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WATER QUALITY CHARACTERISTICS OF STORMWATER RUNOFF IN TRIBUTARIES OF THE ASHLEY RIVER ESTUARY CHARLESTON, SOUTH CAROLINA

S.C. Coastal Management Program

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Water Quality Characteristics of
Stormwater Runoff in Tributaries of the
Ashley River Estuary
Charleston, South Carolina

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Introduction

A study to examine the water quality characteristics of stormwater runoff associated with nonpoint sources in the Ashley River sub-basin was completed between April and October, 1987. The study was conducted in cooperation with the S. C. Coastal Council, and the U. S. Geological Survey.

The two principal categories of inputs which ultimately result in variable surface water quality characteristics are point and nonpoint sources. Some of the more important water quality variables which may be associated with these inputs include bacteria, organic solids, sediment, biochemical oxygen demand (BOD), nutrients, dissolved oxygen, and metals (Thomann and Mueller, 1987). Point sources are inputs originating from a well defined discharge and under most circumstances are continuous. In South Carolina, the main types of point sources are discharges from municipal and industrial waste treatment facilities. The South Carolina Department of Health and Environmental Control regulates these dischargers under the National Pollutant Discharge Elimination System (NPDES) permitting program (Regulation 61-9). Nonpoint source (NPS) discharges have a diffuse origin, are not related to a well defined location, and are generally transient in time. Nonpoint source pollution categories and land use classifications are listed in Table 1.

Stormwater is the runoff resulting from precipitation and its quality generally incorporates the impurities in

Table 1. Nonpoint Source Pollution Categories and Land Use Classifications (from US EPA, 1987)

Urban and Suburban
Industrial
Commercial
Residential
Agricultural
Cultivated
Pasture
Feedlots
Groves/Orchards
Aquaculture
Silviculture (Forestlands)
Construction
Land Disposal
Landfills
Hazardous Waste
Sludge
Wastewater
Septic Tanks
Spills
Waste Storage/Storage Tank Leaks
Mining
Hydrologic/Habitat Modification
Highway/Bridge/Roadside Runoff and Erosion
Recreation
Wildlife
Wetlands
Saltwater Intrusion
Groundwater
Dry Fallout
Precipitation

precipitation plus debris and other impurities deposited on the ground surface (Wanielista, 1978). In recent years it has become increasingly evident that pollution caused by nonpoint sources is one of the major contributors to water quality degradation. The objective of this report is to provide an assessment of various pollutants associated with stormwater runoff from six Ashley River watersheds representing mixed land use associations.

Description of the Study Area

The Ashley River and Cypress Swamp sub-basin is situated in portions of Berkeley, Dorchester, and Charleston Counties. It contains an area about 312 square miles which can be divided into two distinct regions (CH2M Hill and Betz Environmental Engineers, Inc., 1978). Cypress Swamp represents the northern portion of the sub-basin having a dominant land use of rural swampland-forest. The South Carolina highway 165 crossing (Bacon's Bridge) over the Ashley River may be considered as a southern boundary for the Cypress Swamp drainage. Land use in the Ashley River portion of the sub-basin is a gradation from rural to suburban to urban as one proceeds from north to south. Tidal influence within the sub-basin extends into Cypress Swamp.

The Ashley River and Cypress Swamp are hydrologically delineated as sub-basin 03-08-18 (Figure 1). All of the Cypress Swamp tributary to the Ashley River and the

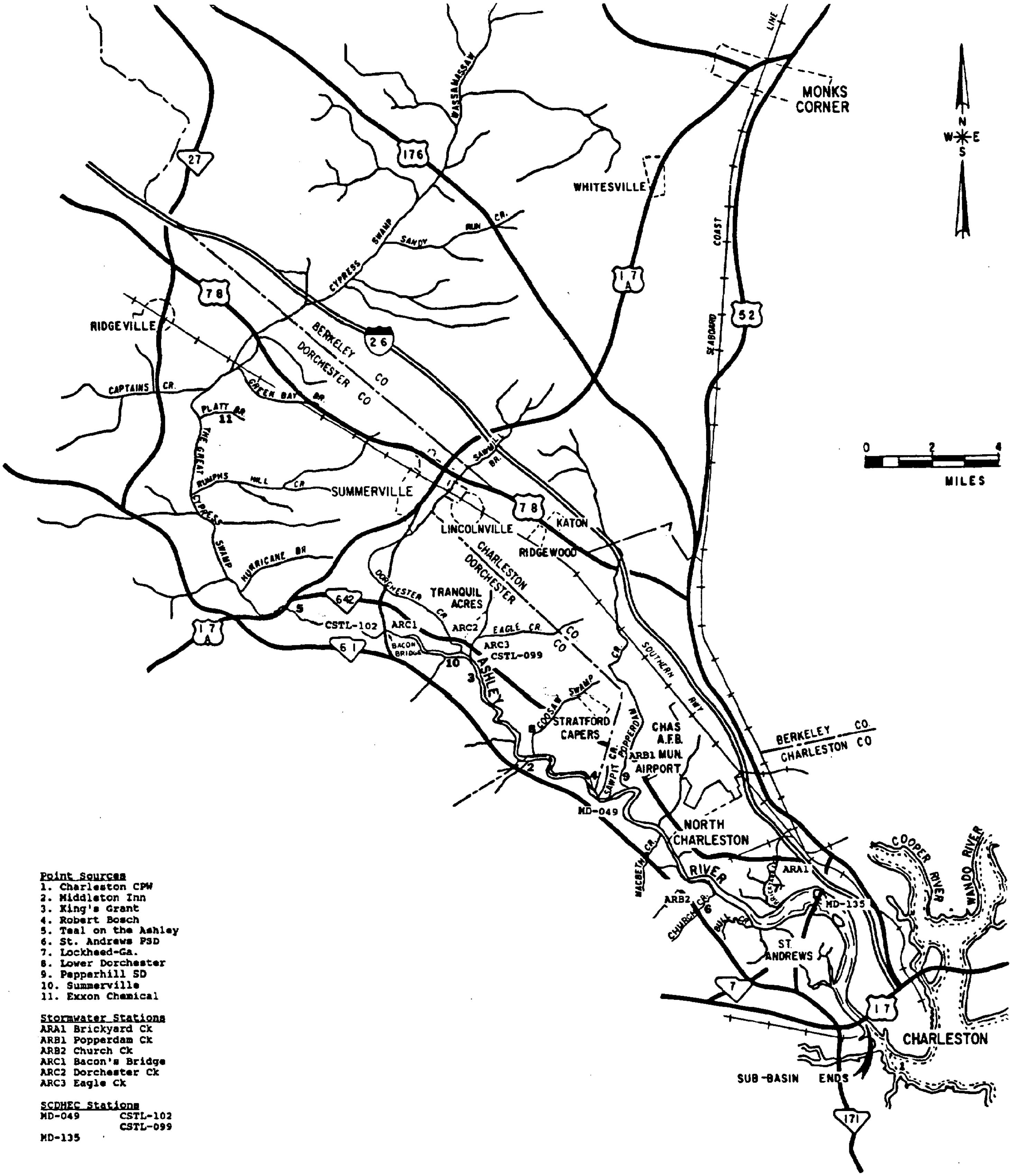


FIGURE 1

UPPER ASHLEY RIVER
ASHLEY RIVER—CYPRESS SWAMP SUB-BASIN
SANTEE-COOPER RIVER BASIN
SOUTH CAROLINA
ADP CODE 03-08-18

freshwater portion of the Ashley River is designated as Class B pursuant to the classification system for protecting water uses described in SCDHEC regulation 61-68. The Ashley River from salt water intrusion to Charleston Harbor is Class SC. Conductivity (salinity) data collected over recent years indicate that the salt water wedge may normally extend to the vicinity of Old Fort Dorchester and even to Bacon's Bridge (SC Hwy 165) during extended periods of very low fresh water discharge from Cypress Swamp. The Department is presently considering a reclassification of part of the salt water portion of the Ashley River from Class SC to SB. Table 2 outlines the dissolved oxygen and fecal coliform water quality standards and uses protected by these classifications.

The Ashley River is an important sub-basin of the Charleston Harbor Estuary. Along the River are many old plantations and gardens of historical significance. Its waters support a diverse fresh and salt water fishery as well as other indigenous aquatic fauna, flora, and waterfowl. Boating, fishing, and swimming are important recreational uses of the River. The Army Corps of Engineers maintains a navigational channel for a few miles above Charleston Harbor and there is some industrial activity along the River itself. The lower Ashley is bounded to the east and northeast by Charleston and North Charleston and to the west by St. Andrews Parish. The City of Summerville and its associated subdivisions are situated adjacent to the

Table 2. Dissolved Oxygen and Fecal Coliform Water Quality Standards Applicable to the Ashley River (from SCDHEC, 1985)

Class	Protected Uses	Standards	
		D.O.	Fecal coliform
B	-Secondary contact recreation -Source for drinking water supply -Fishing -F&F* -Industrial and Agricultural uses	Daily avg not less than 5 mg/l with a low of 4 mg/l	Not to exceed a geometric mean of 1000mpn/100ml from 5 consecutive samples during any 30 day period**
SC	-Secondary contact recreation, crabbing, fishing, except harvesting of clams, mussels, or oysters for market or human consumption -F&F*	Not less than 4 mg/l	Not to exceed a geometric mean of 1000mpn/100ml from 5 consecutive samples during any 30 day period**
SB	-Primary contact recreation -Suitable for uses and exceptions listed in Class SC	Daily avg not less than 5 mg/l with a low of 4 mg/l	Not to exceed a geometric mean of 200mpn/100ml from 5 consecutive samples during any 30 day period***

* :suitable for the survival and propagation of a balanced and indigenous aquatic community of fauna and flora

** :nor shall more than 20% of the samples examined during such period exceed 2000mpn/100ml

*** :nor shall more than 20% of the samples examined during such period exceed 400mpn/100ml

Ashley River within the northeastern portion of the sub-basin.

A number of point sources from wastewater treatment facilities (WWTF) discharge to the Ashley River sub-basin. These are summarized in Table 3 and their discharge points are shown in Figure 2 (back cover insert). The main dischargers are the Charleston CPW Plum Island discharge located at the mouth of the Ashley River; St. Andrews Pierpont WWTF (Church Creek); Lower Dorchester County WWTF (Coosaw Creek); Pepperhill Subdivision WWTF (Popperdam Creek); King's Grant Subdivision WWTF (Upper Ashley River); and the City of Summerville's WWTF (Upper Ashley River). Table 3 includes current permit limits for each discharge and data submitted to SCDHEC in the National Pollutant Discharge Elimination System (NPDES) discharge monitoring reports (DMR's). DMR data in Table 3 represent averages for each discharger over the six month period from April through September, 1987.

Methods

The Ashley River was selected as the site for this study primarily because the sub-basin has and will continue to experience a widespread amount of urban and suburban development. Numerous tidal tributaries carry stormwater into the Ashley River from developed areas; thus, surface water quality in the Ashley estuary has a substantial

Table 3. Main Point Source Discharges in Sub-Basin 03-08-18

		Permit Limits (and DMR* averages for 4/87-9/87)			
Discharger	NPDES#	Flow (mgd)	BOD5 (mg/l)	NH3-N (mg/l)	FC** (MPN or cols/100ml)
Charleston CPW	21229	27.0(16.4)	30.0(4.9)	-	200(30)
Middleton Inn	39063	0.06(0.01)	30.0(31.0)	-	200(1)
King's Grant SD	21911	0.32(0.19)	30.0(6.5)	-	200(114)
Robert Bosch	22951	0.08(.004)	20.0(6.0)	-	-
Teal on the Ashley	30350	0.03(0.02)	10.0(15.3)	7.5(1.1)	200(44)
St. Andrews PSD	26069	4.0(0.95)	15.0(8.4)	5.5(3.2)	200(17)
Lockheed-Ga Corp.	01007	0.06(0.03)	10.0(8.7)	-	-
Lower Dorchester	38822	2.0(1.14)	30.0(7.7)	-(.96)	200(6)
Pepperhill SD	35599	1.2(0.43)	30.0(23.7)	-	1000(27)
Summerville,City of	37541	6.0(4.3)	30.0(14.2)	7.5(4.5)	1000(36)
Exxon Chemical Co.	03905	0.35(0.09)	6.0(4.0)	-	-

* DMR = Discharge Monitoring Reports. They are reviewed by the Enforcement staff in the Bureau of Water Pollution Control (SCDHEC).

** These fecal coliform data are based on either the multiple tube fermentation or membrane filter techniques, which are expressed as MPN/100ml and colonies/100 ml, respectively. Both methods are approved for determining fecal coliform in water under the NPDES program. Results are generally comparable.

potential for nonpoint source degradation when compared to most other similar estuaries in South Carolina.

Using available maps and aerial photography, six watersheds were selected for the study based on land use considerations within the sub-basin. They are identified in Table 4 and Figure 2. In the remainder of this report, study sites will be referred to by their watershed names or the station codes given in Table 4.

A field reconnaissance was completed in each watershed to evaluate the areal distribution of land uses and activities relative to the stream course, station accessibility during rain event sampling, and the feasibility for accurate discharge measurements. One monitoring station was selected for each of the six watersheds. Watershed characteristics are summarized in Table 5.

Three storm events were studied. Flow was measured and water samples were collected during each storm event. All stations were established at bridge or road crossings to provide easy access for sample collection and measurements and to obtain accurate streamflow measurements. Four to five samples were collected at each station during each storm event. An effort was made to analyze samples representing pre-runoff conditions, the rising leg of the runoff hydrograph, maximum discharge, and the receding leg of the runoff hydrograph.

Table 4. ASHLEY RIVER STORMWATER RUNOFF STUDY WATERSHEDS AND STATION IDENTIFICATION

Watershed	USGS Station #	Station Code
Brickyard Creek	325053080002701	ARA1
Popperdam Creek	325410080044001	ARB1
Church Creek	325011080025301	ARB2
Bacon's Bridge, Upper Ashley and Cypress Swamp	325730080120501	ARC1
Dorchester Creek	325708080101401	ARC2
Eagle Creek	325702080093501	ARC3

Table 5. ASHLEY RIVER STORMWATER RUNOFF STUDY - WATERSHED CHARACTERISTICS

Watershed	Station Code	Location	Tidal Influence	Predominant Salinity Range (ppt)	Land Use Characteristics
Brickyard Ck.	ARA1	Lower Ashley R.	tidal saline	10-25	Primarily impervious with high density of industrial /commercial development and moderate density residential areas. Lockheed-Ga point source.
Popperdam Ck.	ARB1	Middle Ashley R.	tidal brackish	1-15	Moderate density residential sites with stormwater drains. Low density commercial-industrial development. Some natural woodlands adjacent to creek. Portions of upper creek have been channelized. Pepperhill SD pt.source.
Church Ck.	ARB2	Mid-Lower Ashley R.	tidal saline	10-25	Low density residential areas, especially in lower portion of watershed; upper section dominated by freshwater wetlands, woodlands, and old strip mine drainages. St. Andrews Pierpont point source.

Table 5., Continued

Watershed	Station Code	Location	Tidal Influence	Predominant Salinity Range (ppt)	Land Use Characteristics
Bacon's Bridge	ARC1	Upper Ashley R.	tidal non-saline	0-2	Primarily influenced by swamp and freshwater wetland sources, with some moderate density residential sites.
Dorchester Ck.	ARC2	Upper Ashley R.	tidal non-saline	0-2	Highly channelized drainageway having high density commercial-industrial-residential areas in and around Summerville, SC. Many storm drains and tributaries empty into this creek. A few woodland areas.
Eagle Ck.	ARC3	Upper Ashley R.	tidal non-saline	0-2	Moderate density residential and commercial sites. Some portions of watershed still dominated by freshwater wetlands, woodlands, and swamp-type drainage.

The parameters analyzed are listed in Table 6. These included: instantaneous discharge and gage height; the field parameters of temperature, pH, specific conductance, and dissolved oxygen (DO); parameters which affect dissolved oxygen dynamics such as biochemical oxygen demand (BOD) and ammonia nitrogen; fecal coliform (an indicator of bacterial contamination); and a scan of numerous elements. Sampling occurred for predicted storm events following relatively dry antecedent conditions which allowed for an accumulation of pollutants on the land surface. Therefore, some measurements in runoff may indicate worst case concentrations.

All water quality analyses were done by the USGS. Water temperature, specific conductance, dissolved oxygen, and pH were field measured (Wood, 1976). BOD determinations (nitrification inhibited) were completed at the USGS laboratory in Columbia, S.C. (APHA et al., 1985). All other analyses were performed by the USGS Control Laboratory in Arvada, Colorado (Skougstad et al., 1979).

Results and Discussion

Sampling for three storm events was completed during the period from April through October, 1987. Appendix 1 includes correspondence from the USGS to the SCDHEC for each study. Included are precipitation data, weather conditions and field observations for each study. Some of this information is summarized in Table 7.

Table 6. ASHLEY RIVER STORMWATER RUNOFF STUDY
PARAMETERS MEASURED

USGS Code	Description
00061	Discharge, Instantaneous (cfs)
00065	Gage Height, (ft above datum)
00010	Temperature, (Deg C)
00095	Specific Conductance (µS/cm)
00300	Oxygen, Dissolved (mg/l)
00310	Biochemical Oxygen Demand, 5-day (mg/l)
00320	Biochemical Oxygen Demand, Ult. Carbonaceous (mg/l)
00400	pH (standard units)
00610	Nitrogen, Ammonia Total (mg/l)
00625	Nitrogen, Ammonia + Org. Total (mg/l)
00915	Calcium, Dissolved (mg/l)
00925	Magnesium, Dissolved (mg/l)
00930	Sodium, Dissolved (mg/l)
00955	Silica, Dissolved (mg/l)
01005	Barium, Dissolved (µg/l)
01010	Berylium, Dissolved (µg/l)
01025	Cadmium, Dissolved (µg/l)
01030	Chromium, Dissolved (µg/l)
01035	Cobalt, Dissolved (µg/l)
01040	Copper, Dissolved (µg/l)
01046	Iron, Dissolved (µg/l)
01049	Lead, Dissolved (µg/l)
01056	Manganese, Dissolved (µg/l)
01060	Molybdenum, Dissolved (µg/l)
01080	Strontium, Dissolved (µg/l)
01085	Vanadium, Dissolved (µg/l)
01090	Zinc, Dissolved (µg/l)
01130	Lithium, Dissolved (µg/l)
71890	Mercury, Dissolved (µg/l)
31625	Coliform, Fecal M-FC as (cols./100ml)

Table 7. ASHLEY RIVER STORMWATER RUNOFF STUDY
STORM EVENTS SAMPLED

Storm 1: April 14-18, 1987

Date	Summerville, S. C. Precipitation in inches	Temperature, °F Max	Temperature, °F Min	Charleston Airport Precipitation in inches	Temperature, °F Max	Temperature, °F Min	Conditions Reported
4/14	0.00	88	51	0.00	79	57	Fog/Haze
4/15	1.82	81	61	1.07	79	62	Fog/Thunderstorm
4/16	0.54	77	57	0.06	72	53	Hail/Thunderstorm
4/17	0.07	77	42	0.03	69	49	Thunderstorm
4/18	0.01	69	45	0.10	71	50	Thunderstorm, Heavy Fog

Remarks: Rainfall began at approximately 7:30 a.m., and stopped at 12:30 p.m. Last rainfall reported was 0.07 inches at Summerville, SC on April 4, 1987.

Storm 2: June 3-7, 1987

Date	Summerville, S. C. Precipitation in inches	Temperature, °F Max	Temperature, °F Min	Charleston Airport Precipitation in inches	Temperature, °F Max	Temperature, °F Min	Conditions Reported
6/3	0.02	91	69	0.00	95	73	
6/4	0.00	93	71	1.07	79	70	Fog/Thunderstorms
6/5	0.86	79	67	0.00	85	68	
6/6	0.00	87	57	0.00	87	63	

Remarks: Rainfall began at approximately 2:30 p.m. on June 4, and continued intermittently for several hours. Last rainfall reported was on May 28, 1987, 0.31 inches at Summerville, SC and May 27,1987, 0.28 inches at Charleston, SC airport.

Table 7., Continued

<u>Storm</u> 3: September 29 - October 2, 1987

Date	Summerville, S. C. Precipitation in inches	Temperature, °F Max	Min	Charleston Airport Precipitation in inches	Temperature, °F Max	Min	Conditions Reported
09/29	0.00	83	64	0.00	86	66	
09/30	0.62	88	67	0.59	76	68	Fog
10/01	0.38	88	56	0.00	73	53	
10/02	0.00	74	43	0.00	81	50	

Remarks: Rainfall began at 5:30 a.m. on September 30, and continued for approximately three hours. Last rainfall reported was 0.21 inches at Summerville, SC on September 20, 1987.

Climatological data are available from three National Oceanic and Atmospheric Administration (NOAA) stations within the study area. The stations are: Summerville, S.C.; Charleston, S.C. Airport; and Charleston, S.C. Customs House. Table 8 contains daily rainfall totals taken from monthly NOAA reports for the period March through September, 1987. These data were used to examine antecedent conditions prior to each study.

Streamflow Determinations

Instantaneous streamflow measurements for each study are included in Appendix 2. Since all stations are to some extent tidal, streamflow measurements made during outgoing tides represent the combination of runoff and tidal flow. These are given as positive values in cubic feet per second (cfs). A flow value of <0 indicates there was upstream flow due to an incoming tide.

The first storm event sampled was in mid-April, 1987. Rainfall data in Table 8 show that the first two weeks of April were relatively dry throughout the sub-basin with only 0.07 inches or less rainfall occurring in the first week. Precipitation totaled 2.36 inches at Summerville, S.C. and 1.13 inches at the Charleston Airport for April 15-16, 1987. This first storm resulted in the greatest instantaneous flow measurements of the three events sampled (see streamflow data in Appendix 2). Stormwater flow overwhelmed tidal effects during this event; therefore measurements and samples were

Table 8. NOAA Daily Precipitation Data

DAILY RAINFALL FOR SUMMERVILLE, SC 1987

DAY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT
1	0.95	0	0	0	0.46	0	2.04
2	0.06	0	0.01	0	0.05	0.12	0
3	0	0	0	0.02	0.15	0	0.14
4	0	0.07	0	0	0.42	0	1.06
5	0	0	1.22	0.86	0.16	0	2.78
6	0	0	0	0	0	0	3.84
7	0	0	0	0	0.01	0.09	0.38
8	0.62	0	0	0	0	0.1	0.11
9	0	0	0	0	0	0	0
10	0.08	0	0	0	0	0.71	0
11	0.02	0	0	0	0	0.47	0
12	0.03	0	0	0	0	0	0.08
13	0	0	0	0	0.25	0.04	0.58
14	0	0	0.8	1.61	0	0	0
15	0	1.62	0.02	0.05	0	0	0
16	0	0.54	0	0.01	0	0	0
17	0	0.07	0	0.15	0	0.02	0
18	0	0.01	0	0	0	0	0
19	1.44	0	0	0.74	0	0	0
20	0.03	0	3.01	0.04	0	1.16	0.21
21	0	0	0.02	0.53	0	0.33	0
22	0	0	0	0.03	0	0	0
23	0	0	0	0.32	0	0	0
24	0	0	0	1.44	0	0	0
25	0.03	0	0	1.06	0	0	0
26	0.98	0	0	0.12	0	0.2	0
27	0.02	0	0	0.02	0	0.13	0
28	0.03	0	0.31	0	0.22	0	0
29	0	0	0	0	0	0	0
30	1.48	0	0	0	0	1.39	0.62
31	0.43	-	0	-	0	0	-

DAILY RAINFALL FOR CHARLESTON, SC AIRPORT 1987

DAY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT
1	0.43	0	0.08	0	0.01	0	0
2	0	0	0	0.02	0	0	0.11
3	0	0.05	0	0	0.43	0	0.4
4	0	0	0.61	1.07	0	0	3.4
5	0	0	0	0	0	0	6
6	0	0	0	0	0.33	0.17	1.24
7	0	0	0	0	0	0	0.2
8	0.73	0	0	0	0	0	0
9	0.17	0	0	0	0	0.46	0
10	0.02	0	0	0	0	0	0
11	0	0	0	0	0	0.03	1.47
12	0	0	0	0	1.71	0	0.4
13	0	0	0.29	0.23	0	0	0
14	0	0	0	0.21	0	0	0
15	0	1.07	0.01	0	0	0	0.08
16	0	0.08	0	0	0	0.53	0.07
17	0	0.03	0	0	0	0	0.14
18	0.02	0.1	0	0.3	0	0	0.39
19	0.72	0	0.32	0.78	0	0.22	0
20	0	0	0.7	0.6	0	0.57	0
21	0	0	0	0	0	0	0
22	0	0	0	0.04	0	0	0
23	0	0	0	0.16	0	0	0
24	0	0	0	0.01	0	0	0
25	1.75	0	0	0.30	0	0.61	0
26	0	0	0	0.05	0.04	0	0
27	0.02	0	0.28	0.06	0.36	0	0
28	0	0	0	0	0.04	0.01	0
29	1.05	0	0	0	0	0.74	0
30	0.4	0	0	1.75	0	1.68	0.59
31	0.24	-	0	-	0	1.95	-

DAILY RAINFALL FOR CHARLESTON, SC CUSTOMS HOUSE

DAY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT
1	0.27	0	0	0	0.31	0	0
2	0	0	0.04	0	0	0.31	0.14
3	0	0.07	0	0	0.06	0	0.5
4	0	0	0.38	0.29	0	0	3.85
5	0	0	0	0	0	0.02	5.04
6	0	0	0	0	0.02	0.56	2.42
7	0.01	0	0	0	0	0.43	0.33
8	0.59	0	0.36	0	0	0	0
9	0.01	0	0	0	0	0	0
10	0.07	0	0	0	0	0	0
11	0	0	0	0	0	0	0.07
12	0	0	0	0	1.78	0	0.5
13	0	0	0	0.12	0	0	0.09
14	0	0.05	0	0.05	0	0	0
15	0	1.07	0	0	0	0	0
16	0	0.09	0	0	0	0	0.28
17	0	0.3	0	0	0	0.06	0.21
18	0.03	0.43	0	0.05	0	0	0
19	0.66	0	0.03	0.18	0	0.24	0.45
20	0	0	0.17	0.01	0	0	0.02
21	0	0	0	0	0	0	0
22	0	0	0	0.01	0	0	0
23	0	0	0	0	0	0.01	0
24	0	0	0	0.71	0	0	0
25	1.91	0	0	0.32	0	0.04	0
26	0	0	0	0	0.02	0	0
27	0.01	0	0	0.11	0	0	0
28	0	0	0	0	0.52	0	0.01
29	0.69	0	0	0	0	0	0
30	0.42	0	0	0.14	0	3.35	1.05
31	0.13	-	0	-	0	2.83	-

taken at the peak of the hydrograph rather than only on outgoing tide as initially planned.

For the first storm, maximum instantaneous flows ranged from 24 cfs in the Brickyard Creek watershed to 1040 cfs in the Dorchester Creek watershed. Except for Popperdam Creek, peak flows occurred during the afternoon of April 15 following the heaviest rainfall between 7:30 AM and 12:30 PM on April 15. The Popperdam Creek watershed had a more rapid runoff response with a peak flow measurement of 202 cfs at 9:00 AM on April 15.

The second storm event occurred on June 4 and 5, 1987. It was preceded by a period of little rainfall as indicated in Table 8. Precipitation began in the lower portion of the basin on June 4, with 1.07 inches at the Charleston Airport and 0.29 inches at the Charleston Customs House station. The storm apparently progressed northwesterly toward Summerville, S.C. where 0.86 inches were measured on June 5, 1987. Runoff for this event was much less than for the first storm and tidal influence was more evident. Maximum flows measured ranged from 34 cfs in Brickyard Creek to 182 cfs at the Bacon's Bridge station. As with the first storm, the Popperdam and Brickyard Creek watersheds had the most rapid runoff response since they are dominated by impervious land cover. Sampling during this storm event was done during outgoing tides to best represent runoff constituents.

The third storm event sampled occurred on September 30 through October 1, 1987. It was similar to the second storm in terms of magnitude and runoff characteristics. Totals of 1.00 and 0.59 inches fell at Summerville, S.C. and the Charleston Airport, respectively. As with the second storm, tidal effects at the sampling stations overwhelmed additional streamflow due to runoff, therefore samples were collected on outgoing tides when possible. Peak flow measurements ranged from 13 cfs for the Popperdam Creek watershed to 255 cfs at the Church Creek station. As indicated by the rainfall data in Table 8, the third storm study was preceded by a very large amount of rainfall between the latter part of August and the first week in September, 1987.

Water Quality Data

Surface water quality data for each study are provided in Appendix 2. These data are presented in four groupings. These include dissolved oxygen and interactive parameters, fecal coliform bacteria, pH, and elements.

Dissolved Oxygen and Interactive Parameters

Dissolved oxygen is the most frequently used indicator of water quality conditions and water quality impacts. Standards for oxygen are essential for the maintenance of fish and other aquatic life as well as for the protection of aesthetic qualities of water. The dynamics of oxygen change in water bodies is primarily due to the addition of oxygen by reaeration, photosynthesis, and D.O. from incoming tributaries or effluents; and, the depletion of oxygen from carbonaceous and nitrogenous oxidation, benthic demands and algal respiration (Thomann and Mueller, 1987). The oxygen carrying capacity of water will also vary with temperature and salinity changes.

In this study dissolved oxygen concentrations were determined instream, along with corresponding values for water temperature and specific conductance. Specific conductance data is expressed in microsiemens per centimeter at 25°C. These units are equivalent to the more frequently used micromhos per centimeter. Specific conductance data were converted to salinity in parts per thousand (ppt) using the following expression (Tetra Tech, Inc. and C.E. Chamberlin, 1985):

$$\text{Salinity} = 5.572 \times 10^{-4}(SC) + 2.02 \times 10^{-9}(SC)^2$$

where (SC) = temperature corrected specific conductance in micromhos/cm determined by:

$$SC = CV(1+X) \quad \text{where } X = ((T-25)0.02) \text{ if } T>25^{\circ}C$$
$$SC = CV/1+X \quad \text{where } X = ((25-T)0.02) \text{ if } T<25^{\circ}C$$

where CV = conductance at 25°C
T = measured temperature of sample

Dissolved oxygen saturation levels for each temperature and salinity were determined using the following expression (Tetra Tech, Inc. and C.E. Chamberlin, 1985):

$$Cs = 14.6244 - 0.367134T + 0.0044972T^2 - 0.0966S + 0.00205ST + 0.0002739S^2$$

where Cs = dissolved oxygen concentration at saturation
T = temperature (C)
S = salinity (ppt)

Dissolved oxygen percent saturation values were determined for each set of D.O., temperature and salinity data by dividing the field measured D.O. levels by D.O. saturation levels and multiplying by 100. These data are summarized in Table 9. This was an effective way to normalize D.O. data for comparative purposes. Percent saturation values corresponding to flows representing increases from stormwater runoff during outgoing tides were averaged for each station and storm study (Table 10).

For this assessment a D.O. saturation criteria of 66% was considered acceptable. This criteria was chosen since it approximates a D.O. concentration of 5.0 mg/l at 30.0°C and 0.0 ppt salinity, and 4.1 mg/l at 30.0°C and 36.1 ppt salinity. Salinities in the Ashley River estuary are nearly always within the range of 0.0 ppt and 36.1 ppt, and instream temperatures seldom exceed 30.0°C. The D.O. range of 4.1 mg/l to 5.0 mg/l is consistent with present D.O. standards for the Ashley River which includes a daily minimum of 4.0 mg/l for the Class SC portion, and a daily average of 5.0 mg/l and a daily minimum of 4.0 mg/l for the Class B portion.

Overall, acceptable D.O. saturation levels were found in the receiving streams following stormwater runoff. This was met at each station except Church Creek, where percent saturation averages fell below 66% in the creek during storms 2 and 3. Furthermore, the Church Creek station was the only watershed with D.O. measurements below the State standard of 4.0 mg/l for Class SC waters. During this study

Table 9. Dissolved Oxygen Percent Saturation and Related Data

Station	Date	D.O. (mg/l)	Temp. (C)	Sp. Cond. (µS/cm)	Salinity (ppt)	Sat.D.O. (mg/l)	% D.O. Saturat.
ARA1 Brickyard Ck	4/14/87	7.0	25.0	690	0.39	8.24	84.96
	4/15/87	6.8	19.5	195	0.10	9.17	74.16
	4/15/87	6.4	22.5	238	0.13	8.63	74.12
	4/15/87	4.2	21.5	2410	1.27	8.74	48.03
	4/16/87	8.6	22.5	480	0.26	8.63	99.68
	6/4/87	6.7	25.0	2700	1.52	8.19	81.82
	6/4/87	4.9	23.0	330	0.18	8.55	57.31
	6/5/87	*	26.5	1060	0.58	8.03	**
	6/5/87	5.3	30.0	1820	0.93	7.63	69.50
	6/6/87	12.0	25.0	15200	8.94	7.87	152.41
	9/30/87	5.2	24.0	1400	0.77	8.37	62.15
	9/30/87	5.9	24.0	330	0.18	8.40	70.28
	10/1/87	7.0	18.0	650	0.32	9.45	74.04
	10/2/87	6.4	16.5	650	0.31	9.77	65.50
ARB1 Popperdam Ck	4/14/87	9.6	21.0	248	0.13	8.89	107.97
	4/15/87	8.9	17.5	123	0.06	9.57	92.97
	4/15/87	6.3	20.5	145	0.07	8.98	70.12
	4/15/87	6.3	20.5	153	0.08	8.98	70.13
	4/16/87	6.5	20.0	140	0.07	9.08	71.61
	6/4/87	6.4	25.0	90	0.05	8.25	77.53
	6/4/87	5.5	25.0	419	0.23	8.25	66.70
	6/5/87	6.8	24.0	201	0.11	8.40	80.97
	6/5/87	7.3	25.0	270	0.15	8.25	88.49
	6/6/87	8.5	28.0	200	0.11	7.87	108.06
	9/30/87	*	24.0	246	0.13	8.40	**
	9/30/87	*	23.0	249	0.13	8.55	**
	10/1/87	*	20.5	212	0.11	8.98	**
	10/2/87	6.2	18.0	230	0.11	9.47	65.50

* No D.O. data - meter malfunctioned
** Could not be determined - no D. O. data

Station	Date	D.O. (mg/l)	Temp. (C)	Sp. Cond. (µS/cm)	Salinity (ppt)	Sat.D.O. (mg/l)	% D.O. Saturat.
ARB2 Church Ck	4/14/87	6.7	20.0	6100	3.15	8.91	75.21
	4/15/87	6.0	20.0	1490	0.76	9.04	66.38
	4/15/87	5.3	22.5	4620	2.49	8.52	62.23
	4/16/87	5.2	20.5	2600	1.34	8.92	58.33
	4/16/87	5.8	22.5	1360	0.73	8.60	67.41
	6/4/87	5.0	28.0	15600	8.64	7.55	66.21
	6/4/87	3.1	26.5	10300	5.77	7.82	39.65
	6/5/87	3.8	27.0	14500	8.16	7.67	49.53
	6/5/87	4.1	28.0	16500	9.16	7.53	54.42
	6/6/87	3.9	25.0	12400	7.22	7.94	49.10
	9/30/87	4.5	25.5	15000	8.72	7.82	57.54
	9/30/87	3.9	25.0	11000	6.37	7.98	48.88
	10/1/87	4.2	21.5	4500	2.38	8.69	48.35
	10/2/87	4.6	19.5	5500	2.81	9.02	51.01
ARC1 Ashley Bacon Br	4/14/87	7.8	18.0	93	0.05	9.47	82.36
	4/15/87	5.6	19.5	76	0.04	9.17	61.05
	4/16/87	5.4	19.0	81	0.04	9.27	58.25
	4/16/87	7.1	19.0	81	0.04	9.27	76.59
	6/4/87	8.1	28.0	408	0.21	7.86	103.03
	6/4/87	5.2	27.0	596	0.32	7.98	65.19
	6/5/87	7.2	26.5	350	0.19	8.05	89.49
	6/6/87	6.3	24.0	191	0.10	8.40	75.01
	6/8/87	8.4	26.0	240	0.13	8.11	103.53
	9/30/87	*	22.0	86	0.05	8.72	**
	9/30/87	*	21.5	86	0.04	8.81	**
	10/1/87	*	20.5	83	0.04	8.99	**
	10/2/87	*	18.0	85	0.04	9.47	**

* No D.O. data - meter malfunctioned
** Could not be determined - no D.O. data

Station	Date	D.O. (mg/l)	Temp. (C)	Sp. Cond. (µS/cm)	Salinity (ppt)	Sat.D.O. (mg/l)	% D.O. Saturat.
ARC2 Dorchester Ck	4/14/87	13.0					
	4/15/87	7.0	19.0	111	0.06	9.27	75.52
	4/15/87	6.8	20.0	108	0.05	9.08	74.91
	4/16/87	7.8	20.0	124	0.06	9.08	85.93
	4/16/87	9.0	21.0	139	0.07	8.89	101.19
	6/4/87	4.5	28.0	848	0.45	7.85	57.30
	6/4/87	4.3	24.5	328	0.18	8.32	51.68
	6/5/87	6.2	29.0	238	0.12	7.76	79.95
	6/5/87	5.6	27.0	297	0.16	7.98	70.14
	6/6/87	9.8	25.0	319	0.18	8.25	118.81
	9/30/87	*	23.5	260	0.14	8.47	**
	9/30/87	*	23.0	200	0.11	8.55	**
	10/1/87	*	21.5	245	0.13	8.80	**
	10/2/87	*	17.0	330	0.16	9.67	**
ARC3 Eagle Ck	4/14/87	8.9	21.0	121	0.06	8.89	100.06
	4/15/87	6.9	18.0	105	0.05	9.47	72.86
	4/15/87	6.1	18.0	78	0.04	9.47	64.41
	4/16/87	6.8	18.5	73	0.04	9.37	72.58
	4/16/87	7.8	19.5	75	0.04	9.17	85.03
	6/4/87	6.1	27.0	875	0.47	7.97	76.53
	6/4/87	3.2	24.0	235	0.13	8.40	38.11
	6/5/87	6.2	28.0	688	0.36	7.86	78.92
	6/5/87	8.2	28.0	914	0.48	7.85	104.44
	6/6/87	5.6	24.0	501	0.27	8.39	66.74
	9/30/87	*	23.0	168	0.09	8.55	**
	9/30/87	*	22.5	210	0.11	8.63	**
	10/1/87	*	18.5	131	0.06	9.37	**
	10/2/87	*	16.5	145	0.07	9.79	**

* No D.O. data - meter malfunctioned
** Could not be determined - no D.O. data

Table 10. Dissolved Oxygen Percent Saturation During Stormwater Runoff and Outgoing Tides (Averaged values)

Station	Storm 1 April 1987	Storm 2 June 1987	Storm 3 Sept-Oct 1987
Brickyard Ck	74.0 (%)	69.5 (%)	69.9 (%)
Popperdam Ck	76.2	78.7	65.5
Church Ck	63.6	47.7	49.4
Ashley, Bacon Bridge	68.8	89.2	*
Dorchester Ck	78.8	70.1	*
Eagle Ck	70.0	85.6	*

* Could not be determined - no D.O. data

treated domestic waste discharged from the Pierpont plant operated by St. Andrews PSD averaged about 0.95 mgd (1.47 cfs) with a BOD5 of 8.4 mg/l and NH3-N of 3.2 mg/l (see Table 3). It would appear that stormwater runoff and tidal flows combined (Appendix 2) diluted this discharge to very low levels during each of these studies; however, hydraulic overloading of this facility during storm events has been known to impact the treatment and disinfection efficiency of the facility. Thus, some storm events may result in excess oxygen demanding solids being discharged to Church Creek via the Pierpont plant. This facility is currently under a SCDHEC compliance schedule to address hydraulic overloading of the secondary clarifier and disinfection efficiency. (Personal communication with Wayne Fanning, SCDHEC, August 1989). The findings from this study alone cannot quantify the influence of the discharge on D.O. levels in Church Creek.

Inputs from stormwater runoff which affect instream D.O. levels include organic and inorganic materials that exert carbonaceous biochemical oxygen demand (CBOD), and nitrogenous biochemical oxygen demand (NBOD). CBOD exertion occurs when heterotrophic organisms decompose organic carbon substrate. CBOD may involve dissolved or suspended material. NBOD results, in the presence of nitrifying bacteria (Nitrosmonas and Nitrobacter), from the oxidation of ammonia to nitrite and then to nitrate in a two-stage process. Organic nitrogen will also eventually contribute to the NBOD (Tetra Tech, Inc. and Chamberlin, 1985).

In this study CBOD was assessed using 5-day biochemical oxygen demand (BOD5) and ultimate biochemical oxygen demand (BODu) measurements. NBOD was evaluated using total ammonia nitrogen (NH3-N) and total ammonia/organic nitrogen (TKN) data. BOD5 and BODu data for each study are represented in Figures 3-8. Each bar represents a determination on a discrete sample, and they are in chronological order from left to right. BOD5, NH3-N, and TKN data collected during this study were compared to SCDHEC ambient long-term trend monitoring data from six stations located in the Ashley River sub-basin. These stations are sampled once a month. While trend data may reflect both dry and wet weather conditions, over time they provide an indication of main channel concentration variability resulting from tributary inflow and tidal influences. Trend data for the months May through October (1986-1988) were evaluated to provide the BOD5, NH3-N, and TKN statistics shown in Table 11.

Station CSTL-102 (located at Bacon's Bridge, SC Hwy 165) provides an ambient reference station for this study's Bacon's Bridge station. CSTL-099 (located on Eagle Creek at Hwy 642) was reference for the Eagle Creek and Dorchester Creek stations. Station MD-049 (near Magnolia Gardens) is located in the Ashley River just downstream of the Popperdam Creek station. Station MD-135 (Located at the Ashley River Memorial Bridge) provides the best reference station for this study's Brickyard Creek and Church Creek stations.

The first storm study in April 1987 resulted in the highest BOD5 and BODu measurements for all watersheds (Figures 3&4). The Brickyard Creek watershed clearly had the highest BOD5 and BODu measurements for storms 1,2 and 3.

Figure 3. Biochemical Oxygen Demand

Stormwater Runoff Study — April '87

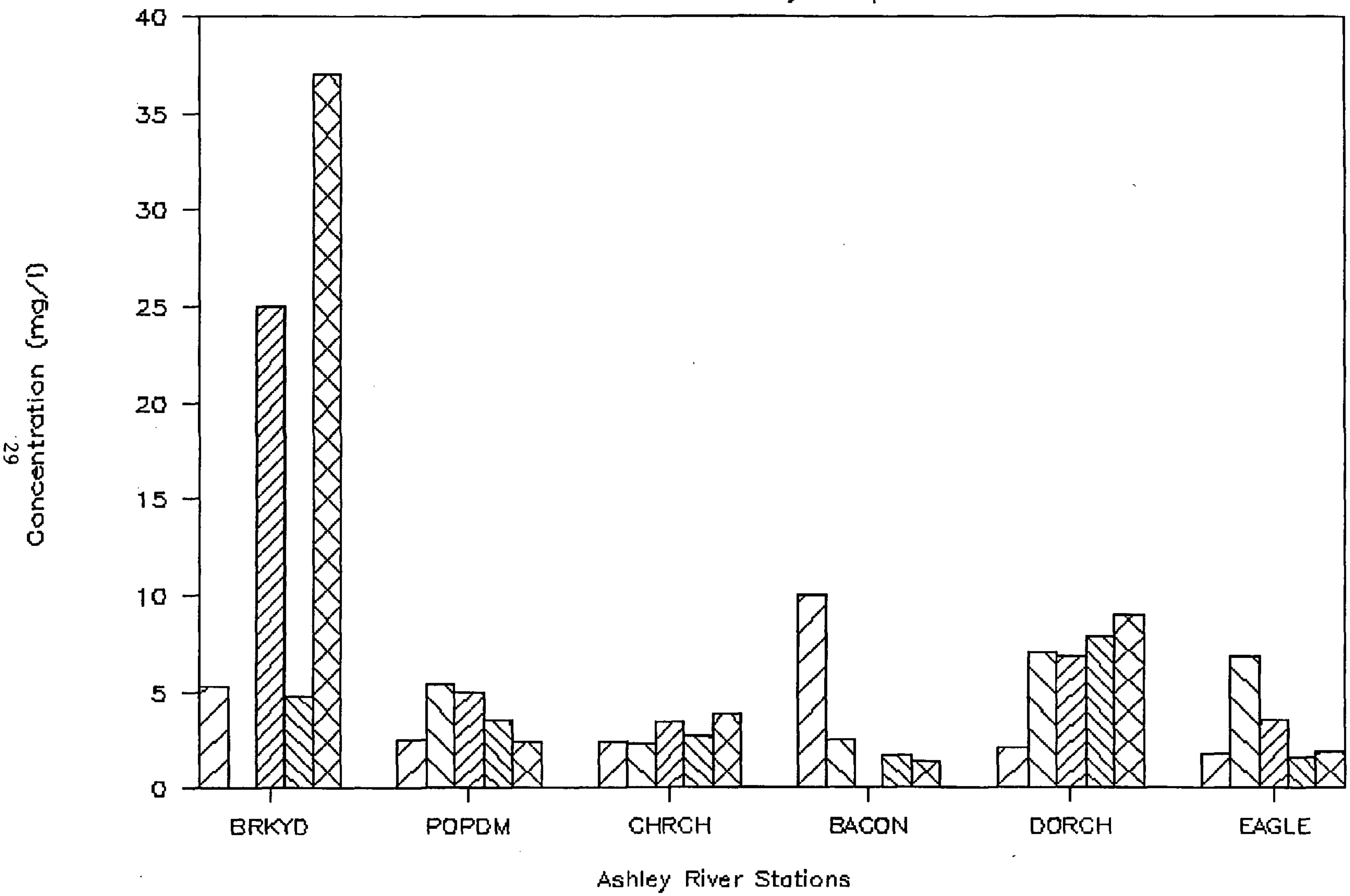


Figure 4. Ultimate BOD in Runoff

Stormwater Runoff Study — April '87

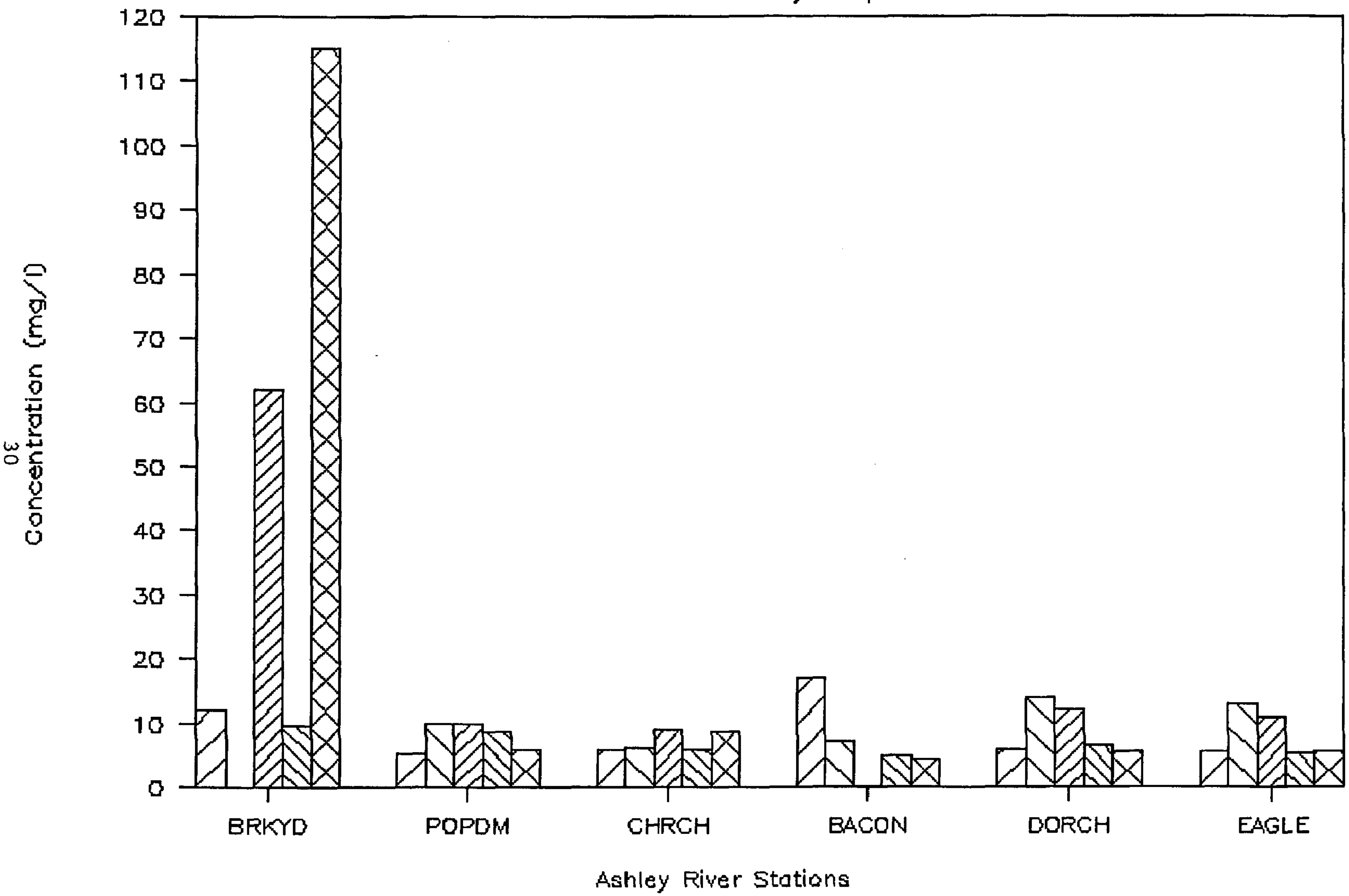


Figure 5. Biochemical Oxygen Demand

Stormwater Runoff Study — June '87

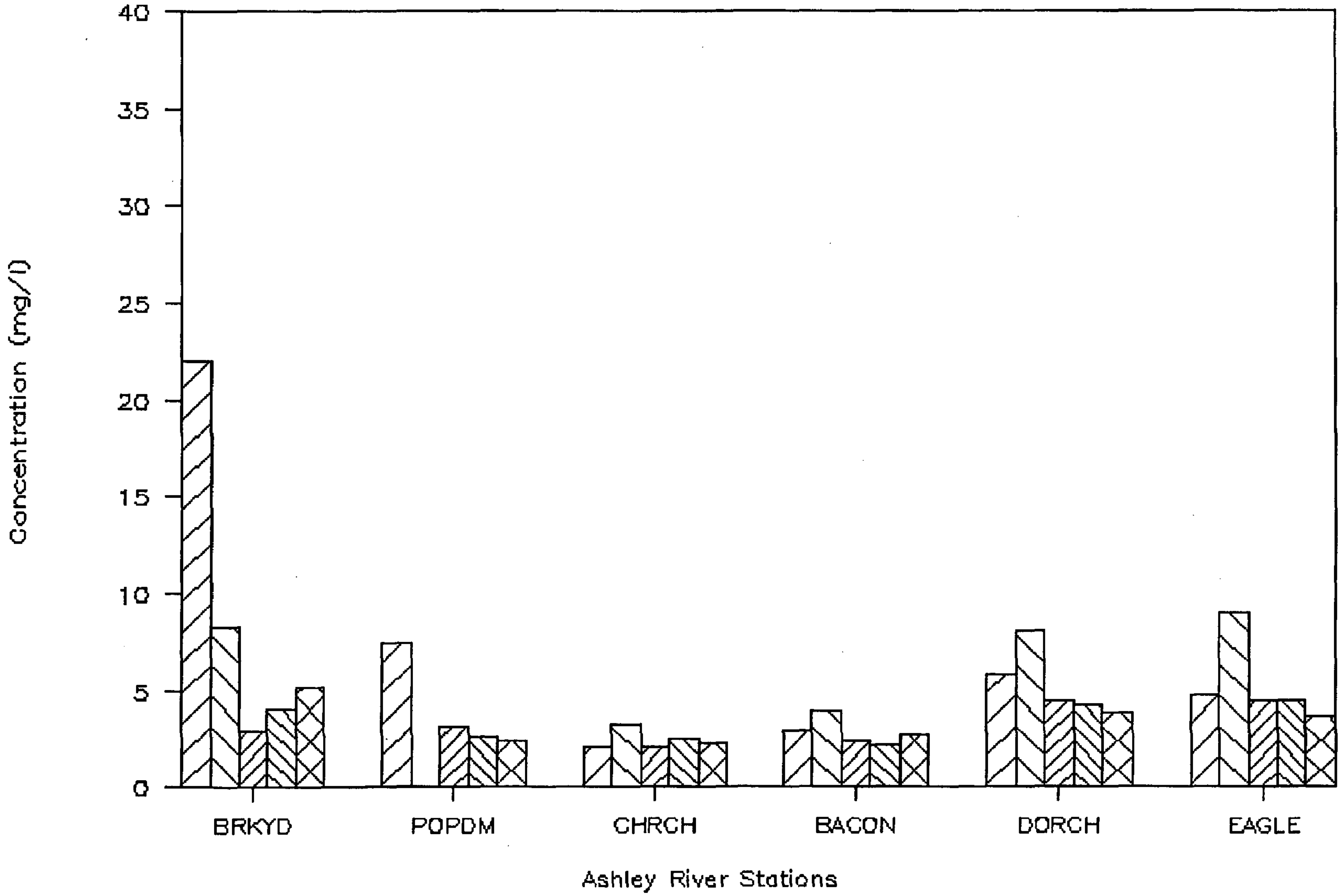


Figure 6. Ultimate BOD in Runoff

Stormwater Runoff Study — June '87

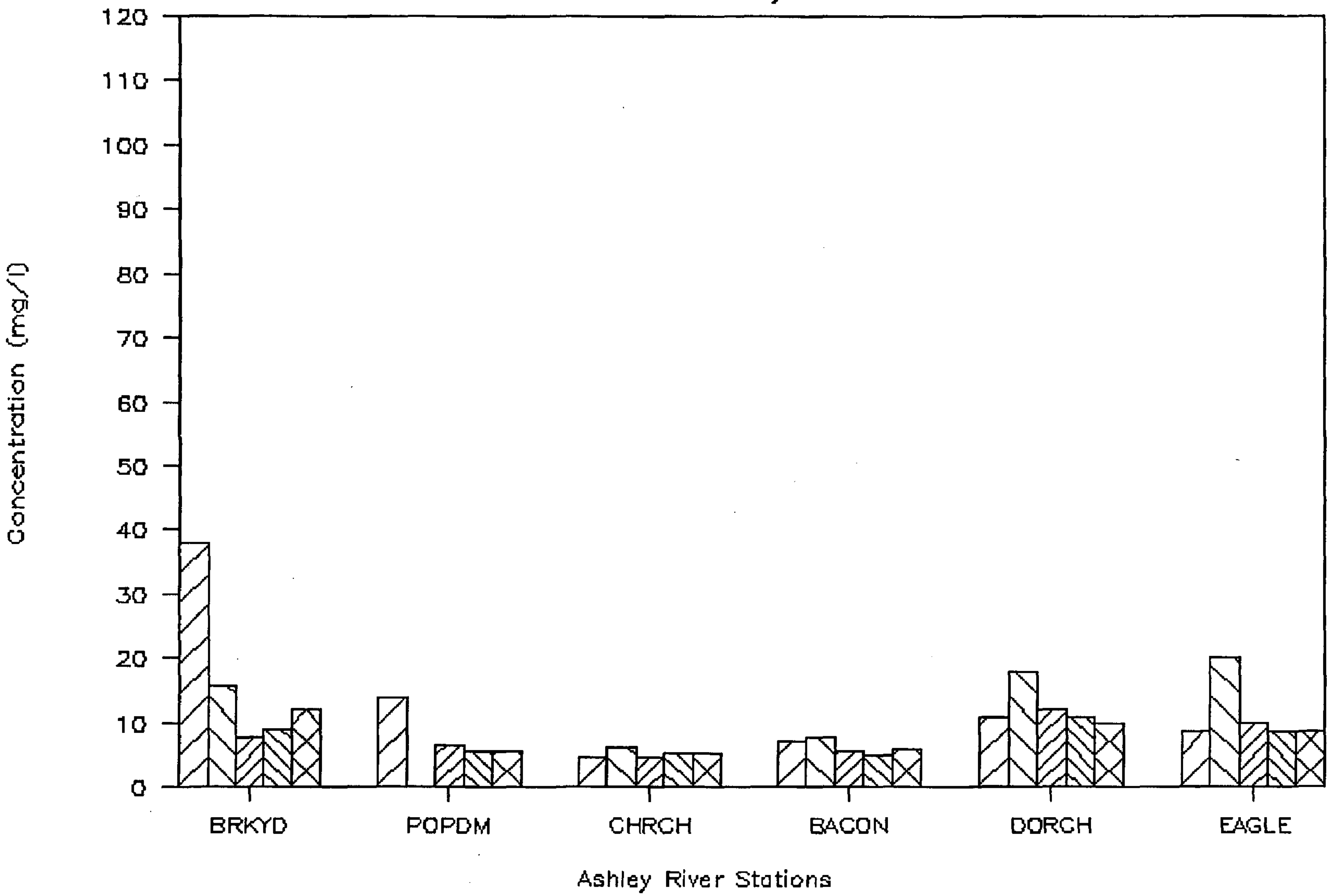


Figure 7. Biochemical Oxygen Demand

Stormwater Runoff Study — Sept—Oct '87

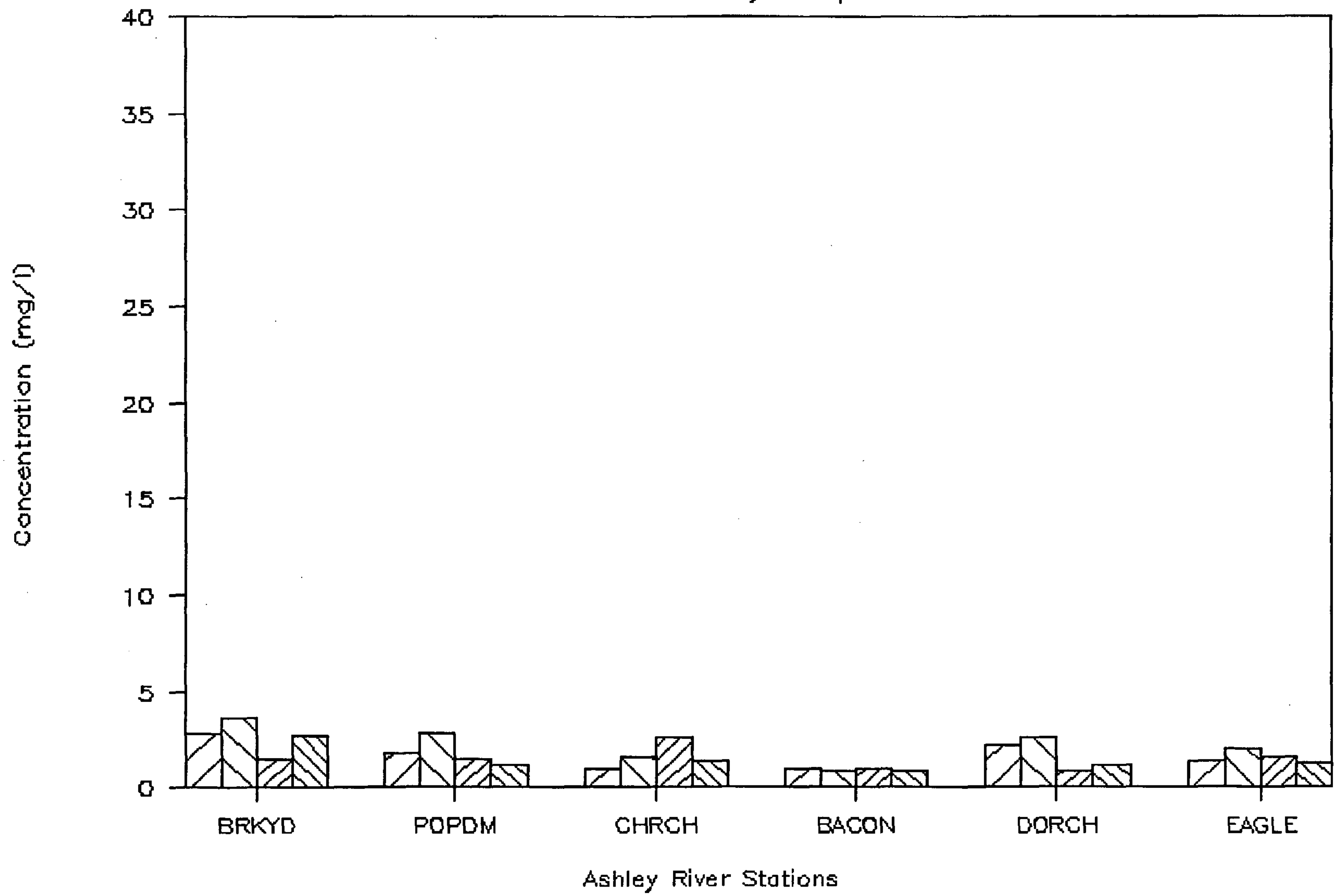
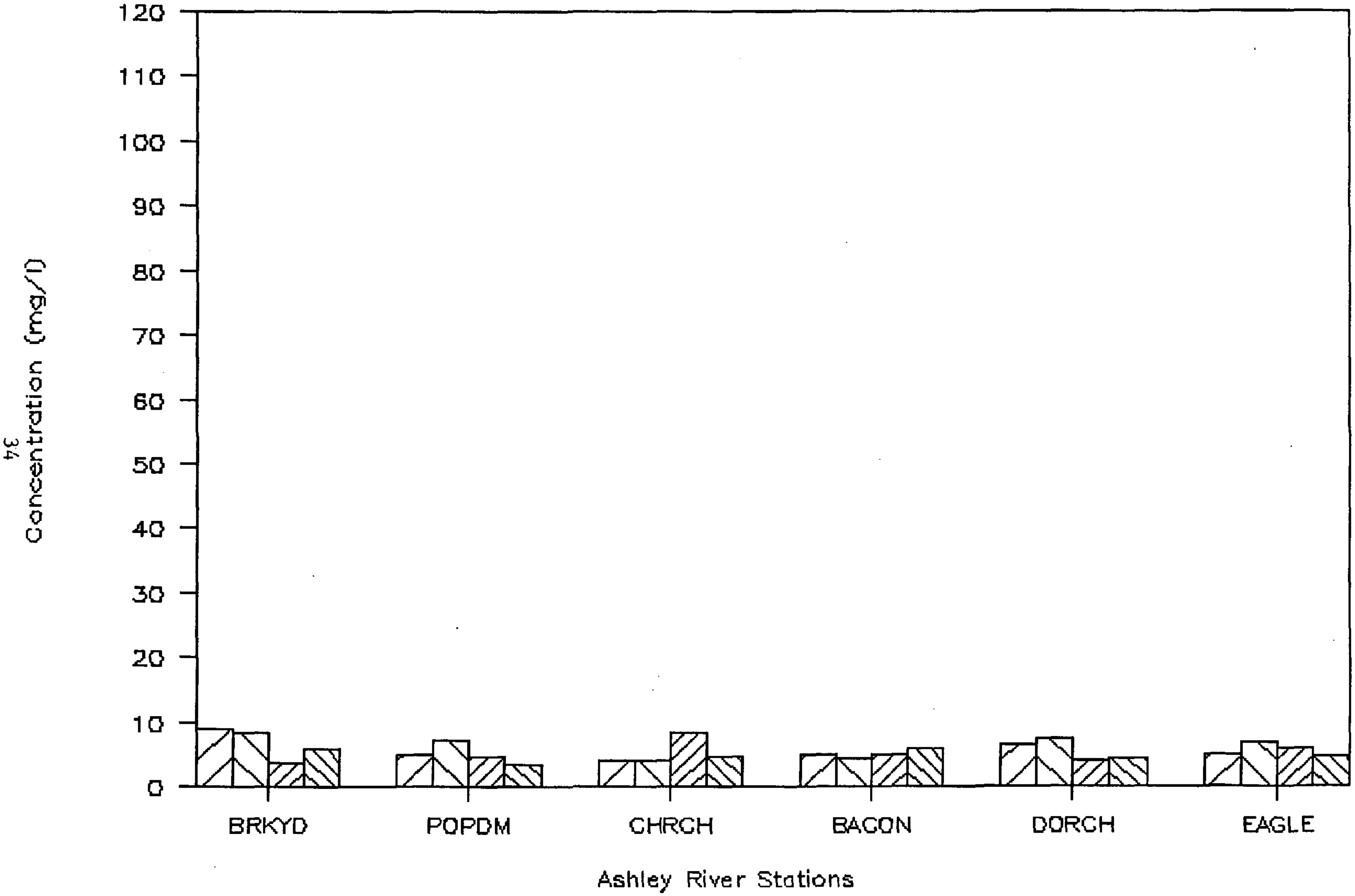


Figure 8. Ultimate BOD in Runoff

Stormwater Runoff Study — Sept–Oct '87



Instream BOD5 concentrations as high as 25.0 mg/l, 37.0 mg/l, 22.0 mg/l and 8.3 mg/l were measured in samples collected during storms 1 and 2. These values are considerably greater than the mean of 2.23 mg/l (n=19) indicated by data from MD-135, and also are outside of the range for that station of 1.4 to 6.6 mg/l. As a means for comparing these stormwater BOD values to those typical of point sources or untreated domestic wastewater, secondarily treated domestic wastewater is considered to have average BOD_5 and BODu concentrations of 30.0 mg/l and 45.0 mg/l, respectively; untreated (raw) domestic wastewater has BOD_5 and BODu concentrations ranging from 160-280 mg/l and 240-420 mg/l, respectively. Lockheed-Georgia Corporation discharges treated waste to Brickyard Creek. It is not likely that this point source contributed measurably to the excessive instream BOD5 and BODu levels, since the average flow and BOD5 discharged during the study period were 0.03 mgd and 8.7 mg/l, respectively. Storm 3 which followed a period of very heavy rainfall in late August and early September resulted in BOD5 levels within the range indicated by station MD-135. Similarly, for the other five stations BOD5 data from storm 3 fell within the range indicated by ambient monitoring stations. Apparently the previous heavy rainfall had flushed the watershed of accumulated organic carbon residues.

With the exception of Brickyard Creek, data from the second storm study indicated BOD5's mostly within the range of corresponding ambient stations. Single BOD5 measurements during stormwater runoff at Popperdam Creek (7.4 mg/l), Dorchester Creek (8.0 mg/l), and Eagle Creek (9.0 mg/l) exceeded the upper range of corresponding ambient stations for storm 2. Based on stream BOD data treated domestic wastewater discharges into Church Creek (St. Andrews Pierpont) and Popperdam Creek (Pepperhill SD) did not clearly influence any BOD's determined during the study period.

As shown in Table 11, data from stations in the Ashley River indicate that mean ambient concentrations of NH3-N are normally less than or equal to 0.18 with a maximum concentration of 0.32 at MD-049. NH3-N data (Figures 9-11) collected during all three storm studies indicate concentrations above mean ambient levels and upper ranges for some stations including Church, Dorchester and Brickyard Creek watersheds (Storm 1); Dorchester, Eagle, Church and Brickyard Creek watersheds (Storm 2); and Church and Brickyard Creek watersheds (Storm 3). When compared to the Popperdam Creek and Bacon's Bridge station, each of the above watersheds has a more substantial amount of urban/suburban and industrial development which is apparently contributing to elevated levels of NH3-N in runoff.

A single total ammonia nitrogen (NH3-N) value slightly exceeded the EPA criteria for acute toxicity to aquatic life. An NH3-N value of 1.8 mg/l was determined for a Dorchester Creek sample (June 1987 study), with a corresponding temperature of 27^{o}C and pH of 8.61. This sample was collected during a peak flow of 39 cfs. Because this was a discrete sample made between two other

Table 11. SCDHEC Trend Monitoring Data
(May-October, 1986-1988)

SCDHEC STATION	BOD5 (mg/l) mean	BOD5 (mg/l) (range)	NH3-N (mg/l) mean	NH3-N (mg/l) (range)	TKN (mg/l) mean	TKN (mg/l) (range)
CSTL-102	3.42	(1.50-5.80)	0.15	(0.12-0.17)	1.38	(1.35-1.41)
CSTL-099	4.45	(2.10-7.20)	0.18	(0.16-0.21)	1.60	(1.35-1.85)
MD-049	2.41	(1.40-5.20)	0.14	(0.05-0.32)	1.16	(0.59-1.80)
MD-135	2.23	(1.40-6.60)	0.08	(0.07-0.08)	0.99	(0.79-1.19)

Figure 9. Total Ammonia-Nitrogen

Stormwater Runoff Study - April '87

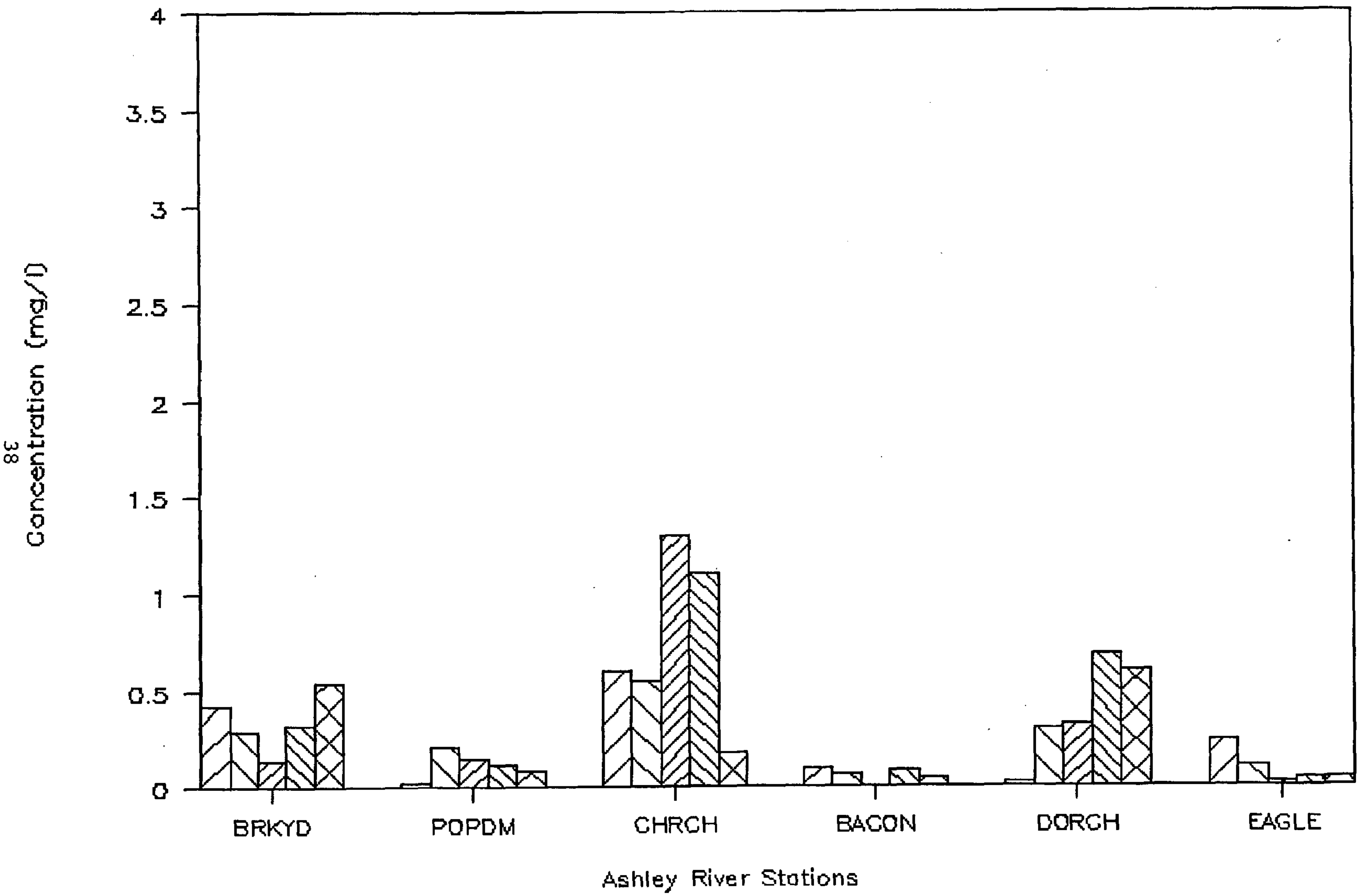


Figure 10. Total Ammonia—Nitrogen

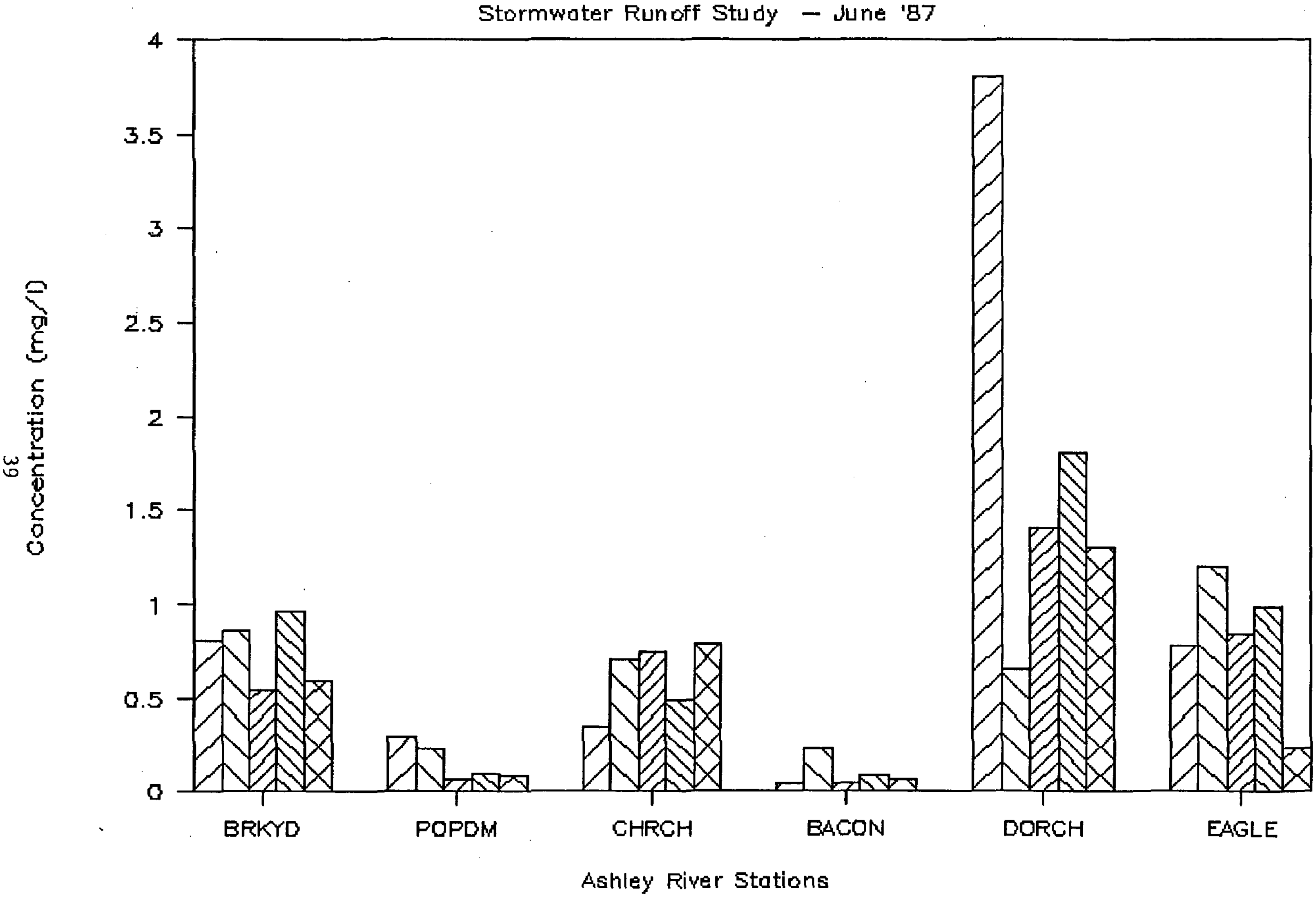
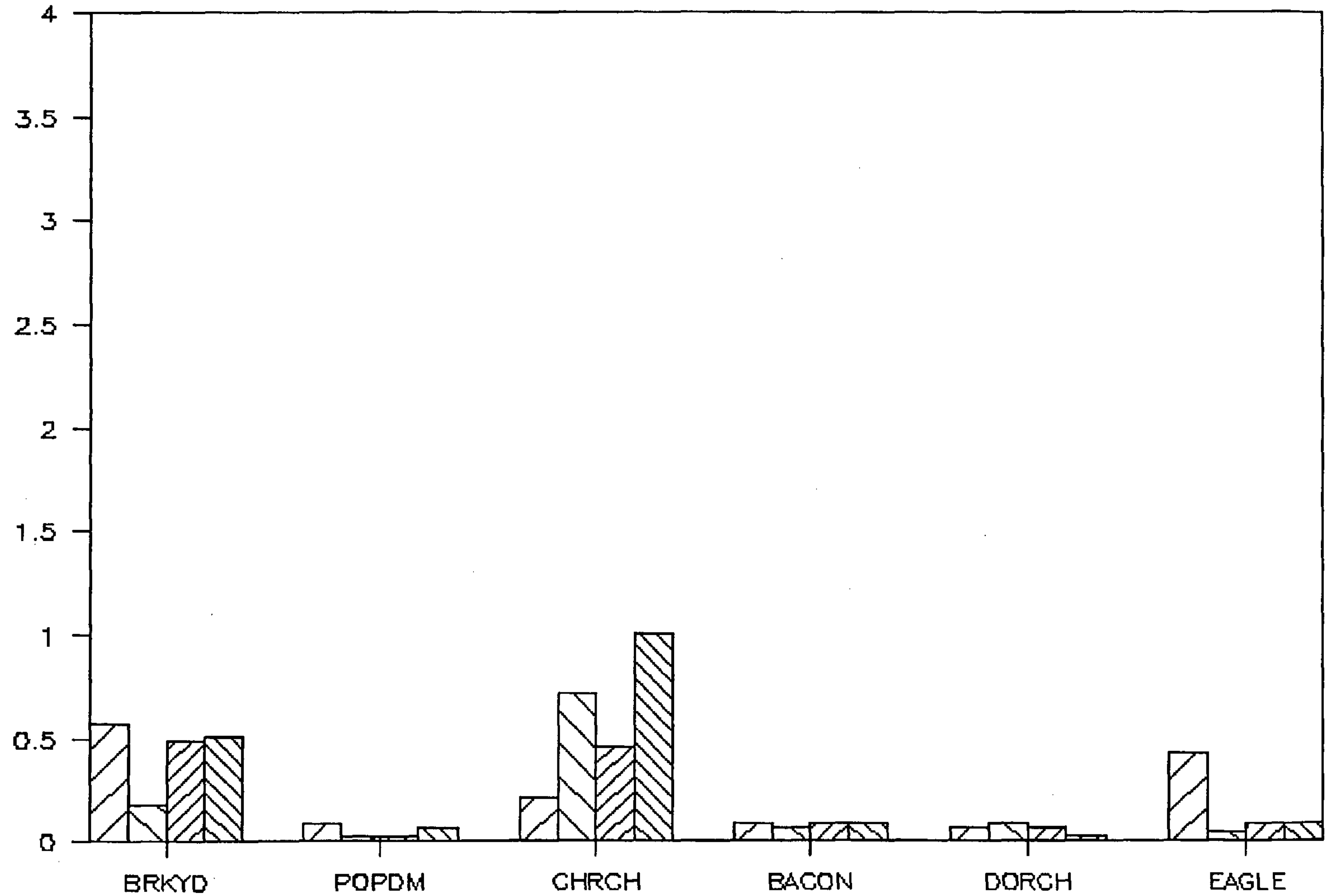


Figure 11. Total Ammonia-Nitrogen

Stormwater Runoff Study - Sept-Oct '87



measurements more than 21 hours apart, it is not possible to determine the duration of this potentially toxic NH_3-N concentration. According to EPA criteria, 1.74 mg/l NH3-N may be toxic to certain aquatic life at a temperature of 27^{o}C and pH of 8.61. This value is a general National criteria and does not represent a State standard. Since any acute toxicity from the single NH_3-N concentration of 1.8 mg/l was not verified through field observation, it can only be viewed as having created a potential for acute toxicity. This potential may be assessed within the scope of future nonpoint source studies in the Ashley River estuary.

TKN data (Table 11) from trend monitoring stations in the Ashley River, show mean ambient concentrations ranging from 0.99 mg/l (MD-0135) to 1.60 mg/l (CSTL-099) with a maximum concentration of 1.85 mg/l. TKN data (Appendix 2), like NH3-N data, indicate concentrations above mean ambient levels and upper ranges for some stormwater sampling stations including Brickyard, Church, and Dorchester Creek watersheds (Storm 1); Brickyard, Church, Dorchester, and Eagle Creek watersheds (Storm 2); and Brickyard and Church Creek watersheds (Storm 3). Overall, the Popperdam Creek and Upper Ashley (Bacon's Bridge) watersheds contributed the lowest concentration of TKN and NH3-N during runoff conditions. These are the least developed watersheds examined in this study.

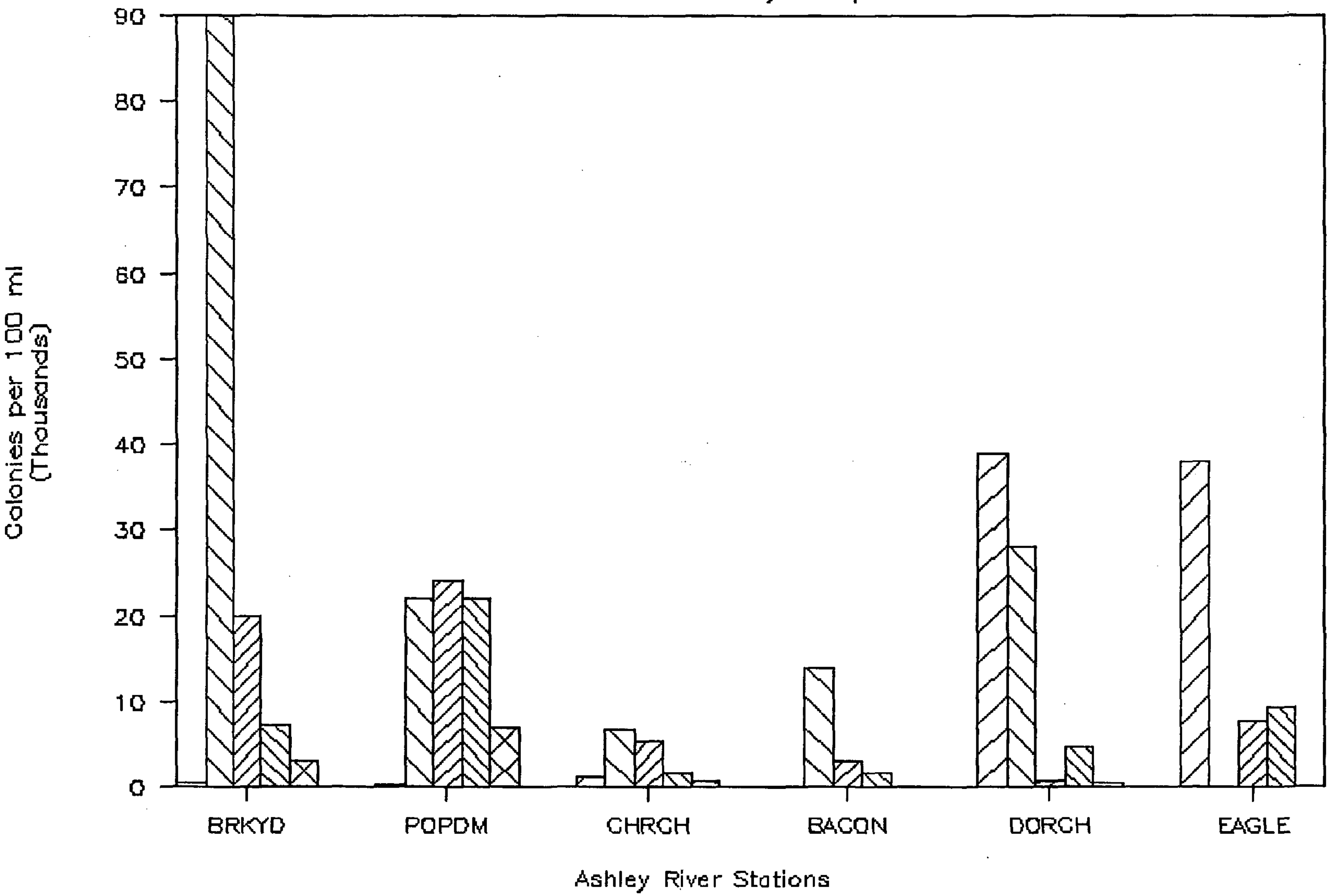
Fecal Coliform Bacteria

Fecal coliform (FC) are a group of bacteria consisting mainly of Escherichia and Klebsiella genera (Tetra Tech, Inc. and Chamberlin, 1985). They are found in the intestinal tract of humans and other warm-blooded animals, and are used as an indicator of the sanitary quality of water.

Fecal coliform concentrations (colonies/100 ml) for each storm event are shown in Figures 12-14. Each bar represents a determination on a discrete sample using the membrane filter technique. Fecal coliform concentrations are expressed as colonies/100 ml. These determinations are generally comparable to those made using the multiple tube fermentation procedure with results as MPN/100 ml. Concentrations indicative of NPS pollution were determined in runoff for all three events at each station. The highest individual concentration for each station occurred during the first event. This was because the first storm was the most intense and it followed two weeks of dry weather. Overall, the Brickyard Creek, Popperdam Creek, Eagle Creek and Dorchester Creek watersheds produced the highest FC concentrations. With the exception of Eagle Creek, the third storm event produced the lowest concentrations of FC in runoff. As demonstrated with other parameters such as BOD5, this was probably due to the substantial amount of rainfall that had occurred in late August and early September. The geometric means of FC data are given in Table 12 for each event and watershed. Geometric mean determinations were made using data for all flows but are primarily indicative of periods with stormwater runoff and outgoing tides. The State fecal coliform standard for

Figure 12. Fecal Coliform in Runoff

Stormwater Runoff Study — April '87



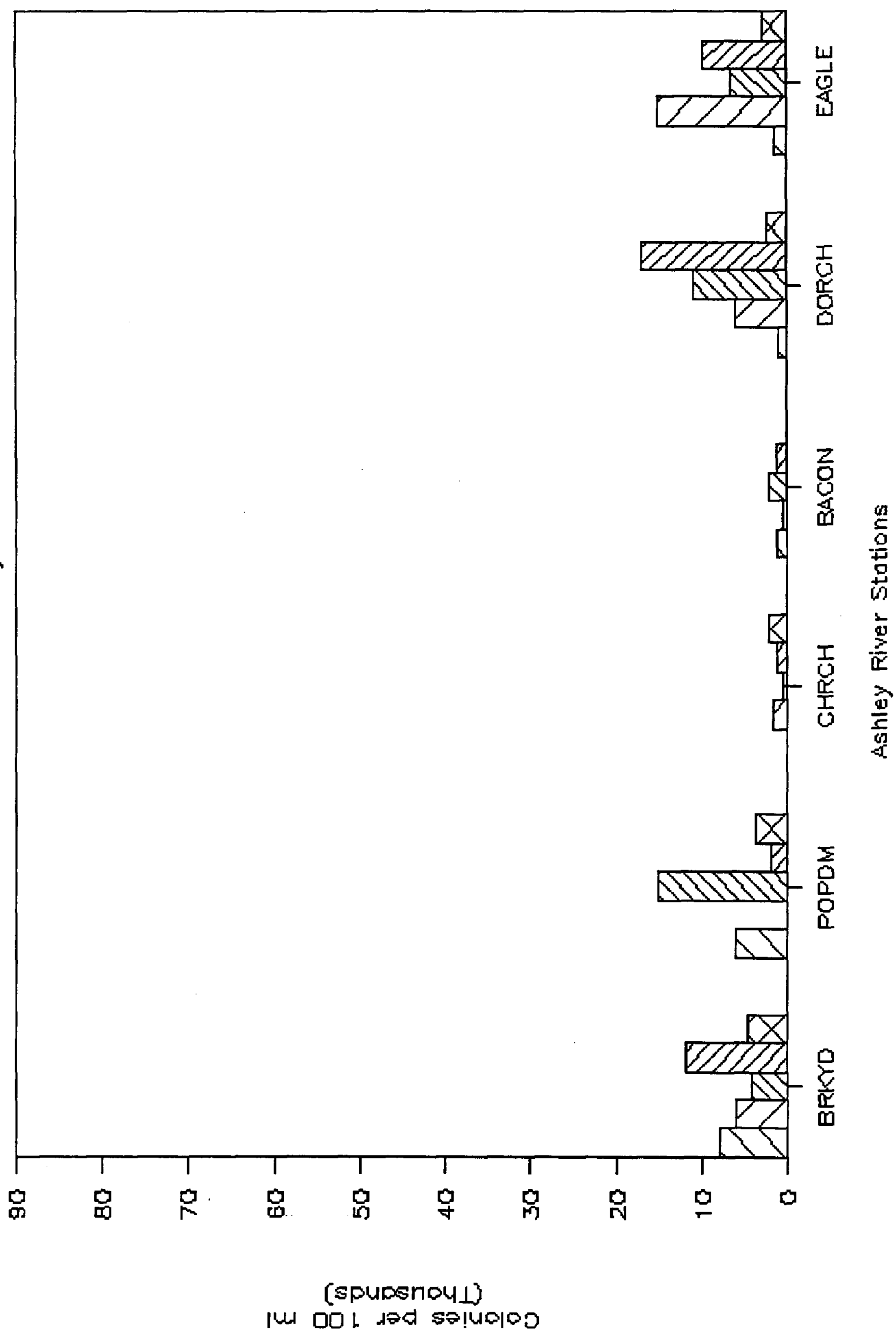


Figure 13. Fecal Coliforms in Runoff

Stormwater Runoff Study — June '87

Figure 14. Fecal Coliforms in Runoff

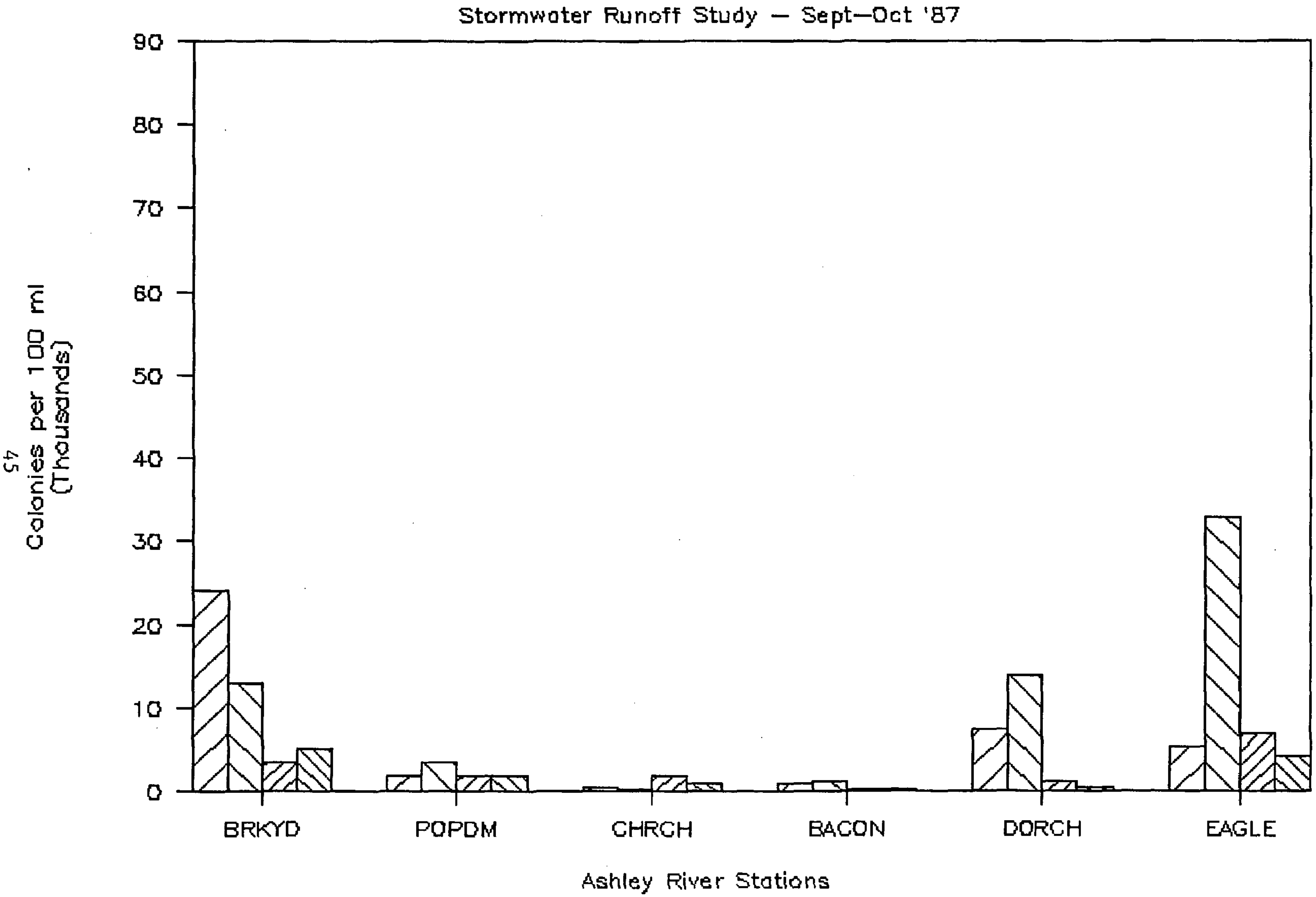


Table 12. Fecal Coliform Geometric Means (cols./100ml)
(n = number of measurements)

Station	Storm 1	Storm 2	Storm 3
Brickyard Creek	7012 (n= 5)	6532 (n = 5)	8742 (n = 4)
Popperdam Creek	7329 (n = 5)	5049 (n = 4)	2212 (n = 4)
Church Creek	2289 (n = 5)	753 (n = 5)	793 (n = 4)
Upper Ashley, Bacon's Bridge	1838 (n = 4)	730 (n = 5)	568 (n = 4)
Dorchester Creek	8030 (n = 4)	4823 (n = 5)	3082 (n = 4)
Eagle Creek	1741 (n = 5)	5310 (n = 5)	8468 (n = 4)

Ashley River waters is that a geometric mean of 1000MPN/100 ml not be exceeded based on five consecutive samples during any thirty-day period. Since four or five FC determinations were made at each station during each study, only those with five FC values can be used to evaluate strict conformance with the FC standard. At stations with only four FC measurements, only a general comparison of geometric mean data to the standard is appropriate. For example, all geometric means for storm 1 exceeded a concentration of 1000/100 ml; however, the FC standard can only conclusively be said to have been exceeded at Brickyard Creek, Popperdam Creek, Church Creek, and Eagle Creek where five measurements were made. With the exception of the Church Creek and Upper Ashley (Bacon's Bridge) stations a concentration of 1000/100 ml was also exceeded for storm 2 and 3. It is clear from these data that the study watersheds are contributing significant concentrations of FC into the Ashley River estuary which, in turn, will increase main channel concentrations of FC to some extent and for some duration. For all stations and storms, geometric means ranged from 568/100 ml (Upper Ashley) to 8742/100 ml (Brickyard Creek). Individual concentration measurements ranged from non-detected (Dorchester Creek) to 90,000/100 ml (Brickyard Creek)

As a means for comparison, Waniellista (1978), based on the results from several studies, reported that FC concentrations in urban stormwater have ranged from 55/100 ml to 112 x 10^6/100 ml. This high degree of variability was due to many factors including land use, sampling times, and meteorological effects. Thomann and Mueller (1987) reported on the bacteriological concentrations found in urban runoff based on the studies of Benzie and Courchaine in Ann Arbor, Michigan, and Weibel et al., in Cincinnati, Ohio. Their results for FC bacteria are summarized below:

	Percent of time FC/100 ml was less than or equal to value indicated		
Fecal coliform	10%	50%	90%
Ann Arbor	7,000	82,000	1,000,000
Cincinnati	500	10,900	76,000

SCDHEC (1980) reported on the results of FC monitoring between 1977 and 1979 in thirteen watersheds located throughout South Carolina which were dominated by agricultural and silvicultural land uses. A total of 106 FC determinations were made during seven storm events, with a range of geometric means from 136MPN/100 ml to 12,718MPN/100 ml.

The geometric means of FC data for SCDHEC Ashley River trend stations (Figure 2) are shown below for the period May through October (1986-1988):

SCDHEC STATION	Fecal Coliform (MPN/100 ml)
CSTL-102	178 (n=17)
CSTL-099	762 (n=16)
MD-049	115 (n=13)
MD-135	56 (n=16)

With the exception of CSTL-099, the data collected in this study show geometric means (Table 12) which are much greater than those indicated in the trend data above. For example, Brickyard Creek geometric means (cols./100 ml) were 7,012 (Storm 1), 6532 (Storm 2) and 8742 (Storm 3). These FC concentrations are much greater than the value of 56 MPN/100 ml indicated by MD-135 for sixteen measurements.

pH

pH is a measure of the hydrogen ion activity in a water sample. It is an important factor in the chemical and biological systems of natural waters. The protected State standard for Cypress Swamp and the fresh water Ashley is a pH range of 6.0 to 8.5. The measurements taken at Upper Ashley (Bacon's Bridge), Dorchester Creek, Eagle Creek, and Popperdam Creek stations fall within this standard. The saline portions of the Ashley River have a pH range standard of 6.5 to 8.5. This applies to the Brickyard and Church Creek stations. With the exception of one pH measurement of 9.92 at the Dorchester Creek station, all pH measurements fell within the Standards' range for the four stations in the Class B portion of the waters sampled. This single high pH cannot be explained, but the measurement was made prior to the initiation of runoff during the first study. All pH measurements fell within the Standards' range for the two stations in the class SC portion.

Analysis of Elements (including metals)

The Ashley River stormwater sampling included analyses for the elements previously listed in Table 6. The analyses were for dissolved species of these elements rather than total-recoverable. Results are included in Appendix 2. All of these elements are natural constituents of freshwater and seawater, with generally higher concentrations in seawater.

Major Elements of Seawater

According to Riley and Chester (1971), major elements in full strength seawater usually occur at concentrations greater than 1 mg/kg and are geochemically unreactive. Major elements of seawater included in this sampling are sodium, magnesium, calcium, and strontium. None of these elements are considered toxic.

Although none of the stations sampled are highly saline, they are estuarine and subject to interactions with ocean water. Specific conductance measurements, an indirect measure of salinity, confirm the assumption. The Church Creek and Brickyard Creek stations are most influenced by saltwater, with only slight saltwater influence seen at the Popperdam Creek, Bacon Bridge, Dorchester Creek, and Eagle Creek stations. The ranges of major element concentrations for the three studies are given below.

Element	Storm 1	Storm 2	Storm 3
Sodium, mg/l	1.6-2500	6.9-3700	5.2-3000
Magnesium, mg/l	0.60-31.0	1.4-450	1.2-330
Calcium, mg/l	7.2-110	15-160	9.8-220
Strontium, ug/l	19-1800	44-2600	26-2000

Simple regression analysis of each element considered a major constituent of seawater at all stations to specific conductance at all stations shows a strong correlation.

Element	Storm 1	Storm 2	Storm 3
Sodium	r = .74	r = .88	r = .99
Magnesium	r = .73	r = .89	r = .99
Calcium	r = .74	r = .93	r = .90
Strontium	r = .76	r = .83	r = .99

The correlation was less (.72-.76) during the first rain event, but the tidal range and freshwater runoff was greater so there would be less influence exerted by saltwater in samples taken at low tide stages.

The spatial and temporal variations in these elements are apparently due to the influence of seawater rather than stormwater.

Minor and Trace Elements of Seawater

Minor elements in seawater are generally not as conservative as major elements, due in part because they are geochemically and biologically reactive. Since the concentration may be controlled by the geology of the drainage area, unusual localized concentrations may be produced from land runoff (Riley and Chester, 1971).

Two minor elements, barium and lithium, showed correlations with specific conductance, much as the major elements did.

Element	Storm 1	Storm 2	Storm 3
Barium	r = .60	r = .77	r = .91
Lithium	r = .75	r = .93	r = .98

Several minor elements showed only slight temporal or spatial variations and were often reported below the analytical detection limit. Beryllium, cadmium, cobalt, copper, lead, and molybdenum showed little or no variation in their range of values.

Chromium values ranged from <10-20 µg/l in the first storm event with the exception of the first sample which was 130 µg/l. This high value probably represents the first flush after the rainfall. Chromium concentrations were elevated at the Church Creek station during the first and second sampling of the third storm event. These measured 30 and 20 µg/l, respectively, and all other samples were below the limits of detection. The first two samples indicate the first flush of stormwater runoff.

Vanadium concentrations ranged from <6 to <18 µg/l except the first two samples collected at the Church Creek station. Although values of 50 µg/l and 79 µg/l were detected, vanadium concentrations correlate strongly with specific conductance (r = 0.87) so the increases are likely from seawater influences rather than runoff influences.

Iron, manganese, and silica varied considerably between stations, but values for these elements were similar at all samplings at each station. These elements are naturally occurring and their concentrations may be affected by the geology of the area. The range of values for these elements are shown below.

Element	Storm 1	Storm 2	Storm 3
Iron, µg/l	48-760	14-270	38-960
Manganese, µg/l	7-650	3-220	5-160
Silica, mg/l	0.9-9.3	1.2-20	5.2-69

Iron, manganese, or silica are not generally associated with pollution sources and are not considered toxic.

Only two elements, zinc and mercury, show variations which could be attributed to stormwater runoff, since they are not closely associated with seawater or local geology. Zinc concentrations ranged from <3 µg/l to 190 µg/l for all storm events (Figures 15-17). Only two values of zinc were detected above EPA national criteria to protect aquatic life. These were reported during the third storm at Dorchester Creek at 130 µg/l and Popperdam Creek at 190 µg/l. All others were less than 65 µg/l at the brackish water stations, Brickyard Creek and Church Creek, and less than 55 µg/l at the stations which are less influenced by saltwater. Since the elevated levels are not recurring, they should be compared with national criteria for acute toxicity, 95 µg/l for saltwater and 65 µg/l for freshwater (US EPA, 1987 Feb).

Mercury concentrations ranged from <0.1 µg/l to 3.4 µg/l (Figures 18-20). Concentrations greater than 1.0 µg/l were reported at four stations, including Popperdam Creek, Church Creek, Dorchester Creek, and Eagle Creek, during the first storm study. At the Church Creek station, these increased values were 3.1 µg/l at the first sampling and 1.7 µg/l at the second sampling. Mercury decreased to 0.8 µg/l by the

Figure 15. Dissolved Zinc in Runoff

Stormwater Runoff Study — April '87

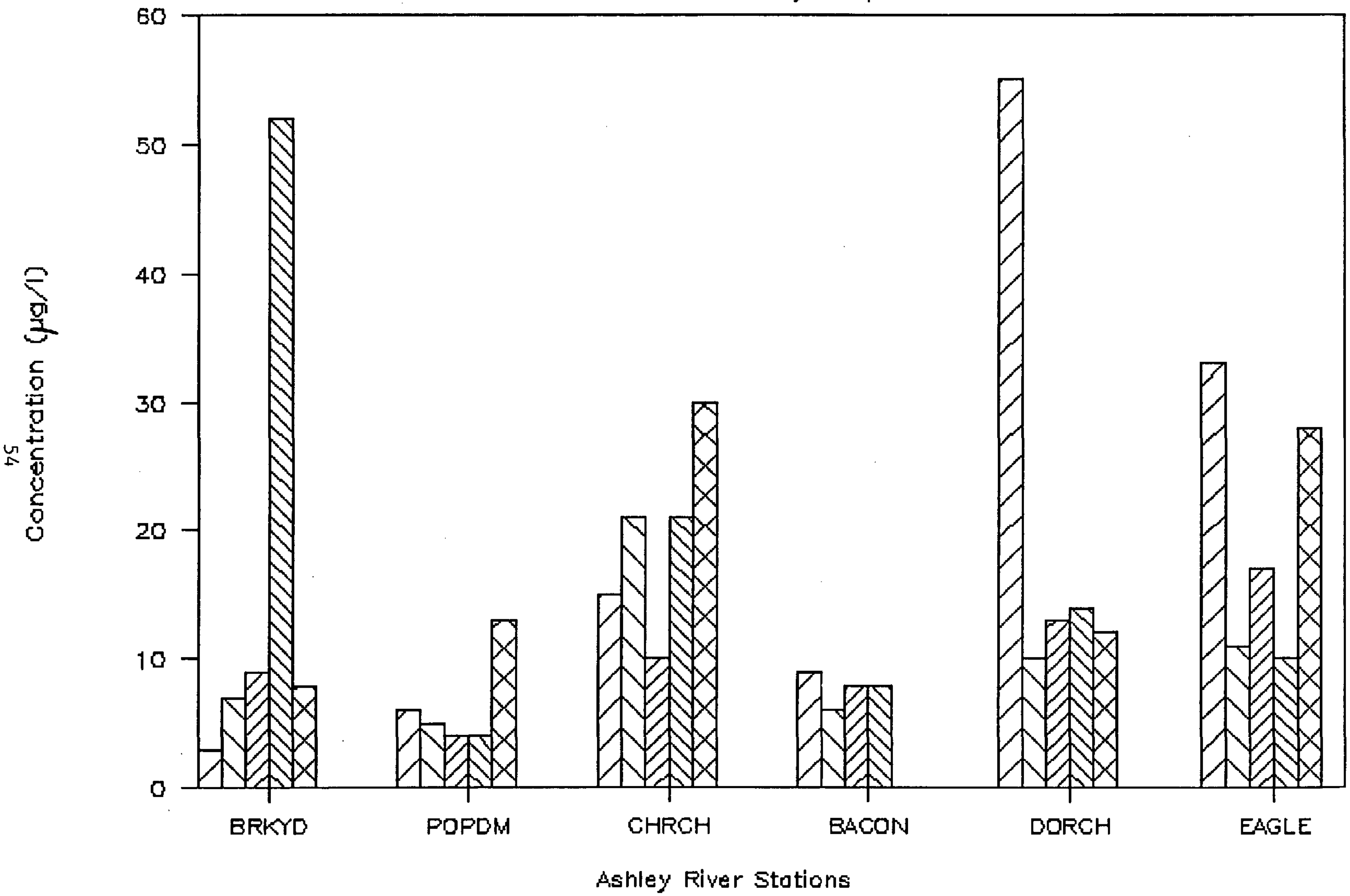


Figure 16. Dissolved Zinc in Runoff

Stormwater Runoff Study — June '87

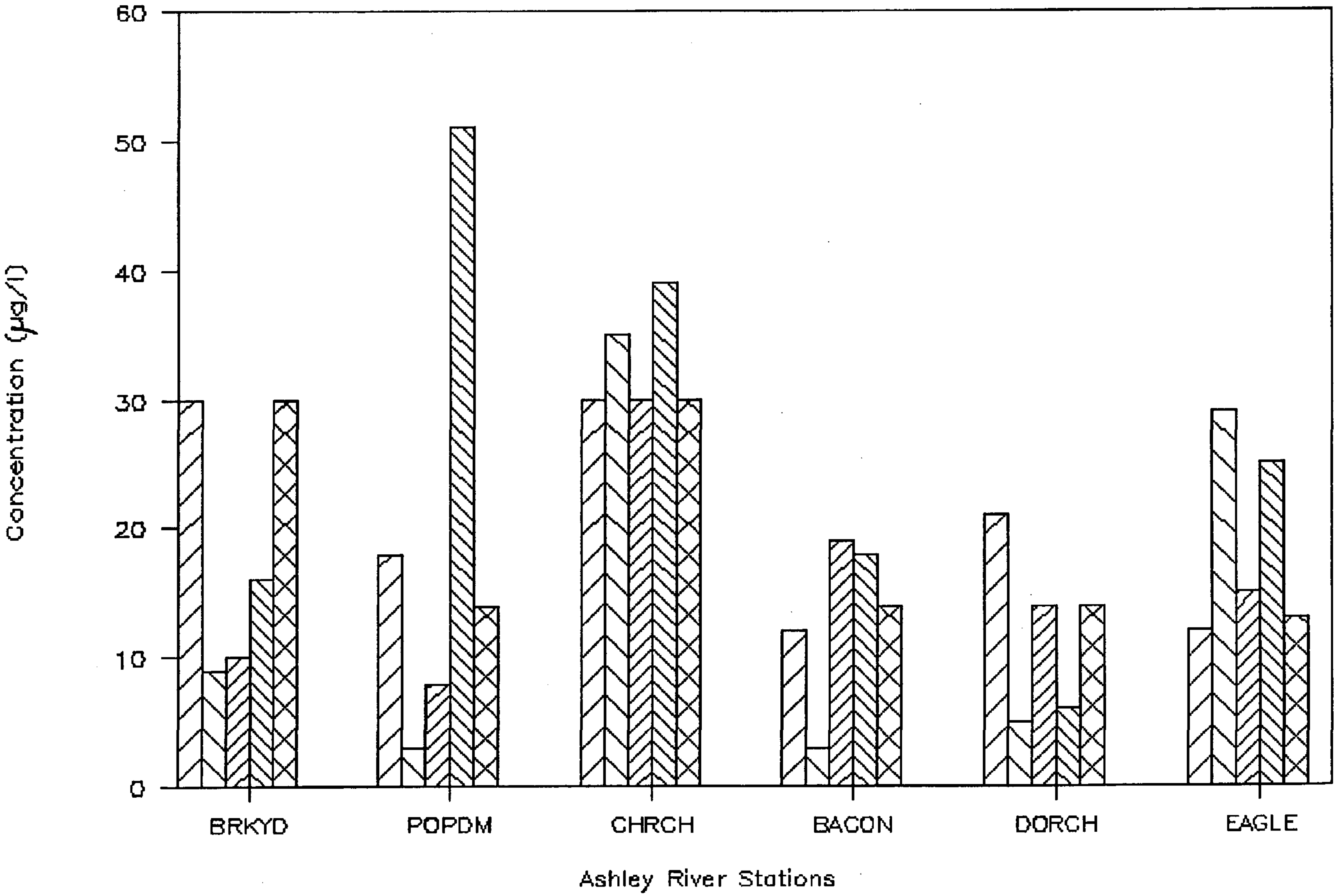


Figure 17. Dissolved Zinc in Runoff

Stormwater Study — Sept–Oct '87

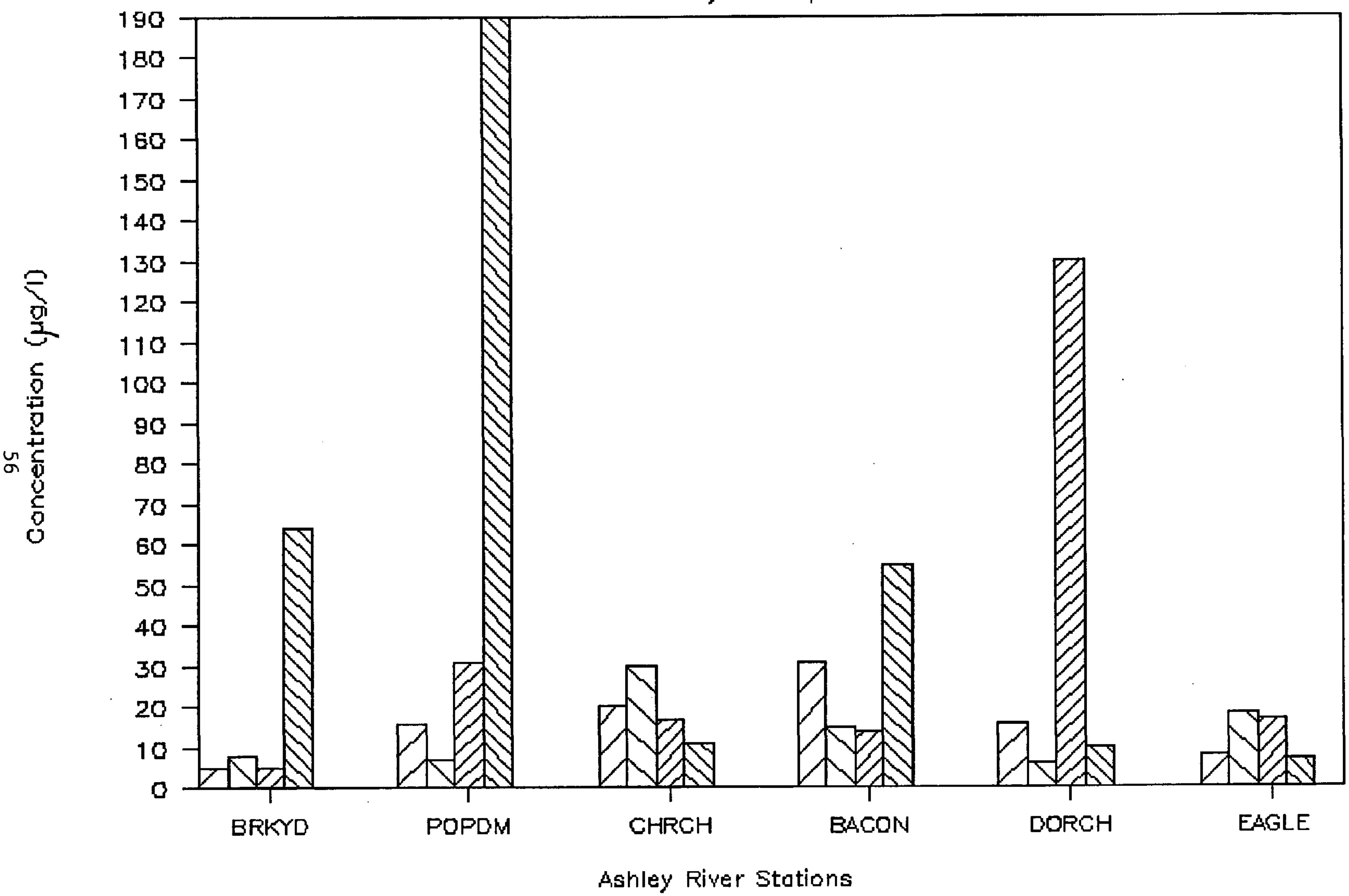


Figure 18. Dissolved Mercury in Runoff

Stormwater Runoff Study — April '87

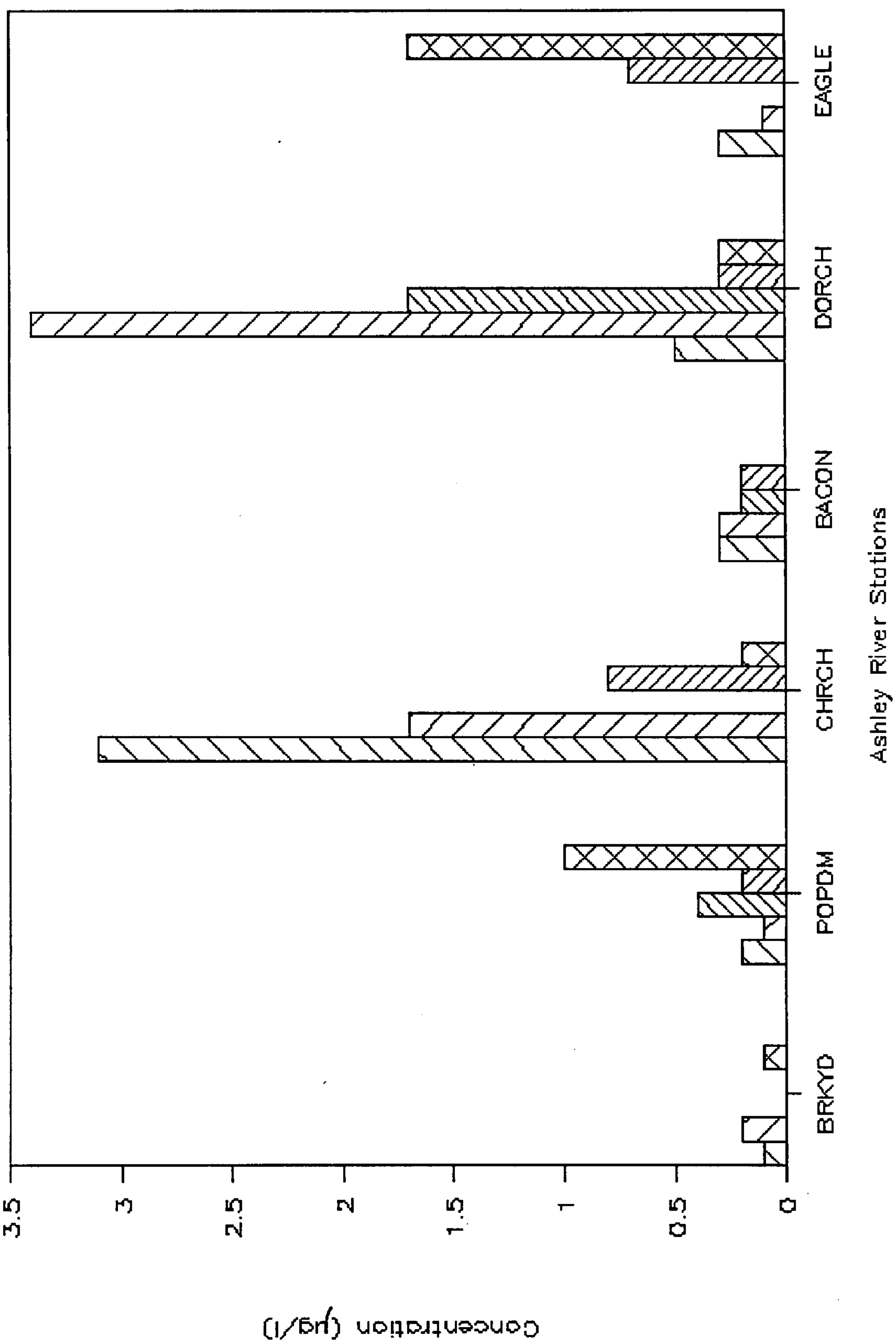


Figure 19. Dissolved Mercury in Runoff

Stormwater Runoff Study — June '87

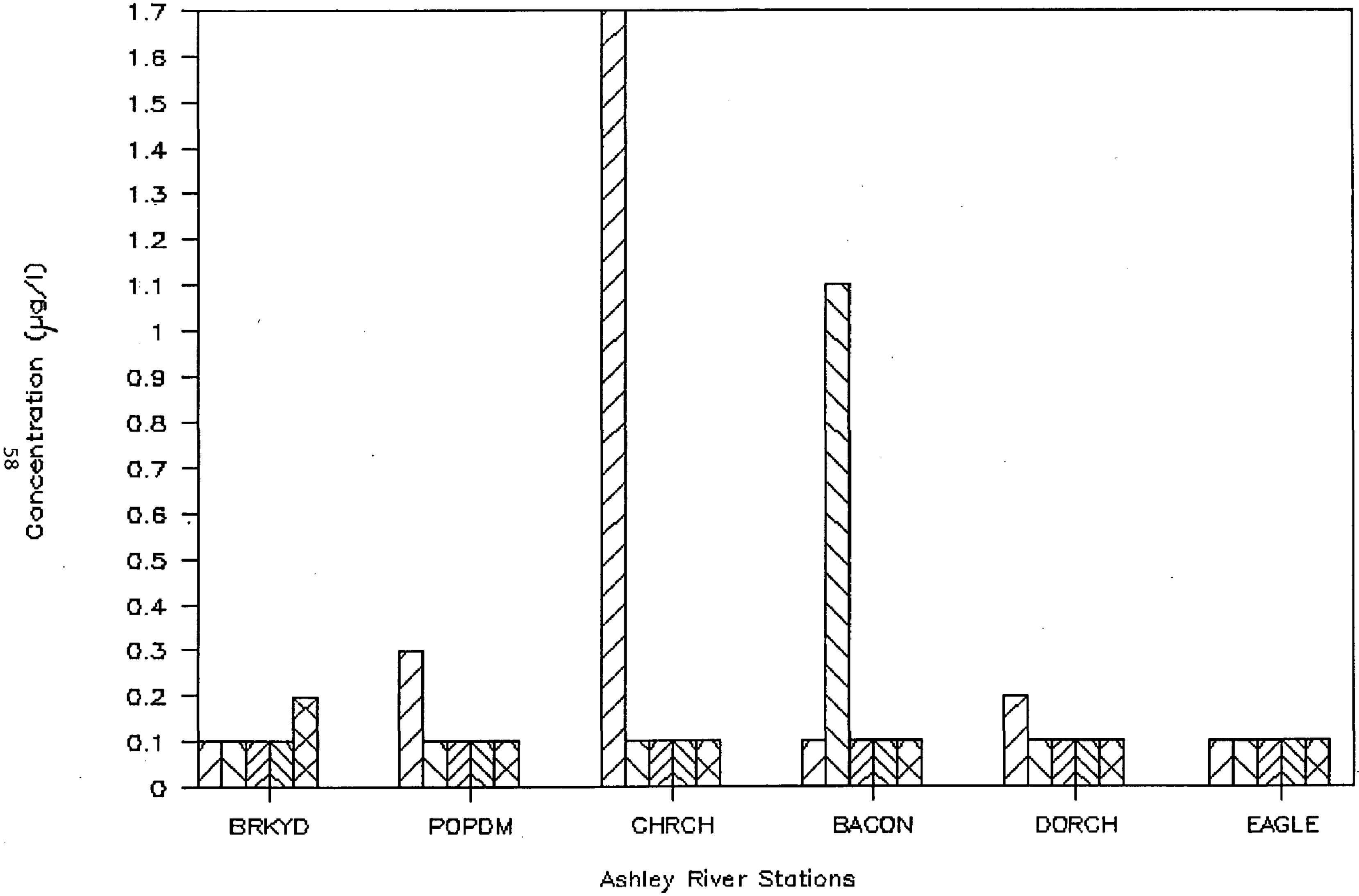
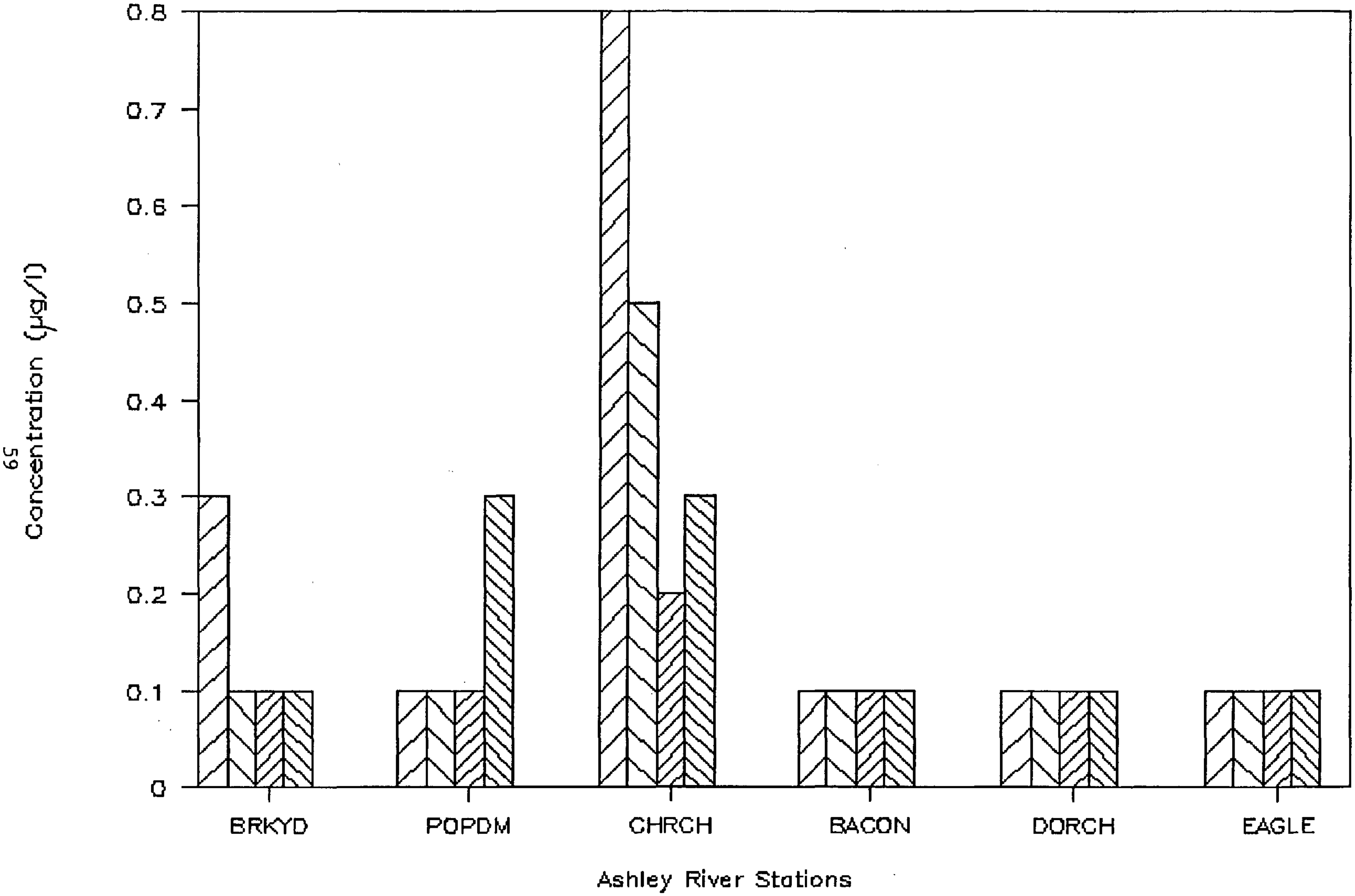


Figure 20. Dissolved Mercury in Runoff

Stormwater Study — Sept—Oct '87



fourth sampling. At the Dorchester Creek station, these increased values were 3.4 µg/l at the second sampling and 1.7 µg/l at the third sampling, with a return to 0.3 µg/l at the fourth sampling. A value of 1.7 µg/l occurred at Eagle Creek at the last sampling, and a value of 1.0 µg/l occurred at Popperdam Creek, presumably after the effect of any stormwater runoff had subsided.

During the second storm study mercury concentrations ranged from <0.1 µg/l to 1.7 µg/l. Only two stations, Church Creek with a value of 1.7 µg/l at the first sampling and Bacon's Bridge with a value of 1.1 µg/l at the second sampling, showed elevated values which may be attributed to stormwater runoff. All other mercury values at all stations were 0.3 µg/l or less.

There were no mercury concentrations measured during the third storm event that were directly attributable to stormwater runoff. Concentrations at all stations except Church Creek ranged from <0.1 µg/l to 0.3 µg/l. At Church Creek the mercury levels ranged from 0.2 µg/l to 0.8 µg/l, but are likely due to seawater influence, since a simple regression of specific conductance to mercury had a correlation coefficient of 0.93.

A few of these levels may be potentially toxic when compared with EPA criteria to protect aquatic life. Since these elevated levels are not recurring they should be compared with criteria for acute toxicity, 2.1 µg/l for saltwater and 2.4 µg/l for freshwater (US EPA, 1985).

Conclusions

The water quality characteristics of stormwater runoff were assessed in six Ashley River tributaries having variable land use associations. Three storm events were studied to measure various constituents influencing water quality. The major conclusions from this study are:

Dissolved oxygen and associated saturation data indicate with few exceptions acceptable levels in the stormwater runoff associated with tributary watersheds when compared to State D.O. standards and a 66% D.O. saturation criteria. An exception was the Church Creek site, with four sub-standard D.O. determinations. It is expected that total D.O. deficits resulted from inputs of oxygen demanding material from natural background sources, nonpoint sources, and a point source discharge in Church Creek.

High concentrations of carbonaceous and nitrogenous oxygen demanding materials are discharged by tributary watersheds into the main stem of the Ashley River estuary following storm events. Brickyard Creek, the most urban and industrial watershed, contributes the highest levels of BOD5/BODu of those watersheds sampled. Less developed watersheds, such as the upper Ashley (Bacon's Bridge), contribute much lower levels of BOD5/BODu. Similarly, the highest NH3-N and TKN concentrations correspond to the more developed watersheds (Church, Brickyard, Dorchester and Eagle Creeks).

The extent to which nonpoint source oxygen demanding material entering the main stem of the Ashley River system is causing dissolved oxygen depression in the main stem is a complex question and not fully understood. Recent Ashley River dissolved oxygen and related data from SCDHEC long-term ambient monitoring stations (MD-049 and MD-135) and similar data from USGS continuous real time stations indicate that at times dissolved oxygen levels are depressed below 4.0 mg/l (as a daily minimum) throughout the system. When these depressed D.O. levels do occur, it is usually during portions of the summer months from June through September when the lowest D.O. and D.O. saturation levels are naturally expected. While data indicate that dissolved oxygen levels in the Ashley River and Charleston Harbor are spatially and temporally quite variable, the majority of those values below 4.0 mg/l have occurred at stations in the upper and middle Ashley River, with a small percentage at stations in the lower Ashley and Charleston Harbor. Data also indicate that the months from October through May almost always have daily minimums above 4.0 mg/l and daily averages above 5.0 mg/l throughout the estuary.

Dissolved oxygen dynamics in the Ashley River and Charleston Harbor estuary, like other estuarine systems, is dependent on a complex set of interactive factors which are spatially and temporally variable. Using water quality and biological data assessment, as well as appropriate modelling studies, the SCDHEC will continue to evaluate the relative importance of nonpoint and point sources on the dissolved oxygen dynamics of this system.

Fecal coliform concentrations, as geometric means, exceeded 1000 cols./100 ml in all watersheds during the first storm event. The highest concentrations were found in the Brickyard, Popperdam, Dorchester and Eagle Creek watersheds. For some storm events, each of these sites had geometric means exceeding the State FC standard.

The range of pH data met the State standard in stormwater runoff at all watersheds.

Elevated levels of zinc were found in Dorchester and Popperdam Creek stormwater runoff measurements. Elevated concentrations of mercury were found in Church and Dorchester Creek stormwater runoff measurements.

In summary, water quality analyses indicate that stormwater runoff from culturally developed watersheds is contributing elevated concentrations of some pollutants to the Ashley River estuary. Cumulatively, this stormwater runoff contributes to the degradation of water quality. Currently, the S. C. Department of Health and Environmental Control and several cooperating agencies are involved in a Nonpoint Source Management Program. So that environmental and use benefits may be maintained and improved, a primary objective of this program is to implement Best Management Practices (BMPs) to control stormwater runoff and associated pollutants. The South Carolina NPS Management Plan identifies the Ashley River sub-basin as a waterbody impacted by nonpoint source pollution. As such, BMPs should be utilized within the Ashley River sub-basin to control nonpoint source pollution related to current and future impacts.

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APPENDIX 1

Correspondence from the U. S. Geological Survey

United States Department of the Interior

GEOLOGICAL SURVEY

Water Resources Division
1835 Assembly Street, Suite 677A
Columbia, SC 29201-2492
January 14, 1988

RECEIVED
JAN 15 1988
DIVISION OF
WATER QUALITY

Mr. John Chigges
S.C. Department of Health
and Environmental Control
2600 Bull Street
Columbia, SC 29201

Dear Mr. Chigges:

Enclosed are the data from the first and second storm events sampled by the U.S. Geological Survey in the Ashley River Basin. The data from the third storm are nearly complete, and I expect to have them to you in February.

Also enclosed are some pages containing general information on the study as well as field observations and weather conditions for each storm.

Lastly, I am including a single page of data for station ARC1, in order to show you a different format that is available through our water quality data system. If you would like to have the Ashley River data in that format in addition to the tables provided, please let me know.

If you have any questions, feel free to call. You can reach me at 253-3690.

Sincerely,

Donna L. Belval

Donna L. Belval
Hydrologist

Enclosure

DB/vh

ASHLEY RIVER RUNOFF STUDY

The Sampling Stations and Station Numbers are as follows:

Station	DHEC Station Number	USGS Station Number
Brickyard Creek	A1	325053080002701
Popperdam Creek	B1	325410080044001
Church Creek	B2	325011080025301
Bacon's Bridge	C1	325730080120501
Dorchester Creek	C2	325708080101401
Eagle Creek	C3	325702080093501

Numbering System

The following numbering system was used to provide each sample with a unique sample number:

STORM NUMBER AR (Ashley River) STATION NUMBER - SAMPLE NUMBER

For example, 2ARC3-4 is the fourth sample taken at Eagle Creek, Station C3, during the second storm.

Analyses

The Biochemical Oxygen Demand (BOD) for each sample was determined at the USGS laboratory in Columbia, South Carolina. All other analyses were performed by the USGS Central Laboratory in Arvada, Colorado.

Key to Printout Codes

Parameter	Code	Key
Streamflow, Instantaneous	<0	Indicates that there was upstream flow due to incoming tide.
Coliform, Fecal	K	Non-ideal colony count, meaning that results are based on a colony count outside of the acceptable range.
Coliform, Fecal	ND	Bacteria were specifically analyzed for but not detected.

Note

Gage height is described on the printout as "feet above datum". These values, however are actually feet below the measuring point on each bridge. There is no common datum elevation.

NOTES FOR ASHLEY RIVER RUNOFF SAMPLING
STORM 1: April, 1987

Sampling Personnel: Gary Speiran, Donna Belval, John Barton, Carol Lowery

Weather conditions as reported by the National Weather Service:

Date	Summerville			Charleston Airport			
	Precipitation, in inches	Temperature, °F Max	Temperature, °F Min	Precipitation, in inches	Temperature °F Max	Temperature °F Min	Conditions Reported
4/14	0	88	51	0	79	57	Fog, Haze
4/15	1.82	81	61	1.07	79	62	Fog, Thunderstorm
4/16	.54	77	57	.06	72	53	Hail, Thunderstorm
4/17	.07	77	42	.03	69	49	Thunderstorm
4/18	.01	69	45	.10	71	50	Thunderstorm, Heavy Fog

Remarks: Rainfall began at approximately 7:30 am, and stopped at 12:30 pm.

Original plans were to sample only on the outgoing tide. However, it soon became apparent that the high stormwater flow overcame the effects of the tide. The schedule was revised to take measurements at the peak of the storm hydrograph rather than only on the outgoing tide.

On inspection of the streams late on the afternoon of the 16th, the flow appeared to be only slightly higher than during the background sample, so sampling was discontinued. Tidal effects were in evidence by that time.

Due to problems with the fixative, mercury concentration could not be determined for the following samples: 1ARA1-3
1ARA1-4
1ARB2-3
1ARC3-3

NOTES FOR ASHLEY RIVER RUNOFF SAMPLING
STORM 2: June, 1987

Sampling Personnel: Donna Belval, John Barton, Larry Harrelson, Paul Conrads

Weather conditions as reported by the National Weather Service:

	Summerville			Charleston Airport			
	Precipitation,	Temperature, °F		Precipitation,	Temperature, °F		Conditions
Date	in inches	Max	Min	in inches	Max	Min	Reported
6/3	.02	91	69	0	95	73	
6/4	0	93	71	1.07	79	70	Fog, Thunderstorms
6/5	.86	79	67	0	85	68	
6/6	0	85	68	0	87	64	
6/7	0	87	57	0	87	63	

Remarks: Rainfall begin at approximately 2:30 pm on June 4, and continued intermittantly for several hours.

Because stormwater runoff was much less than that of the previous storm, the influence of the tide was more in evidence.

Some discharge measurements could not be made because of severe lightning.

Sampling was done on the outgoing tide whenever possible.

United States Department of the Interior

GEOLOGICAL SURVEY

RECEIVED

FEB 12 1988

DIVISION OF WATER QUALITY

Water Resources Division
1835 Assembly Street, Suite 677A
Columbia, SC 29201-2492
February 11, 1988

Mr. John Chigges
S.C. Department of Health
and Environmental Control
2600 Bull Street
Columbia, SC 29201

Dear Mr. Chigges:

Enclosed are the data from the third storm event sampled by the U.S. Geological Survey in the Ashley River Basin.

During our conversation on January 19, you asked about the use of the term "conductance" on the printout from the USGS laboratory. Our water-quality standards require that we report field-measured specific conductance in micromhos/cm at 25 °C. We use both temperature-compensated meters, from which we read value directly, and meters which are not temperature-compensated. For the latter type of meter, specific conductance at 25 °C is computed using the following formulas:

A. If measured temperature is greater than 25 °C:

$$CV = \frac{MV}{1+X} \quad \text{where } X = ((T-25)0.02)$$

B. If measured temperature is less than 25 °C:

$$CV = MV\,(1+X) \quad \text{where } X = ((25-T)0.02)$$

and CV = conductance at 25 °C
MV = measured conductance value
T = measured temperature of sample.

These formulas are from the USGS Training Manual for Water-Quality Field Techniques for the Southeastern Region. If you need a more specific reference, please let me know.

Free free to call, if you have any questions. I can be reached at 253-3690.

Sincerely,

Donna L. Belval

Donna L. Belval
Hydrologist

Enclosure

DLB/vwf

United States Department of the Interior

GEOLOGICAL SURVEY

Water Resources Division
1835 Assembly Street, Suite 677A
Columbia, SC 29201-2492
June 3, 1988

Mr. John Chigges
South Carolina Department of
Health and Environmental Control
2600 Bull Street
Columbia, South Carolina 29201

Dear Mr. Chigges:

Enclosed are the data from the third storm event sampled by the U.S. Geological Survey in the Ashley River Basin. Included are the dissolved oxygen values that were not given in the previous table. Dissolved oxygen values were not obtained at all sites because of a meter malfunction.

As you requested, I asked our metals chemist at the National Water Quality Laboratory (NWQL) about the chromium values obtained for the Ashley River. The NWQL can determine concentrations of chromium (II), chromium (III) and chromium (VI) on request; however, for this study specific oxidation states were not asked for, so that the values reported are total chromium only.

If you have any further questions, please do not hesitate to call me in Columbia at 765-5966.

Sincerely,

Donna L. Belval
Hydrologist

Enclosure

cc: Glenn Patterson
Assistant District Chief

DLB/vb

NOTE FOR ASHLEY RIVER RUNOFF SAMPLING
STORM 3: September-October, 1987

Sampling Personnel: Donna Belval, John Barton, Paul Drewes, Whitney Stringfield

Weather conditions as reported by the National Weather Service:

	Summerville			Charleston Airport			
	Precipitation in inches	Temperature, °F		Precipitation in inches	Temperature, °F		Conditions Reported
Date		Max	Min		Max	Min	
09/29	0	83	64	0	86	66	
09/30	0.62	88	67	0.59	76	68	Fog
10/01	0.38	88	56	0	73	53	
10/02	0	74	43	0	81	50	

Remarks: Rainfall began at 5:30 am on September 30, and continued for approximately three hours.

Because the total rainfall was a relatively small amount, the effects of the tide easily overcame the additional streamflow due to the storm. Sampling, therefore, was conducted on the outgoing tides when possible.

APPENDIX 2

Streamflow and Water Quality Data from the U. S. Geological Survey

STUDY 1

April 14-16, 1987

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 1-13-88
MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER		DATE	TIME	LAT-I-TUDE	LONG-I-TUDE	STREAM-FLOW, INSTAN-TANEOUS (CFS) (00061)	GAGE HEIGHT (FEET ABOVE DATUM) (00065)	TEMPER-ATURE WATER (DEG C) (00010)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)
ARA1	BRICKYARD CREEK	04-14-87	1800	32 50 53 N	080 00 27 W	0.10	10.57	25.0	690
		04-15-87	1215			24	7.24	19.5	195
		04-15-87	1530			9.7	9.87	22.5	238
		04-15-87	2340			16	6.63	21.5	2410
		04-16-87	1630			0.92	10.40	22.5	430
ARB1	POPPERDAM CREEK	04-14-87	2040	32 54 10 N	080 04 40 W	0.0	--	21.0	248
		04-15-87	0900			202	2.91	17.5	123
		04-15-87	1645			113	3.26	20.5	145
		04-15-87	2045			51	5.11	20.5	153
		04-16-87	1415			17	6.63	20.0	140
ARB2	CHURCH CREEK	04-14-87	2030	32 50 11 N	080 02 53 W	246	9.40	20.0	6100
		04-15-87	1345			277	9.82	20.0	1490
		04-15-87	1650			142	12.39	22.5	4620
		04-16-87	1230			165	9.48	20.5	2600
		04-16-87	1740			77	13.12	22.5	1360
ARC1	BACON BRIDGE	04-14-87	2140	32 57 30 N	080 12 05 W	0.0	14.44	18.0	93
		04-15-87	1730			576	15.34	19.5	76
		04-16-87	1320			0.0	--	19.0	81
		04-16-87	1645			385	16.50	19.0	81
ARC2	DORCHESTER CREEK	04-14-87	1800	32 57 08 N	080 10 14 W	0.0	10.15	--	--
		04-15-87	1340			1040	4.57	19.0	111
		04-15-87	1835			374	7.94	20.0	108
		04-16-87	1215			121	6.63	20.0	124
		04-16-87	1600			--	9.38	21.0	139
ARC3	EAGLE CREEK	04-14-87	1845	32 57 02 N	080 09 35 W	98	9.87	21.0	121
		04-15-87	1240			521	5.72	18.0	105
		04-15-87	2000			375	8.25	18.0	78
		04-16-87	1115			148	6.74	18.5	73
		04-16-87	1540			--	9.76	19.5	75

LOCAL IDENT-I-FIER		OXYGEN, DIS-SOLVED (MG/L) (00300)	OXYGEN DEMAND, BIO-CHEM-ICAL, 5 DAY (MG/L) (00310)	OXYGEN DEMAND, BIOCHEM ULT. CARBON-ACEOUS (MG/L) (00320)	PH (STAND-ARD UNITS) (00400)	NITRO-GEN, AMMONIA TOTAL (MG/L AS N) (00610)	NITRO-GEN, AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)
ARA1	BRICKYARD CREEK	7.0	5.3	12	8.20	0.420	1.8	63	11	57
		6.8	--	--	7.80	0.290	1.7	25	2.1	12
		6.4	25	62	7.40	0.140	3.6	27	4.0	24
		4.2	4.8	9.8	7.40	0.320	1.0	42	51	430
		8.6	37	115	8.00	0.540	2.3	55	7.7	39
ARB1	POPPERDAM CREEK	9.6	2.5	5.4	7.37	0.020	1.2	32	2.7	12
		8.9	5.4	10	7.76	0.210	1.6	10	0.60	1.6
		6.3	5.0	10	7.60	0.150	2.6	21	1.1	3.8
		6.3	3.5	8.7	7.17	0.120	0.90	20	1.2	5.3
		6.5	2.4	5.9	6.79	0.090	1.8	18	1.3	5.2
ARB2	CHURCH CREEK	6.7	2.4	6.0	7.30	0.600	2.4	96	260	2200
		6.0	2.3	6.2	7.20	0.550	2.3	110	310	2500
		5.3	3.4	9.1	7.20	1.30	3.0	61	91	760
		5.2	2.7	6.0	7.10	1.10	2.6	70	150	1300
		5.8	3.8	8.8	7.40	0.180	1.7	42	25	180
ARC1	BACON BRIDGE	7.8	10	17	6.86	0.100	2.3	8.9	1.2	5.9
		5.6	2.5	7.3	6.26	0.070	1.9	7.3	0.90	4.8
		5.4	1.7	5.2	6.28	0.080	1.4	7.5	0.90	5.1
		7.1	1.4	4.4	6.23	0.040	1.9	7.5	0.90	5.3
ARC2	DORCHESTER CREEK	13.0	2.1	6.1	9.92	0.030	7.5	26	4.1	48
		7.0	7.0	14	7.31	0.300	2.1	14	0.90	4.3
		6.8	5.0	12	6.91	0.320	1.8	12	1.0	6.2
		7.8	2.2	6.5	6.95	0.680	2.2	12	1.2	11
		9.0	2.0	5.5	7.16	0.600	2.4	12	1.2	11
ARC3	EAGLE CREEK	8.9	1.8	5.6	6.63	0.240	1.8	12	1.4	10
		6.9	6.8	13	6.79	0.110	1.5	10	0.80	3.2
		6.1	3.5	11	6.66	0.030	1.5	9.1	0.80	3.4
		6.8	1.6	5.3	6.24	0.040	2.1	7.2	0.80	3.5
		7.8	1.9	5.6	6.53	0.040	1.9	8.0	0.90	4.3

LOCAL IDENT-I-FIER	SILICA, DIS-SOLVED (MG/L AS SIO2) (00955)	BARIUM, DIS-SOLVED (UG/L AS BA) (01005)	BERYL-LIUM, DIS-SOLVED (UG/L AS BE) (01010)	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	COBALT, DIS-SOLVED (UG/L AS CO) (01035)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)
ARA1 BRICKYARD CREEK	8.0	22	<0.5	<1	<10	<3	<10	46	<10
	3.3	11	<0.5	1	<10	<3	10	200	10
	4.2	13	<0.5	<1	<10	<3	<10	290	<10
	3.6	14	<2	<3	<10	<9	<30	760	<30
	10	22	<0.5	<1	<10	<3	<10	94	<10
ARB1 POPPERDAM CREEK	9.3	24	<0.5	1	<10	<3	<10	280	10
	0.9	5	<0.5	<1	<10	<3	<10	74	<10
	2.7	12	<0.5	<1	<10	<3	<10	81	10
	3.9	14	<0.5	1	<10	<3	<10	160	<10
	6.0	16	<0.5	<1	<10	<3	<10	350	<10
ARE2 CHURCH CREEK	4.1	26	3	<3	130	<9	<30	100	<30
	3.5	26	1	1	10	<3	10	77	10
	4.5	23	<2	<3	<10	<9	<30	210	<30
	4.4	23	<2	<3	<10	<9	<30	160	<30
	5.5	13	<0.5	<1	<10	<3	<10	760	<10
ARC1 BACON BRIDGE	4.5	16	1	1	<10	<3	<10	420	10
	4.1	12	<0.5	<1	<10	<3	<10	390	<10
	4.6	13	<0.5	<1	<10	<3	<10	470	<10
	4.7	14	<0.5	<1	<10	<3	<10	420	<10
ARC2 DORCHESTER CREEK	5.3	13	<0.5	2	<10	<3	10	190	<10
	2.5	13	<0.5	1	<10	<3	<10	230	20
	3.7	16	<0.5	1	<10	<3	<10	370	<10
	5.7	14	<0.5	<1	10	<3	<10	340	<10
	5.8	16	<0.5	<1	<10	<3	<10	300	<10
ARC3 EAGLE CREEK	4.9	16	<0.5	<1	<10	<3	<10	480	<10
	2.9	9	<0.5	1	<10	<3	<10	330	30
	3.4	11	<0.5	<1	<10	<3	<10	310	10
	4.4	11	<0.5	<1	<10	<3	<10	420	<10
	4.8	11	<0.5	<1	20	<3	<10	430	<10

MULTIPLE STATION ANALYSES

LOCAL IDENT- I- FIER	MANGA- NESE, DIS- SOLVED (UG/L AS MN) (01056)	MOLYB- DENUM, DIS- SOLVED (UG/L AS MO) (01060)	STRON- TIUM, DIS- SOLVED (UG/L AS SR) (01080)	VANA- DIUM, DIS- SOLVED (UG/L AS V) (01085)	ZINC, DIS- SOLVED (UG/L AS ZN) (01090)	LITHIUM DIS- SOLVED (UG/L AS LI) (01130)	COLI- FORM, FECAL, 0.7 UM-MF (COLS./ 100 ML) (31625)	MERCURY DIS- SOLVED (UG/L AS HG) (71890)
ARA1 BRICKYARD CREEK	60	<10	330	<6	<3	9	430	0.1
	31	<10	83	<6	7	6	K90000	0.2
	49	<10	120	<6	9	<4	20000	--
	650	<30	370	<18	52	16	7300	--
	76	<10	280	<6	8	5	K3000	0.1
ARB1 POPPERDAM CREEK	26	<10	96	<6	6	7	260	0.2
	5	<10	25	<6	5	<4	K22000	<0.1
	15	<10	43	<6	4	5	K24000	0.4
	23	<10	48	<6	4	5	K22000	0.2
	28	<10	47	<6	13	<4	7000	1.0
ARB2 CHURCH CREEK	100	<30	1600	<18	15	69	1300	3.1
	120	<10	1800	<6	21	65	6700	1.7
	220	<30	610	<18	10	17	K5300	--
	170	<30	940	<18	21	38	1600	0.8
	120	<10	240	<6	30	7	350	0.2
ARC1 BACON BRIDGE	48	<10	28	<6	9	<4	K150	0.3
	57	<10	22	<6	6	<4	14000	0.3
	25	<10	21	<6	8	<4	K3200	0.2
	31	<10	22	<6	8	<4	1700	0.2
ARC2 DORCHESTER CREEK	7	<10	130	<6	55	5	ND	0.5
	23	<10	30	<6	10	<4	K39000	3.4
	32	<10	30	<6	13	<4	K28000	1.7
	26	<10	33	<6	14	<4	810	0.3
	23	<10	34	<6	12	<4	K4700	0.3
ARC3 EAGLE CREEK	38	<10	40	<6	33	<4	490	0.3
	22	<10	25	<6	11	<4	K38000	<0.1
	23	<10	25	<6	17	<4	>12	--
	14	<10	19	<6	10	<4	7700	0.7
	16	<10	23	<6	28	<4	9300	1.7

STUDY 2

June 4-6, 1987

LOCAL IDENT-I-FIER		DATE	TIME	LAT-I-TUDE	LONG-I-TUDE	STREAM-FLOW, INSTAN-TANEOUS (CFS) (00061)	GAGE HEIGHT (FEET ABOVE DATUM) (00065)	TEMPER-ATURE WATER (DEG C) (00010)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)
ARA1	BRICKYARD CREEK	06-04-87	1545	32 50 53 N	080 00 27 W	34	8.14	25.0	2700
		06-04-87	1950			2.5	10.28	23.0	330
		06-05-67	1100			0.27	10.55	26.5	1060
		06-05-87	1820			13	8.80	30.0	1820
		06-06-87	0950			0.25	10.57	25.0	15200
ARB1	POPPERDAM CREEK	06-04-87	1500	32 54 10 N	080 04 40 W	--	--	25.0	90
		06-04-87	1740			69	5.14	25.0	419
		06-05-87	1030			1.9	7.61	24.0	201
		06-05-87	2125			1.0	7.84	25.0	270
		06-06-87	1300			0.91	7.57	28.0	200
ARB2	CHURCH CREEK	06-04-87	1415	32 50 11 N	080 02 53 W	--	9.78	28.0	15600
		06-04-87	2120			43	13.11	26.5	10300
		06-05-87	1320			<0.0	10.60	27.0	14500
		06-05-87	2000			155	18.81	28.0	16500
		06-06-87	1045			47	13.05	25.0	12400
ARC1	BACON BRIDGE	06-04-87	1415	32 57 30 N	080 12 05 W	0.0	16.57	28.0	408
		06-04-87	1700			0.0	15.12	27.0	596
		06-05-87	2015			182	17.21	26.5	350
		06-06-87	1200			23	17.99	24.0	191
		06-08-57	1325			32	18.22	26.0	240
ARC2	DORCHESTER CREEK	06-04-87	1400	32 57 08 N	080 10 14 W	<0.0	--	28.0	848
		06-04-87	2245			0.0	13.33	24.5	328
		06-05-87	1255			0.0	8.49	29.0	233
		06-05-87	1910			39	7.76	27.0	297
		06-06-87	1025			0.0	10.44	25.0	319
ARC3	EAGLE CREEK	06-04-87	1535	32 57 02 N	080 09 35 W	<0.0	7.48	27.0	875
		06-04-87	2100			73	--	24.0	235
		06-05-87	1210			<0.0	10.58	28.0	686
		06-05-87	1820			91	7.79	23.0	914
		06-06-87	0930			13	11.81	24.0	501

LOCAL IDENT-I-FIER	OXYGEN, DIS-SOLVED (MG/L) (00300)	OXYGEN DEMAND, BIC-CHEM-ICAL, 5 DAY (MG/L) (00310)	OXYGEN DEMAND, BIOCHEM ULT. CARBON-ACEOUS (MG/L) (00320)	PH (STAND-ARD UNITS) (00400)	NITRO-GEN, AMMONIA TOTAL (MG/L AS N) (00610)	NITRO-GEN, AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)
ARA1 BRICKYARD CREEK	6.7	22	38	7.40	0.800	2.7	51	60	520
	4.9	8.3	16	7.40	0.860	2.0	28	4.7	25
	--	2.9	7.9	8.20	0.540	1.3	59	19	140
	5.3	4.0	9.2	7.70	0.960	1.9	46	36	310
	12.0	5.2	12	8.10	0.590	2.1	69	30	230
ARB1 POPPERDAM CREEK	6.4	7.4	14	7.28	0.290	1.3	34	2.6	13
	5.5	--	--	7.82	0.230	1.5	42	2.2	10
	6.8	3.1	6.7	7.50	0.060	1.4	26	1.4	6.9
	7.3	2.6	5.8	7.43	0.100	1.0	29	2.1	16
	8.5	2.4	5.5	7.90	0.090	1.2	33	3.6	22
ARB2 CHURCH CREEK	5.0	2.1	4.6	7.40	0.340	1.2	160	450	3700
	3.1	3.2	6.4	7.40	0.700	2.7	110	250	2100
	3.8	2.1	4.8	7.30	0.740	2.3	130	350	2900
	4.1	2.5	5.3	7.30	0.490	1.7	150	410	3400
	3.9	2.3	5.4	7.30	0.730	2.6	120	280	2300
ARC1 BACON BRIDGE	8.1	2.9	7.1	7.45	0.040	1.7	21	4.4	47
	5.2	3.9	7.9	7.52	0.230	2.1	21	6.6	78
	7.2	2.4	5.6	7.52	0.040	1.6	21	4.4	46
	6.3	2.2	5.1	6.53	0.080	1.7	15	2.0	18
	8.4	2.7	5.9	7.60	0.060	1.4	16	2.6	27
ARC2 DORCHESTER CREEK	4.5	5.8	11	7.30	3.80	4.7	22	8.2	120
	4.3	8.0	18	7.82	0.650	2.7	22	2.1	41
	6.2	4.4	12	8.46	1.40	2.7	25	1.3	19
	5.6	4.2	11	8.61	1.80	2.9	25	2.1	26
	9.8	3.8	10	8.12	1.30	3.1	30	2.5	30
ARC3 EAGLE CREEK	6.1	4.3	8.6	7.46	0.770	2.2	21	11	130
	3.2	9.0	20	7.36	1.20	3.2	20	1.6	18
	6.2	4.4	10	7.60	0.840	2.4	24	5.7	67
	8.2	4.5	8.8	7.85	0.960	2.2	24	11	130
	5.6	3.6	8.6	7.80	0.230	1.9	28	4.7	53

LOCAL IDENT-I-FIER	SILICA, DIS-SOLVED (MG/L AS SIO2) (00955)	BARIUM, DIS-SOLVED (UG/L AS BA) (01005)	BERYL-LIUM, DIS-SOLVED (UG/L AS BE) (01010)	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	COBALT, DIS-SOLVED (UG/L AS CO) (01035)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)
ARA1 BRICKYARD CREEK	4.1	23	2	3	<10	<9	<30	140	<30
	4.3	14	<0.5	<1	<10	<3	<10	270	<10
	10	19	<0.5	<1	10	<3	<10	39	<10
	7.3	18	<0.5	<1	<10	<3	<10	33	<10
	11	18	<5	<10	<50	<30	<100	91	<100
ARB1 POPPERDAM CREEK	6.0	18	<0.5	<1	<10	<3	<10	31	<10
	3.8	24	<0.5	<1	<10	<3	<10	14	<10
	3.4	16	0.9	<1	<10	<3	<10	64	<10
	4.8	19	0.5	<1	<10	<3	20	63	<10
	5.3	18	0.6	<1	20	<3	<10	150	<10
ARB2 CHURCH CREEK	1.9	27	<5	<10	<50	<30	<100	120	<100
	4.5	32	<5	<10	<50	<30	<100	85	<100
	3.6	29	<5	<10	<50	<30	<100	53	<100
	3.0	29	<5	<10	<50	<30	<100	57	<100
	4.9	30	<5	<10	<50	<30	<100	87	<100
ARC1 BACON BRIDGE	1.3	14	<0.5	<1	<10	<3	<10	220	<10
	1.2	12	0.5	<1	<10	<3	<10	220	<10
	1.3	14	0.9	<1	<10	<3	<10	190	<10
	4.9	13	<0.5	<1	10	<3	<10	220	<10
	3.7	12	<0.5	<1	<10	<3	<10	98	<10
ARC2 DORCHESTER CREEK	5.4	13	<0.5	<1	<10	<3	<10	84	<10
	4.0	12	<0.5	<1	<10	<3	<10	120	<10
	5.7	15	1	<1	<10	<3	<10	36	<10
	5.9	14	<0.5	<1	<10	<3	<10	40	<10
	7.2	18	0.6	<1	<10	<3	<10	43	<10
ARC3 EAGLE CREEK	20	12	0.6	<1	<10	<3	<10	95	<10
	4.4	14	<0.5	<1	20	<3	<10	100	<10
	3.8	13	<0.5	<1	<10	<3	<10	78	<10
	3.2	13	<0.5	<1	<10	<3	<10	73	<10
	2.9	12	<0.5	<1	<10	<3	<10	74	<10

MULTIPLE STATION ANALYSES

LOCAL IDENT- I- FIER		MANGA- NESE, DIS- SOLVED (UG/L AS MN) (01056)	MOLYB- DENUM, DIS- SOLVED (UG/L AS MO) (01060)	STRON- TIUM, DIS- SOLVED (UG/L AS SR) (01080)	VANA- DIUM, DIS- SOLVED (UG/L AS V) (01085)	ZINC, DIS- SOLVED (UG/L AS ZN) (01090)	LITHIUM DIS- SOLVED (UG/L AS LI) (01130)	COLI- FORM, FECAL, 0.7 UM-MF (COLS./ 100 ML) (31625)	MERCURY DIS- SOLVED (UG/L AS HG) (71890)
ARA1	BRICKYARD CREEK	110	<30	470	<18	30	24	K8000	<0.1
		69	<10	140	<6	9	7	>6000	<0.1
		97	<10	320	<6	10	10	4300	<0.1
		100	<10	340	<6	16	13	>12000	0.1
		160	<100	400	<60	<30	42	4800	0.2
ARB1	POPPERDAM CREEK	31	<10	96	<6	18	7	>6000	0.3
		44	<10	100	<6	<3	6	--	<0.1
		14	<10	64	<6	8	6	K15000	<0.1
		17	<10	84	<6	51	7	1900	<0.1
		11	<10	97	<6	14	7	3800	<0.1
ARB2	CHURCH CREEK	78	<100	2600	<60	<30	120	K120	1.7
		190	<100	1500	<60	35	52	1700	<0.1
		160	<100	2100	<60	<30	80	470	0.1
		130	<100	2400	<60	38	81	1200	<0.1
		220	<100	170	<60	<30	55	2100	<0.1
ARC1	BACON BRIDGE	19	<10	69	<6	12	<4	1300	<0.1
		7	<10	82	<6	<3	5	450	1.1
		8	<10	72	<6	19	4	2100	<0.1
		37	<10	44	<6	18	<4	1300	<0.1
		24	<10	50	<6	14	<4	K130	<0.1
ARC2	DORCHESTER CREEK	9	<10	93	<6	21	4	930	0.2
		24	<10	59	<6	5	<4	>6000	<0.1
		6	<10	67	<6	14	7	11000	<0.1
		3	<10	68	<6	6	<4	K17000	<0.1
		14	<10	97	<6	14	7	2500	<0.1
ARC3	EAGLE CREEK	9	<10	100	<6	12	4	K1500	<0.1
		31	<10	53	<6	29	<4	K15000	<0.1
		15	<10	82	<6	15	6	6600	<0.1
		4	<10	110	<6	25	6	9300	<0.1
		9	<10	84	<6	13	6	2900	<0.1

STUDY 3

September 30 - October 2, 1987

LOCAL IDENT-I-FIER	DATE	TIME	LAT-I-TUDE	LONG-I-TUDE	STREAM-FLOW, INSTAN-TANEOUS (CFS) (00061)	GAGE HEIGHT (FEET ABOVE DATUM) (00065)	TEMPER-ATURE WATER (DEG C) (00010)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)
ARA1 BRICKYARD CREEK	09-30-87	1500	32 50 53 N	080 00 27 W	<0.0	7.59	24.0	1400
	09-30-87	1815			21	8.62	24.0	330
	10-01-87	0815			0.54	10.40	18.0	650
	10-02-87	0815			1.1	10.30	16.5	650
ARB1 POPPERDAM CREEK	09-30-87	1445	32 54 10 N	080 04 40 W	13	6.05	24.0	246
	09-30-87	1950			6.1	6.85	23.0	249
	10-01-87	0815			2.9	7.46	20.5	212
	10-02-87	0919			1.2	7.70	18.0	230
ARB2 CHURCH CREEK	09-30-87	1615	32 50 11 N	080 02 53 W	<0.0	8.96	25.5	15000
	09-30-87	1910			255	10.42	25.0	11000
	10-01-87	0955			25	13.47	21.5	4500
	10-02-87	1033			81	13.06	19.5	5500
ARC1 BACON BRIDGE	09-30-87	1717	32 57 30 N	080 12 05 W	0.0	14.12	22.0	86
	09-30-87	2145			111	15.31	21.5	86
	10-01-87	1100			54	15.95	20.5	83
	10-02-87	0825			113	14.12	18.0	85
ARC2 DORCHESTER CREEK	09-30-87	1805	32 57 08 N	080 10 14 W	0.0	6.69	23.5	260
	09-30-87	2235			26	9.60	23.0	200
	10-01-87	1150			8.3	10.10	21.5	245
	10-02-87	0920			6.1	11.18	17.0	330
ARC3 EAGLE CREEK	09-30-87	1615	32 57 02 N	080 09 35 W	<0.0	6.10	23.0	168
	09-30-87	2050			32	10.43	22.5	210
	10-01-87	1000			10	11.07	18.5	131
	10-02-87	1005			6.4	11.20	16.5	145

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 5-11-88

MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER		OXYGEN, DIS-SOLVED (MG/L) (00300)	OXYGEN DEMAND, BIO-CHEM-ICAL, 5 DAY (MG/L) (00310)	OXYGEN DEMAND, BIOCHEM ULT. CARBON-ACEOUS (MG/L) (00320)	PH (STAND-ARD UNITS) (00400)	NITRO-GEN, AMMONIA TOTAL (MG/L AS N) (00610)	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)
ARA1	BRICKYARD CREEK	5.2	2.8	9.2	7.50	0.570	2.0	31	24	210
		5.9	3.6	8.3	7.40	0.180	1.0	32	5.0	29
		7.0	1.5	3.8	7.60	0.490	1.1	60	11	65
		6.4	2.7	5.9	7.50	0.510	1.4	60	12	74
ARB1	POPPERDAM CREEK	--	1.8	5.0	7.41	0.080	1.3	35	2.3	11
		--	2.8	7.3	7.62	0.030	0.90	33	2.0	13
		--	E1.5	4.6	7.34	0.020	0.70	32	2.1	8.9
		6.2	E1.2	3.6	7.50	0.060	0.50	36	2.6	12
ARB2	CHURCH CREEK	4.5	1.0	4.0	7.20	0.210	1.7	220	330	3000
		3.9	1.6	4.0	7.10	0.710	2.4	88	210	1700
		4.2	2.6	8.4	7.40	0.460	2.3	58	93	760
		4.6	1.4	4.8	7.40	1.00	3.0	63	110	920
ARC1	BACON BRIDGE	--	1	5.0	6.17	0.090	1.6	11	1.3	5.8
		--	0.9	4.5	6.60	0.070	1.5	10	1.2	5.2
		--	1	5.0	6.41	0.080	1.5	9.8	1.2	5.2
		--	0.9	5.9	6.53	0.090	1.8	10	1.3	5.3
ARC2	DORCHESTER CREEK	--	2.2	6.6	7.41	0.060	1.2	20	1.7	30
		--	2.6	7.6	7.45	0.090	1.0	22	1.5	19
		--	0.9	4.0	8.05	0.060	0.80	26	1.8	23
		--	1.2	4.5	7.75	0.020	0.70	33	2.6	25
ARC3	EAGLE CREEK	--	1.4	5.1	6.77	0.430	2.2	13	2.0	19
		--	2.0	6.8	7.32	0.050	1.1	18	1.3	11
		--	1.6	5.9	7.29	0.080	0.90	15	1.4	11
		--	1.3	4.6	7.02	0.080	1.0	17	1.7	13

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MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	SILICA, DIS-SOLVED (MG/L AS SIO2) (00955)	BARIUM, DIS-SOLVED (UG/L AS BA) (01005)	BERYL-LIUM, DIS-SOLVED (UG/L AS BE) (01010)	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	COBALT, DIS-SOLVED (UG/L AS CO) (01035)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)
ARA1 BRICKYARD CREEK	5.7	14	<0.5	<1	<5	<3	<10	100	<10
	6.0	15	<0.5	<1	<5	<3	<10	180	<10
	13	25	<0.5	<1	<5	<3	<10	87	<10
	12	24	<0.5	<1	<5	<3	<10	94	<10
ARB1 POPPERDAM CREEK	7.2	22	<0.5	<1	<5	<3	<10	160	<10
	6.1	18	<0.5	<1	<5	<3	<10	300	<10
	69	19	<0.5	<1	<5	<3	<10	100	<10
	7.7	19	<0.5	<1	<5	<3	<10	260	<10
ARB2 CHURCH CREEK	5.8	<100	<10	2	30	4	3	160	<5
	7.2	<100	<10	1	20	2	4	160	<5
	7.2	18	<2	<3	<20	<9	<30	120	<30
	7.8	18	<2	<3	<20	<9	<10	96	<30
ARC1 BACON BRIDGE	10	17	<0.5	<1	<5	<3	<10	920	20
	10	17	<0.5	<1	<5	<3	<10	950	<10
	10	18	<0.5	<1	<5	<3	<10	920	<10
	10	18	<0.5	<1	<5	<3	<10	960	<10
ARC2 DORCHESTER CREEK	7.1	15	<0.5	<1	<5	<3	<10	38	<10
	5.2	17	<0.5	<1	<5	<3	<10	70	<10
	7.6	19	<0.5	<1	<5	<3	<10	72	20
	8.0	24	<0.5	<1	<5	<3	<10	51	<10
ARC3 EAGLE CREEK	9.1	12	<0.5	<1	<5	<3	<10	650	10
	5.2	13	<0.5	<1	<5	<3	<10	230	<10
	8.9	13	<0.5	<1	<5	<3	<10	480	<10
	9.6	15	<0.5	<1	<5	<3	<10	500	<10

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MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MOLYB-DENUM, DIS-SOLVED (UG/L AS MO) (01060)	STRON-TIUM, DIS-SOLVED (UG/L AS SR) (01080)	VANA-DIUM, DIS-SOLVED (UG/L AS V) (01085)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)	LITHIUM DIS-SOLVED (UG/L AS LI) (01130)	COLI-FORM, FECAL, 0.7 UM-MF (COLS./100 ML) (31625)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)
ARA1 BRICKYARD CREEK	66	<10	210	<6	5	4	K24000	0.3
	37	<10	140	<6	8	<4	K13000	<0.1
	96	<10	280	<6	5	<4	3600	<0.1
	90	<10	290	<6	64	<4	5200	<0.1
ARB1 POPPERDAM CREEK	45	<10	87	<6	16	<4	2000	<0.1
	25	<10	76	<6	7	<4	3500	<0.1
	20	<10	76	<6	31	<4	1900	<0.1
	24	<10	89	<6	190	<4	K1600	0.3
ARB2 CHURCH CREEK	80	<1	2000	50	20	50	630	0.8
	120	<1	1300	79	30	40	300	0.5
	160	<30	600	<18	17	<12	1900	0.2
	140	<30	700	<6	11	25	1100	0.3
ARC1 BACON BRIDGE	80	<10	32	<6	31	<4	900	<0.1
	78	<10	28	<6	15	<4	1300	<C.1
	74	<10	26	<6	14	<4	270	<0.1
	74	<10	28	<6	55	<4	330	0.1
ARC2 DORCHESTER CREEK	7	<10	49	<6	16	<4	K7400	<0.1
	8	<10	50	<6	6	<4	K14000	<0.1
	5	<10	61	<6	130	<4	1300	<0.1
	7	<10	85	<6	10	<4	670	<0.1
ARC3 EAGLE CREEK	67	<10	37	<6	8	5	5300	<0.1
	12	<10	42	<6	18	<4	K33000	<0.1
	18	<10	38	<6	17	<4	7000	<0.1
	15	<10	43	<6	7	<4	4200	<0.1

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