.6	--	--	17.51	40.54	16.81	53.45	70.26	54.17	1,249.32	100.38
PF-E-5	9/25/01	16:35	0.010	123.60	17.5	--	--	0.10	0.19	0.12	0.38	0.50	0.24	2.80	0.23
PF-E-6	9/25/01	17:13	0.002	14.40	2.4	--	--	0.02	0.03	0.02	0.07	0.09	0.04	0.39	0.03
PF-E-7 (Dupl.)	9/25/01	17:13	0.002	16.34	2.5	--	--	0.02	0.04	0.02	0.08	0.10	0.04	0.38	0.03
PF-E-8	9/25/01	17:45	0.006	64.80	4.5	--	--	0.06	0.08	0.06	0.25	0.31	0.10	1.02	0.11
PF-E-9	9/25/01	18:17	0.004	88.20	5.3	--	--	0.04	0.05	0.05	0.19	0.23	0.09	0.87	0.10
PF-E-10	9/25/01	18:45	0.001	21.00	2.5	--	--	0.01	0.02	0.02	0.07	0.09	0.04	0.39	0.04

-- No measured.

(1) Flow rates were integrated from measurements before and after water sampling time.

(2) Total Kjeldahl Nitrogen determined by Toxikon.

(3) Total Kjeldahl Nitrogen, as calculated from data by SMAST by adding ammonia, DON and PON.

(4) For FC concentrations below the detection limit, 50% of the detection limit was used for the load calculations.

Table 5-4b

Stormwater Quality - Cherry Hill Site - Loads (Storms A, C, F)

Sample ID	Date	Time	Flow (1)	Fecal Coliform (4)	TSS	Total Kjeldahl Nitrogen (2)	Total Kjeldahl Nitrogen (3)	PO4	TP	NH4	NO3+NO2	DIN	DON	POC	PON
		h	cfs	col/h x 10^6	g/h	g/h	g/h	g/h P	g/h P	g/h N	g/h N	g/h N	g/h N	g/h	g/h N
Storm A: Cherry Hill, August 23, 2000															
CH-A-2	8/23/00	18:53	0.053	194.89	144.5	129.92	135.10	4.37	4.42	8.05	10.21	18.26	95.72	31.34	2.96
CH-A-3	8/23/00	19:17	0.029	*0.15*	37.0	44.43	45.66	3.09	3.13	4.23	4.78	9.02	32.54	8.89	0.78
CH-A-4	8/23/00	19:47	0.070	24.31	75.2	92.95	89.89	4.35	4.51	8.63	10.06	18.69	60.38	20.89	1.71
CH-A-5	8/23/00	20:35	0.182	*0.93*	100.0	46.47	90.86	6.19	6.46	15.61	14.63	30.24	45.96	29.29	2.40
CH-A-6 (Dupl.)	8/23/00	20:35	0.182	*0.93*	96.7	52.05	92.40	6.21	6.71	15.63	14.62	30.26	48.44	28.33	2.00
CH-A-7	8/23/00	20:52	0.098	*0.50*	36.5	10.01	17.72	1.26	1.48	3.77	3.35	7.12	5.07	8.89	0.64
CH-A-8	8/23/00	21:25	0.074	12.09	42.6	8.31	15.46	0.57	0.81	2.56	2.95	5.51	2.29	10.60	0.62
CH-A-9	8/23/00	21:53	0.080	*0.41*	9.7	5.15	10.66	0.48	0.63	3.40	4.81	8.21	2.75	4.51	0.44
CH-A-10	8/23/00	23:49	0.001	*0.01*	0.2	0.09	0.25	0.01	0.01	0.04	0.10	0.14	0.03	0.17	0.01
Storm C: Cherry Hill, November 10, 2000															
CH-C-2	11/10/00	2:57	0.015	0.40	22.2	--	--	0.03	0.08	0.48	1.25	1.73	1.03	5.12	0.25
CH-C-3	11/10/00	3:27	0.021	0.36	30.3	--	--	0.05	0.15	0.56	2.07	2.63	2.93	6.36	0.26
CH-C-4	11/10/00	3:57	0.021	4.93	32.2	--	--	0.06	0.17	0.42	1.76	2.18	2.88	7.22	0.25
CH-C-5	11/10/00	6:00	0.014	0.64	4.1	--	--	0.04	0.06	0.16	0.75	0.91	0.67	1.70	0.06
CH-C-6	11/10/00	8:02	0.111	*0.06*	144.9	--	--	0.34	0.65	0.64	1.30	1.94	9.49	32.58	0.94
CH-C-7 (Dupl.)	11/10/00	8:02	0.111	*0.06*	111.2	--	--	0.42	0.46	0.64	0.92	1.57	2.20	29.82	0.86
CH-C-8	11/10/00	10:02	0.155	*0.08*	127.4	--	--	0.65	0.96	0.85	0.56	1.42	1.09	37.52	1.15
CH-C-9	11/10/00	12:08	0.056	0.34	24.3	--	--	0.15	0.17	0.46	0.64	1.10	0.97	6.18	0.19
CH-C-10	11/10/00	14:05	0.190	*0.10*	121.8	--	--	0.50	0.60	1.87	2.15	4.02	4.57	24.17	0.60
CH-C-11	11/10/00	16:00	0.106	*0.05*	113.3	--	--	0.18	0.33	0.89	0.93	1.82	1.04	22.65	0.49
Storm F: Cherry Hill, April 25, 2002															
CH-F-2	4/25/02	17:40	0.316	322.77	3,450.4	--	--	0.62	5.71	10.72	38.72	49.43	25.84	379.83	16.11
CH-F-3	4/25/02	18:13	0.257	23.63	771.8	--	--	0.37	2.06	5.81	11.42	17.24	6.24	121.46	4.90
CH-F-4	4/25/02	19:22	0.550	44.94	3,662.8	--	--	0.46	5.32	7.45	11.56	19.00	8.64	472.64	17.75
CH-F-10	4/25/02	19:45	0.319	6.52	856.9	--	--	0.29	2.35	2.80	4.51	7.30	2.65	112.96	3.97
CH-F-5	4/25/02	20:41	0.269	153.87	203.3	--	--	0.25	0.60	2.55	3.94	6.49	3.23	34.68	1.54
CH-F-6	4/25/02	21:34	0.324	6.62	632.1	--	--	0.16	1.96	1.74	1.82	3.56	2.41	88.44	3.64
CH-F-7	4/25/02	22:24	0.674	20.65	2,092.8	--	--	0.33	4.08	1.96	1.93	3.89	3.27	298.20	11.16
CH-F-8A	4/25/02	23:29	0.886	18.10	407.2	--	--	0.28	1.10	1.42	3.59	5.01	6.46	62.57	2.77
CH-F-8B	4/25/02	23:29	0.886	--	343.9	--	--	--	0.80	--	--	--	--	58.35	2.93
CH-F-9A	4/26/02	0:25	0.379	27.10	336.8	--	--	0.12	0.47	0.56	1.56	2.12	1.45	48.01	1.83
CH-F-9B	4/26/02	0:25	0.379	--	228.4	--	--	--	0.79	--	--	--	--	36.61	1.28
Catchbasin Content															
Storm Sample	Date	Time		col x 10^6	g	g N	g N	g P	g P	g N	g N	g N	g N	g	g N
CH-A-1	8/23/00	17:30		0.18	2.5	0.207	0.847	0.001	0.007	0.212	0.056	0.268	0.011	0.624	0.078
CH-C-1	11/10/00	1:50		0.02	0.5	--	--	0.002	0.034	0.079	0.066	0.145	0.059	0.235	0.018
CH-F-1	4/25/02	14:50		1.55	3.1	--	--	0.003	0.026	0.125	0.655	0.779	0.197	0.777	0.079

Table 5-5

Stormwater Runoff Loads

Storm ID	Sampling Date	Duration of Rainfall	Rainfall, total	Rainfall Volume in Impervious Part of Drainage Area *(5)*	Rainfall Volume in Total Drainage Area *(5)*	Duration of Flow Period	Flow Volume *(6)*	Fecal Coliform	Total Petroleum Hydrocarbon	TSS	Total Kjeldahl Nitrogen *(2)*	Total Kjeldahl Nitrogen *(3)*	PO4 *(as P)*	TP	NH4 *(as N)*	NO3+NO2 *(as N)*	DIN	DON	POC	PON
		h	cubic inch	cubic inch	cubic meter	h	cubic meter	col x10^6	gram / storm											
Pinefield Site																				
Storm B	9/15/00	5.3	1.23	***618***	***2,403***	7.83	*497*	40,793.9	nd	8,928	--	--	61.5	81.2	95.7	280.5	376.2	286.3	1,454.9	186.3
Storm D	9/21/01	8.8	0.30	***151***	***586***	4.00	*13*	851.1	--	304	--	--	1.8	2.5	5.0	19.6	24.7	5.1	17.7	3.0
Storm E	9/25/01	4.6	0.60	***301***	***1,172***	4.57	*337*	76,344.0	--	11,261	--	--	28.6	102.0	49.5	160.6	210.1	83.0	1,575.7	131.8
Total *(all 3 storms)*		**18.6**	**2.13**	1,070	4,162	**16.4**	**848**	**117,989.0**	**nd**	**20,494**	**--**	**--**	**91.9**	**185.8**	**150.3**	**460.7**	**611.0**	**374.4**	**3,048.2**	**321.1**
Annual Load *(1)*								2,407,939	nd	418,238	--	--	1,876	3,791	3,067	9,403	12,470	7,640	62,208	6,553
Annual Loads per m2 of total drainage area								**31.30**	nd	**5.44**	--	--	**0.024**	**0.049**	**0.040**	**0.122**	**0.162**	**0.099**	**0.809**	**0.085**
Annual Loads per m2 of impervious part of drainage area								**121.77**	nd	**21.15**	--	--	**0.095**	**0.192**	**0.155**	**0.475**	**0.631**	**0.386**	**3.146**	**0.331**
Cherry Hill Site																				
Storm A	8/23/00	4.5	0.32	***43***	***45***	5.0	*37*	85.8	nd	247	192.1	234.8	12.5	13.2	29.1	31.6	60.7	138.9	66.8	5.5
Storm C	10/10/00	14.3	1.12	***150***	***156***	13.1	*152*	10.7	nd	1,216	--	--	4.9	7.1	13.0	19.4	32.4	46.4	292.2	8.4
Storm F	4/25/02	8.8	0.93	***125***	***130***	8.4	*326*	436.7	--	8,902	--	--	2.2	17.0	25.5	53.7	79.2	41.5	1,183.6	46.4
Storm F (adjusted) (3)		8.8	0.93	125	130	8.4	*125*	*167.2*	--	*3,409*	--	--	*0.8*	*6.5*	*9.8*	*20.6*	*30.3*	*15.9*	*453.3*	*17.8*
Total *(all 3 storms) (2)*		**27.6**	**2.37**	318	330	**26.5**	**313**	**263.7**	**nd**	**4,872**	**192.1**	**234.8**	**18.2**	**26.8**	**51.8**	**71.6**	**123.4**	**201.2**	**812.3**	**31.7**
Annual Load - *based on rainfall (1)*								4,709	nd	87,001	--	--	326	478	925	1,279	2,204	3,592	14,506	566
Annual Load - *based on number of storms (4)*								8,262	nd	152,657	--	--	571	839	1,624	2,244	3,867	6,303	25,453	993
Annual Loads per m2 of total drainage area *(1, 3)*								0.86	nd	**15.85**	--	--	**0.059**	**0.087**	**0.169**	**0.233**	**0.401**	**0.654**	**2.642**	**0.103**
Annual Loads per m2 of impervious part of drainage area *(1, 3)*								0.89	nd	**16.45**	--	--	**0.062**	**0.090**	**0.175**	**0.242**	**0.417**	**0.679**	**2.742**	**0.107**
Annual Loads per m2 of total drainage area *(4, 3)*								**1.50**	nd	27.81	--	--	0.104	0.153	0.296	0.409	0.704	1.148	4.636	0.181
Annual Loads per m2 of impervious part of drainage area *(4, 3)*								**1.56**	nd	28.86	--	--	0.108	0.159	0.307	0.424	0.731	1.192	4.812	0.188

(1) Based on annual rainfall volume of 43.2 inches, and given that 5.6% of this volume fell during the three measured storms.
(2) Storm F data were adjusted *(in italics)*. The discharge volume measured with the flow meter was 2.5 times greater than the volume of rain that fell in the drainage area, based on the rain gage data.
(3) The total loads utilize the *adjusted* data for Storm F.
(4) Based on number of storms with an average of 94 rain storms with 0.04inches of rainfall or more per year.
(5) Based on multiplication of drainage area times rainfall rate for the respective storm.
(6) Based on measurements at the stormwater drainage pipe with flow monitoring devices.

Figure 5-4

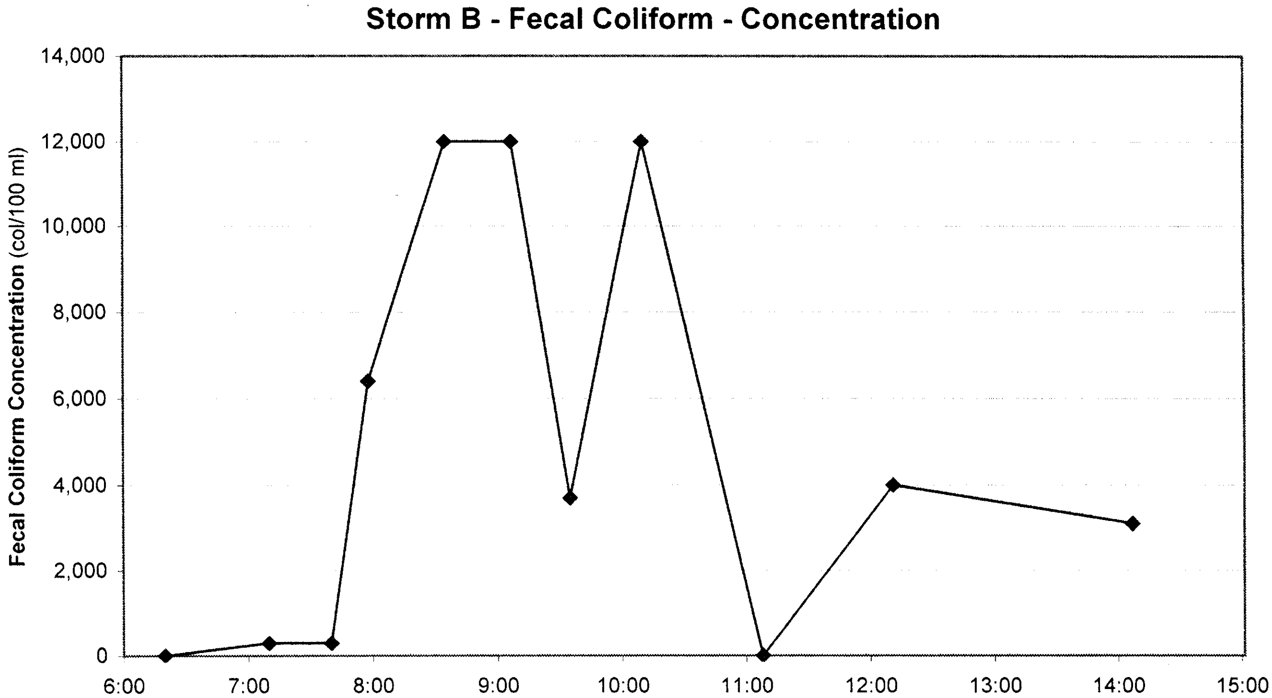


Figure 5-5

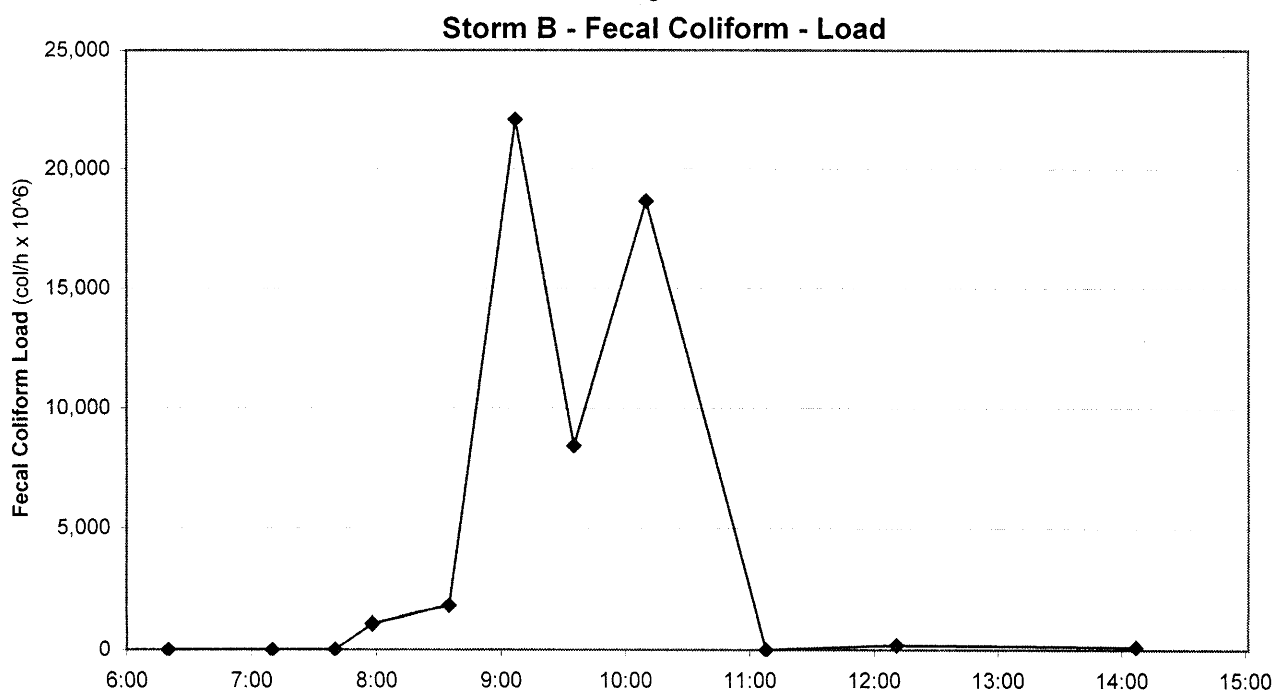


Figure 5-6

Storm D - Fecal Coliform - Concentration

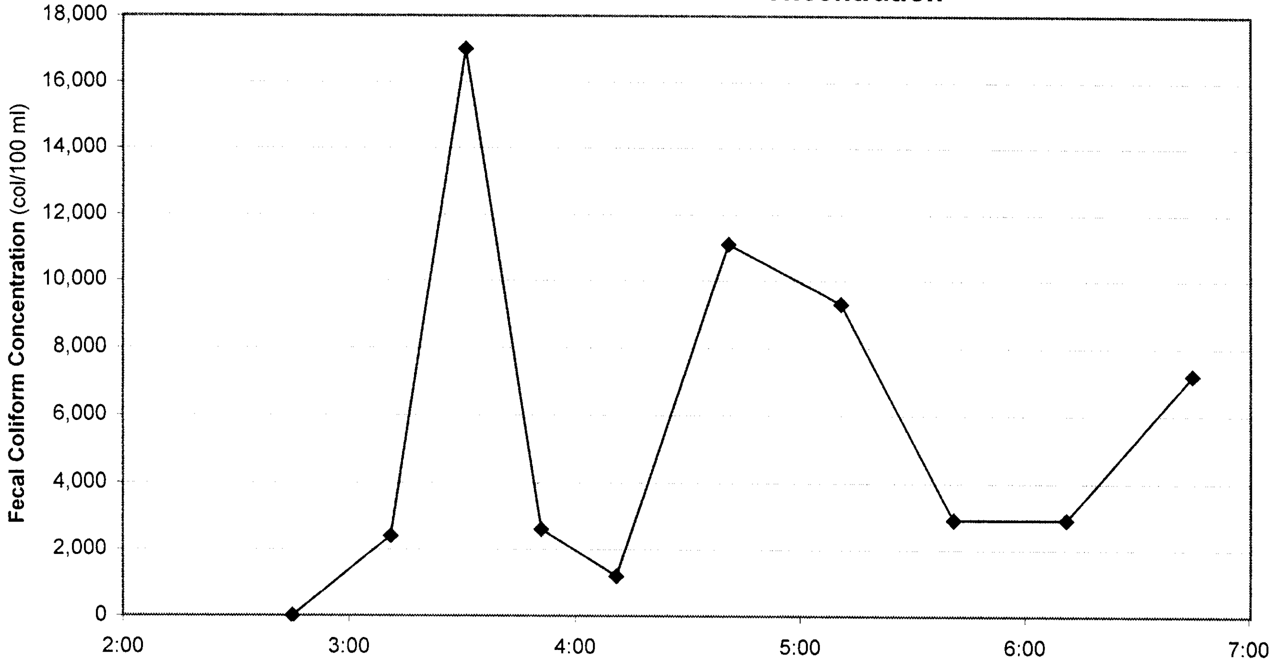


Figure 5-7

Storm D - Fecal Coliform - Load

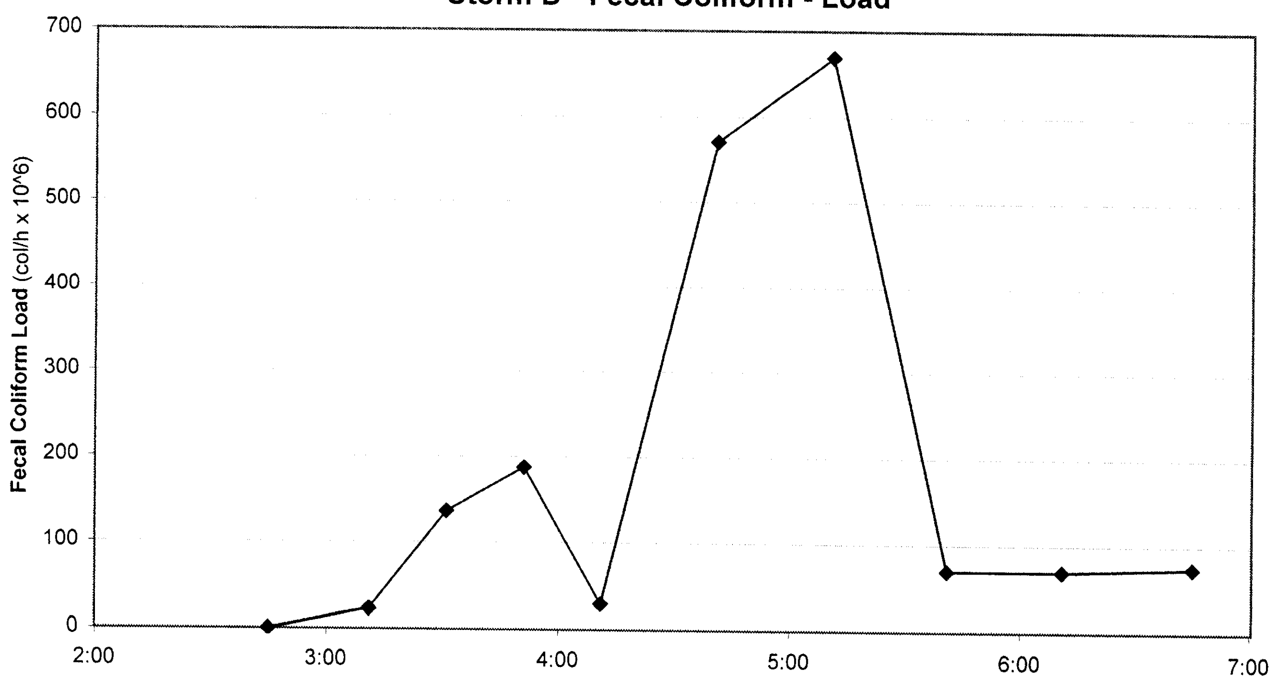


Figure 5-8

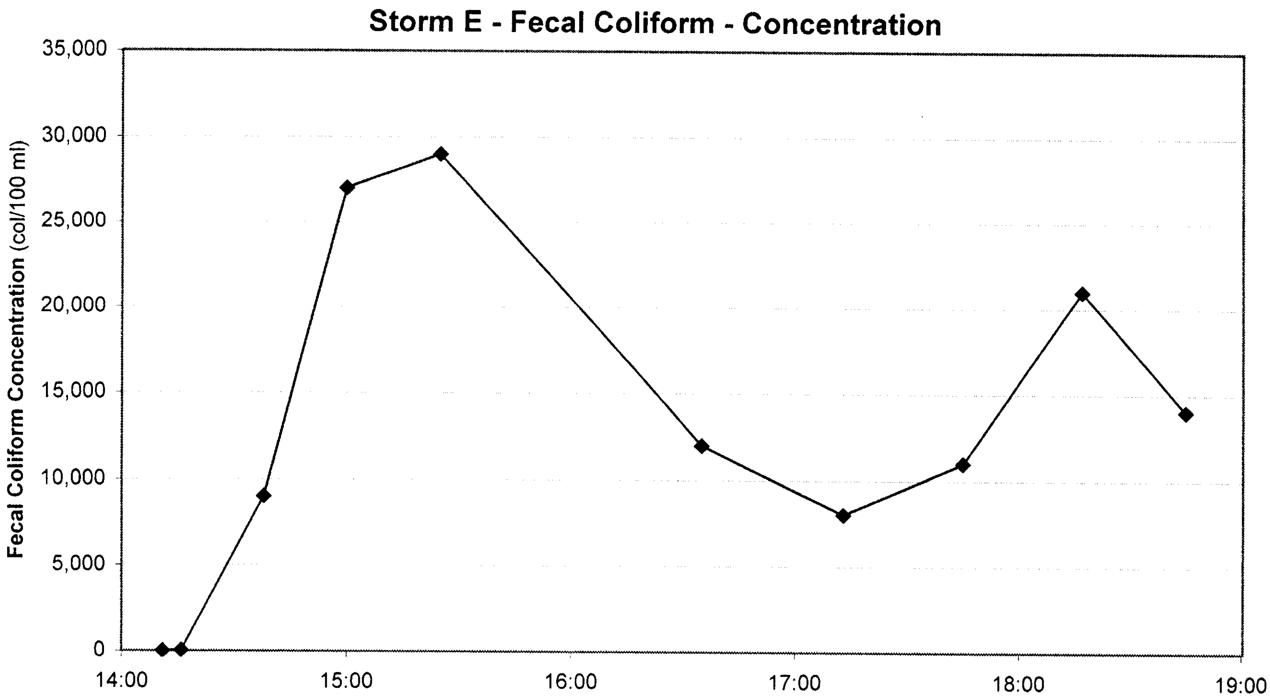


Figure 5-9

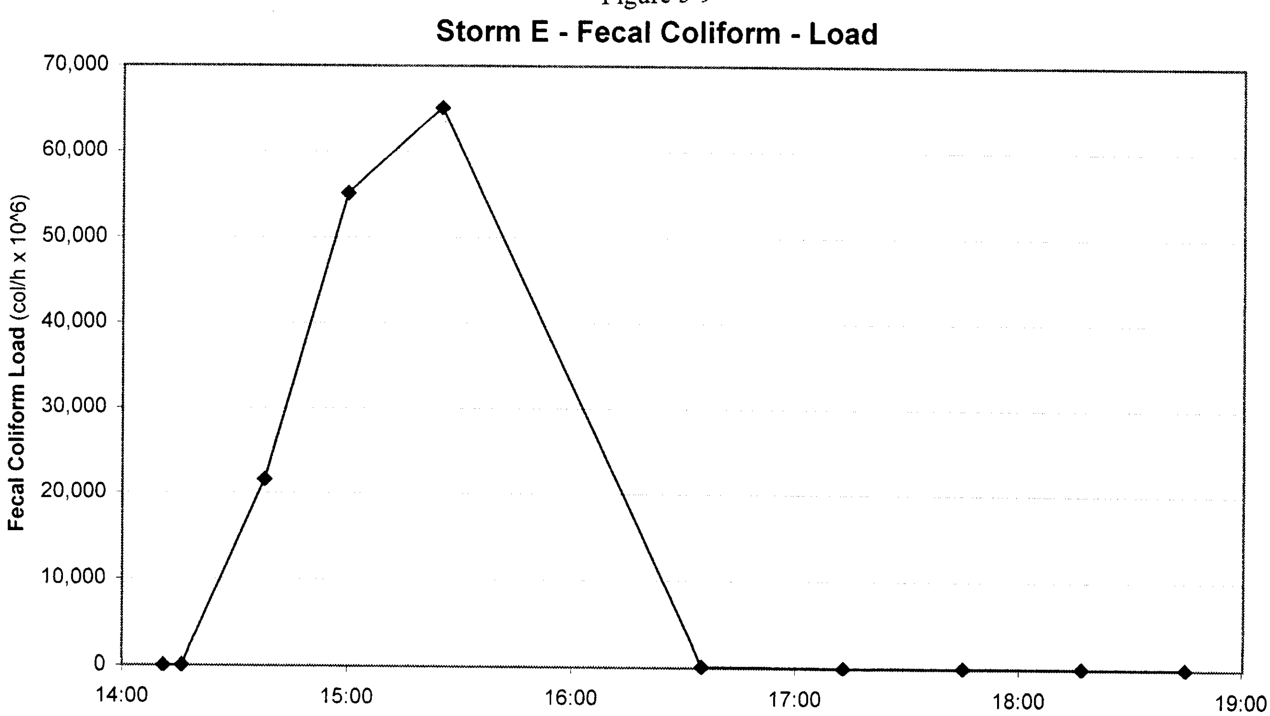


Figure 5-10

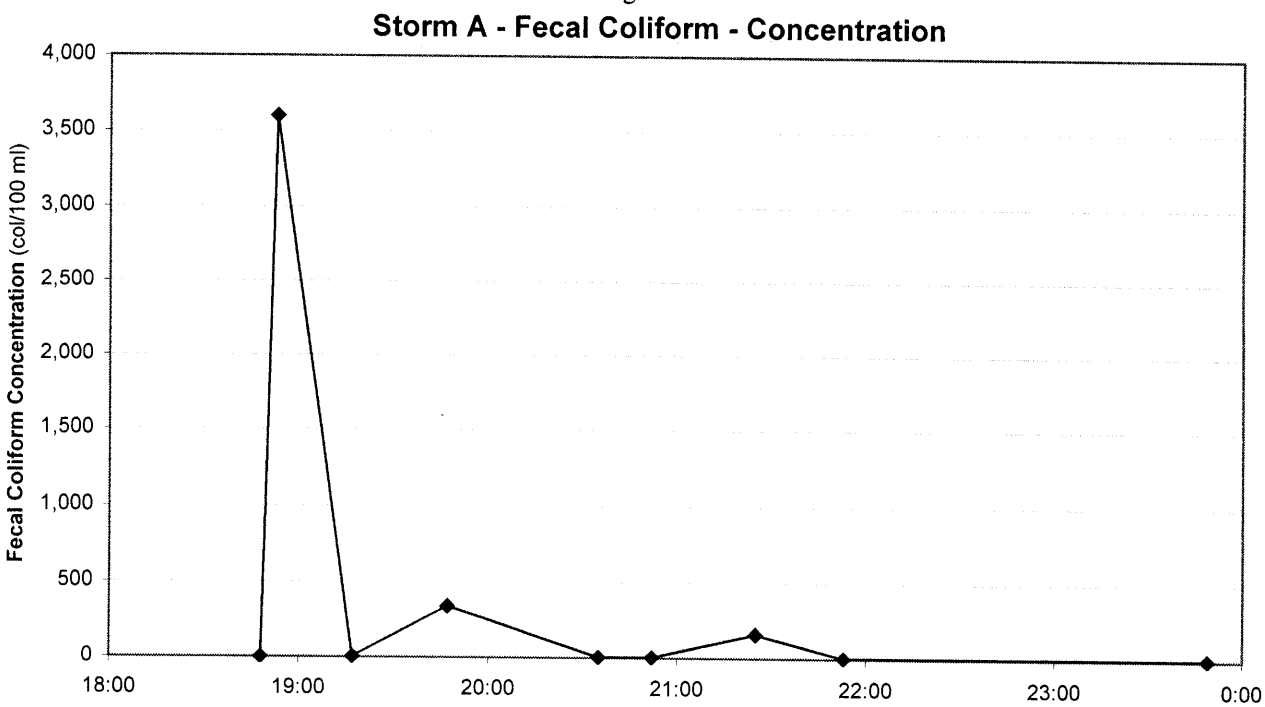


Figure 5-11

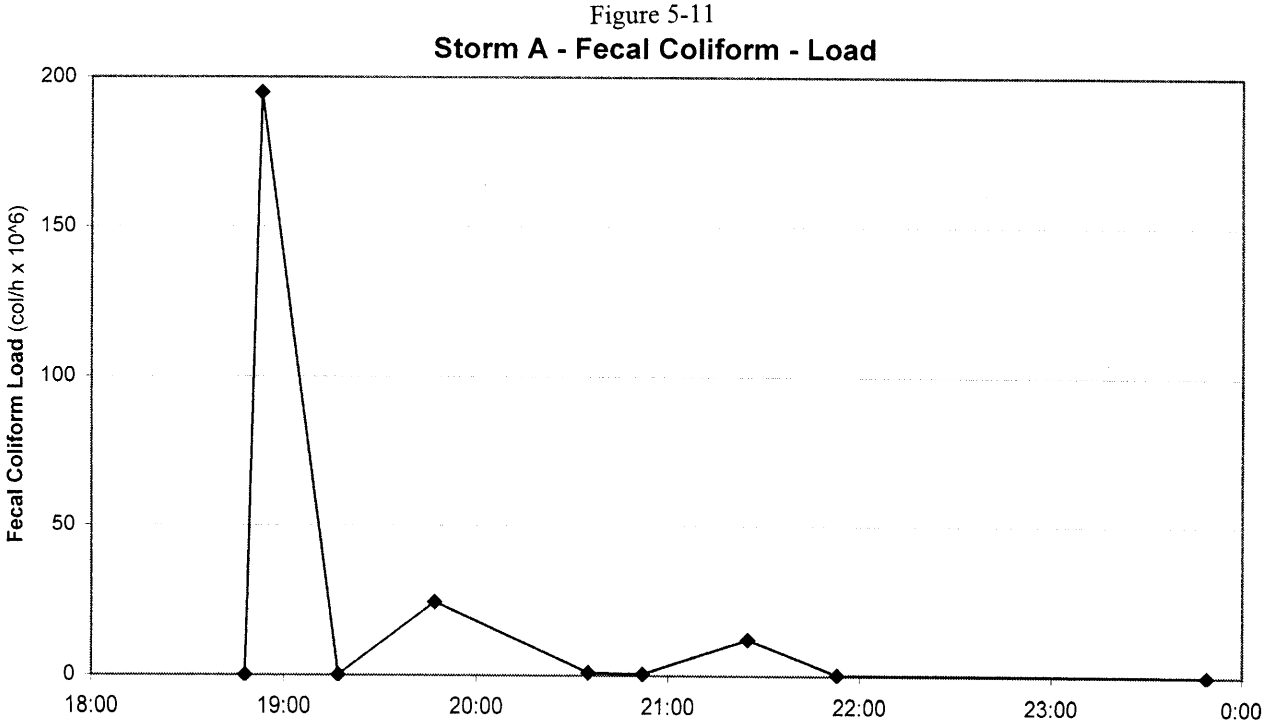


Figure 5-12

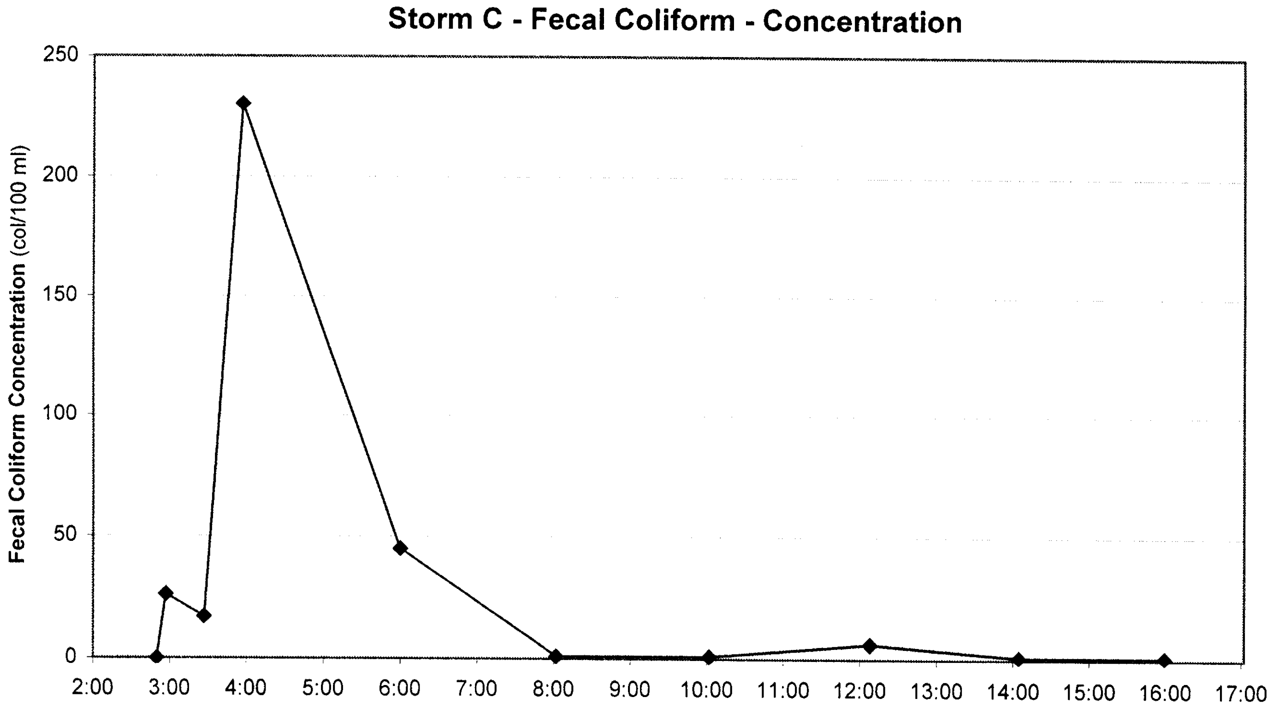


Figure 5-13

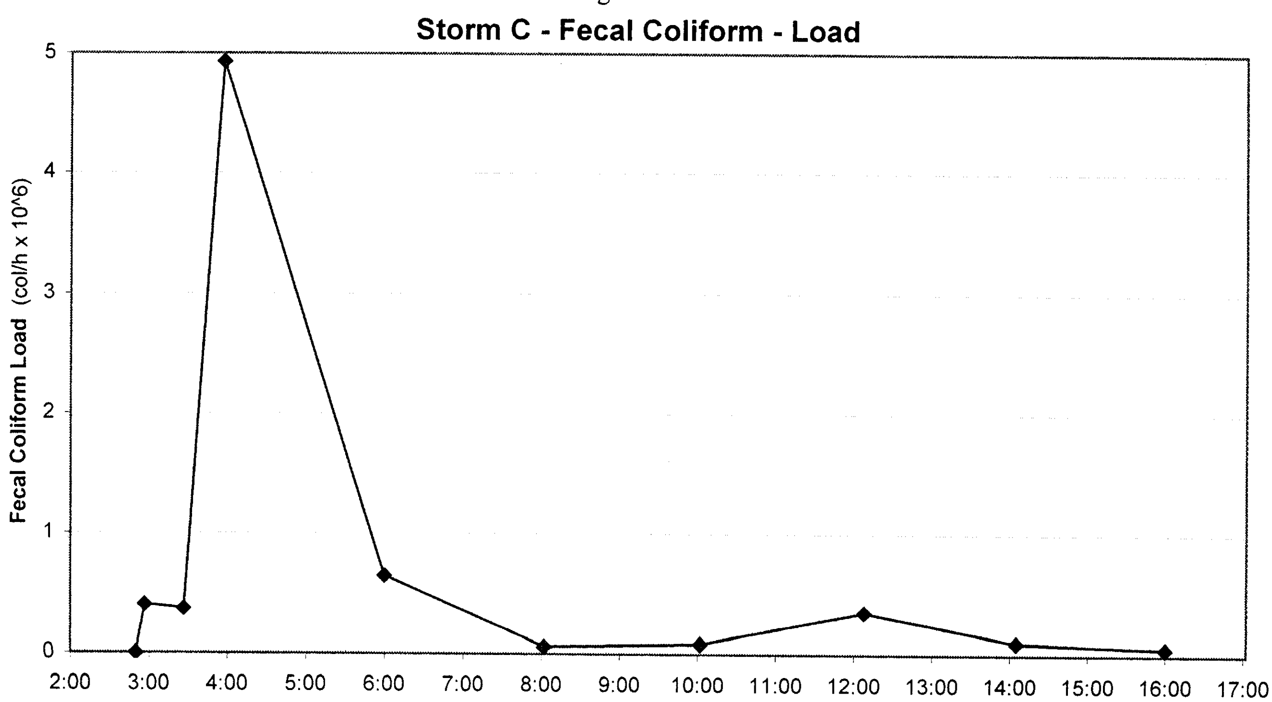


Figure 5-14

Storm F - Fecal Coliform - Concentration

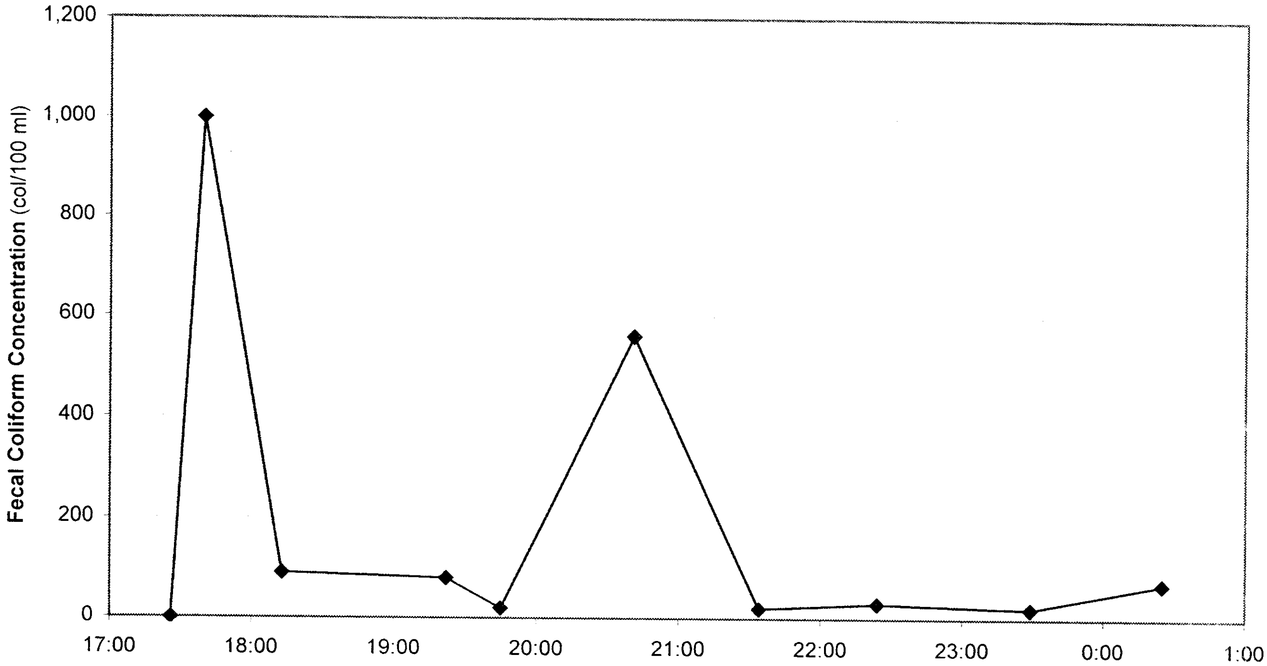


Figure 5-15

Storm F - Fecal Coliform - Load

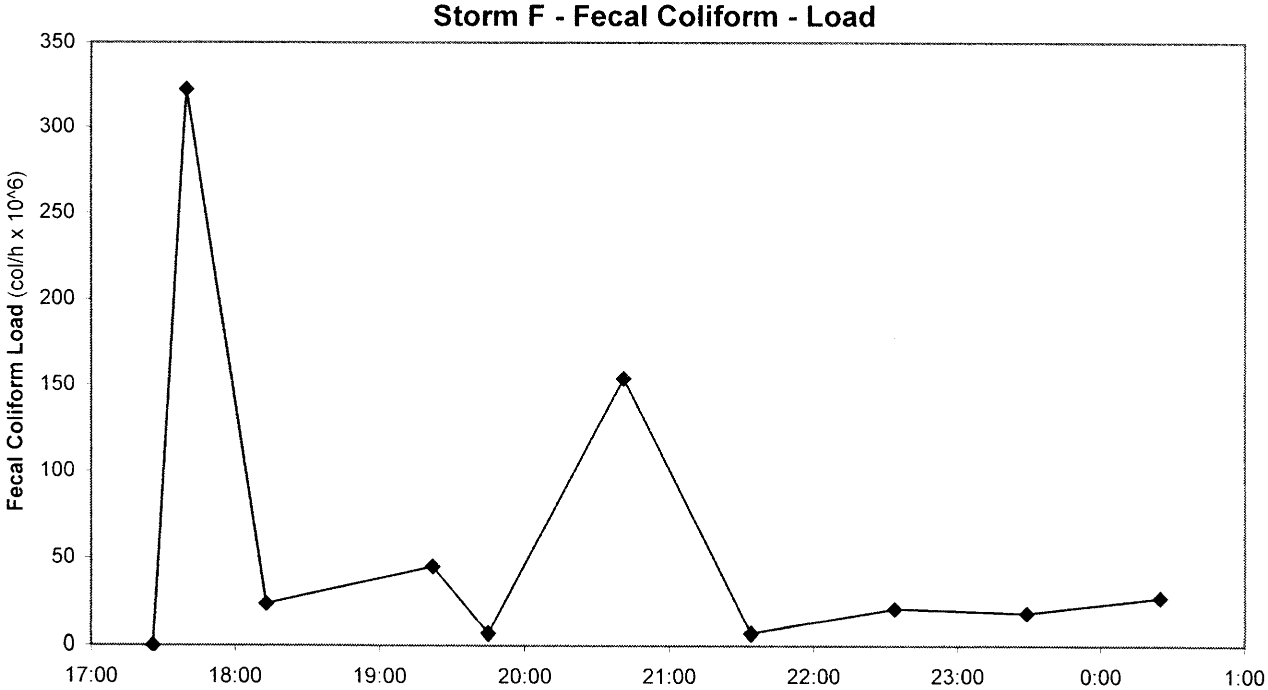


Figure 5-16

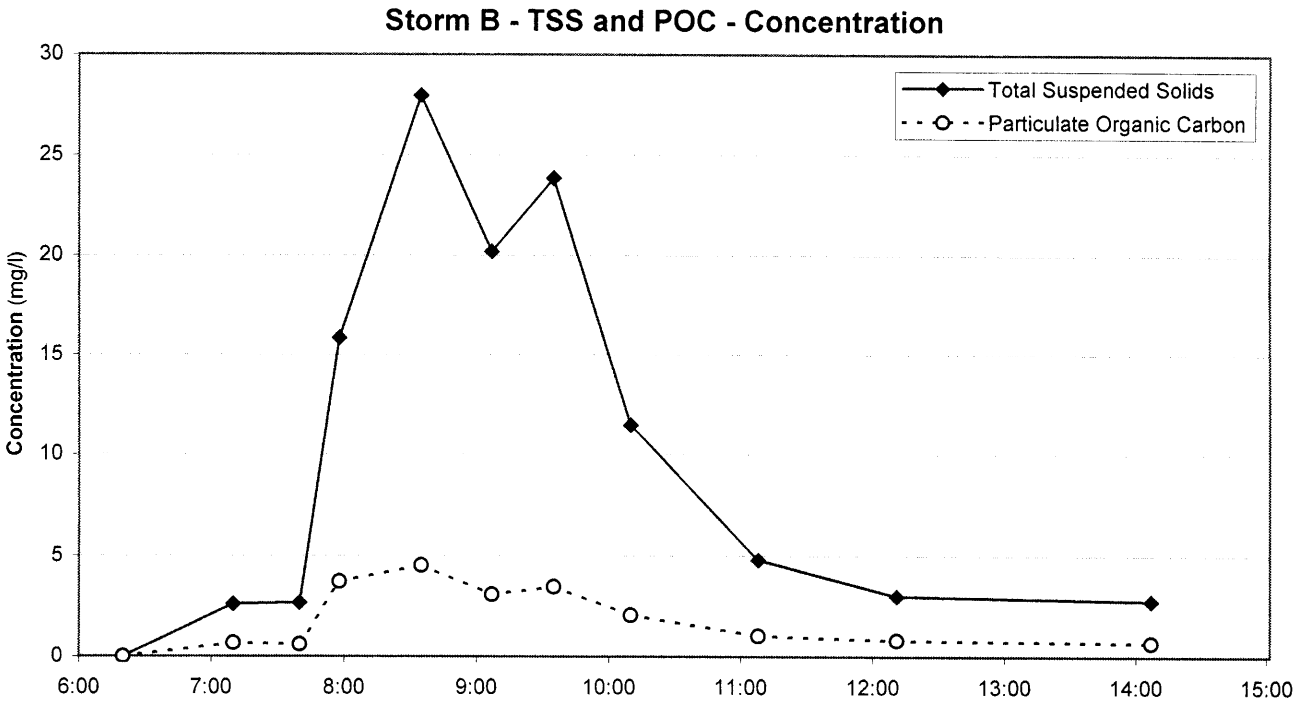


Figure 5-17

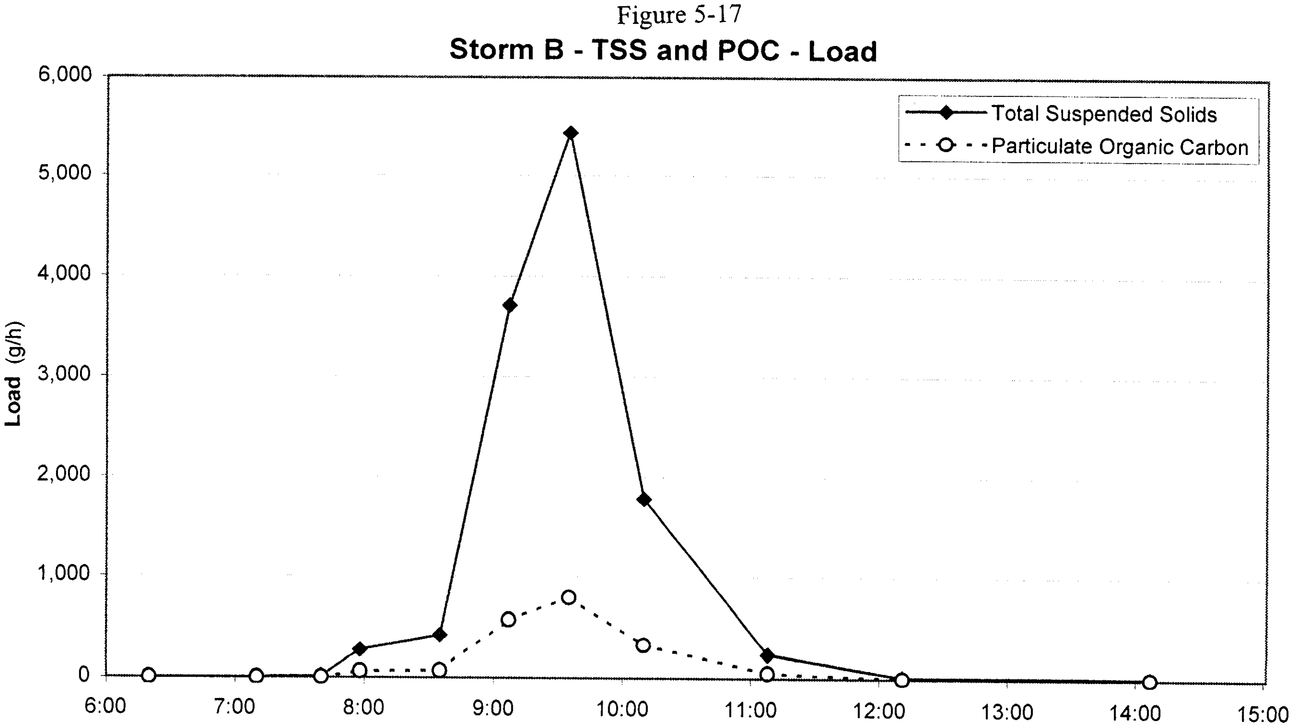


Figure 5-18

Storm D - TSS and POC - Concentration

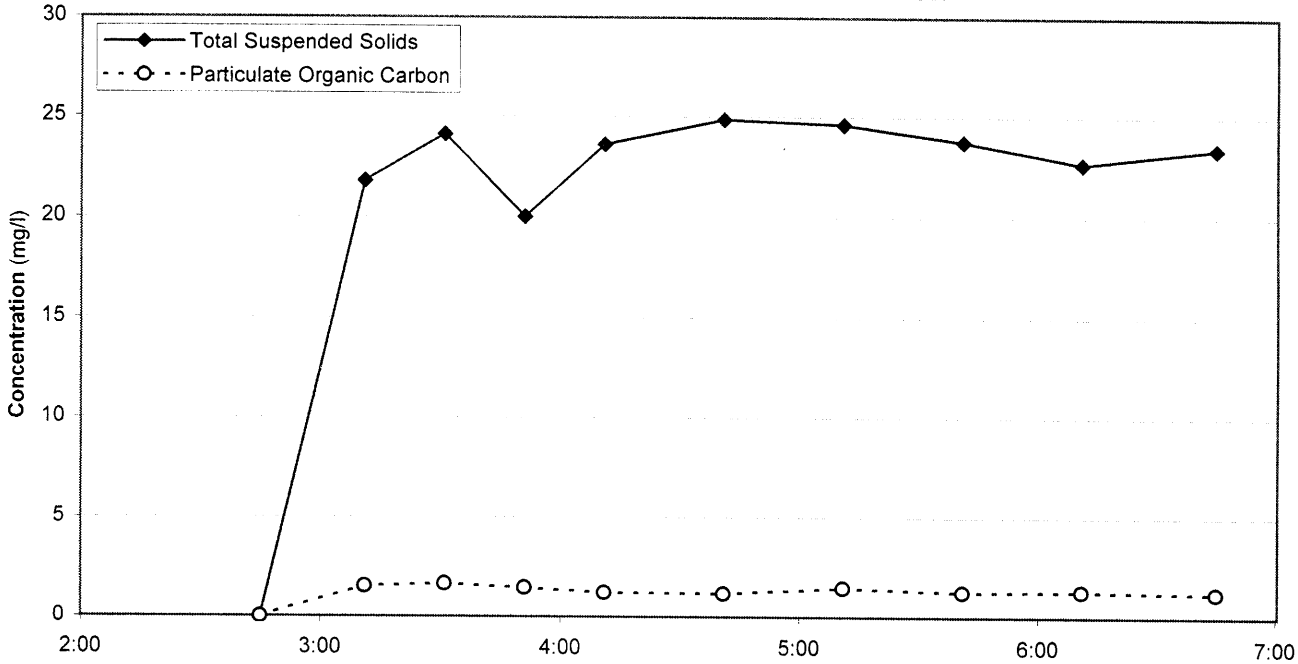


Figure 5-19

Storm D - TSS and POC - Load

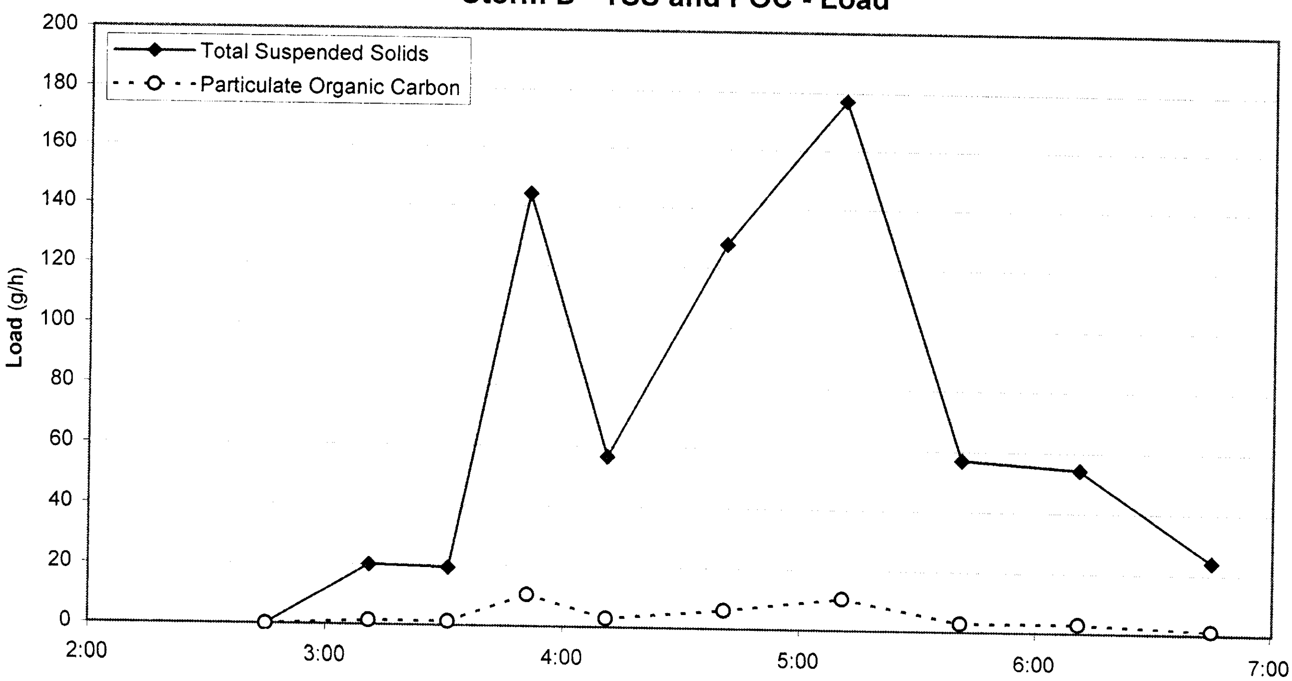


Figure 5-20

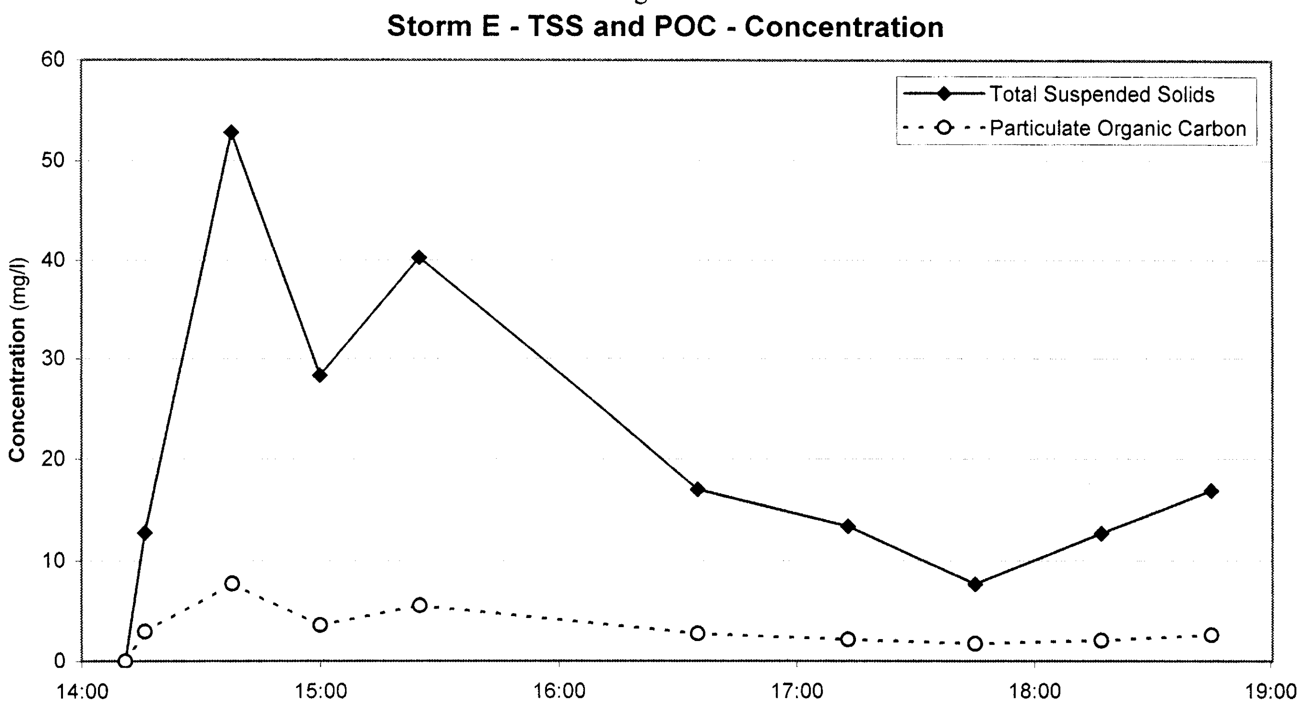


Figure 5-21

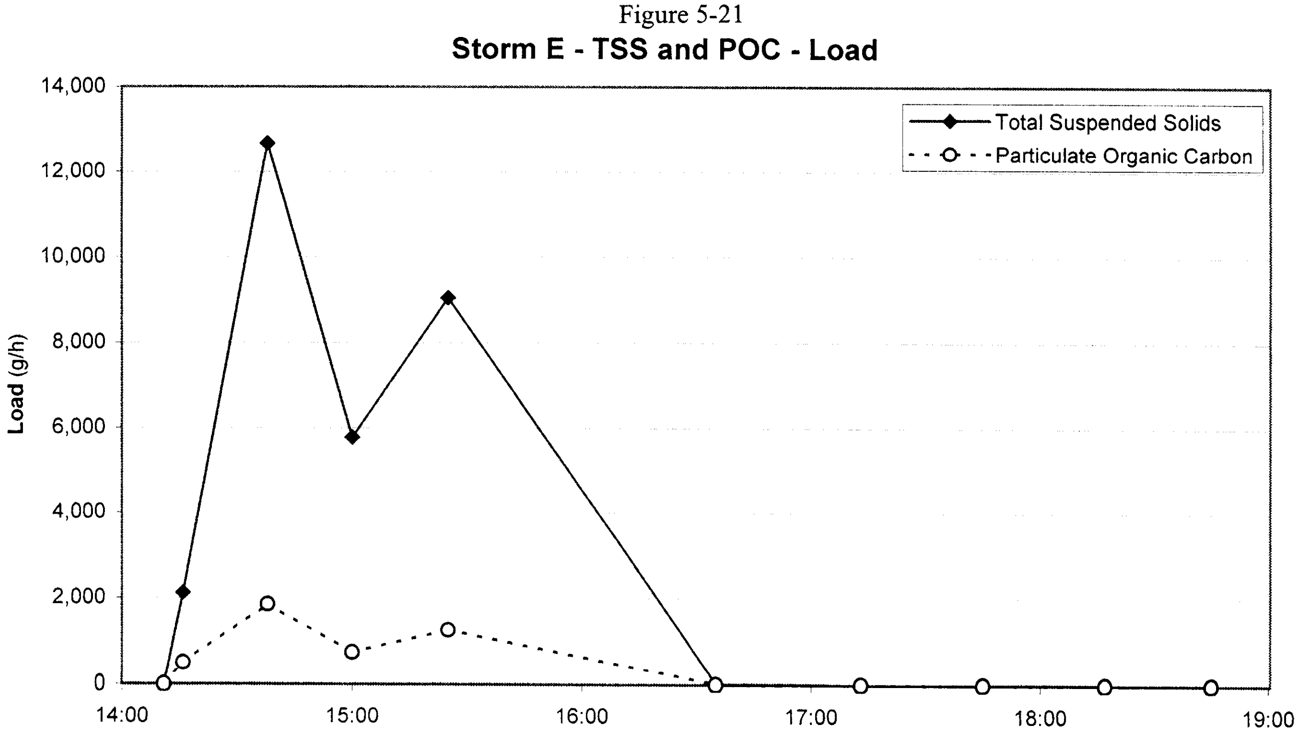


Figure 5-22

Storm A - TSS and POC - Concentration

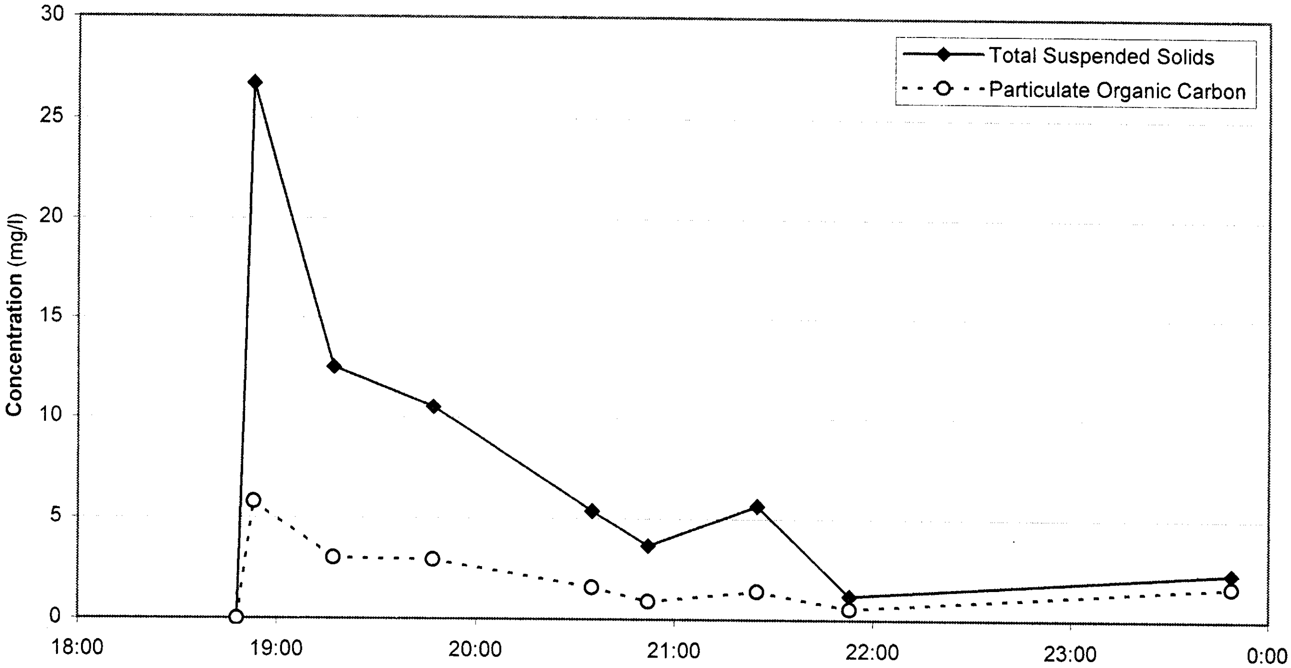


Figure 5-23

Storm A - TSS and POC - Load

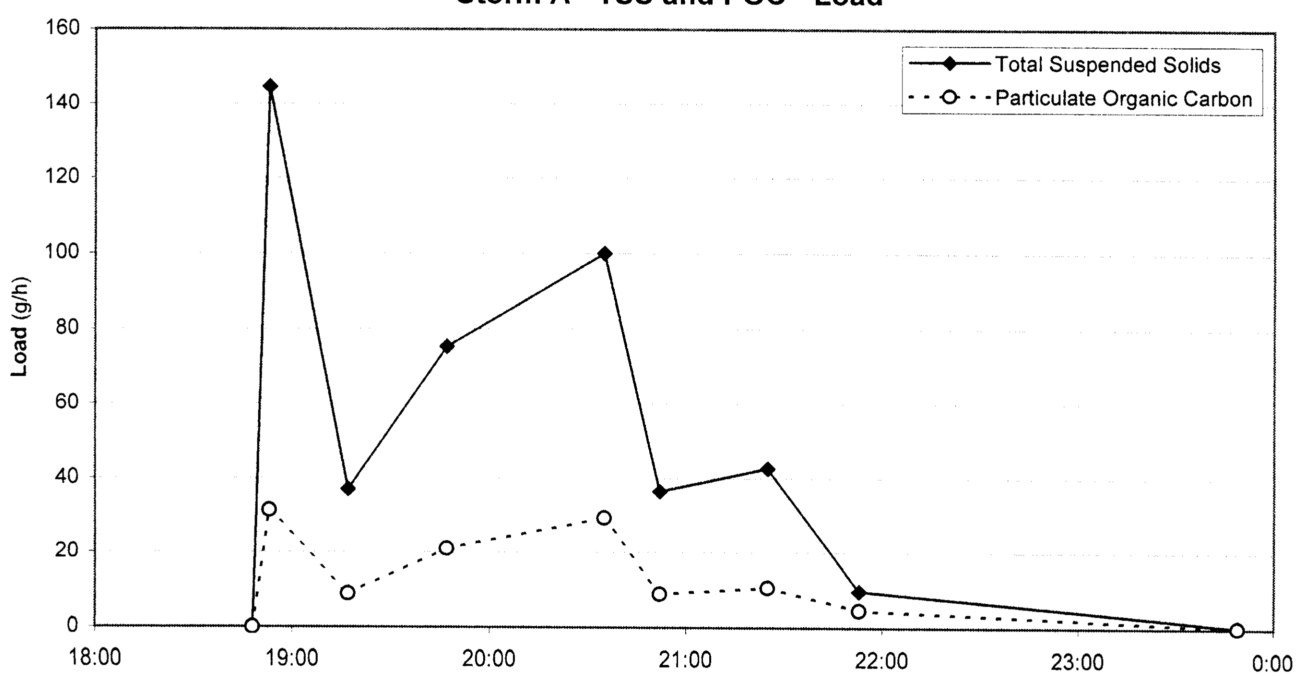


Figure 5-24

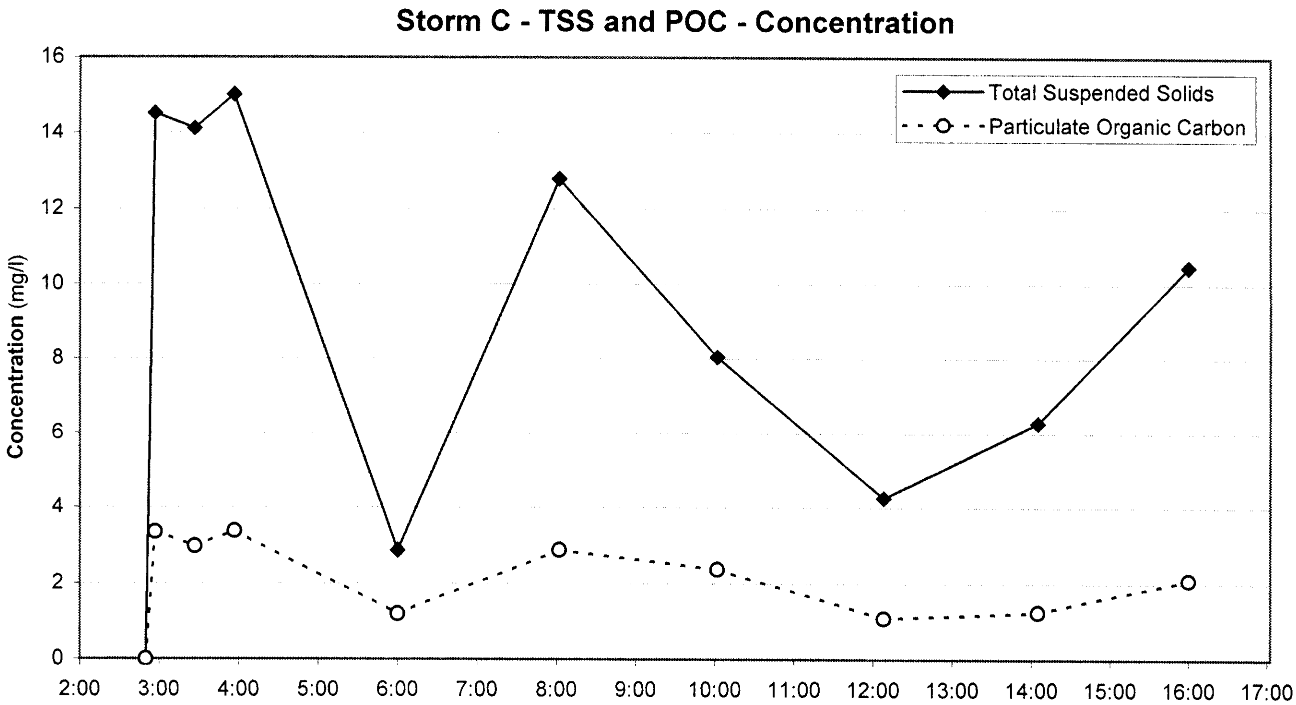


Figure 5-25

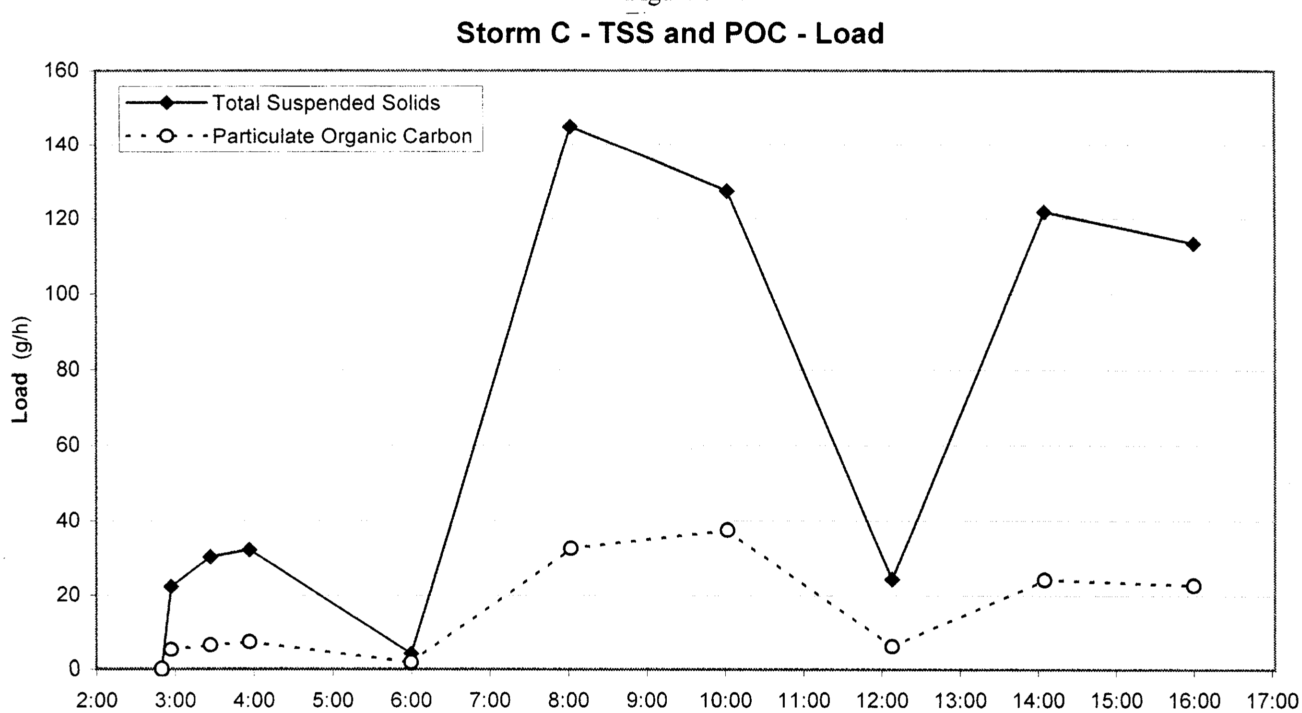


Figure 5-26

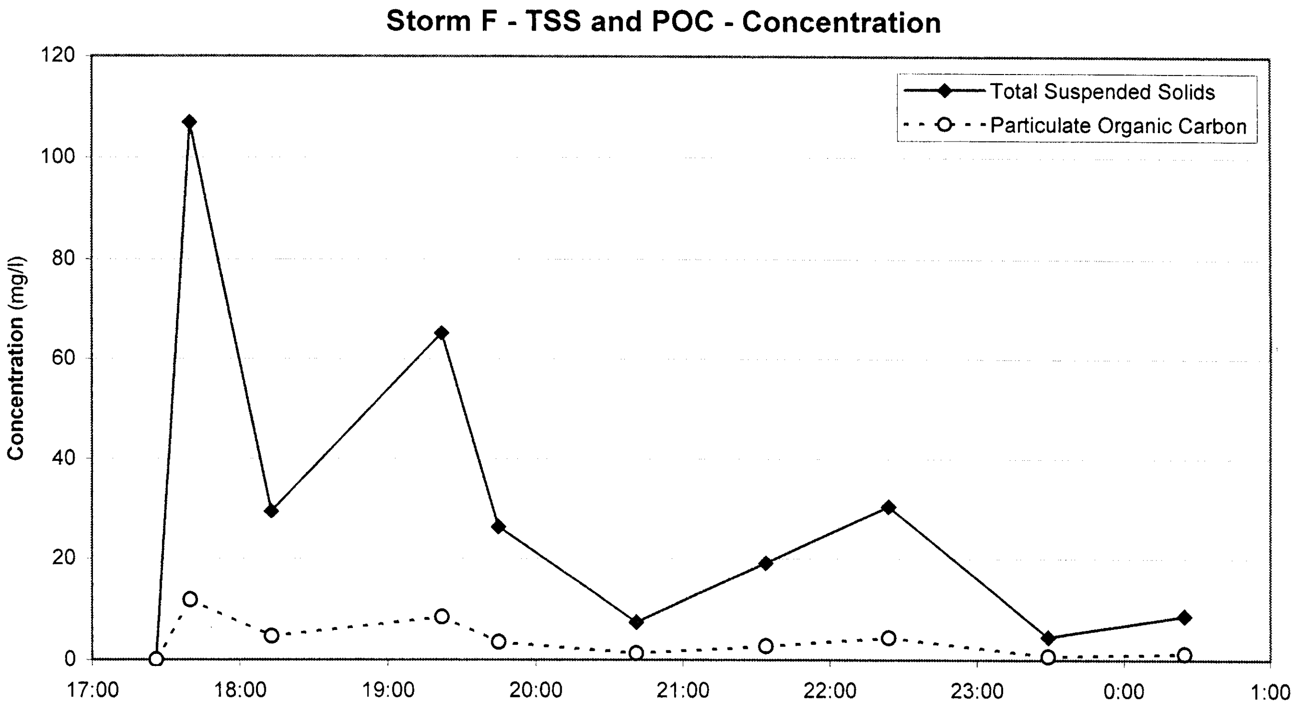


Figure 5-27

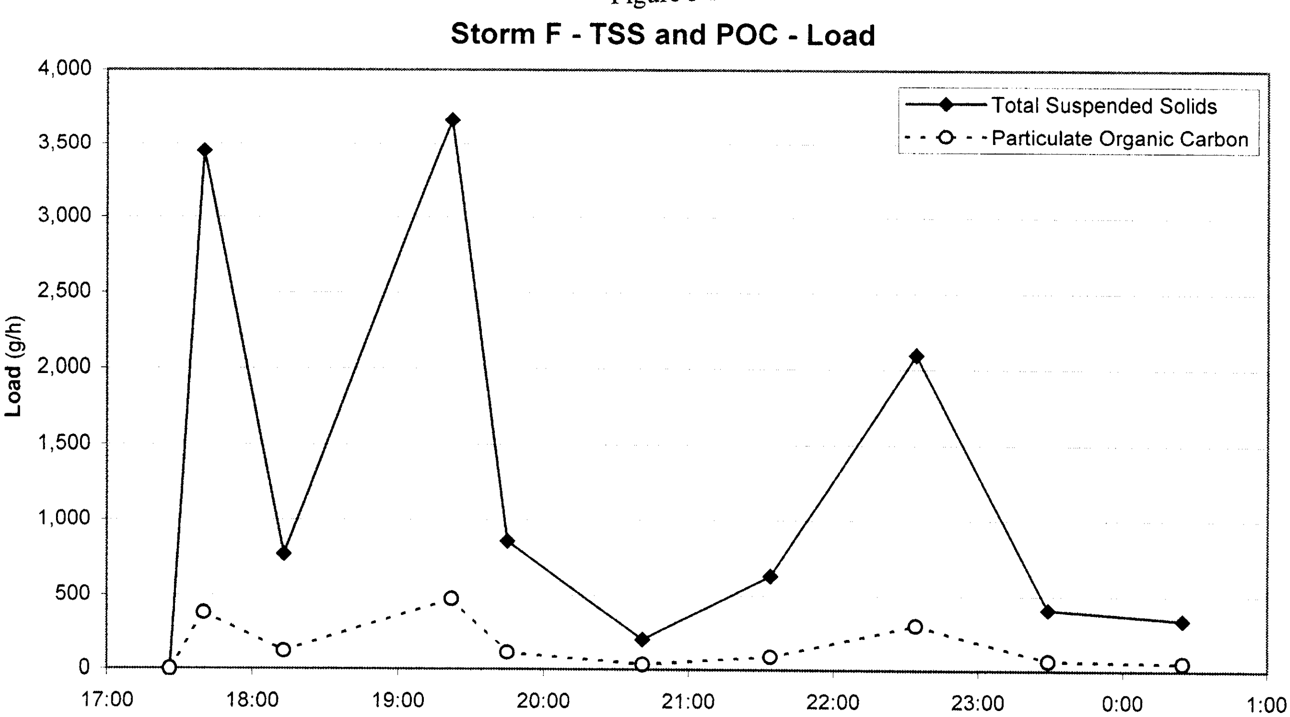


Figure 5-28

Storm B - Phosphorus - Concentration

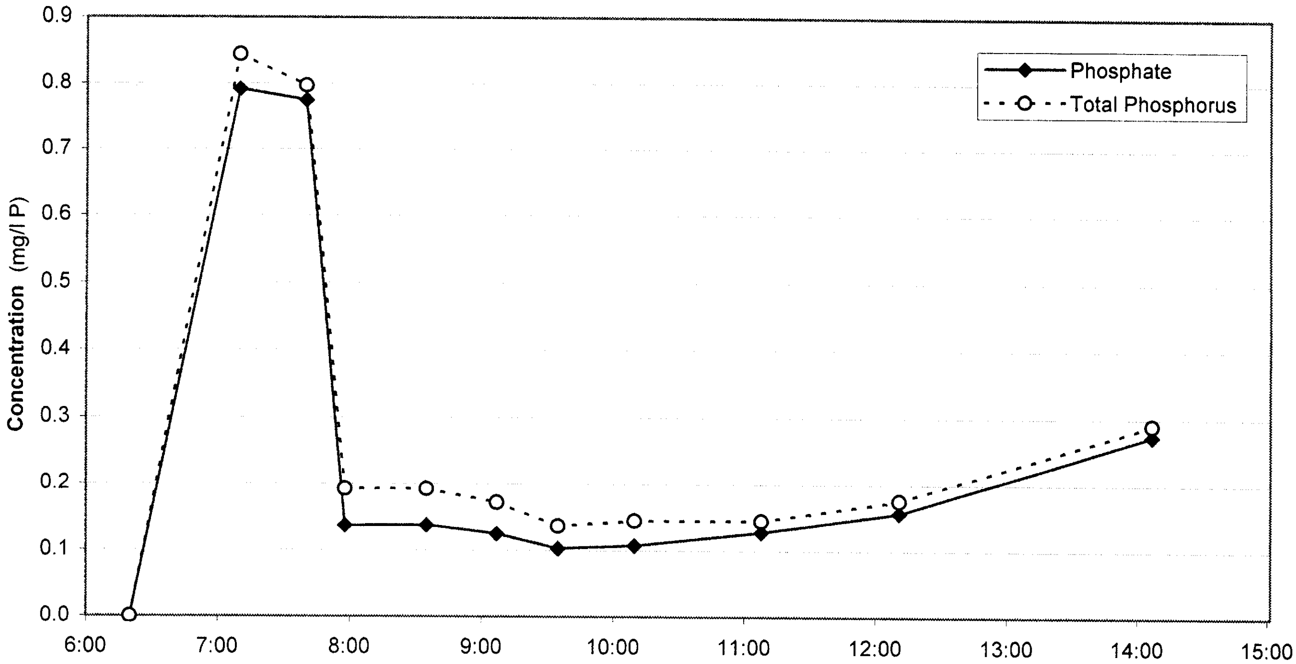


Figure 5-29

Storm B - Phosphorus - Load

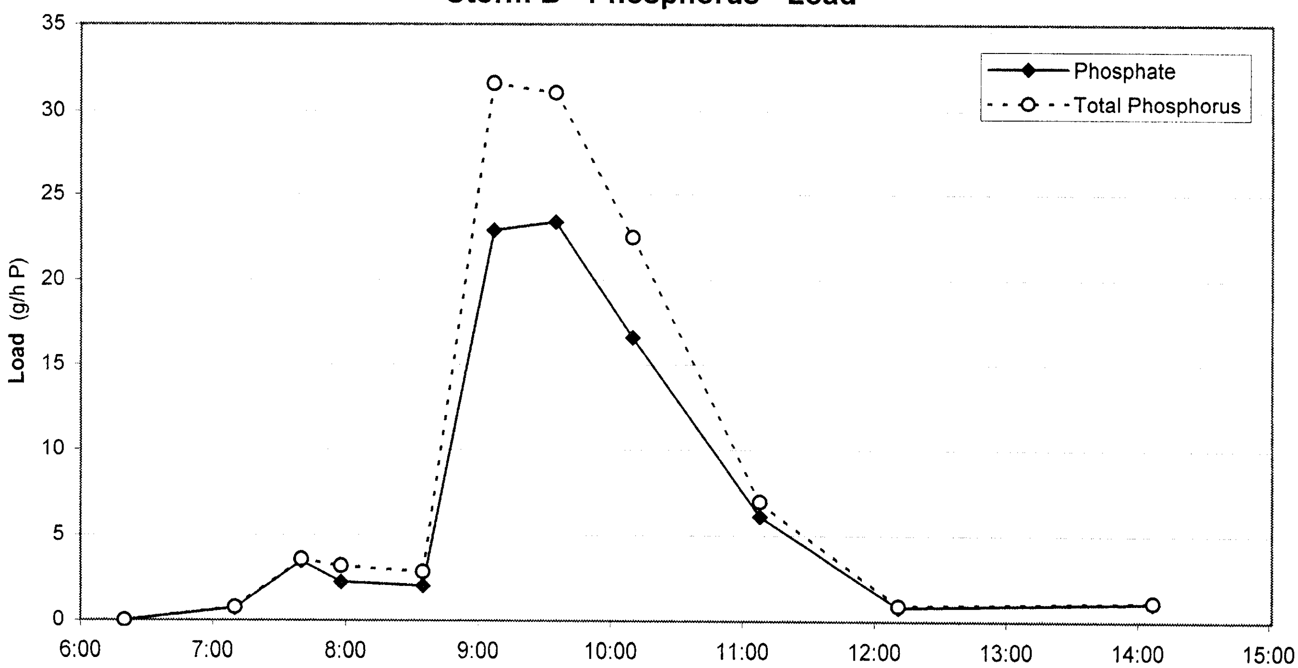


Figure 5-30

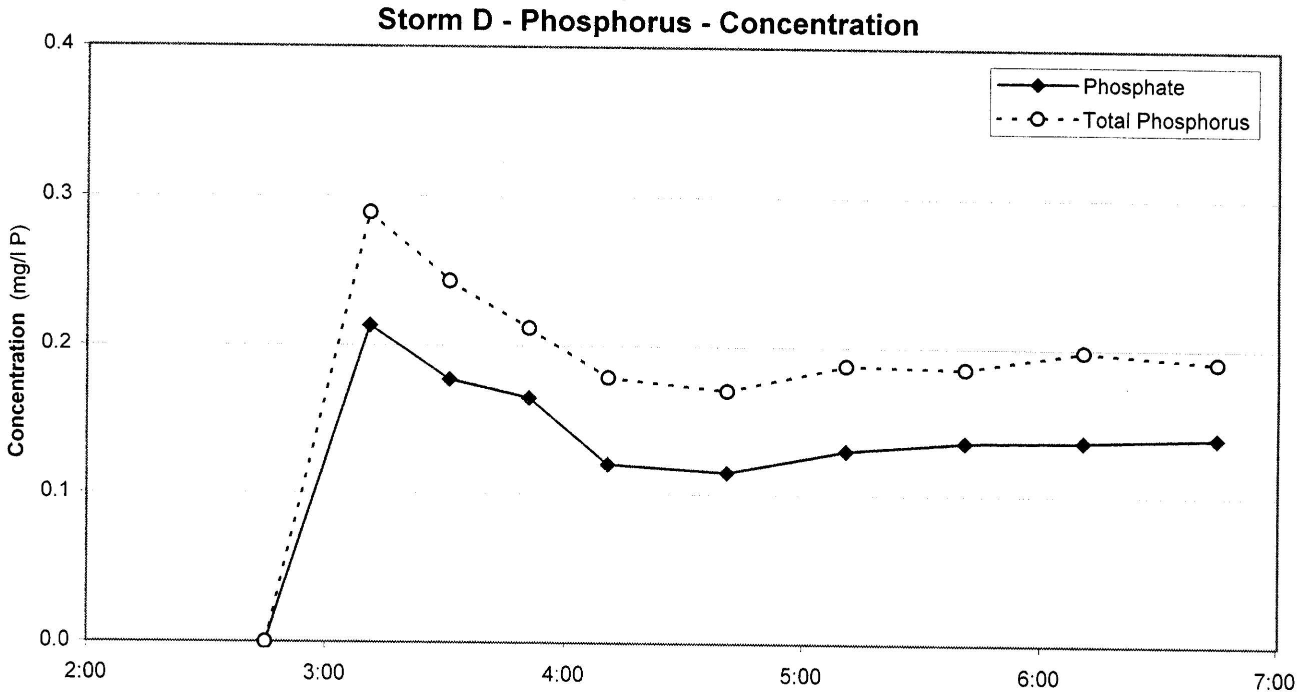


Figure 5-31

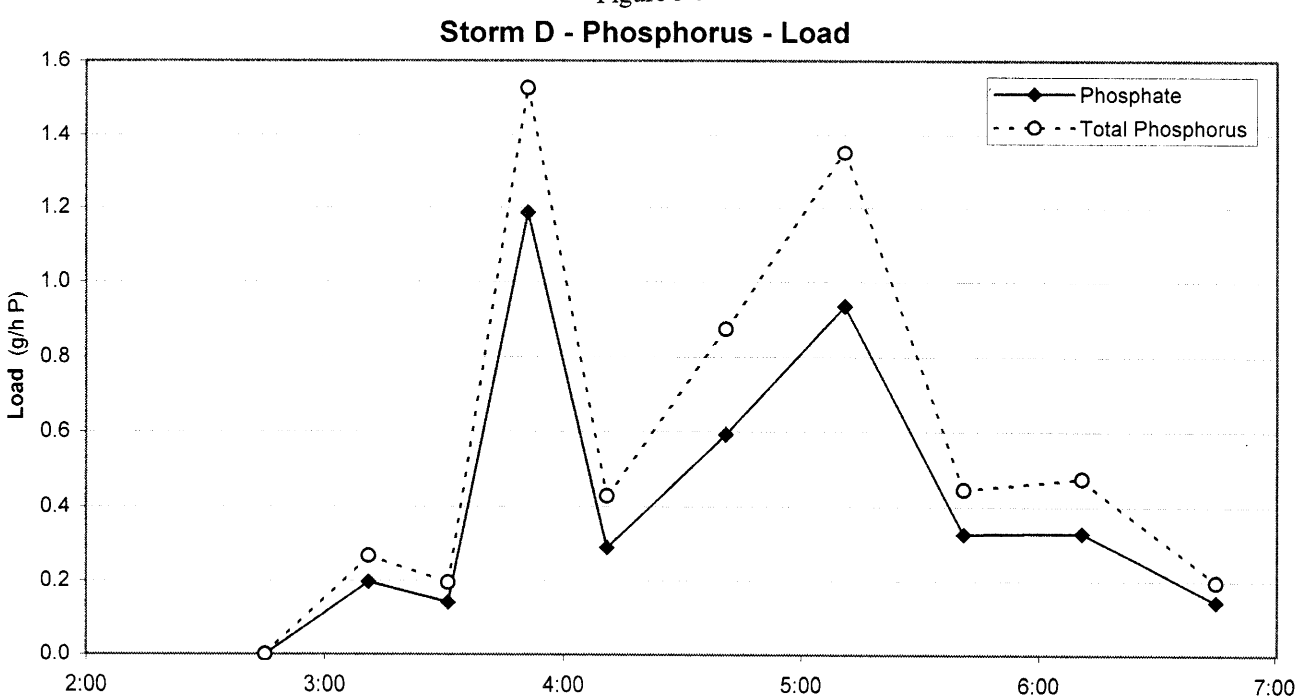


Figure 5-32

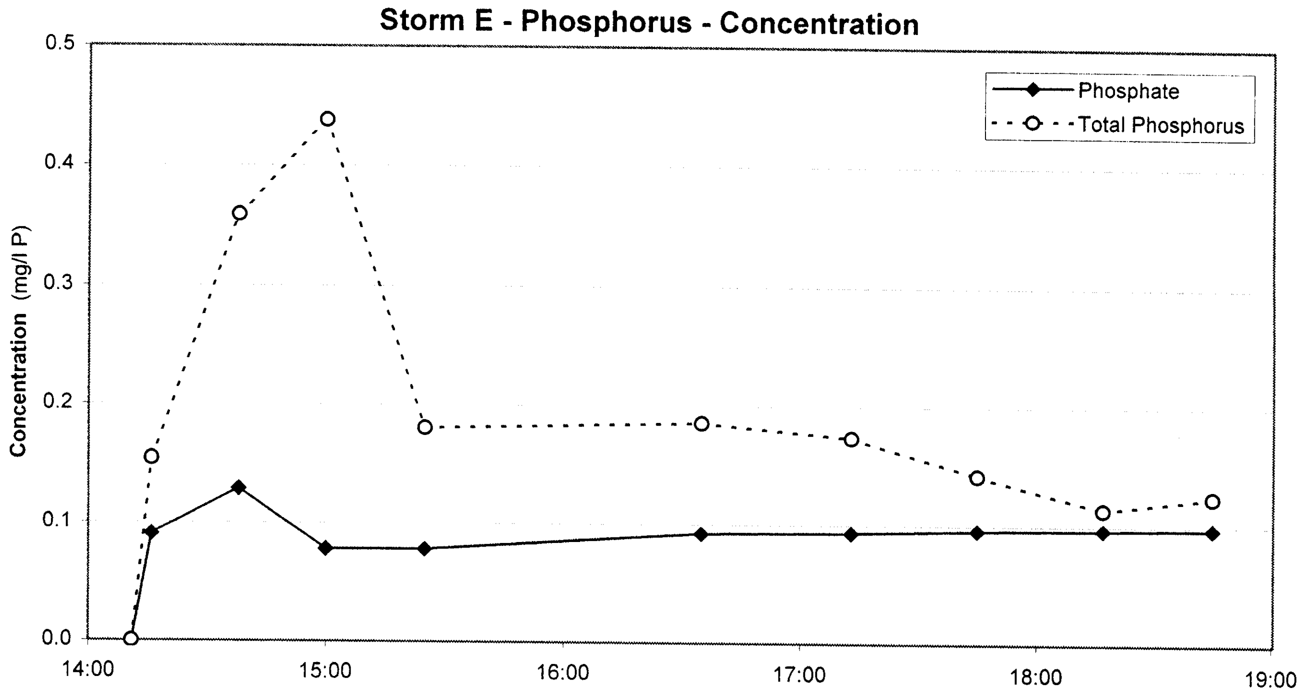


Figure 5-33

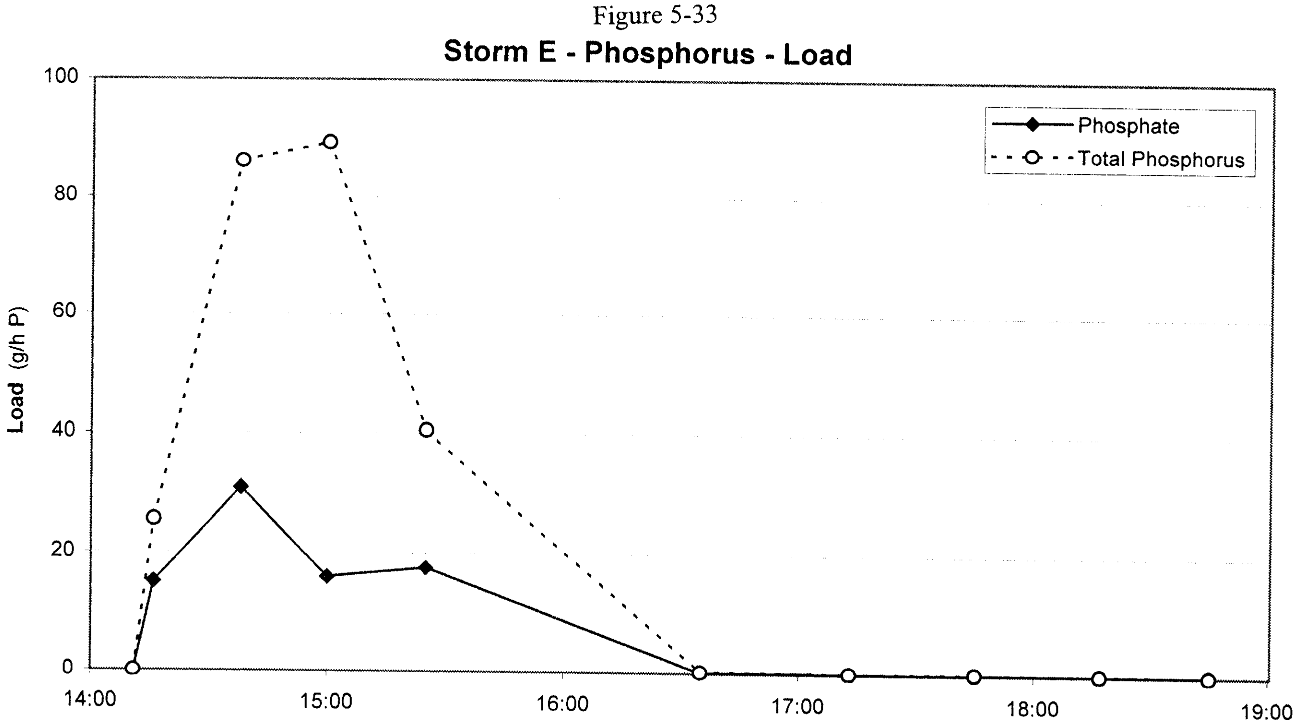


Figure 5-34

Storm A - Phosphorus - Concentration

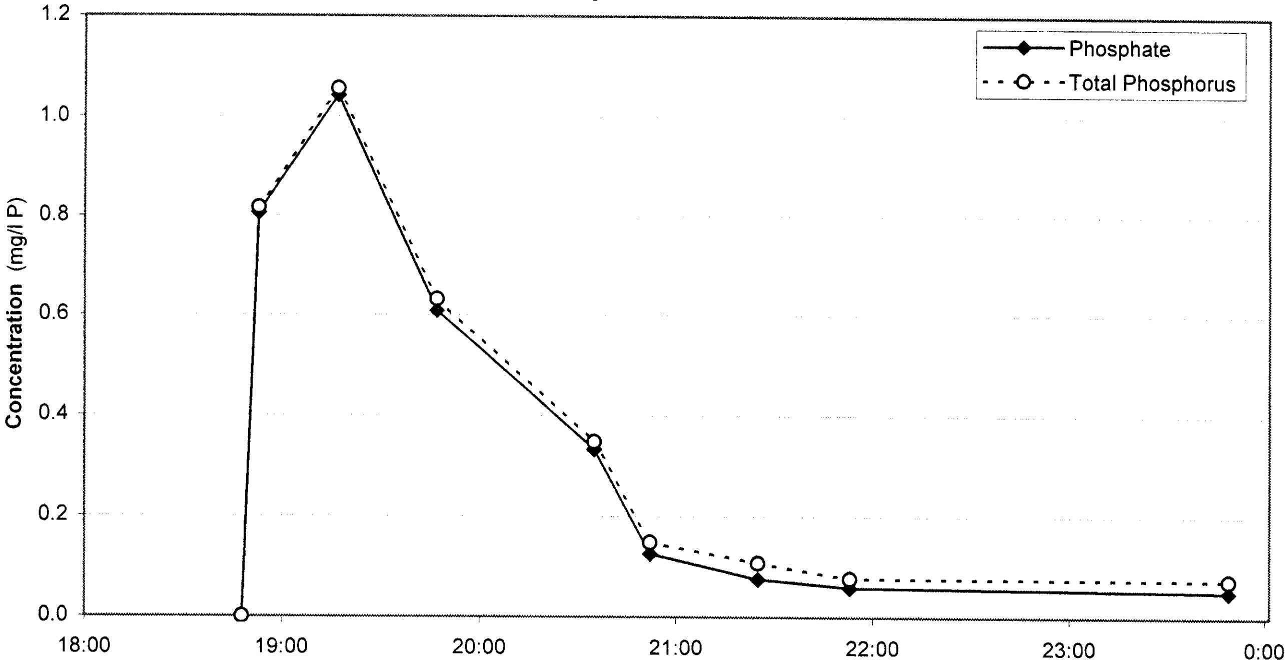


Figure 5-35

Storm A - Phosphorus - Load

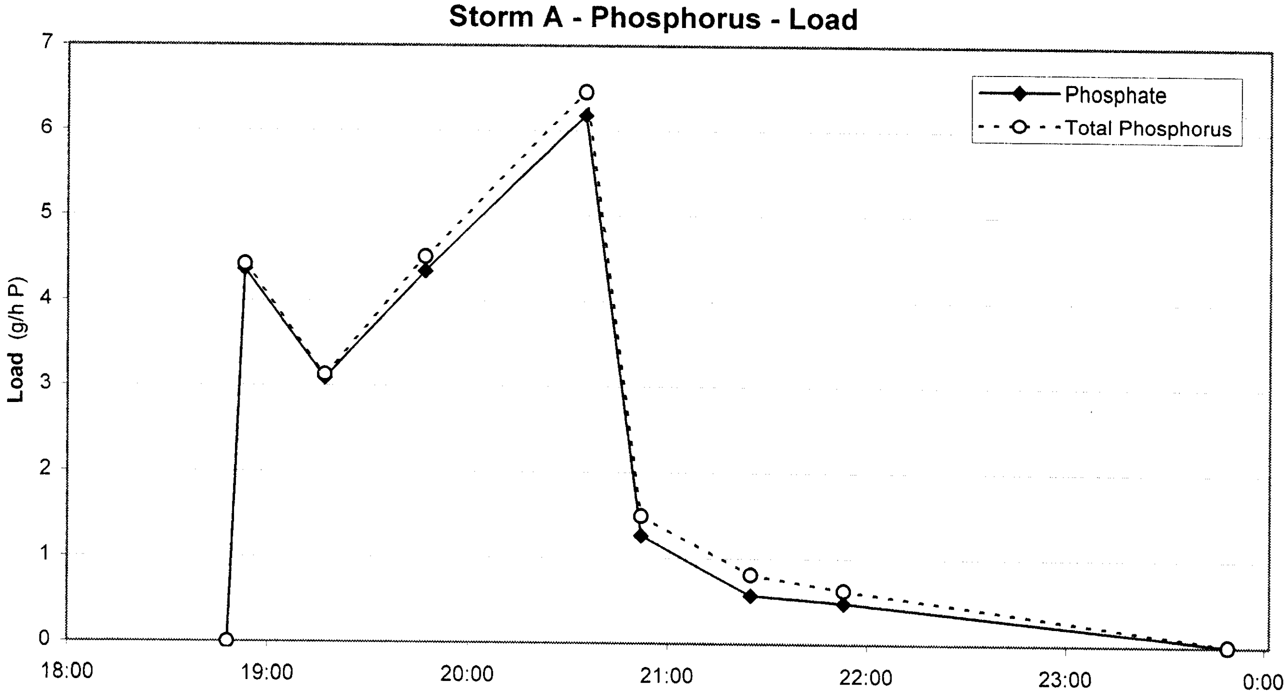


Figure 5-36

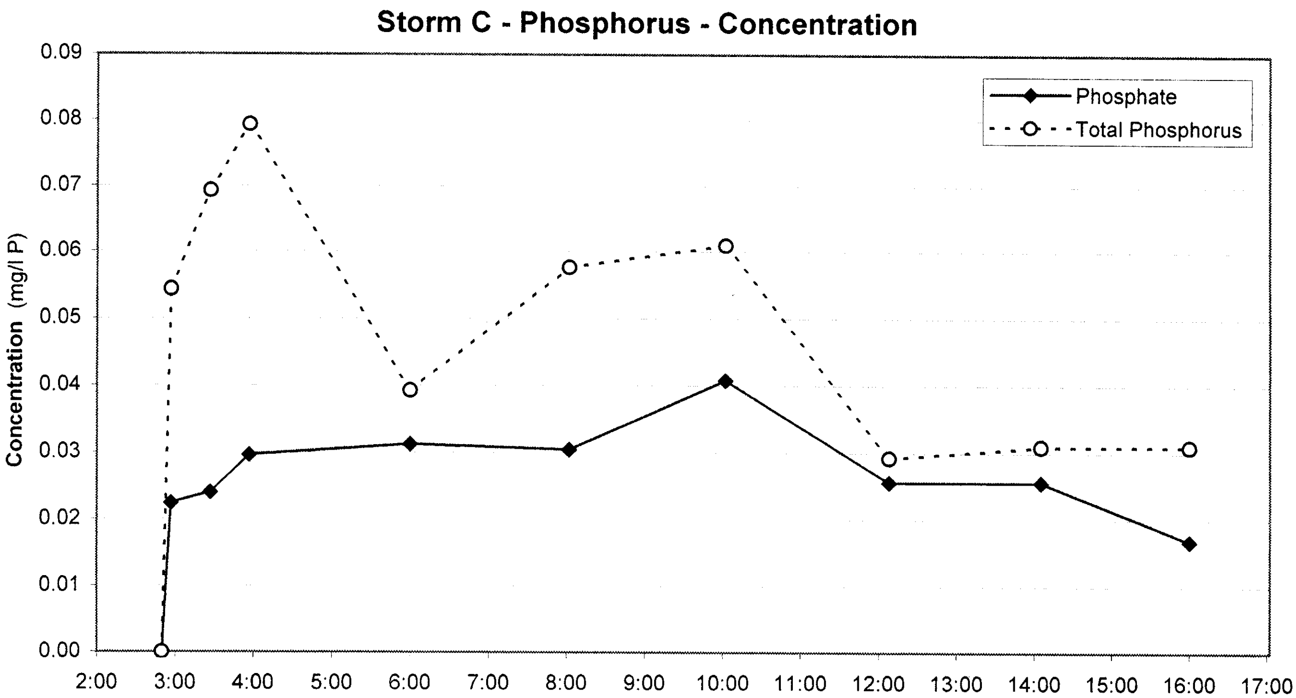


Figure 5-37

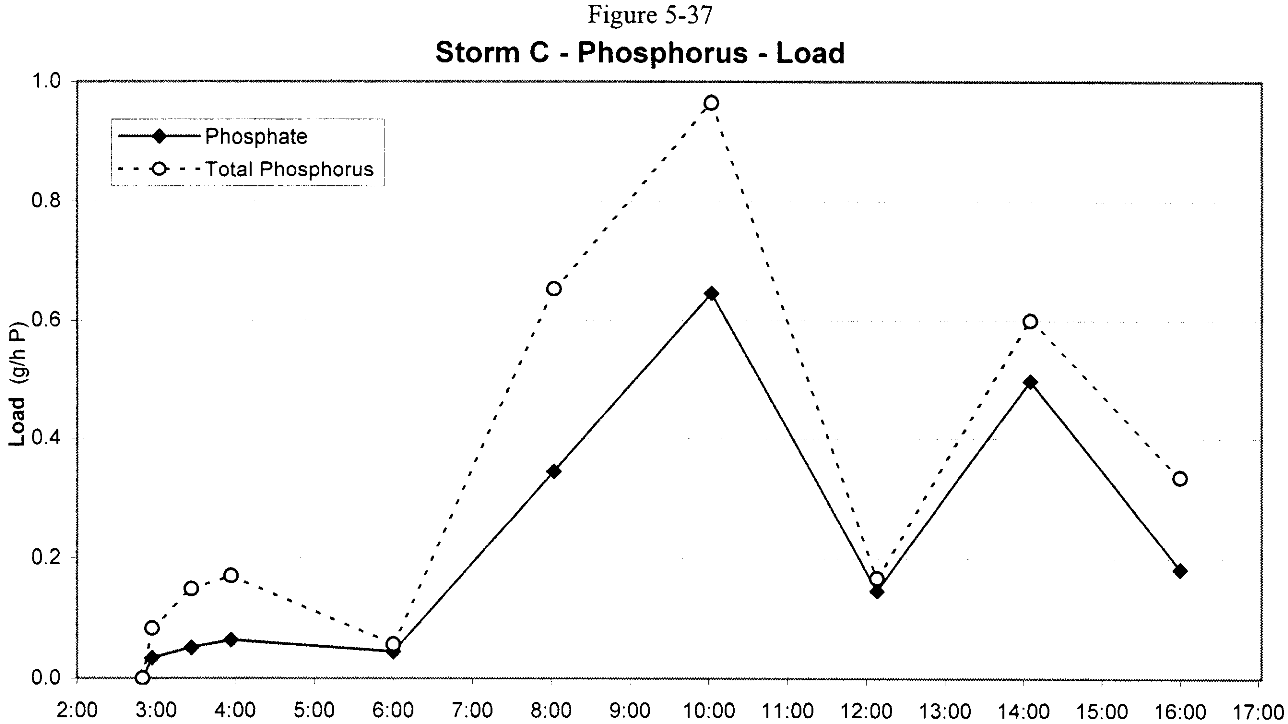


Figure 5-38

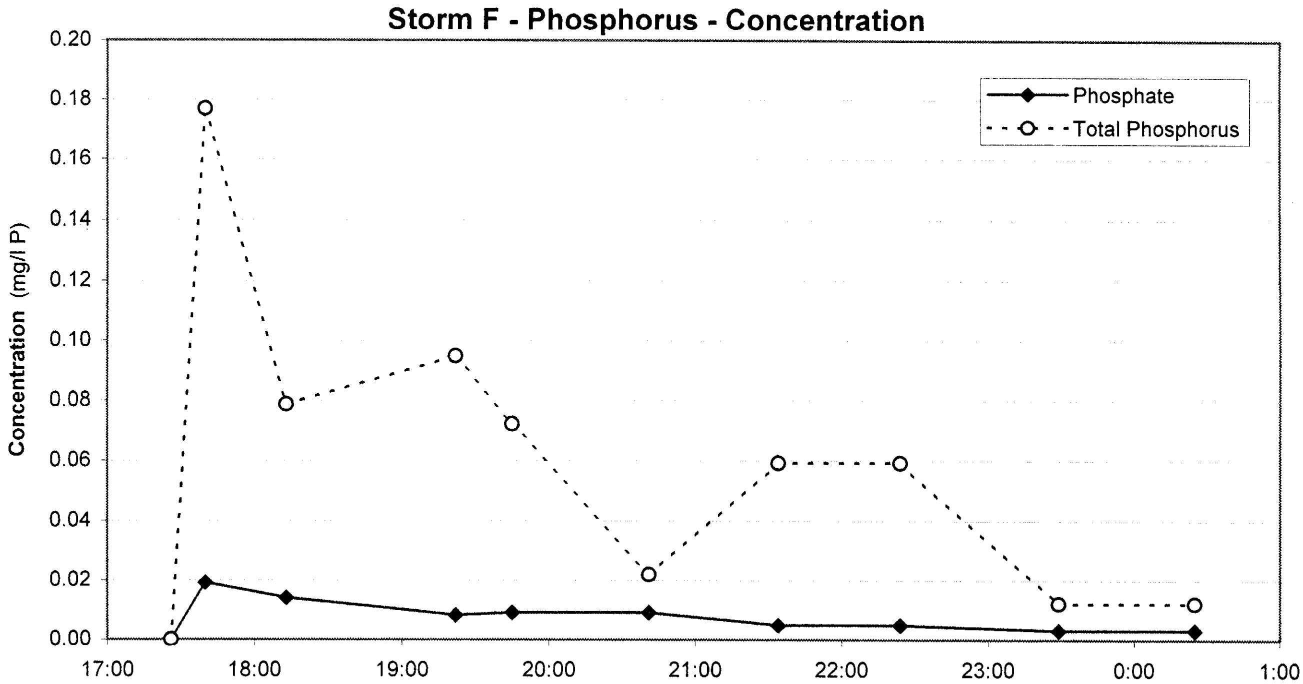


Figure 5-39

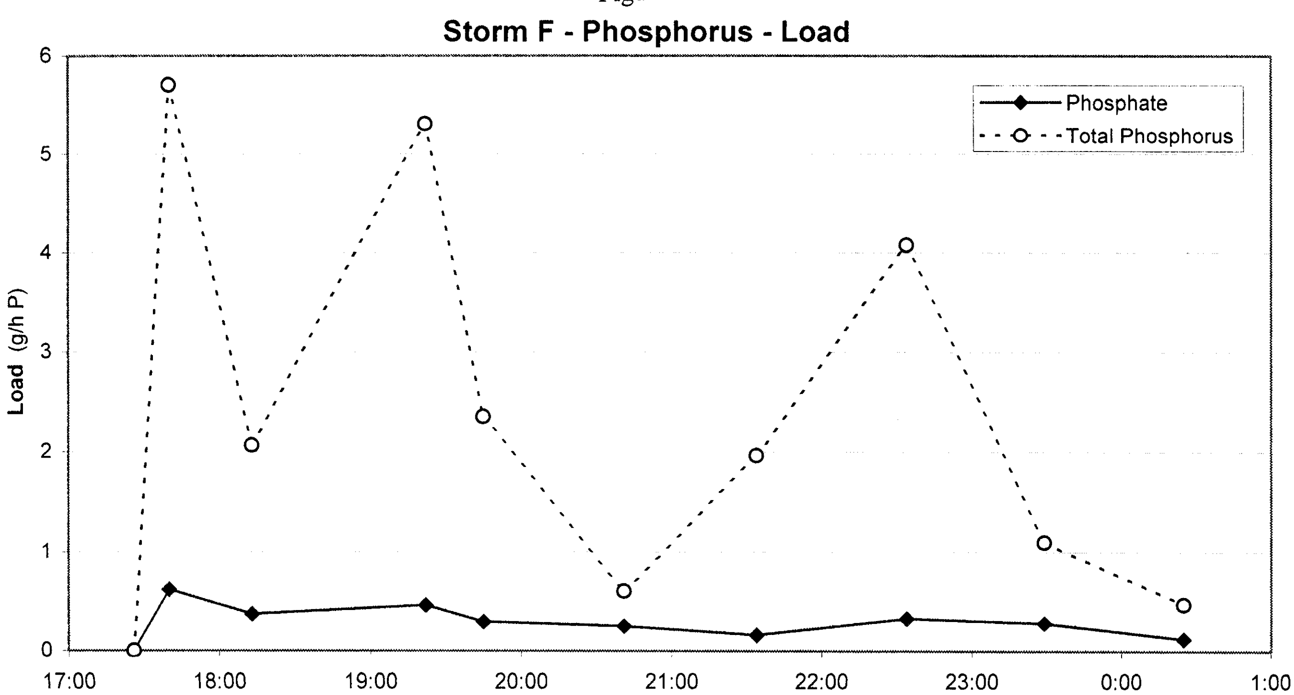


Figure 5-40

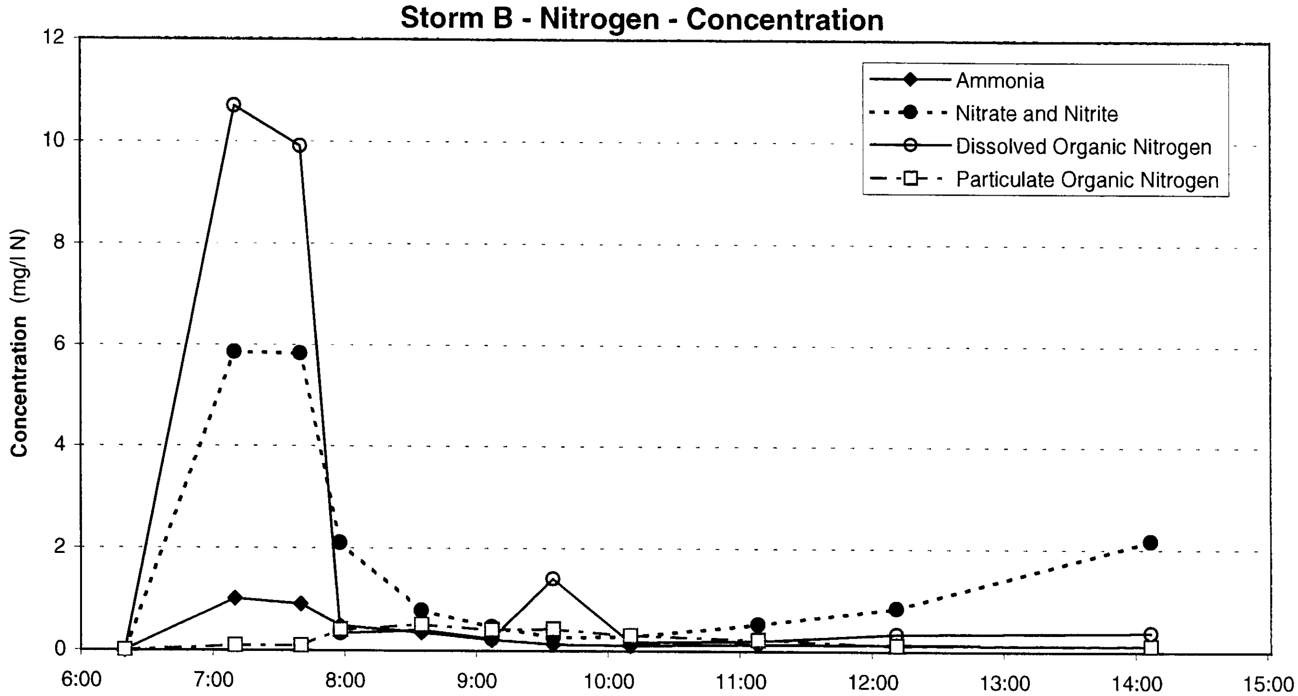


Figure 5-41

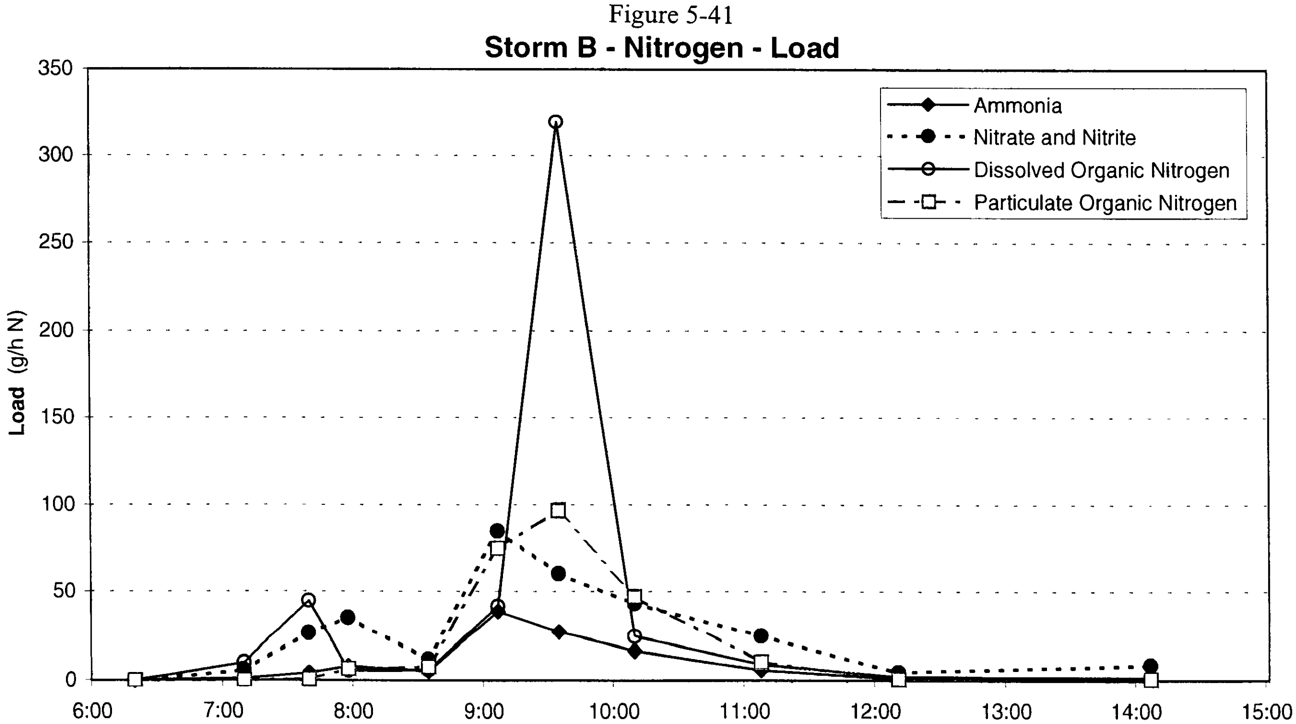


Figure 5-42

Storm D - Nitrogen - Concentration

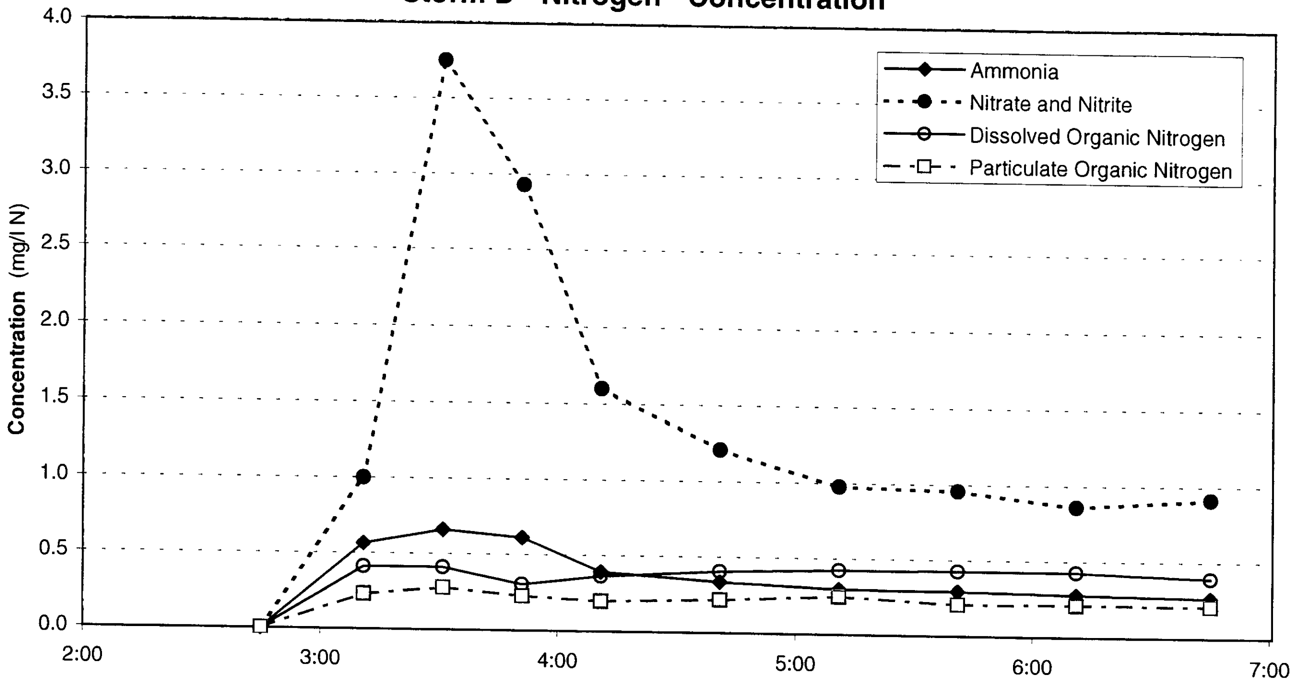


Figure 5-43

Storm D - Nitrogen - Load

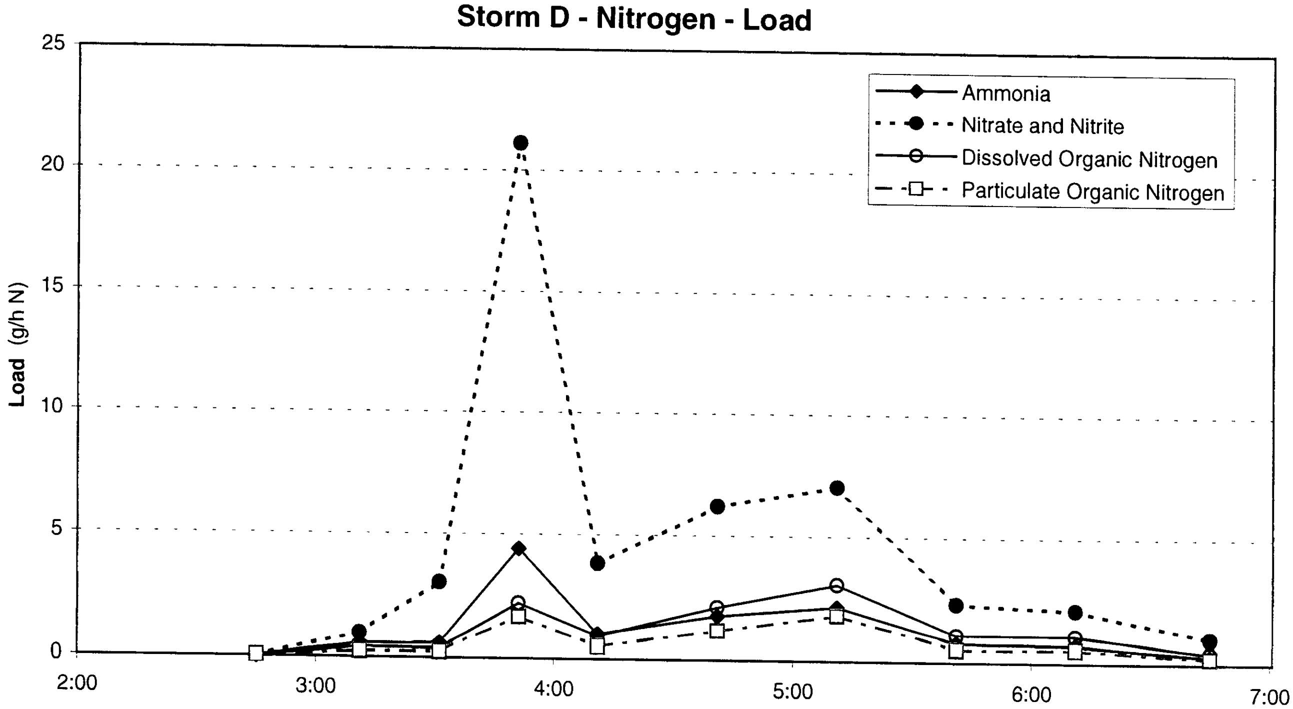


Figure 5-44

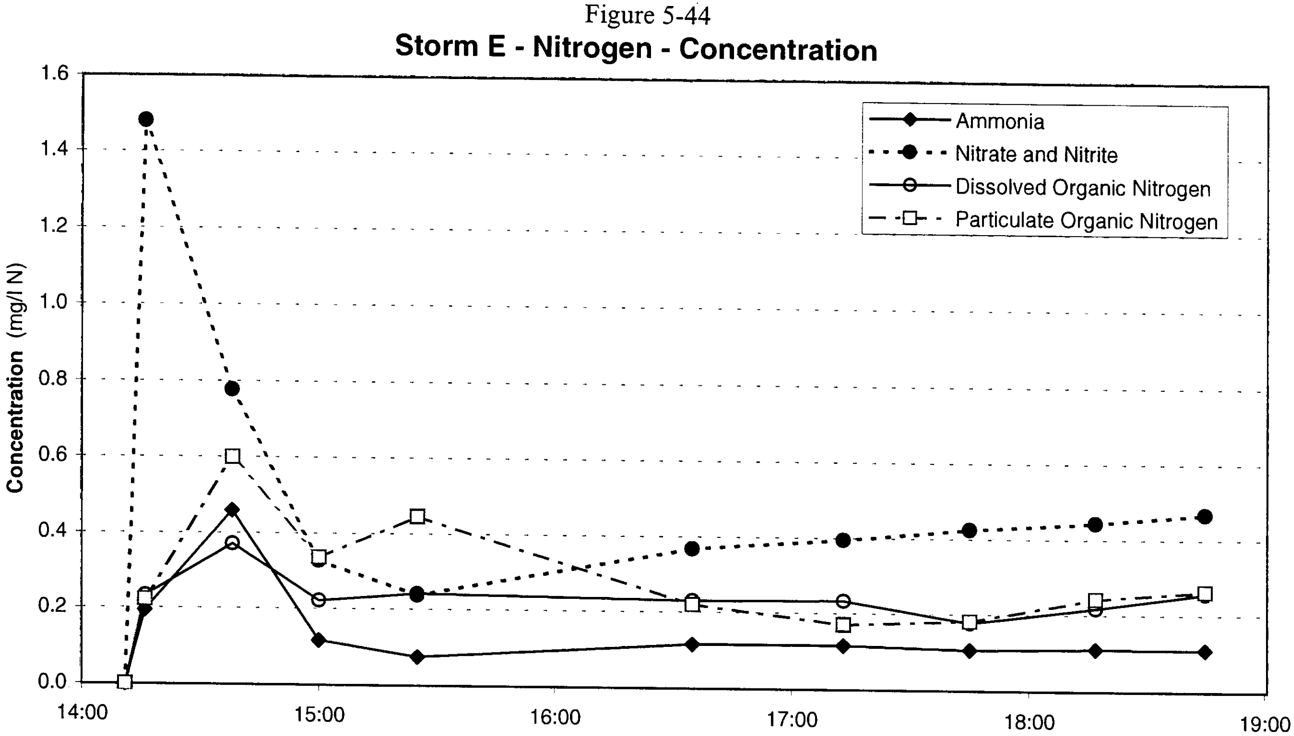


Figure 5-45

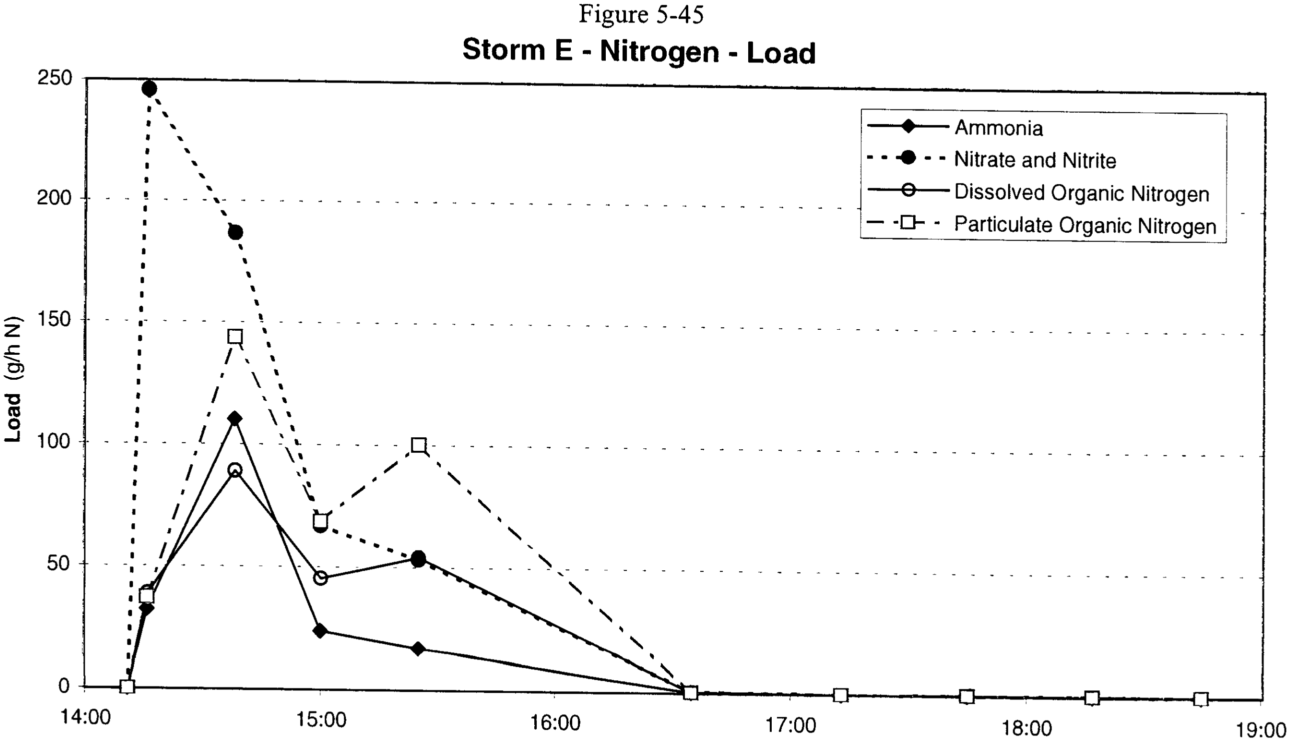


Figure 5-46

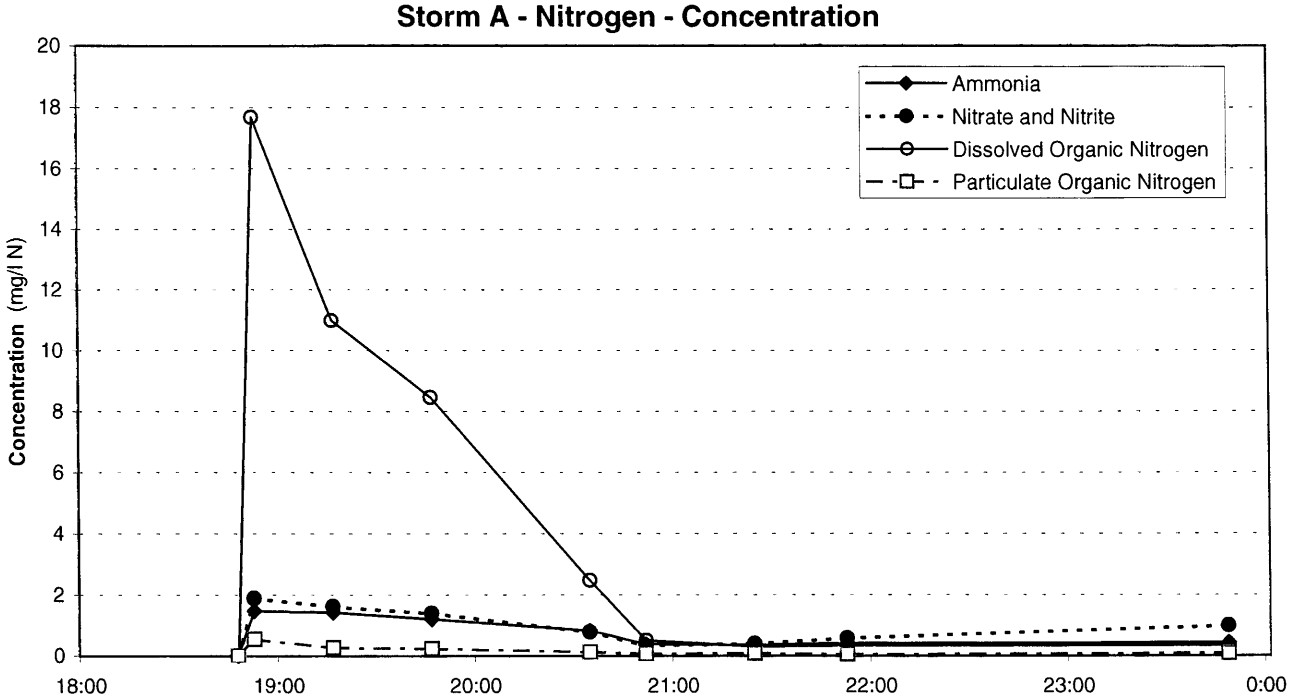


Figure 5-47

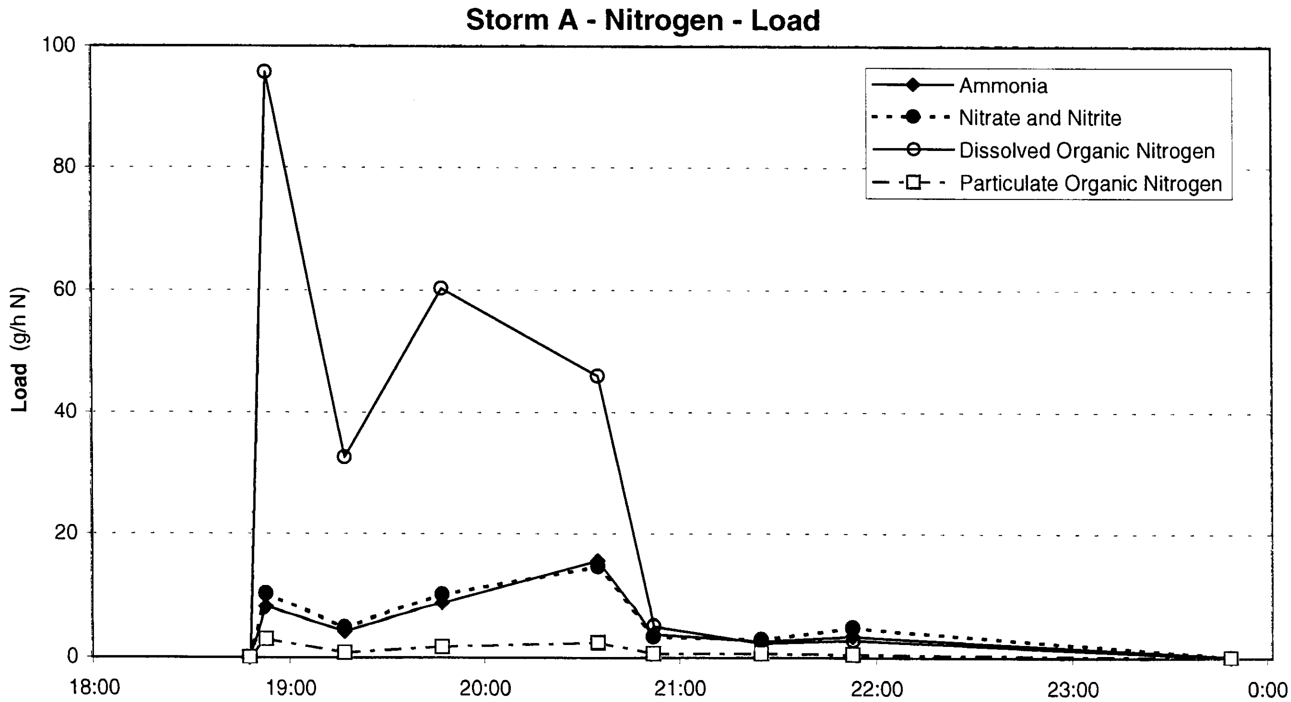


Figure 5-48

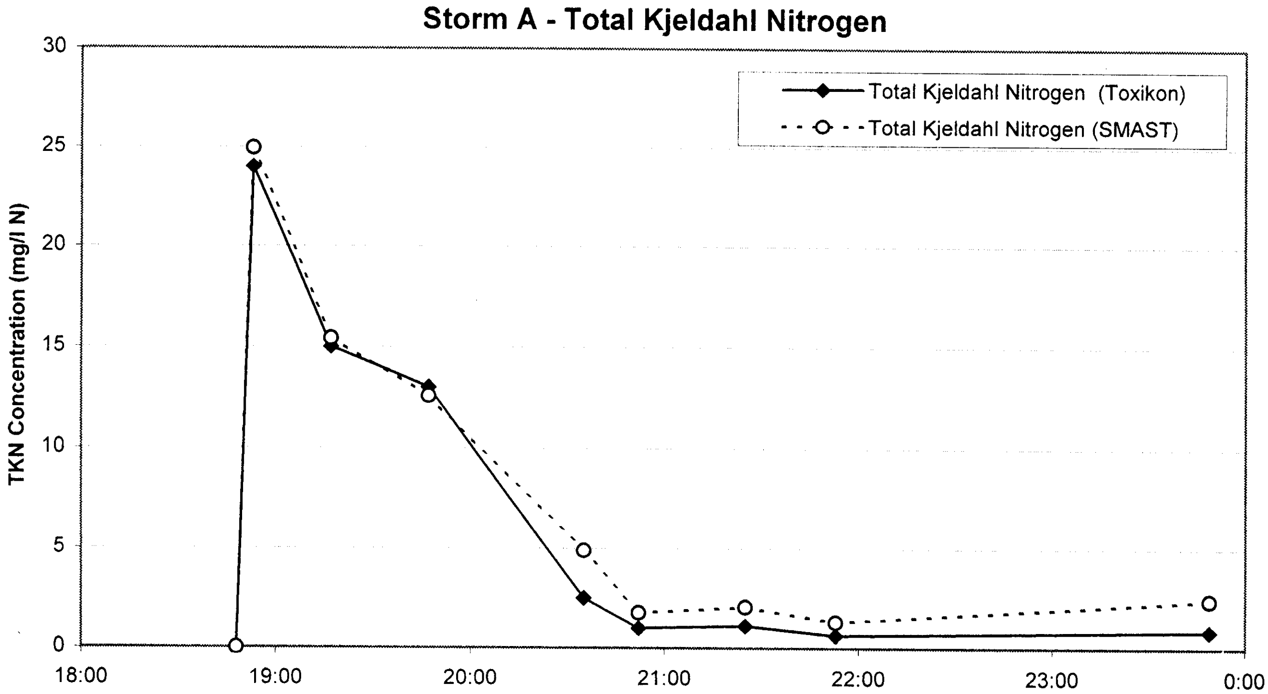


Figure 5-49

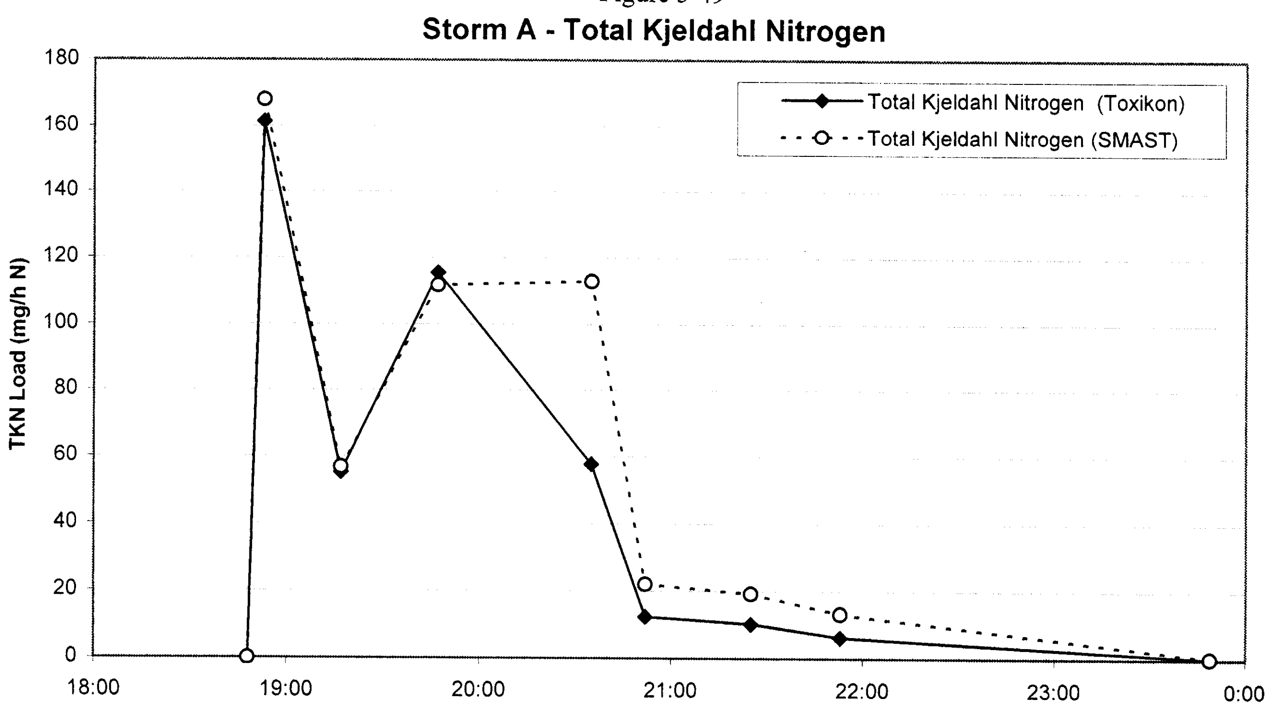


Figure 5-50

Storm C - Nitrogen - Concentration

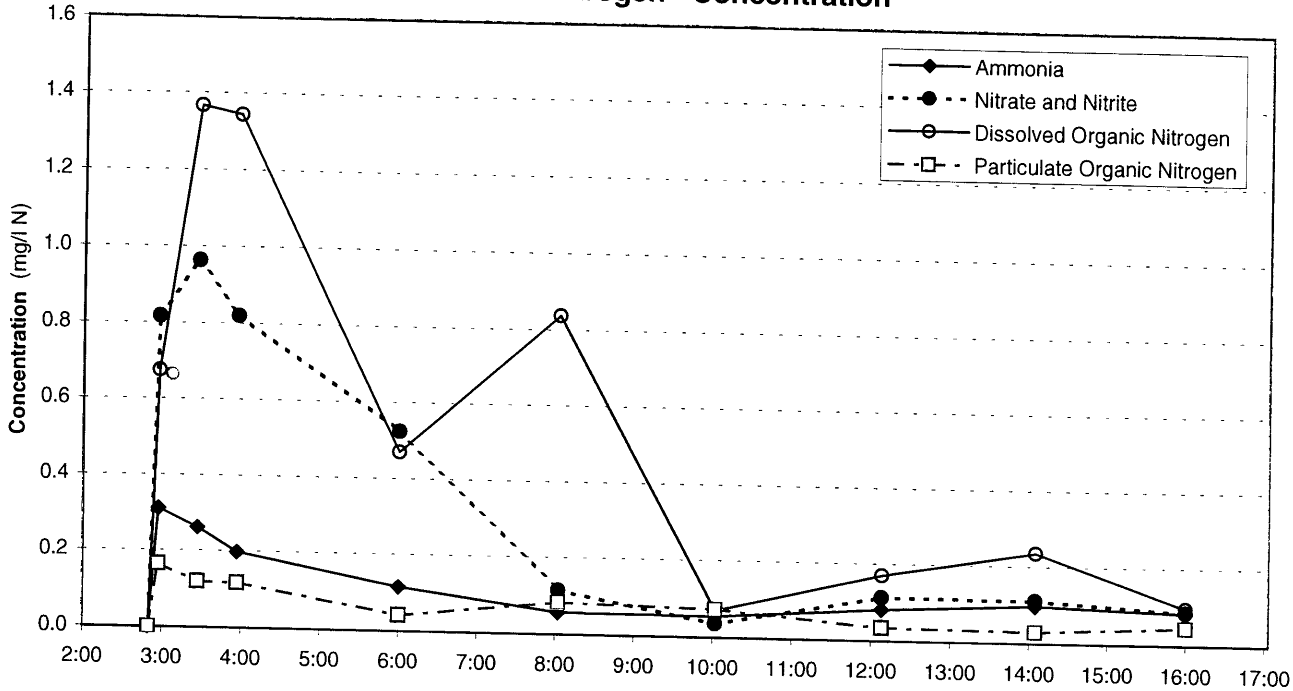


Figure 5-51

Storm C - Nitrogen - Load

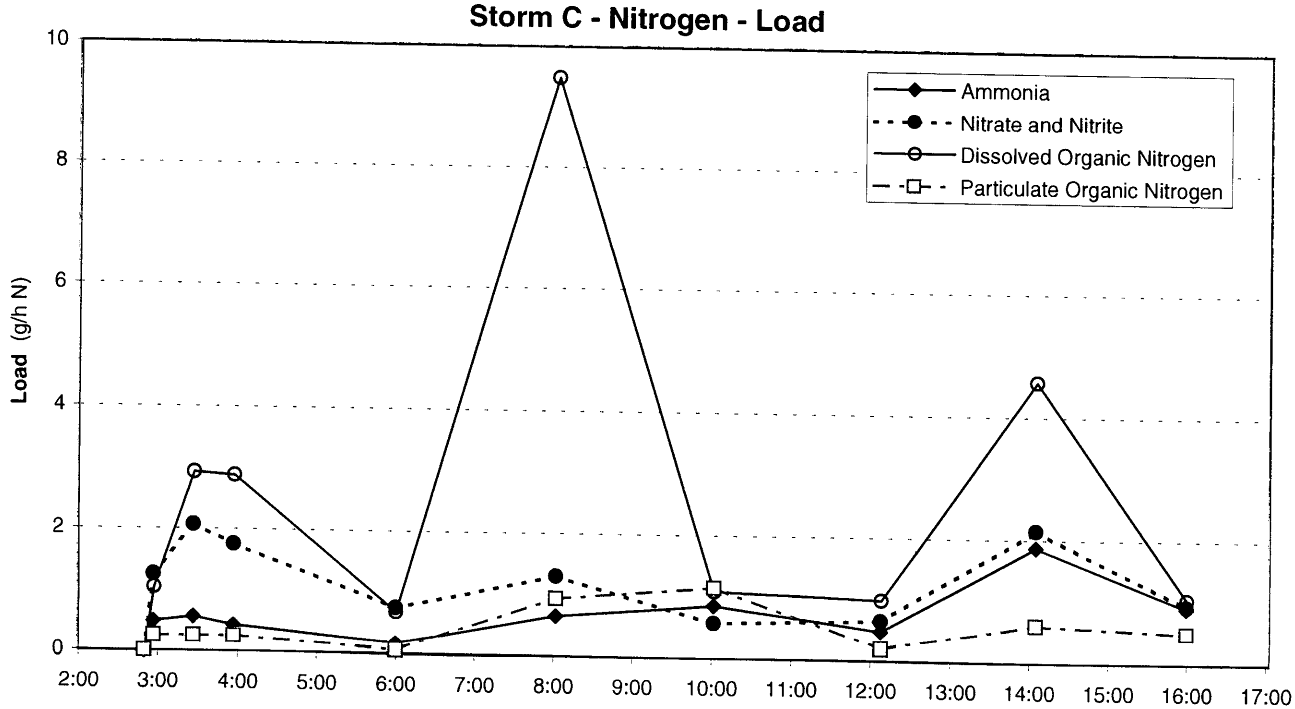


Figure 5-52

Storm F - Nitrogen - Concentration

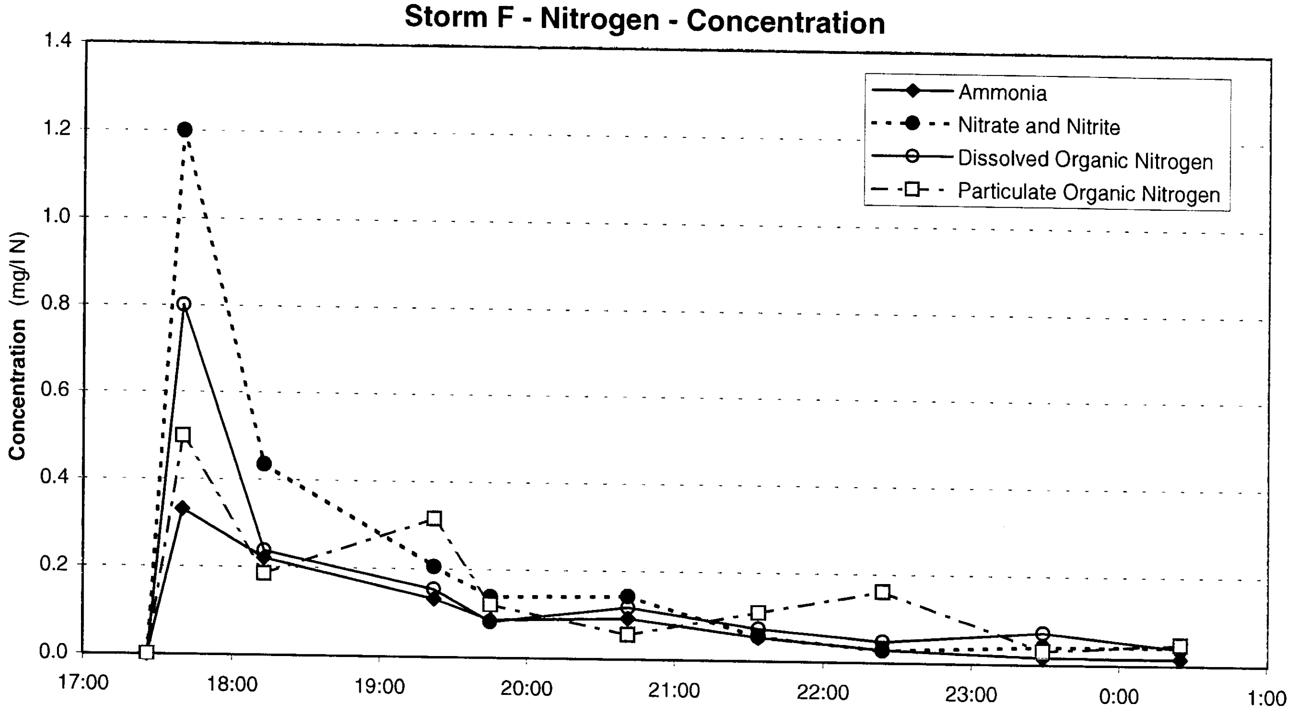


Figure 5-53

Storm F - Nitrogen - Load

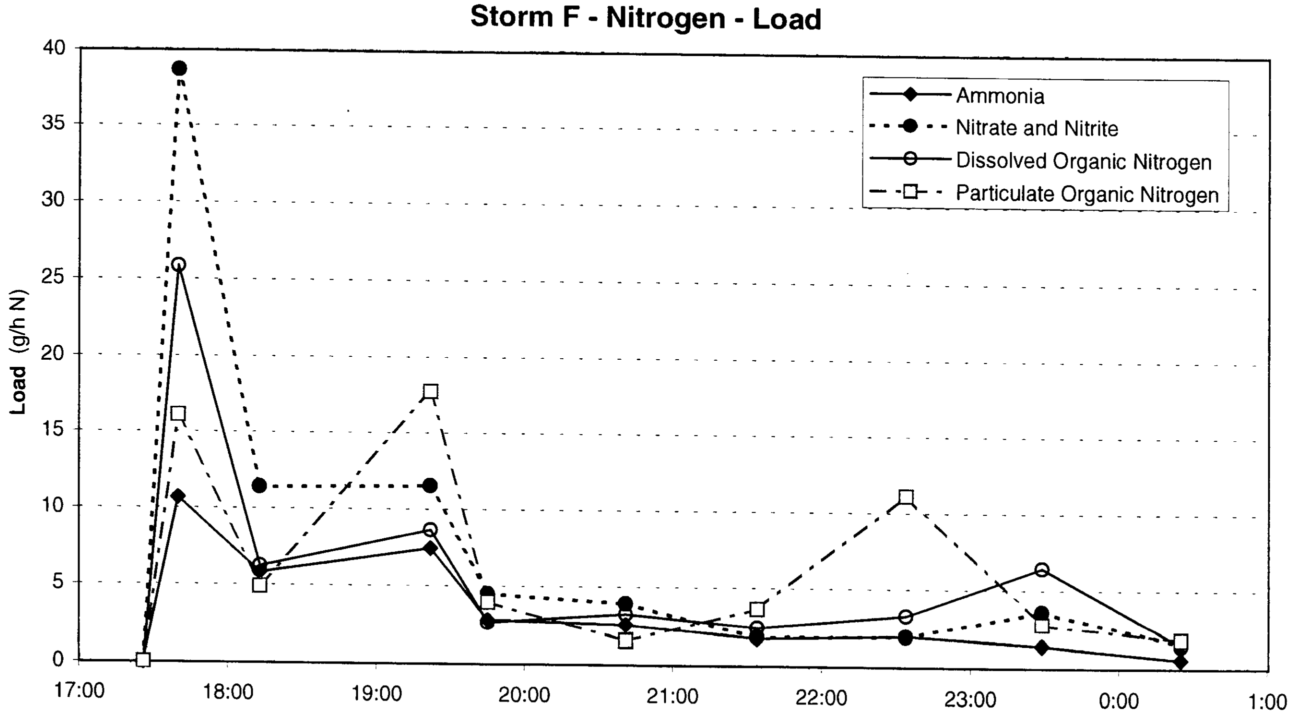


Figure 5-54

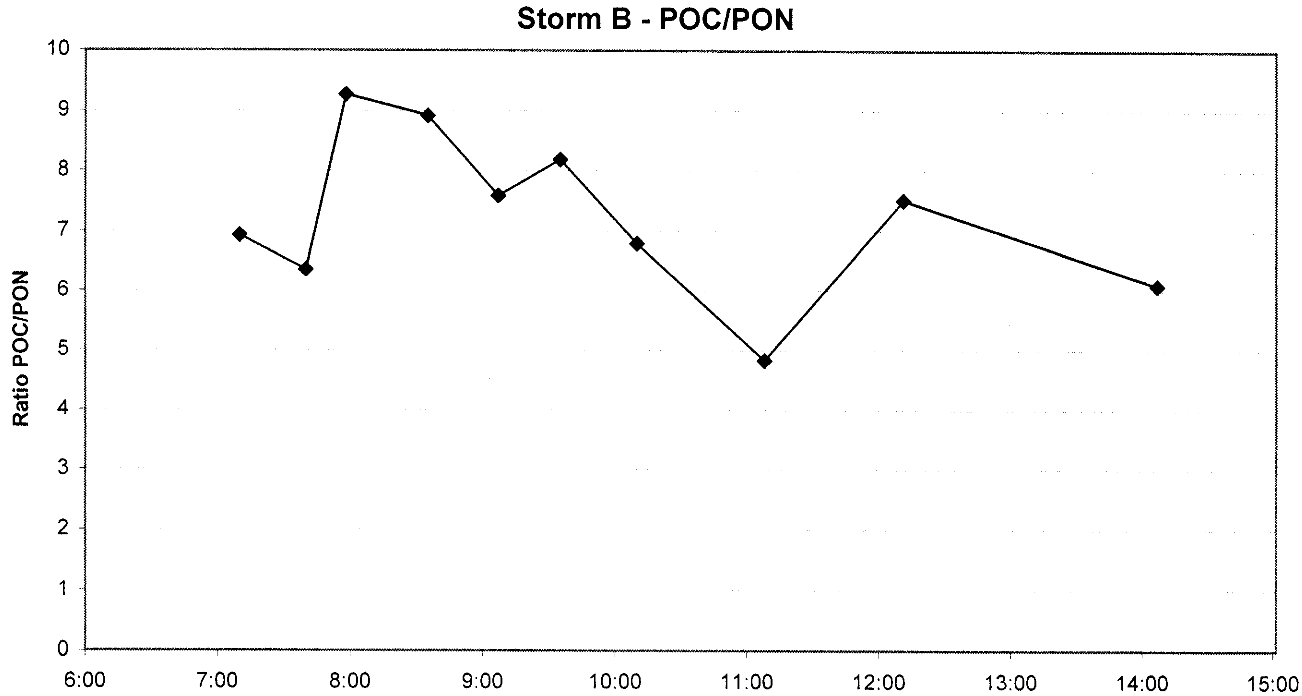


Figure 5-55

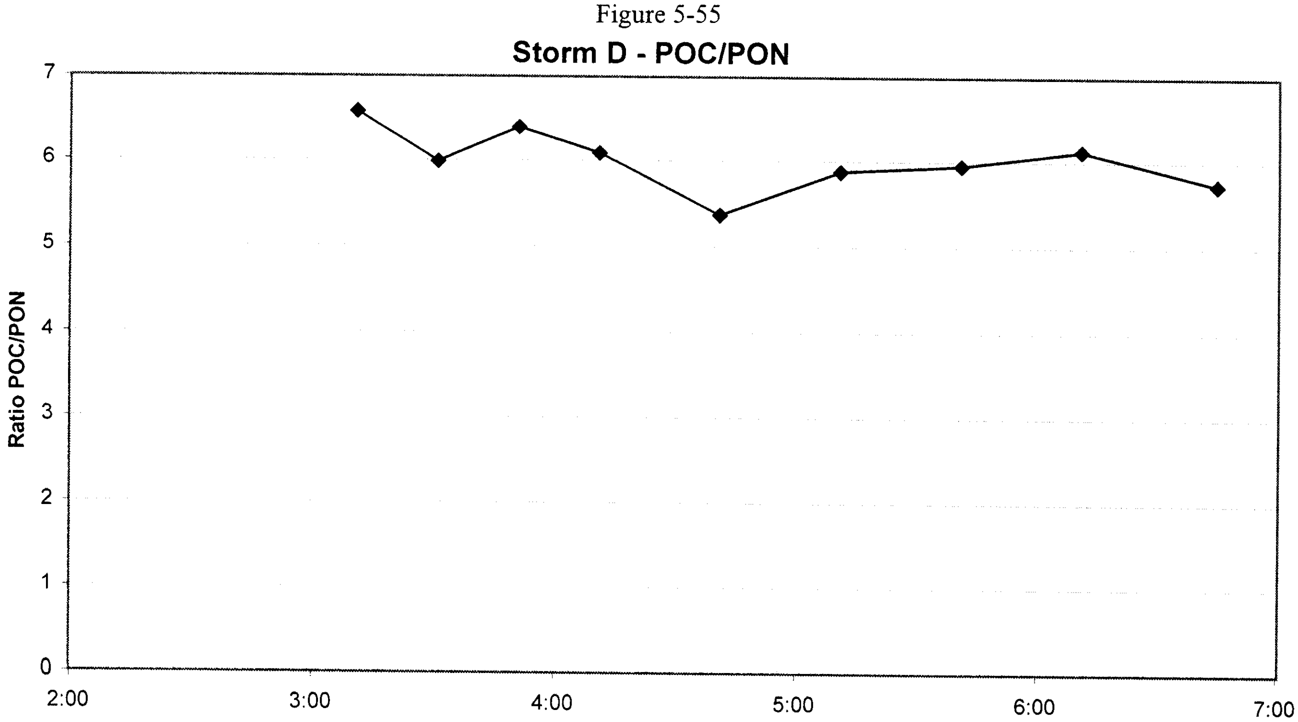
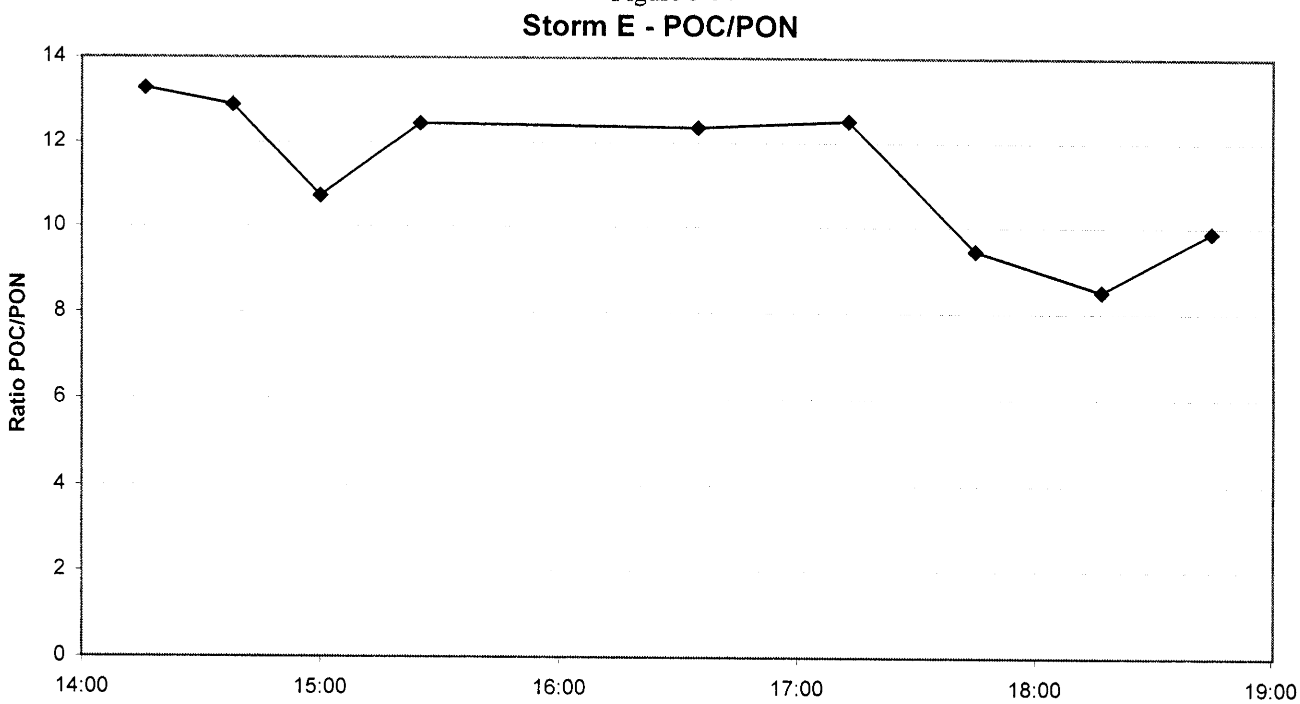


Figure 5-56



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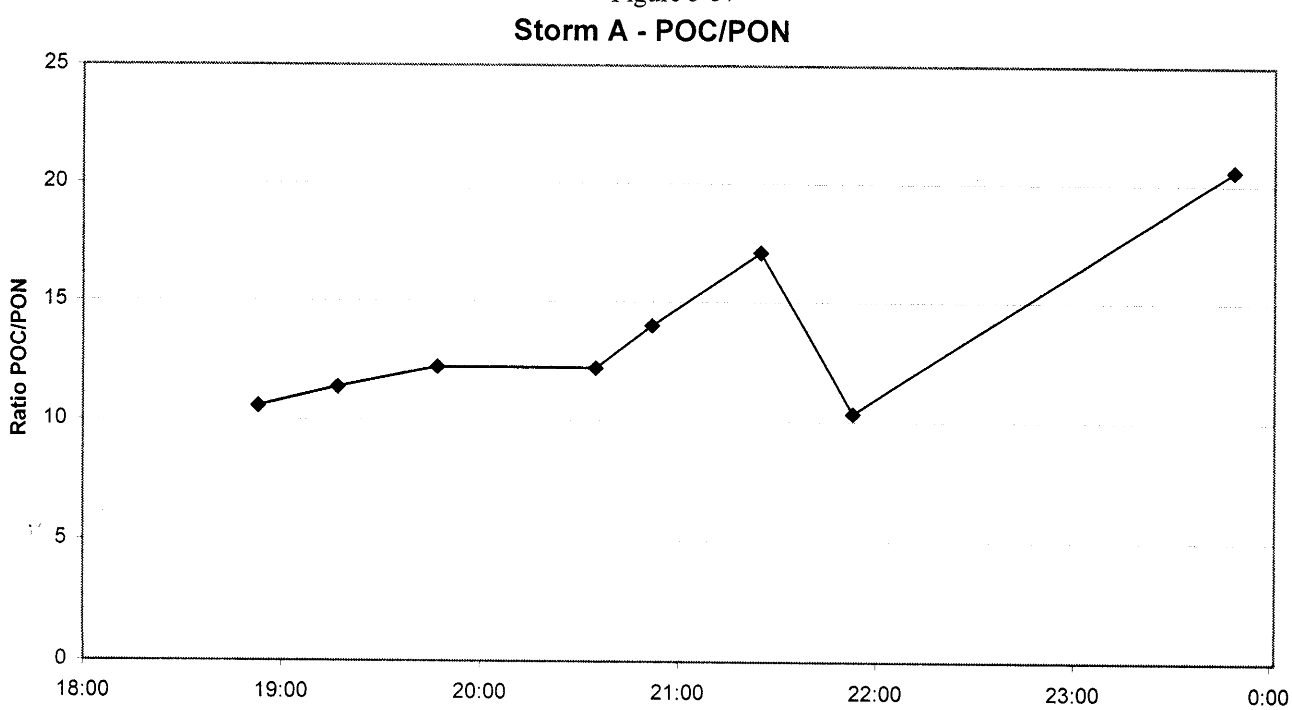


Figure 5-58

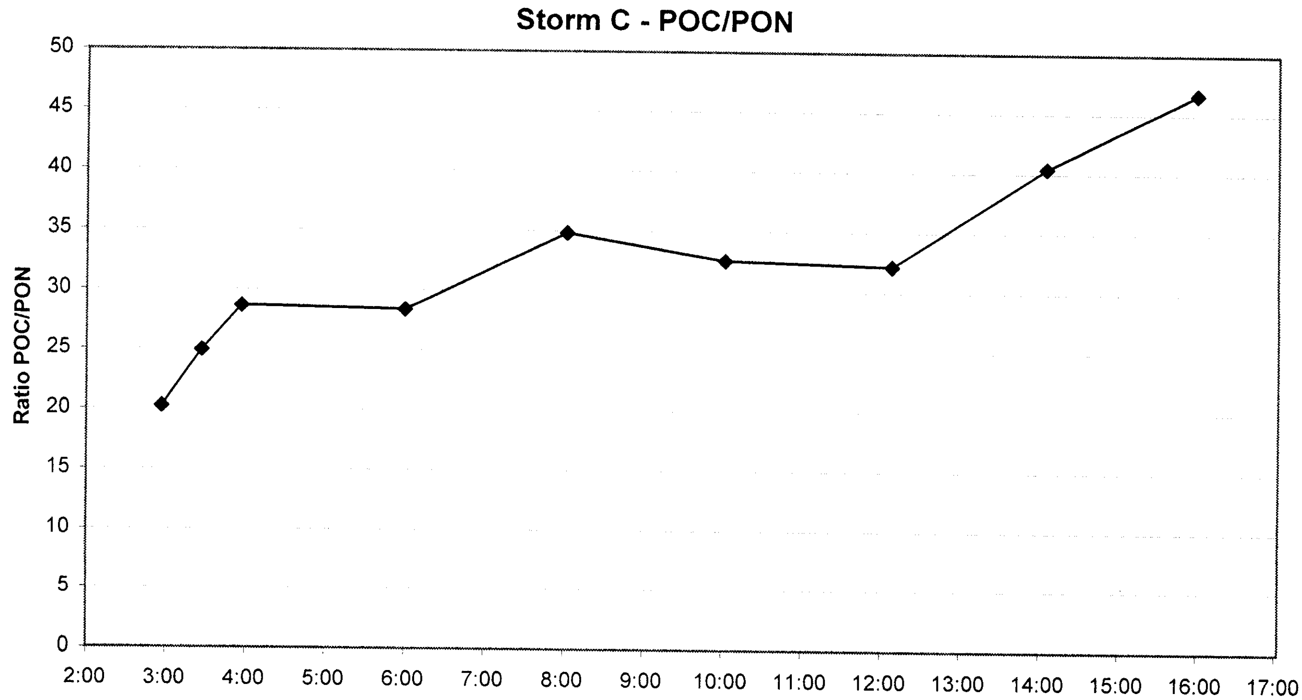


Figure 5-59

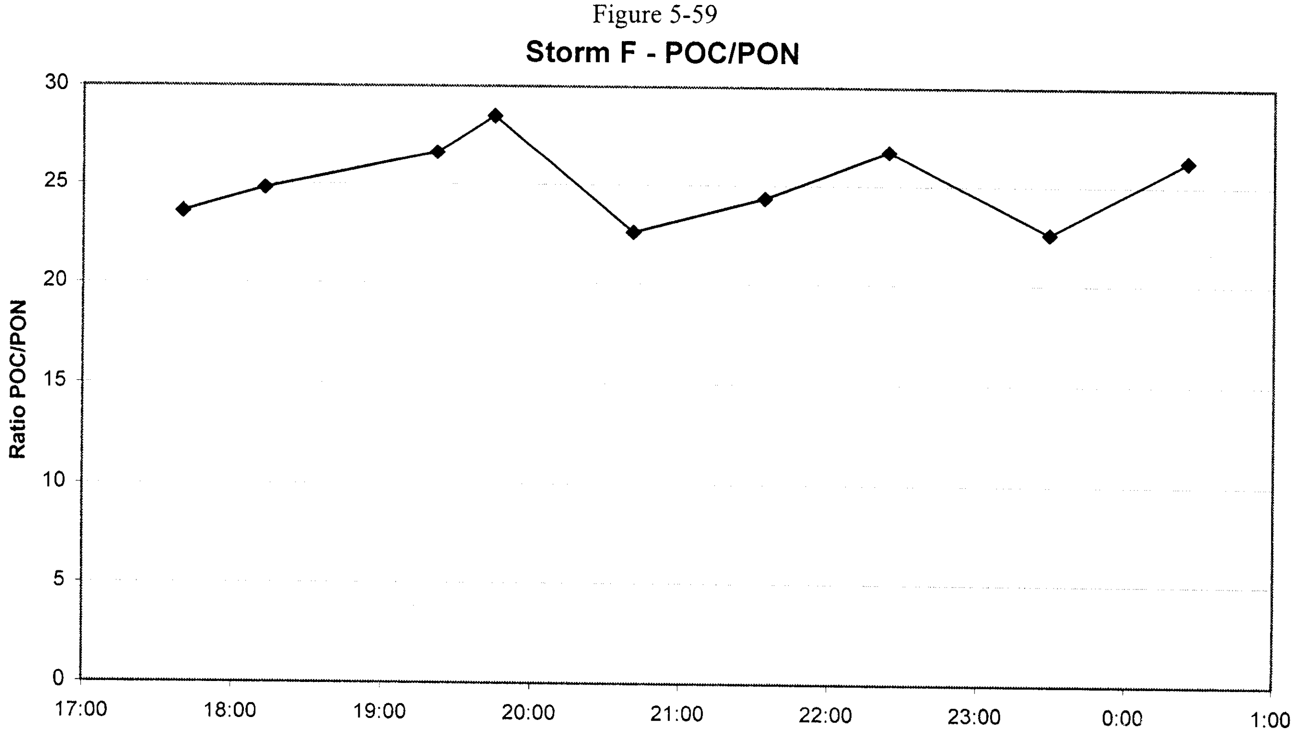


Figure 5-60

Storm B - Conductivity

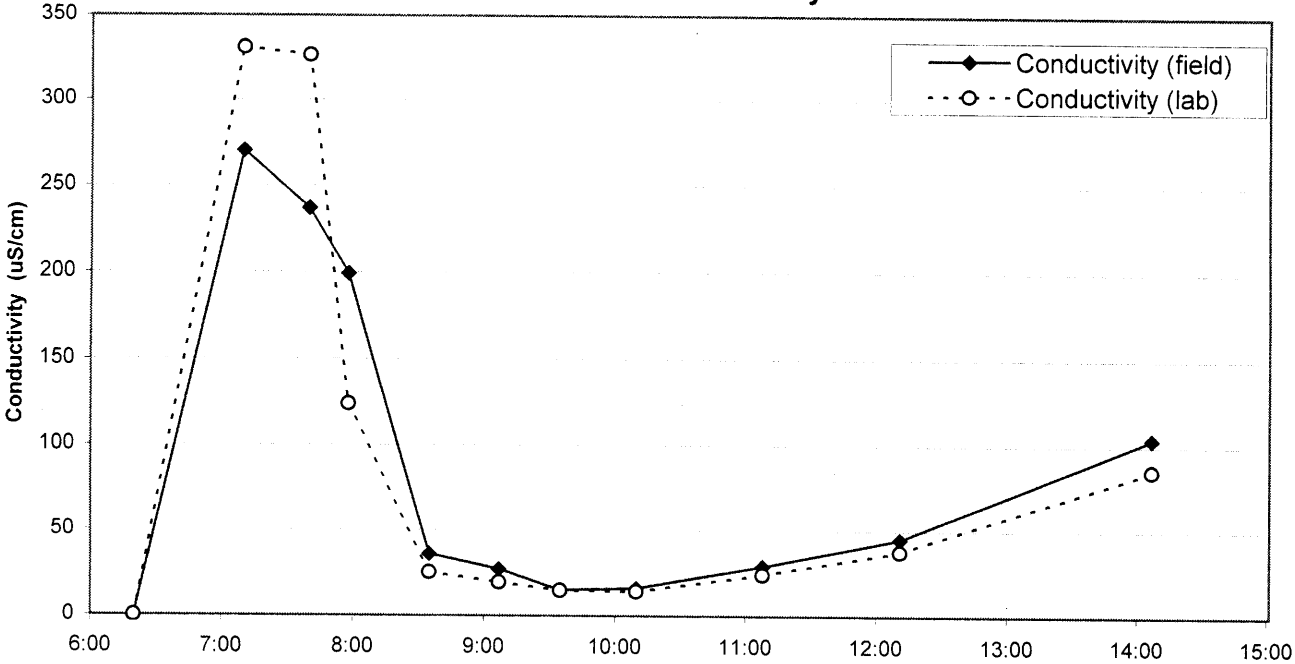


Figure 5-61

Storm D - Conductivity

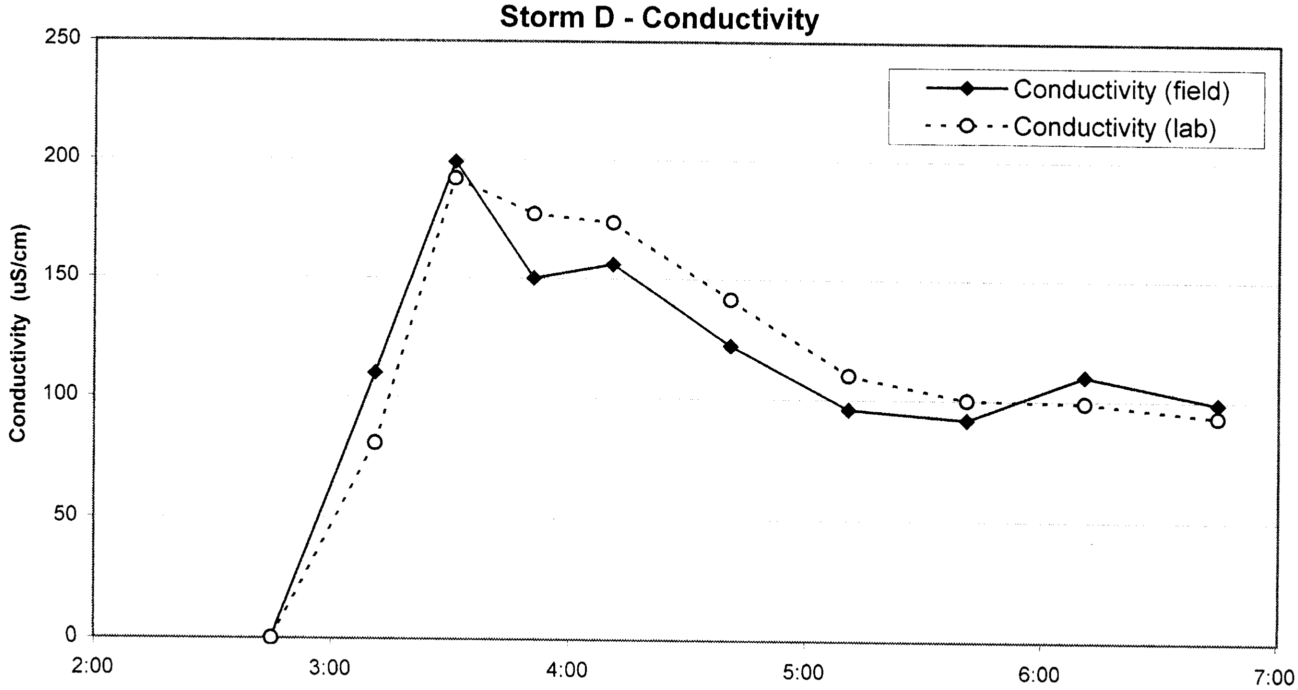


Figure 5-62

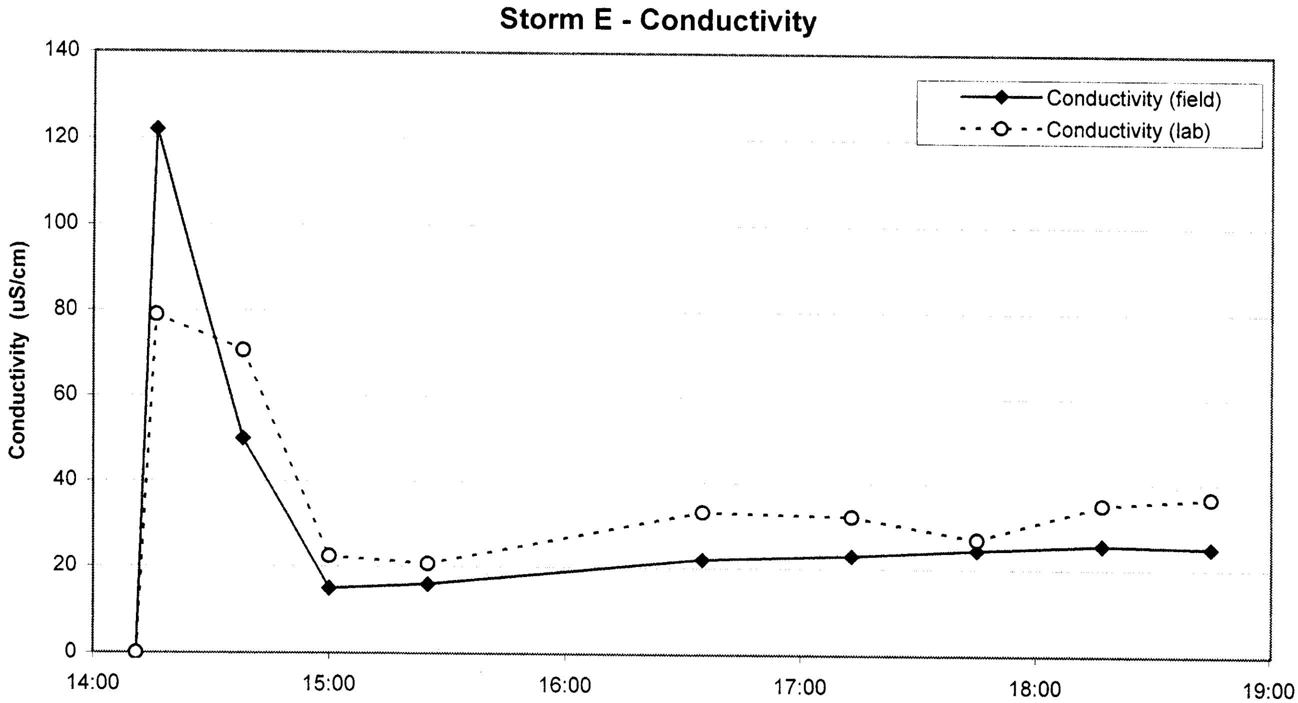


Figure 5-63

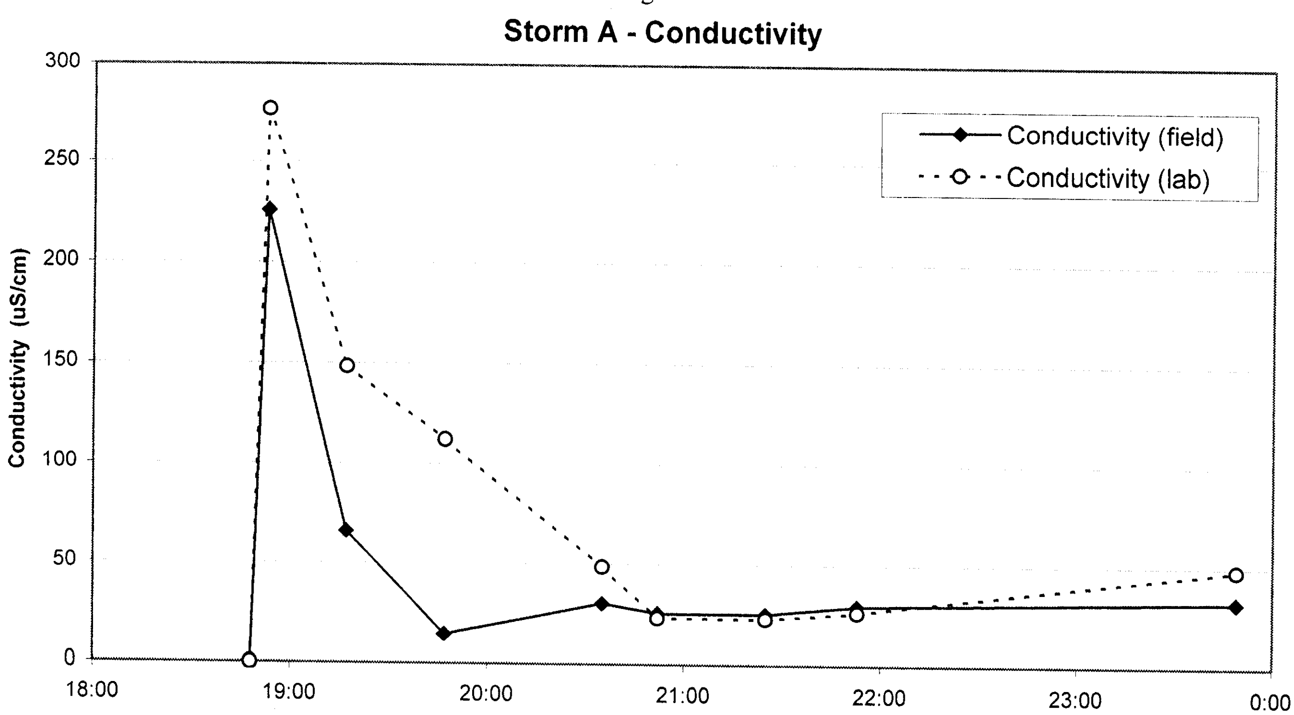


Figure 5-64

Storm C - Conductivity

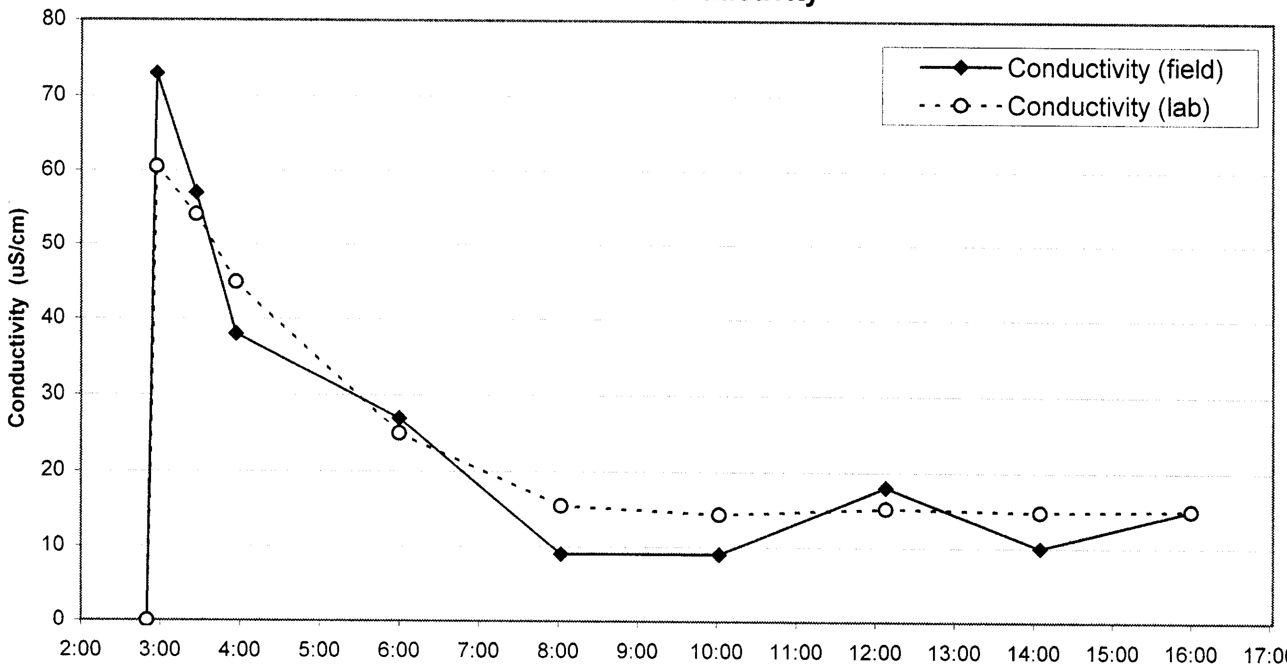


Figure 5-65

Storm F - Conductivity

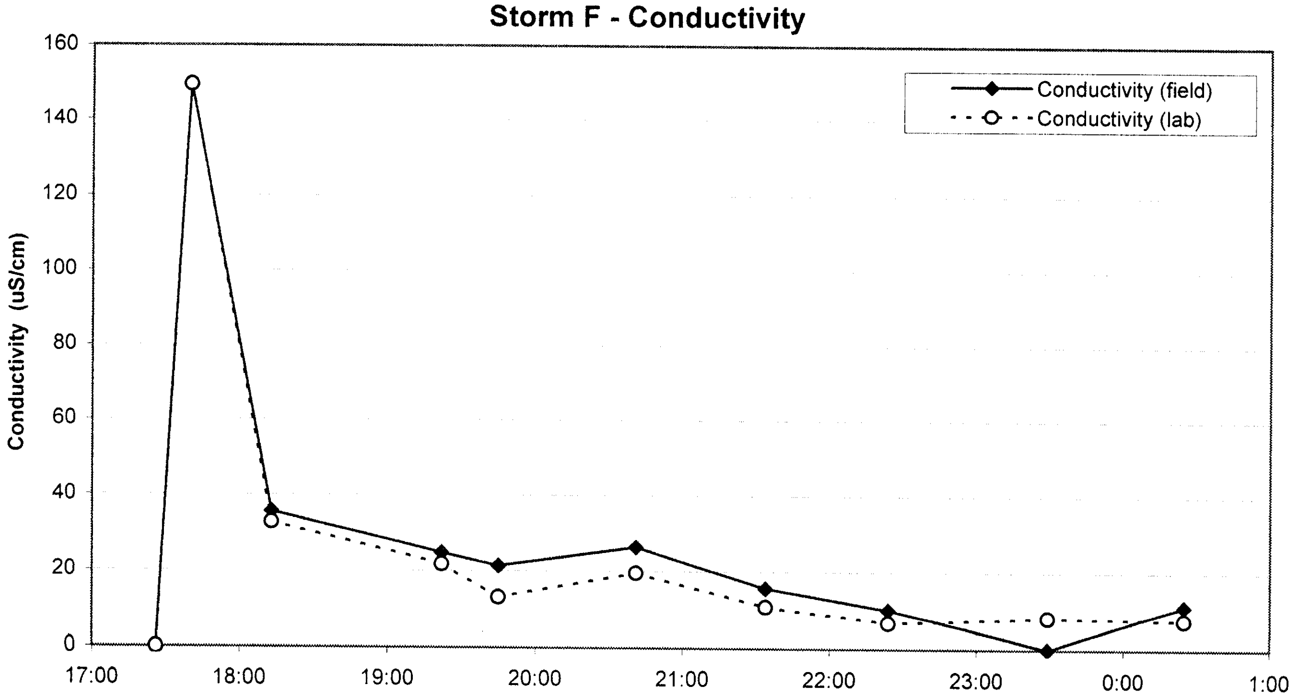


Figure 5-66

Discharge Rate: Comparison Flow Meter vs. Bucket Method

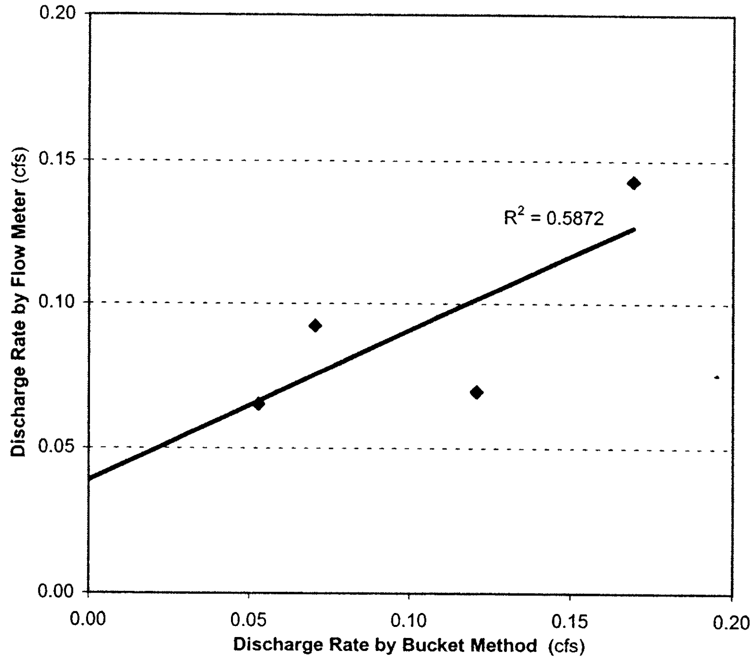
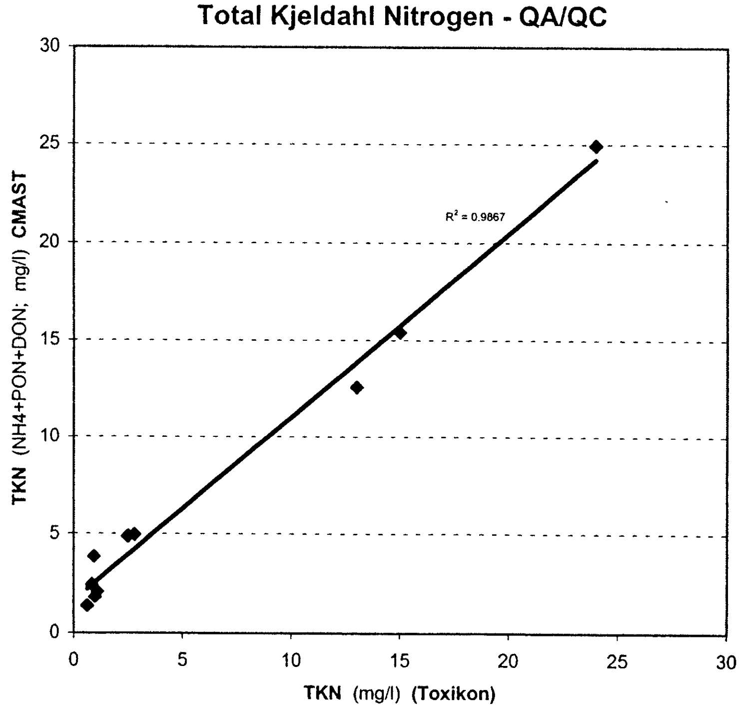


Figure 5-67

Total Kjeldahl Nitrogen - QA/QC



6.0 Relevance for Wetland Protection Program

The stormwater investigation of the Pinefield and Cherry Hill discharge sites supports the contention that process level studies are required in order to develop loading coefficients for general application over larger areas. The difference between the Pinefield and Cherry Hill sites is significant when trying to extrapolate from site specific drainage basins to whole watersheds. The Pinefield Site is primarily residential with significant vegetation and access for both wild and domestic animals. The Cherry Hill Site is primarily a parking lot with little bordering vegetation. This difference in basin structure appears to be the dominant underlying cause of the differences in fecal coliform loads between the sites. Similarly, it is central to the pattern of discharge of each of the major stormwater contaminants assayed. However, even with the observed relatively large differences between the two sites, there were common trends in contaminant discharge. In fact, the major difference in nitrogen discharge was in the nitrogen forms rather than in the total nitrogen mass released per square meter of impermeable surface. The major contamination difference between the sites appears to be in bacterial loads with much higher loading from the residential watershed.

SECTION 7

ATTACHMENT

Sampling Protocol

PROTOCOL FOR FIELD SAMPLING

§104(b)(3) Wetlands Ecological Assessment Project: North Coastal and Ipswich Basins Stormwater Sampling, Analysis, and Assessment Assistance

EOEA, Coastal Zone Management

The goals of the field portion of the Project are to:

1. to collect representative water samples throughout three storms (over a 12 hour period)
2. to measure the flow, DO, and pH during the storm
3. to measure the rainfall during the storm.

The order of activity is as follows:

A. ACTIVITIES PRIOR TO GOING TO THE SITES

1. Calibrate sampling equipment (DO meter, pH meter). Record information in field notebooks.
2. Verify adequate number of sampling bottles for the various analyses.
3. Verify availability of all other sampling equipment (see Section 6.3 in QAPP).
4. Pre-label bottles to the extent possible.
5. Purchase sufficient ice and ziplock bags.

B. SET-UP AFTER ARRIVAL ON SITE, PRIOR TO BEGINNING OF RAINFALL

1. Deploy raingage in open area (completely unobstructed by trees, houses, etc.).
2. Setup the flume for flow measurements.
3. Setup the depression for the graduated bucket (as the second form of flow measurement) at the downstream side of the flume.
4. Verify the calibration of instruments (DO meter, pH meter).
5. Enter information into the Field Information Log and field notebooks.
6. Prepare sample coolers by placing ice into ziplock bags. Each bag needs to be double-packed with a second ziplock bag. Each bag needs to be sealed separately with duct tape to avoid leakage of melt water out of the bag into the cooler.

C. SAMPLING PRIOR TO STORM (CHERRY HILL SITE ONLY)

1. Open catch basin cover.

2. Measure dissolved oxygen and temperature in catch basin:
   - Rinse DO probe and wire with distilled water.
   - Measure DO and temperature with DO meter by lowering DO carefully into the water.
   - Record information on Sampling Log.

3. Measure pH:
   - Use autoclaved sterile-clean dipper to collect sample from the catch basin.
   - Pour water into an autoclaved open container.
   - Rinse pH meter with distilled water.
   - Measure pH in the open container.
   - Record information on Sampling Log.

4. Collection of sample in catch basin:
   - Use autoclaved sterile-clean dipper to collect sample from the catch basin.
   - Fill each of the sample bottles to approximately 25% .
   - Close each bottle, shake, and empty each bottle away from the catch basin.
   - Repeat two times.
   - Collect additional water and fill bottles to the top.
   - Close tightly and label bottles.
   - Place in cooler with ice for storage.

• Filter the samples for nitrate+nitrite, dissolved ammonium, total dissolved nitrogen, and orthophosphate in the field right after sample collection using appropriate equipment that includes a syringe, a 0.45um filter with holder:
   - Place new 0.45um filter on sterile-cleaned filter holder; use tweezers only.
   - Attach syringe
   - Rinse the syringe, filter and filter holder by pushing 30 ml of collected stormwater through it. Let the water discharge onto the ground, NOT into the bottle for the filtered water.
   - Fill syringe and push water through the filter, letting it flow into the bottle for filtered water for analysis.
   - Change filter as needed with tweezers, rinsing each filter for 5 to 10 seconds first.
   - Cap and label bottle and place into cooler.
   - Rinse the syringe and filter holder with distilled water.

5. Record information on Chain of Custody and field notebooks.

6. Close catch basin cover.

D. SAMPLING DURING STORM

1. Collect first sample during first 20 minutes to collect the first flush. The time of sampling after the beginning of the storm will depend on how fast the rain falls, and hence how fast runoff starts to appear at the sampling location.

2. Measure flow:
   - For low flow, use the graduated bucket. Repeat measurement once.
   - For high flow, use the flow meter by placing the meter into the center of the flume and reading the flow velocity. Immediately afterwards, measure the height and width of the water in the flume with a ruler.
   - If the flow rate permits, use both flow meter and graduated bucket.
   - Record information on Sampling Log

3. Measure DO and temperature:
   - Rinse the probe and cable with distilled water.
   - Place the probe into the flow of the runoff at the end of stormwater pipe.
   - Record information on Sampling Log.

4. Measure pH:
   - Rinse the pH probe with distilled water.
   - Place the probe into the flow of the runoff at the end of stormwater pipe.
   - Record information on Sampling Log.

5. Collect rain information:
   - Read the rainfall amount on the rain gage. DO NOT empty gage.
   - Record information on Sampling Log.

6. Collect water samples: Collect samples at the end of the stormwater pipe. (DO NOT collect samples from water collected in the graduated bucket.) Collect samples by holding the sampling containers underneath the end of the pipe, letting the water run into the container "naturally". The following steps should be followed:
   Note: Water sampling needs to be done expediently, especially for the first flush, to assure that the bottles for the different analyses are filled as close as possible at a specific "time slice".
   - Fill each of the bottles for a sample set to approximately 25%
   - Close each bottle, shake, and empty the bottle DOWNSTREAM from the sampling site
   - Repeat two times
   - Fill bottles to the top for the actual sample
   - Close tightly and label each bottle
   - Place bottles in cooler with ice for storage

7. Filter the samples for nitrate+nitrite, dissolved ammonium, total dissolved nitrogen, and orthophosphate in the field right after sample collection using appropriate equipment that includes a syringe, a 0.45um filter with holder.
   - Rinse the syringe and filter holder with distilled water.
   - Place new 0.45um filter on sterile-cleaned filter holder; use tweezers only.
   - Attach syringe
   - Rinse the syringe, filter and filter holder by pushing 30 ml of collected stormwater through it. Let the water discharge onto the ground, NOT into the bottle for the filtered water.
   - Refill syringe and push water through the filter, letting it flow into the bottle for filtered water for analysis.
   - Change filter as needed with tweezers, rinsing each filter for 5 to 10 seconds first.
   - Cap and label bottle and place into cooler.
   - Rinse the syringe and filter holder with distilled water.

8. Record information on Chain of Custody Log and field notebook.

E. DETERMINATION OF SAMPLING FREQUENCY

The frequency for sampling depends on the rainfall pattern of the storm. The goal is to capture sufficient samples at appropriate intervals that, in combination, are representative of the contaminant load of the storm. The sampling frequency will be set by Dr. Hay, the Project Manager, prior to sampling, based on the forecasted nature of the storm. The frequency may be modified in the field by Dr. Hay based on the actual pattern and update in the storm forecast. He will communicate with the staff person at the second site, Mr. Medford, by telephone.

Unless the storm pattern dictates otherwise, samples are planned to be collected at the following intervals: First flush, 20 min, 40 min, 60 min, 1.5 h, 2 h, 2.5 h, 3 h, 4 h, 5 h, 6 h, 8 h, 10 h, 12h.

Flow and raingage measurements will be collected along with the collection of water samples, but at least every 30 minutes during the first 6 hours and every hour between the 6th and 12th hour.

Calibration will of the DO and pH meter will be conducted in duplicate once during the storm sampling event.

Calibration of the Global Water Flow Probe will be conducted in duplicate during the sampling event by simultaneously using the flow probe AND the graduated bucket flow measurement method at a time when the flow rate allows both measurements (i.e., the rate should not be too high for the bucket method, and not be too low for the flow meter method).

One duplicate water sample will be collected during the first two hours of a sampling event. Dr. Hay will determine in the field where and when the sample will be taken.

F. DEPARTURE FROM SITE

1. Reconfirm that all coolers contain adequate ice.
2. Collect all sampling equipment, including the rain gage and the flume.
3. Make sure catch basin cover is closed (Cherry Hill site).
4. Complete Field Information Log.
5. Check the calibration of the DO and pH meters.
6. Mr. Medford, who sampled the Pinefield site will meet with Dr. Hay, who sampled the Cherry Hill site for sample transfer.
7. Dr. Hay will determine which samples will be composited by the laboratory.
8. Dr. Hay will transport fecal coliform samples to Analytical Testing Laboratory in Bedford as soon as possible, certainly in less than 24 hrs from the start of sampling.
9. He will also transport TPH to Toxikon in Bedford, and arrange for the transport of the nutrient and solids samples to SMAST laboratory in New Bedford.
10. Dipper and filtration equipment will be returned to SMAST for sterilization in preparation of the next storm sampling event.

SECTION 8

ATTACHMENT

Rainfall Data
Beverly Salem Water Supply Board

- Monthly: 1950 to 2002
- Daily: 1987 to 2002

Table 8-1

Rainfall Data - Beverly Salem Water Supply Board
1950 - 2002

Source: MaDEM, Vicky Garland (for Station BEV609)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum (per year)
1950	4.32	3.10	3.08	1.87	1.81	1.32	2.29	4.15	0.96	2.29	7.33	4.05	36.57
1951	3.46	3.12	4.23	2.72	4.56	1.72	2.40	2.31	2.20	4.89	6.95	3.99	42.55
1952	3.91	3.09	3.23	3.28	6.28	1.63	1.20	7.78	1.33	1.53	1.68	3.82	38.76
1953	4.75	3.18	9.87	5.15	3.91	1.08	2.64	1.72	1.95	5.02	6.30	4.46	50.03
1954	2.93	3.09	3.19	4.46	9.73	2.04	3.36	6.24	7.52	3.55	5.41	5.13	56.65
1955	0.93	4.15	4.58	3.62	1.41	2.97	2.25	10.63	2.09	6.06	5.62	0.99	45.30
1956	5.95	4.19	4.50	3.29	1.78	1.71	3.06	1.59	4.00	4.92	3.49	4.07	42.55
1957	2.15	1.69	2.12	2.74	2.96	0.59	1.03	2.10	0.83	2.73	4.79	4.63	28.36
1958	8.43	4.53	2.49	5.77	3.51	1.48	4.10	3.01	4.95	3.75	3.19	1.31	46.52
1959	2.79	2.73	4.40	3.21	1.23	6.57	6.61	1.96	0.81	5.33	4.02	4.01	43.67
1960	2.42	4.40	2.11	2.86	3.82	2.53	4.87	2.35	5.00	2.31	2.72	2.70	38.09
1961	1.64	2.68	4.61	5.50	3.64	2.10	4.65	4.29	8.09	2.41	4.24	3.09	46.94
1962	2.93	3.15	3.99	2.67	2.24	2.53	3.45	3.78	3.65	10.38	2.66	5.21	46.64
1963	3.26	2.57	3.73	1.65	3.14	0.98	3.37	1.62	3.59	2.13	7.53	1.91	35.48
1964	3.68	3.08	3.06	4.91	0.63	1.85	3.49	1.48	2.10	3.17	2.56	3.44	33.45
1965	2.01	3.51	1.89	2.59	1.03	4.04	0.69	2.46	2.80	2.42	2.48	1.53	27.45
1966	3.84	3.76	1.72	1.52	2.97	1.63	2.31	1.74	4.71	2.75	4.30	2.42	33.67
1967	2.46	1.94	2.67	4.06	6.57	4.27	2.94	2.34	2.90	1.17	2.85	5.47	39.64
1968	2.92	1.22	5.98	2.00	3.04	8.26	1.12	1.94	1.33	2.16	7.66	6.63	44.26
1969	2.96	5.30	2.74	3.30	2.00	2.05	3.43	2.61	5.22	1.98	8.22	9.30	49.11
1970	0.56	4.40	3.87	3.77	3.02	4.83	1.75	5.19	3.38	3.62	3.67	5.82	43.88
1971	1.49	5.89	2.91	3.00	4.33	1.70	2.48	2.88	1.39	3.36	6.71	2.78	38.92
1972	1.56	4.88	5.91	4.20	5.79	8.06	4.20	0.78	3.44	3.28	7.54	5.47	55.11
1973	2.48	1.89	2.49	7.50	4.67	5.42	4.60	4.44	2.61	3.22	2.00	7.90	49.22
1974	2.87	2.53	4.11	3.59	3.46	3.26	0.82	2.54	5.39	2.33	2.29	5.06	38.25
1975	4.85	2.96	2.88	2.08	1.77	3.95	1.42	6.55	6.19	5.68	5.59	5.57	49.49
1976	5.21	2.36	2.44	2.30	2.07	1.03	6.20	4.58	1.25	4.24	0.46	2.64	34.78
1977	4.62	2.75	5.78	4.33	3.60	4.49	2.63	2.00	5.09	5.22	2.32	5.43	48.26
1978	9.66	4.36	3.42	2.91	4.84	1.13	1.65	3.16	0.40	3.27	2.34	3.89	41.03
1979	11.07	3.00	3.25	3.41	4.53	0.75	1.01	4.36	3.45	4.22	3.85	1.58	44.48
1980	0.37	0.87	4.37	4.43	2.11	3.33	4.16	1.04	1.02	4.70	3.18	1.10	30.68
1981	0.58	6.46	0.67	3.49	1.79	1.11	5.19	1.19	2.15	3.74	4.23	5.37	35.97
1982	6.30	1.87	2.06	2.40	3.34	10.78	3.21	2.91	1.23	4.09	3.12	1.10	42.41
1983	5.18	4.73	7.92	6.47	2.73	2.61	0.31	3.08	0.98	3.59	10.08	5.82	53.50
1984	2.14	7.30	7.77	3.58	8.21	1.98	3.99	0.85	0.54	3.15	0.88	1.88	42.27
1985	0.97	1.33	2.58	1.21	2.47	2.93	3.20	2.89	1.24	1.11	5.52	1.02	26.47
1986	4.00	2.17	2.61	1.76	0.97	5.99	4.43	2.89	1.98	2.79	6.58	7.64	43.81
1987	7.38	0.36	3.38	13.17	2.43	1.87	1.64	2.92	9.15	3.09	1.79	3.95	51.13
1988	2.53	3.01	3.27	2.70	3.94	1.08	7.19	2.96	1.74	1.98	6.36	0.86	37.62
1989	0.58	2.68	3.27	4.52	4.13	5.32	4.19	5.26	3.85	5.52	5.65	0.93	45.90
1990	4.57	3.88	1.39	5.61	6.73	1.16	6.21	6.55	1.38	7.37	2.13	3.19	50.17
1991	3.95	1.66	4.26	6.01	0.83	2.89	2.65	6.42	7.55	4.04	6.14	2.80	49.20
1992	3.52	2.94	3.38	2.90	1.75	5.20	3.14	5.14	3.99	2.51	4.21	5.28	43.96
1993	1.94	5.30	6.46	4.52	0.76	1.95	2.15	2.63	4.74	4.00	4.02	5.48	43.95
1994	2.66	1.83	4.90	2.12	6.00	0.94	1.35	5.80	7.21	0.30	5.69	7.09	45.89
1995	4.67	2.88	2.56	1.73	2.29	1.86	2.73	1.00	3.35	6.32	8.36	3.81	41.56
1996	6.41	2.61	2.72	5.29	3.51	1.62	4.73	1.13	6.85	14.11	2.49	6.69	58.16
1997	2.93	6.85	4.56	6.46	2.54	0.64	1.13	3.43	1.42	1.85	6.85	4.56	43.22
1998	6.70	6.97	4.74	3.78	5.13	11.70	4.07	2.82	1.45	6.48	1.32	1.47	56.63
1999	6.36	3.40	4.03	0.49	3.57	0.00	2.81	1.35	8.62	4.87	2.29	2.17	39.96
2000	3.80	3.78	3.95	8.11	3.03	5.26	7.53	2.17	3.23	3.60	5.69	4.60	54.75
2001	2.21	2.45	12.27	1.28	1.57	5.87	2.81	4.22	2.34	1.36	0.87	3.00	40.25
2002	3.05	3.07	3.99	4.00	5.55								

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum (per year)
Mean	**3.68**	**3.36**	**3.93**	**3.78**	**3.39**	**3.12**	**3.17**	**3.29**	**3.36**	**3.85**	**4.39**	**3.93**	**43.20**
Minimum	0.37	0.36	0.67	0.49	0.63	0.00	0.31	0.78	0.40	0.30	0.46	0.86	*26.47*
Maximum	11.07	7.30	12.27	13.17	9.73	11.70	7.53	10.63	9.15	14.11	10.08	9.30	*58.16*
Count	53	53	53	53	53	52	52	52	52	52	52	52	*52*

Table 8-2

Rainfall data for 1987

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		0.01		2.00					0.31	0.12		1.01
2	0.85		0.16	0.27								0.03
3	1.00		1.46			0.03	0.98	0.39		1.69	0.02	0.05
4			0.20	0.01	0.32		0.05	0.04			0.08	
5				3.77	0.43	0.40				0.03		0.02
6				2.29	0.86							
7				1.79	0.01				0.07	0.04		
8				0.14			0.04	0.11	0.05			
9				0.05					1.45			
10	1.16	0.35						1.35	0.01		0.32	
11	0.20						0.05			0.04	0.38	
12										0.34	0.24	0.79
13				0.24								0.09
14			0.20	0.78		0.29			2.40			
15	0.02											
16				0.01	0.34	0.20						1.41
17				0.18								
18				0.21					0.10			
19	0.80			0.17					1.16			
20	0.43			0.01					2.42	0.09	0.30	
21			0.24						0.86			0.31
22			0.27			0.24						
23	1.41		0.02			0.40		0.02	0.06			
24					0.36							
25	0.08			0.02								
26	0.07					0.26	0.50				0.04	
27			0.08				0.02				0.17	0.08
28					0.11	0.05				0.74		
29								0.06				0.16
30				1.23				0.80				
31	1.36		0.75					0.15	0.26		0.20	
Days with rain	11	2	9	17	7	8	6	8	12	8	9	10
Total rainfall	**7.38**	**0.36**	**3.38**	**13.17**	**2.43**	**1.87**	**1.64**	**2.92**	**9.15**	**3.09**	**1.75**	**3.95**
Minimum rainfall	0.02	0.01	0.02	0.01	0.01	0.03	0.02	0.02	0.01	0.03	0.02	0.02
Maximum rainfall	1.41	0.35	1.46	3.77	0.86	0.40	0.98	1.35	2.42	1.69	0.38	1.41

Table 8-3

Rainfall data for 1988

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1						0.02	0.03	0.20				
2		0.54					0.14				2.18	
3										0.22		
4		0.64		0.15						0.02		
5	0.30		0.36	0.03	0.02					0.28		
6					0.09				1.40	0.08	0.29	
7				0.35								
8								0.20		0.13		
9	0.56					0.04				0.74		
10					0.11		0.12		0.09			
11		0.24		0.12	0.22						0.24	
12		0.85			0.27		0.22					
13												0.03
14			0.30								0.57	0.07
15		0.33		0.35			0.05	0.02				
16								0.13				
17								0.98			0.05	
18				0.17	0.24		0.89				0.41	
19	0.28				1.00					0.02		
20		0.41			0.04		0.38				0.20	
21	0.29				0.05		0.28		0.25		1.65	
22							0.59			0.19		
23				0.10	0.15	0.70	0.04			0.27		
24					0.45		1.63	0.01				
25	1.10		0.20		0.25		0.35	0.87		0.03		0.60
26					0.05							
27			2.41				0.25					
28				1.43							0.47	
29							2.22				0.30	0.16
30						0.32		0.55				
31					1.00							
Days with rain	5	6	4	8	14	4	14	8	3	10	10	4
Total rainfall	**2.53**	**3.01**	**3.27**	**2.70**	**3.94**	**1.08**	**7.19**	**2.96**	**1.74**	**1.98**	**6.36**	**0.86**
Minimum rainfall	0.28	0.24	0.20	0.03	0.02	0.02	0.03	0.01	0.09	0.02	0.05	0.03
Maximum rainfall	1.10	0.85	2.41	1.43	1.00	0.70	2.22	0.98	1.40	0.74	2.18	0.60

Table 8-4

Rainfall data for 1989

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1				0.08							1.28	
2					0.56							
3					0.44	0.90				1.17	0.80	0.15
4		0.27		0.15							1.22	
5			0.03	0.04			0.93					
6				0.36	0.60	0.02						
7				0.29		0.33	0.58	0.14		0.02		0.15
8	0.01	0.09	0.02	0.33		0.42						
9				0.14		0.15					0.56	
10				0.05		1.90					0.24	
11				0.02	0.78		0.48			0.45		
12			0.02		1.39			1.34				
13	0.18		0.12			0.12		1.10				
14		0.05						1.25				
15	0.15	0.03				0.20			1.20	0.57	0.15	
16		0.39		1.60	0.01	0.03		0.04			0.16	0.40
17				0.69		1.10	0.78		0.34		0.57	
18						0.02	0.25			1.10		
19			0.35	0.22		0.08			0.08	0.10		
20								0.35	0.52	0.96	0.22	
21		0.33					0.05	0.02	0.45	1.10	0.17	
22		0.95			0.08				0.09			
23		0.20							0.08			
24						0.03		0.09			0.09	
25		0.15	1.39		0.14							
26		0.01	0.04						0.42			
27	0.20	0.21							0.67		0.07	
28					0.13	0.02	0.95				0.12	
29							0.09					0.10
30	0.04			0.55				0.53				0.07
31			1.30				0.08			0.05		0.06
Days with rain	5	11	8	13	9	14	9	9	9	9	13	6
Total rainfall	**0.58**	**2.68**	**3.27**	**4.52**	**4.13**	**5.32**	**4.19**	**4.86**	**3.85**	**5.52**	**5.65**	**0.93**
Minimum rainfall	0.01	0.01	0.02	0.02	0.01	0.02	0.05	0.02	0.08	0.02	0.07	0.06
Maximum rainfall	0.20	0.95	1.39	1.60	1.39	1.90	0.95	1.34	1.20	1.17	1.28	0.40

Table 8-5

Rainfall data for 1990

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.50				0.52			0.01		0.14		
2					0.02		0.05		0.50			
3		0.65					0.01					
4		0.29		3.31	0.58	0.07						0.76
5		0.88			0.09					0.53		
6											0.65	
7			0.04		0.03	0.01		0.14				
8				0.06	0.18	0.01		0.46				0.05
9					0.02		0.03	0.15		0.54		
10		0.10				0.05	0.01		0.13			
11		0.08		0.24	0.88	0.55		0.04			1.11	
12						0.35		2.47		0.04		
13			0.15		0.48		0.24			0.02		
14			0.13		0.27					2.18		
15												
16	0.35	1.15		1.17	0.69				0.42			0.74
17					0.42				0.04			0.03
18			0.38	0.10							0.03	0.05
19					0.12	0.01		0.12		1.12	0.01	0.28
20			0.28			0.02		0.23	0.28			
21	0.42		0.31	0.20	0.32		0.20		0.01			
22	0.47			0.32	0.23							0.12
23	0.06	0.10			0.03		0.21	0.07		0.02		
24	0.12	0.48					0.30			2.38	0.27	0.45
25		0.10					2.25	2.78				
26	0.53	0.05					2.81	0.08			0.01	
27	0.52						0.10					
28												0.23
29										0.40	0.05	
30	1.60			0.21	1.71	0.09						0.25
31			0.10		0.14							0.23
Days with rain	9	10	7	8	18	9	11	11	6	10	7	11
Total rainfall	**4.57**	**3.88**	**1.39**	**5.61**	**6.73**	**1.16**	**6.21**	**6.55**	**1.38**	**7.37**	**2.13**	**3.19**
Minimum rainfall	0.06	0.05	0.04	0.06	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.03
Maximum rainfall	1.60	1.15	0.38	3.31	1.71	0.55	2.81	2.78	0.50	2.38	1.11	0.76

Table 8-6

Rainfall data for 1991

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1						0.03					1.38	
2			0.14				0.21		0.04		0.16	
3			0.02									0.98
4			1.29			0.26		0.03				0.67
5						0.73		0.24	0.76			
6						0.02			0.31	0.84		0.18
7		0.04	0.42	0.02	0.05		0.07					
8		0.41										
9												
10	0.55			0.01				0.60				
11				0.06				0.17			1.20	
12	1.50					0.24				0.25	0.33	
13	0.19					0.27						
14		0.80					0.86		0.15			0.26
15			0.37						0.01			0.38
16		0.27		0.33		0.90		0.10	0.29	0.52	0.03	
17	1.10				0.43	0.17						0.03
18										1.14		
19		0.14	0.56					0.80				0.20
20						0.12		2.40	1.73			
21	0.11			0.66				1.88	0.03			0.10
22			0.19	3.64				0.20			1.12	
23				0.02		0.15	0.25				0.75	
24			0.81						0.13		0.75	
25			0.23						2.19		0.17	
26					0.01		0.06		1.53			
27				0.01			1.15		0.38			
28	0.01				0.23		0.05					
29				0.17							0.25	
30			0.23	1.09	0.01							
31	0.49				0.10					1.29		
Days with rain	7	5	10	10	6	10	7	9	12	5	10	8
Total rainfall	**3.95**	**1.66**	**4.26**	**6.01**	**0.83**	**2.89**	**2.65**	**6.42**	**7.55**	**4.04**	**6.14**	**2.80**
Minimum rainfall	0.01	0.04	0.02	0.01	0.01	0.02	0.05	0.03	0.01	0.25	0.03	0.03
Maximum rainfall	1.50	0.80	1.29	3.64	0.43	0.90	1.15	2.40	2.19	1.29	1.38	0.98

Table 8-7

Rainfall data for 1992

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		0.02		0.02		1.62		0.90				
2		0.02	0.04		0.11	0.68		0.01				
3					1.20						0.53	0.45
4							0.13		1.02		0.39	
5	1.56	0.07					0.08	0.01				0.11
6						1.72	0.56				0.22	
7		0.02	0.06			0.08						
8		0.06	0.48									
9		0.04			0.20	0.20	0.58	0.23	0.15			
10	0.14							0.67		0.71		
11			0.32	0.12			0.32	0.01	0.66	0.52	0.04	
12			0.29	0.38	0.01			0.47		0.45	0.02	2.40
13					0.01		0.02				0.28	0.89
14	0.04	0.12						0.25				
15	0.32	1.60					0.10	0.05				
16					0.04		0.52	0.36				
17				0.97			0.01	0.81		0.12		0.01
18				0.17			0.06	1.28			0.27	0.27
19		0.27	0.10	0.08	0.02			0.09	0.22	0.02		
20			0.31			0.12	0.04		0.02	0.11		0.07
21						0.03				0.02		
22			0.04			0.02			0.03	0.13	0.05	
23			0.19	0.10					0.75		1.49	
24	1.46						0.29				0.20	
25				0.82	0.16	0.52				0.32	0.29	
26		0.72		0.24						0.03	0.07	
27			0.72						1.14		0.36	
28			0.10			0.21						
29			0.35									
30							0.43			0.08		0.50
31			0.38									0.58
Days with rain	5	10	13	9	8	10	13	13	8	11	13	9
Total rainfall	**3.52**	**2.94**	**3.38**	**2.90**	**1.75**	**5.20**	**3.14**	**5.14**	**3.99**	**2.51**	**4.21**	**5.28**
Minimum rainfall	0.04	0.02	0.04	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.01
Maximum rainfall	1.56	1.60	0.72	0.97	1.20	1.72	0.58	1.28	1.14	0.71	1.49	2.40

Table 8-8

Rainfall data for 1993

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		0.07				0.66					0.81	
2		0.02		0.60		0.13					0.01	
3								0.01		0.36		0.02
4				0.07					0.38	0.17	0.03	
5	0.22		0.71					1.62	0.77	0.11		1.05
6	0.19		0.40		0.04	0.52					0.23	1.38
7						0.11						
8							0.13		0.08			
9						0.05	0.09		0.49			
10			0.08						0.19			
11			0.25	0.15					0.06			0.82
12				0.22	0.08	0.06						0.16
13	0.08	2.82		0.11						0.89		
14	0.63		2.80	0.01	0.01	0.02					0.05	0.14
15	0.09									0.08	0.02	0.05
16	0.07								0.10	0.06		0.12
17		1.26		0.57	0.05		0.09		0.06			
18			0.51	0.58				0.42	0.17	0.05	1.38	
19		0.02			0.46			0.02	0.02			
20							0.64	0.01		0.14	0.47	0.02
21					0.09	0.20	0.03	0.55		0.15		0.28
22	0.02	1.11	0.02			0.08			0.69	0.54		1.20
23	0.35			0.92					0.01			
24			1.12	0.02			0.03		0.02			
25	0.08				0.03						0.07	0.01
26									0.09			
27				1.26			0.72		0.80	0.06		
28				0.01		0.02	0.40		0.81	0.27		
29			0.53			0.10						
30			0.03				0.02				0.95	0.23
31	0.21		0.01							1.12		
Days with rain	10	6	11	12	7	11	9	6	16	13	10	13
Total rainfall	**1.94**	**5.30**	**6.46**	**4.52**	**0.76**	**1.95**	**2.15**	**2.63**	**4.74**	**4.00**	**4.02**	**5.48**
Minimum rainfall	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.05	0.01	0.01
Maximum rainfall	0.63	2.82	2.80	1.26	0.46	0.66	0.72	1.62	0.81	1.12	1.38	1.38

Table 8-9

Rainfall data for 1994

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1					0.03						0.46	
2					0.24	0.20			0.02		0.42	
3			0.15									
4	0.72		0.43	0.02				0.14				
5	0.31				1.10				0.03			0.05
6					0.41			0.56	0.54			1.25
7	0.18			0.23	0.35	0.08						0.03
8	0.80		0.16		0.43		0.10					0.24
9	0.09	0.43	0.02		0.51		0.02				0.02	
10		0.17	0.44						0.29		0.01	0.05
11				0.23								1.08
12		0.42				0.04				0.02		
13	0.13			0.05	0.04	0.15		0.07	0.07			
14				0.62				1.02	0.24			
15						0.03	0.01	0.02				
16			0.12		0.49							
17			0.70	0.45	1.32		0.16					
18					0.20			1.80	1.14			0.05
19			0.09		0.06		0.02	0.41	0.01	0.03	2.05	0.47
20				0.02				0.01				
21										0.02		
22		0.04	0.97			0.08		0.78			0.85	
23			0.90					1.00	0.94			
24	0.04	0.63			0.29		0.18		3.63	0.23		1.97
25		0.09			0.10	0.09			0.03			1.95
26	0.11	0.05		0.29	0.30							
27					0.13		0.34					
28	0.25		0.44	0.21			0.04		0.27		1.26	
29	0.03		0.26			0.05	0.48				0.62	
30			0.22			0.22						
31												
Days with rain	10	7	13	9	16	9	9	10	12	4	8	10
Total rainfall	**2.66**	**1.83**	**4.90**	**2.12**	**6.00**	**0.94**	**1.35**	**5.81**	**7.21**	**0.30**	**5.69**	**7.14**
Minimum rainfall	0.03	0.04	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.02	0.01	0.03
Maximum rainfall	0.80	0.63	0.97	0.62	1.32	0.22	0.48	1.80	3.63	0.23	2.05	1.97

Table 8-10

Rainfall data for 1995

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.42		0.32									
2	1.12								0.02		0.66	
3								0.04			0.75	
4				0.01		0.18		0.19			0.07	0.10
5		1.52		0.20				0.05		0.21		
6			0.30					0.35		2.70		0.15
7	0.54					0.25		0.33		0.05		
8	0.15					0.47				0.04	1.07	
9			0.75			0.15	0.37					
10				0.12								1.52
11					0.02							
12	0.48				0.70	0.15	0.10				0.90	
13	0.02			0.43	0.04	0.20						
14				0.05	0.05	0.19					0.04	
15				0.01	0.18	0.04			0.05	0.65	4.20	0.70
16		0.31			0.38	0.17					0.01	
17	0.13		0.11									0.34
18			0.52		0.08		0.38		2.58			
19	0.07										0.29	
20	0.05			0.65	0.12						0.10	0.95
21	1.55		0.02				0.01				0.02	0.05
22	0.07		0.26	0.21						1.76		
23	0.07								0.24			
24		0.23										
25		0.14	0.20		0.52		0.17					
26						0.06			0.40			
27							0.67		0.04			
28		0.67						0.04		0.01		
29				0.03	0.11		0.45			0.90	0.25	
30				0.02	0.09		0.58					
31			0.08									
Days with rain	12	5	9	10	11	10	8	6	6	8	12	7
Total rainfall	**4.67**	**2.87**	**2.56**	**1.73**	**2.29**	**1.86**	**2.73**	**1.00**	**3.33**	**6.32**	**8.36**	**3.81**
Minimum rainfall	0.02	0.14	0.02	0.01	0.02	0.04	0.01	0.04	0.02	0.01	0.01	0.05
Maximum rainfall	1.55	1.52	0.75	0.65	0.70	0.47	0.67	0.35	2.58	2.70	4.20	1.52

Table 8-11

Rainfall data for 1996

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1					0.22		0.32	0.60				0.07
2				0.32					0.05			1.25
3	0.44	0.17	0.58						1.17			
4	0.50				0.22	0.35	0.08					
5					0.42	0.05	0.15					
6			0.45		0.13	0.02						
7			0.24	0.01	0.35							0.80
8	0.38		0.75	0.55					0.54		0.05	1.45
9	0.65	0.15	0.11			0.04	0.10			2.31		
10	0.13			1.00	0.09	0.02	0.11	0.22			0.32	
11	0.04	0.09		0.27	0.12	0.05			0.08	0.06	0.01	
12		0.10			0.46	0.01						0.07
13	1.56				0.27		0.63	0.06	0.16			0.21
14				0.30			1.87	0.08	0.14			0.16
15		0.33		0.08					0.03			0.47
16				0.06			0.03		0.01			0.13
17		0.34		1.67	0.81				0.18	0.08		0.22
18									2.60			0.57
19					0.15				0.79			0.13
20	0.73		0.58			0.03	0.07			0.58	0.20	0.75
21		0.02				0.02				9.44		
22	0.03	0.86			0.05	0.02		0.01		1.12		
23				0.27		0.20			0.39	0.08		
24		0.05		0.04			1.04	0.09		0.04		
25	0.36	0.50				0.68		0.07	0.31		0.03	0.40
26											0.55	
27				0.03			0.16				1.00	
28	1.44					0.12					0.33	
29									0.40	0.28		0.01
30	0.15			0.68								
31					0.22					0.10		
Days with rain	12	10	6	13	13	13	11	7	14	10	8	15
Total rainfall	**6.41**	**2.61**	**2.71**	**5.28**	**3.51**	**1.61**	**4.56**	**1.13**	**6.85**	**14.09**	**2.49**	**6.69**
Minimum rainfall	0.03	0.02	0.11	0.01	0.05	0.01	0.03	0.01	0.01	0.04	0.01	0.01
Maximum rainfall	1.56	0.86	0.75	1.67	0.81	0.68	1.87	0.60	2.60	9.44	1.00	1.45

Table 8-12

Rainfall data for 1997

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.11	0.07		1.07							0.04	0.85
2	0.06		0.10	1.83	0.27		0.11		0.01		2.48	
3	0.12		0.02		0.12		0.10				0.13	
4		0.14					0.55	0.70	0.12	0.22		0.07
5		0.54	0.02					0.05		0.20		
6	0.10	0.24	0.68	0.01								
7			0.05		0.09							
8			0.12						0.12		0.31	
9								0.07		0.03	0.94	
10	0.19		0.30		0.11		0.15				0.53	
11					0.05							
12		0.07	0.10					0.01	0.30			
13				0.71								
14				0.02	0.13	0.23		0.86			0.06	
15		0.71	1.15		0.07		0.11				1.37	
16					0.29		0.04	0.01				
17	0.51	0.14			0.03							
18				0.82		0.05	0.02	0.34				
19				1.25	0.10	0.33						
20				0.02	0.94							
21					0.02			0.19	0.50			
22			0.28				0.04	1.15			0.60	
23	0.05					0.02		0.02			0.37	0.01
24									0.02			2.09
25	1.00				0.02		0.01			0.09		0.12
26			0.65		0.30	0.01				0.47		0.51
27		0.42								0.64		
28	0.49	0.10		0.23						0.20		
29	0.26			0.60				0.03	0.35			
30			0.77								0.02	
31	0.04		0.05									0.91
Days with rain	11	9	13	10	14	5	9	11	7	7	11	7
Total rainfall	**2.93**	**2.43**	**4.29**	**6.56**	**2.54**	**0.64**	**1.13**	**3.43**	**1.42**	**1.85**	**6.85**	**4.56**
Minimum rainfall	0.04	0.07	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.03	0.02	0.01
Maximum rainfall	1.00	0.71	1.15	1.83	0.94	0.33	0.55	1.15	0.50	0.64	2.48	2.09

Table 8-13

Rainfall data for 1998

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1			0.27			1.69	1.09			0.03		
2			0.01	0.41	0.80		0.18					
3				0.11		0.32			0.05			
4					0.02							
5	0.06				0.60							
6	0.11	0.13			0.50							
7	0.04				0.47			0.12	0.08			
8	1.16				0.23	0.03		0.01	0.23	0.03		
9	0.25		0.79	0.11	0.01					2.58		0.30
10	0.25		1.47	0.05	0.64				0.02	0.75		
11					0.72					1.58	0.14	
12		0.72			0.86			0.61		0.22	0.37	
13		0.01				0.33		0.93				
14	0.08					5.98						
15			0.01			0.72				1.07		
16	0.52					1.83			0.08			
17	0.55					0.04					0.07	
18		1.75		0.48				0.63			0.18	0.22
19	0.08	1.33	0.58			0.01		0.20				
20	0.09	0.05	0.84	0.92			0.01				0.16	
21											0.08	
22			0.77									0.06
23									0.90			0.12
24	3.26	0.62		1.44		0.13	1.80	0.03				
25	0.20	2.36		0.03								
26				0.17		0.61		0.09				
27				0.05	0.13				0.09		0.32	
28						0.01						
29								0.15		0.22		
30					0.15		0.43	0.05				0.77
31	0.05						0.56					
Days with rain	14	8	8	10	12	12	6	10	7	8	7	5
Total rainfall	**6.70**	**6.97**	**4.74**	**3.77**	**5.13**	**11.70**	**4.07**	**2.82**	**1.45**	**6.48**	**1.32**	**1.47**
Minimum rainfall	0.04	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.02	0.03	0.07	0.06
Maximum rainfall	3.26	2.36	1.47	1.44	0.86	5.98	1.80	0.93	0.90	2.58	0.37	0.77

Table 8-14

Rainfall data for 1999

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1			1.25				0.48			0.39		
2							0.30					
3		1.85									0.75	
4	1.61		0.41		0.20		0.01				0.01	
5		0.25			0.55					0.54		
6					0.09							
7	0.01		0.77	0.02			0.37	0.09	0.29			1.15
8			0.05		0.01				0.02			0.01
9	0.56				0.17				0.13	0.08		
10	0.24			0.02			0.08					
11									4.37	0.23	0.43	
12	0.11		0.10									
13		0.17					0.04				0.09	
14	0.03							0.03		0.43		0.30
15	1.10		0.34					0.70		0.33	0.03	0.18
16	0.82		0.17	0.28				0.04	0.55			0.12
17									2.82			
18										1.44		
19	0.75	0.72			0.23					0.01		
20				0.04	0.45		0.44			0.02		
21								0.10		0.85	0.18	0.41
22			0.22		0.09			0.32	0.18			
23	0.03			0.05			0.08	0.01	0.12	0.54		
24	0.10			0.07	0.97					0.01		
25		0.11	0.10		0.79		1.01					
26		0.30			0.02				0.14		0.36	
27	0.54			0.01							0.11	
28	0.09		0.45					0.06			0.33	
29	0.37		0.17									
30												
31												
Days with rain	14	6	11	7	11	0	9	8	9	12	9	6
Total rainfall	**6.36**	**3.40**	**4.03**	**0.49**	**3.57**	**0.00**	**2.81**	**1.35**	**8.62**	**4.87**	**2.29**	**2.17**
Minimum rainfall	0.01	0.11	0.05	0.01	0.01	0.00	0.01	0.01	0.02	0.01	0.01	0.01
Maximum rainfall	1.61	1.85	1.25	0.28	0.97	0.00	1.01	0.70	4.37	1.44	0.75	1.15

Table 8-15

Rainfall data for 2000

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1								0.09			0.23	0.07
2			0.02		0.15			0.18	0.10			
3	0.02				0.10	0.37			0.32			
4	0.14			0.14				0.06				
5	0.93			0.14		0.01				0.02	0.42	
6					0.10				0.01	0.80	0.50	
7				0.11		3.54				0.08		
8						0.13		0.01				
9				0.47	0.09							
10	0.01		0.03	0.18		0.01	0.81	0.09		0.01	0.15	
11	0.92				0.57						1.88	0.04
12		0.10	1.51	0.07		0.19					0.07	0.02
13			0.18						0.19			
14	0.16	0.82			0.23	0.04		0.63	0.04		0.01	0.32
15		0.61					1.77	0.26	0.01		0.95	0.30
16							0.02		1.26			
17	0.02		0.95	0.02				0.35		0.57		0.88
18			0.03				0.82					1.58
19		0.80		0.76	0.22	0.17		0.22		0.97		
20		0.03		0.14	0.37				0.82			0.42
21	0.10			0.03			0.72		0.01			
22			0.02	3.24	0.02	0.01						
23				1.53	0.31	0.20	0.01					
24				0.24	0.11			0.28				
25	0.02	0.43			0.76		0.06					
26	1.02	0.65		0.13			0.75					
27		0.05		0.91		0.10	1.73		0.47		1.42	
28		0.08	0.78			0.40						
29		0.21	0.43			0.06					0.01	
30						0.03				1.15	0.05	
31	0.46						0.84					0.97
Days with rain	11	10	9	15	12	14	10	10	10	7	11	9
Total rainfall	**3.80**	**3.78**	**3.95**	**8.11**	**3.03**	**5.26**	**7.53**	**2.17**	**3.23**	**3.60**	**5.69**	**4.60**
Minimum rainfall	0.01	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Maximum rainfall	1.02	0.82	1.51	3.24	0.76	3.54	1.77	0.63	1.26	1.15	1.88	1.58

☐ Sampled storm

Table 8-16

Rainfall data for 2001

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		0.15					0.48		0.03		0.21	
2						0.05	0.98				0.01	
3						1.27					0.06	
4								0.62				
5			0.23				0.10	0.04	0.22		0.02	0.01
6	0.42	1.09	2.28				0.19				0.18	
7			0.41	0.08						0.02		
8				0.26			0.08					
9	0.15	0.07		0.02			0.01				0.08	0.67
10	0.06	0.16	0.59	0.07								0.05
11							0.04	1.72				
12				0.17		0.63		0.05				
13			0.53	0.23				1.48				
14								0.07	0.11			0.06
15		0.18					0.32		0.02	0.09		0.49
16	0.35				0.20					0.06		
17		0.15			0.09		0.01			1.19		
18				0.40		2.74	0.26					0.92
19												0.05
20	0.35							0.14				
21	0.18					0.35		0.07	0.27			
22			2.78	0.02	0.03				0.71			
23		0.16	2.69		0.19	0.38						
24	0.04				0.17							0.69
25				0.03	0.11	0.45					0.01	0.06
26		0.49							0.87		0.18	
27			0.03		0.57		0.34					
28					0.05			0.03				
29					0.07				0.11		0.04	
30			0.31		0.06						0.08	
31	0.66		2.42		0.03							
Days with rain	8	8	10	9	11	7	11	9	8	4	10	9
Total rainfall	**2.21**	**2.45**	**12.27**	**1.28**	**1.57**	**5.87**	**2.81**	**4.22**	**2.34**	**1.36**	**0.87**	**3.00**
Minimum rainfall	0.04	0.07	0.03	0.02	0.03	0.05	0.01	0.03	0.02	0.02	0.01	0.01
Maximum rainfall	0.66	1.09	2.78	0.40	0.57	2.74	0.98	1.72	0.87	1.19	0.21	0.92

[box] Sampled storm

Table 8-17

Rainfall data for 2002

Source: Salem Beverly Water Supply Board

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		0.80		1.17								
2		0.18										
3			0.69	0.04	0.52							
4				0.25								
5												
6												
7	0.50											
8	0.15											
9												
10			0.21	0.06	0.21							
11		0.45										
12	0.10	0.06										
13	0.26				0.63							
14	0.84			0.02	2.44							
15	0.33			0.12	0.01							
16			0.12									
17			0.28									
18	0.05	0.38		0.04	0.55							
19			0.27		0.79							
20	0.20											
21		0.28	1.10									
22	0.23	0.03										
23				0.20								
24												
25	0.16		0.01									
26				**1.12**								
27		0.43	1.20									
28		0.46			0.07							
29	0.23			0.78	0.14							
30			0.11	0.20	0.19							
31												
Days with rain	11	9	9	11	10							
Total rainfall	**3.05**	**3.07**	**3.99**	**4.00**	**5.55**							
Minimum rainfall	0.05	0.03	0.01	0.02	0.01							
Maximum rainfall	0.84	0.80	1.20	1.17	2.44							

[box] Sampled storm