Prepared in cooperation with the

Arkansas Soil and Water Conservation Commission

WATER-QUALITY, BIOLOGICAL, AND HABITAT ASSESSMENT OF THE BOEUF RIVER BASIN, SOUTHEASTERN ARKANSAS, 1994-96

Water-Resources Investigations Report 02-4187

U.S. Department of the Interior
U.S. Geological Survey

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By C. Shane Barks, James C. Petersen, and Faron D. Usrey

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ABSTRACT

Water-quality and biological samples were collected at several sites in the Boeuf River Basin between November 1994 and December 1996. Water-quality and benthic macroinvertebrate community samples were collected and habitat was measured once at 25 ambient monitoring sites during periods of seasonal low flow. Water-quality storm-runoff samples were collected during 11 storm events at two sites (one draining a cotton field and one draining a forested area). Water-quality samples were collected at one site during the draining of a catfish pond.

Water-quality samples from the 25 ambient sites indicate that streams in the Boeuf River Basin typically are turbid and nutrient enriched in late fall during periods of relatively low flow. Most suspended solids concentrations ranged from about 50 to 200 milligrams per liter (mg/L), most total nitrogen concentrations ranged from about 1.1 to 1.8 mg/L, and most total phosphorus concentrations ranged from about 0.25 to 0.40 mg/L.

Suspended solids, total nitrogen, total ammonia plus organic nitrogen, total phosphorus, and dissolved orthophosphorus concentrations from samples collected during storm events were typically higher at the cotton field site than at the forested site. Estimated annual yields of suspended solids, nitrogen, and phosphorus were substantially higher from the cotton field than from the forested area. Dissolved chloride concentrations typically were higher at the forested site than from the cotton field site. Typically, the suspended solids and nutrient concentrations from the 25 ambient sites were lower than concentrations in runoff from the cotton field but higher than concentrations in runoff from the forest area. Concentrations of sulfate, chloride, suspended solids, and some nutrients in samples from the catfish pond generally were greater than concentrations in samples from other sites. Total phosphorus, orthophosphorus, and fecal coliform bacteria concentrations from the catfish pond generally were lower than concentrations in samples from other sites.

Biological condition scores calculated using macroinvertebrate samples and U.S. Environmental Protection Agency Rapid Bioassessment Protocol II indicated that most of the 25 ambient sites would be in the "moderately impaired" category. However, substantial uncertainty exists in this rating because bioassessment data were compared with data from a reference site outside of the Boeuf River Basin sampled using different methods. Several metrics indicated that communities at most of the ambient sites are composed of more tolerant macroinvertebrates than the community at the reference site.

Habitat assessments (using Rapid Bioassessment Protocol II) indicated the reference site outside the Boeuf River Basin had better habitat than the ambient sites. Physical habitat scores for the 25 ambient sites indicated that most ambient sites had poor bottom substrate cover, embeddedness values, and flow and had poor to fair habitat related to most other factors. Most habitat factors at the reference site were considered good to excellent.

Part of the variation in biological condition scores was explained by physical habitat scores and concentrations of suspended solids and dissolved oxygen. However, a considerable amount of variability in biological condition scores is not explained by these factors.

INTRODUCTION

The Boeuf River Basin has undergone major land changes during the last century. Deforestation of bottomland hardwoods, increased agricultural land-use, and channelization of natural stream geomorphology for flood control and irrigation are the main changes that have occurred within the basin. Data collected by the Arkansas Department of Environmental Quality (formerly Arkansas Department of Pollution Control and Ecology) in the Boeuf River Basin indicate that aquatic life is impacted by runoff of silt and nutrients from agricultural activities (Arkansas Department of Pollution Control and Ecology, 1996; 1998). Discharge from aquaculture reservoirs within the Boeuf River Basin also may impact the water quality of the receiving streams.

In 1994, the U.S. Geological Survey (USGS), in cooperation with the Arkansas Soil and Water Conservation Commission, began a study to assess the water quality in selected drainages within the Boeuf River Basin. The objectives of this study were to sample concentrations of dissolved chloride, suspended solids and nutrients from three different land-use drainages (cotton field, catfish pond, and forested); estimate individual storm loads, annual loads, and yields with each of the three drainages; and collect and compile baseline data on benthic macroinvertebrate communities and water quality for 25 sites in the basin.

Purpose and Scope

The purpose of this report is to describe the results of a water-quality and biological investigation of selected drainages in the Boeuf River Basin of southeastern Arkansas. Water quality is assessed using water-quality data collected during three types of sampling efforts—a synoptic sampling of 25 sites during relatively low flow conditions during November through December 1994, stormwater runoff sampling of a forested area and a cotton field during January 1995 through December 1996, and sampling of a catfish pond discharge in April and May of 1995. Biological benthic macroinvertebrate and habitat information for the 25 synoptic sites also was used in the assessment. Thus, four aspects of water quality in the Boeuf River Basin were sampled—late-fall to winter low flow, stormwater runoff from areas of negligible and more intensive agricultural land practices, periodic discharges from catfish ponds, and biological communities integrating the effects of water quality and habitat conditions.

Samples were collected between November 1994 and December 1996. Water-quality data were collected one time per site during November and December 1994 at 25 sites distributed throughout much of the basin. Discharge and water-quality data were collected downstream from a cotton field and downstream from a forested area during 11 storms during January 1995 through December 1996. Data also were collected during the draining of a catfish pond in April and May 1995. Benthic macroinvertebrate and physical habitat data were collected at the 25 sites sampled in November and December 1994 as part of a bioassessment (Plafkin and others, 1989).

Description of Study Area

The Boeuf River Basin (fig. 1) is located in the Mississippi Alluvial Plain physiographic province in southeastern Arkansas. The drainage area of the Boeuf River at the Arkansas-Louisiana State line is 755 square miles (Yanchosek and Hines, 1979). The basin drains from north to south through a network of channels, canals and ditches.

The land use in this area is predominately agriculture and aquaculture. In Desha and Chicot Counties (which include most of the basin), the primary crops grown in 1995 were soybeans (26 percent of the land in the two counties), cotton (16 percent), and rice (10 percent) (Arkansas Agricultural Statistics Service, 2001a). Catfish and minnows are produced by commercial aquaculture operations in the area. Area of catfish ponds in Desha and Chicot Counties in 1999 was 11,600 acres; this is about 35 percent of the total catfish pond acreage in Arkansas (Arkansas Agricultural Statistics Service, 2001b).

Acknowledgments

The authors express appreciation to Mr. Jimmy Appleberry and the Dermott Hunting Club for allowing the installation and operation of water data collection equipment on their properties, and to Mr. David Yocum for allowing access to his property to perform data collection.

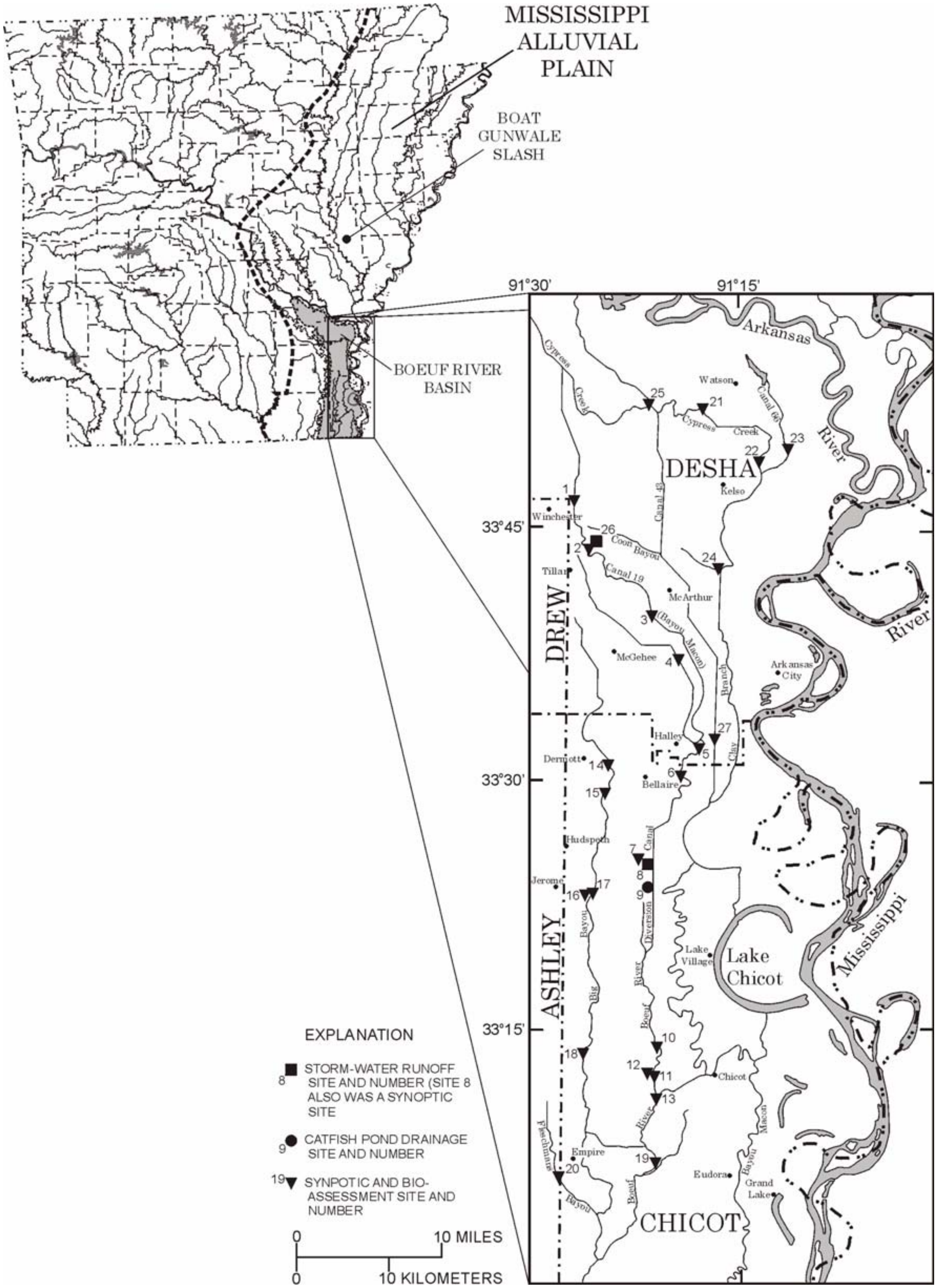

Figure 1. Location of study area.

DATA COLLECTION METHODS

Water-quality and streamflow data were collected at 25 synoptic sites, 2 stormwater runoff sites, and 1 catfish pond drainage site (fig. 1, table 1). Biological (macroinvertebrate) and physical habitat data also were collected at the 25 ambient sites. The 25 ambient sites were selected primarily based on biological sampling criteria to be described later.

Water-Quality and Discharge Data

Water-quality samples at the 25 ambient sites were collected in conjunction with the macroinvertebrate bioassessment. Sample collection, processing, and preservation methods followed guidelines outlined by Shelton (1994). Prior to water sampling, the stream was divided into equal-width-increments (EWI). This EWI procedure resulted in 10 sampling points across the cross section. Water was collected at each sampling point with a Teflon/polypropylene depth integrating sampler. Samples were collected in November and December 1994 during a period of relatively low flow.

Water-quality analyses included specific conductance, pH, temperature, dissolved oxygen, turbidity, suspended solids, sulfate, chloride, fluoride, and nutrients. Specific conductance, pH, temperature, and dissolved oxygen were determined on-site using field meters. Analyses of the remaining constituents were conducted at the USGS Water Quality Laboratory in Ocala, Florida.

Table 1. Water-quality and rapid bioassessment sampling sites

[RBA, rapid bioassessment]

USGS station identification number	Site number	Station name	Site type
073676583	1	Canal 19 (Bayou Macon) near Winchester, Ark.	Ambient-RBA
073676585	2	Canal 19 (Bayou Macon) near Tillar, Ark.	Ambient-RBA
073676587	3	Canal 19 (Bayou Macon) near McArthur, Ark.	Ambient-RBA
073676593	4	Canal 18 (Bayou Macon Diversion) near McGehee, Ark.	Ambient-RBA
073676595	5	Canal 19 (Bayou Macon) near Halley, Ark.	Ambient-RBA
073676597	6	Canal 19 (Bayou Macon) near Bellaire, Ark.	Ambient-RBA
073676604	7	Diversion Canal Boeuf River beside Highway 293 near Hudspeth, Ark.	Ambient-RBA
073676607	8	Diversion Canal Boeuf River near Hudspeth, Ark.	Forest storm runoff-ambient-RBA
0736766077	9	Fish Pond Drainage near Jerome, Ark.	Catfish pond drainage
073676612	10	Boeuf River northwest of Chicot, Ark.	Ambient-RBA
073676614	11	Boeuf River near Chicot, Ark.	Ambient-RBA
073676616	12	Bill Young Bayou near Chicot, Ark.	Ambient-RBA
073676618	13	Boeuf River northwest of Eudora, Ark.	Ambient-RBA
073676625	14	Big Bayou Slough near Dermott, Ark.	Ambient-RBA
07367663	15	Big Bayou near Dermott, Ark.	Ambient-RBA
07367665	16	Drainage Ditch to Big Bayou near Jerome, Ark.	Ambient-RBA
07367666	17	Big Bayou near Jerome, Ark.	Ambient-RBA
07367669	18	Big Bayou near Portland, Ark.	Ambient-RBA
07367681	19	Boeuf River Tributary near Eudora, Ark.	Ambient-RBA
07367692	20	Fleschmans Bayou near Empire, Ark.	Ambient-RBA
07369630	21	Canal 81 near Watson, Ark.	Ambient-RBA
07369635	22	Cypress Creek near Kelso, Ark.	Ambient-RBA
07369640	23	Canal 66 near Kelso, Ark.	Ambient-RBA
07369645	24	Coon Bayou near McArthur, Ark.	Ambient-RBA
07369653	25	Canal 43 near Watson, Ark.	Ambient-RBA
07369654	26	Coon Bayou Tributary near Tillar, Ark.	Cotton field storm runoff
07369657	27	Canal 43 near Halley, Ark.	Ambient-RBA

Two sites were selected to monitor storm runoff water quality. One site (site 26) was downstream from a homogenous agricultural land use (cotton) and the other site (site 8) was downstream from a forested area. The agricultural site selected was located in west-central Desha County. The monitoring station for the agricultural site was established on a ditch that drains approximately 76 acres of a cotton field and is a tributary to Coon Bayou. The forested site was located in north-central Chicot County. The monitoring station for the forested site was established on a ditch that drains approximately 1,230 acres and drains into the Boeuf River Diversion Canal. It is possible that the size of the basin that drains to the location of the monitoring station could change with extreme magnitudes of storm runoff events. The ditch intersects other ditches at three places within the basin and during events with extreme runoff water may be diverted into or out of the ditch.

Streamflow-gaging stations (Buchanan and Somers, 1974) were installed at both storm runoff sites (figs. 2 and 3). A sharp-crested rectangular weir was installed at the cotton-field site and a 24-in. diameter culvert was installed at a dirt road crossing downstream of the forested site. Stage-discharge ratings (Kennedy, 1984) were developed using indirect measurement computations for weirs (Hulsing, 1984) and indirect measurement computations for culverts (Bodhaine, 1982). The ratings were verified using current-meter streamflow measurements (Buchanan and Somers, 1984). Stage data were collected at 0.01-foot increments at both sites using float and stilling-well combinations (Buchanan and Somers, 1974). Staff gages were installed and read during storm events to verify stage data. Continuous stream-stage data were measured and recorded on an electronic data logger in 15-minute increments. Using the stage data and the stage-discharge ratings, continuous discharge values were computed (Kennedy, 1989) and recorded in 15-minute increments. Continuous rainfall data were collected at both sites using tipping-bucket rain gages. Rainfall data were collected at 0.01-inch increments and recorded at 15-minute increments.

Figure 2. Cotton field storm monitoring station at Coon Bayou Tributary near Tillar, Arkansas.

Figure 3. Forested storm monitoring station at Boeuf River Diversion Canal near Hudspeth, Arkansas.

Automatic samplers using peristaltic pumps powered by 12-volt batteries were installed at each site and used to collect storm-water samples. The sample water was pumped into four 1-gallon glass bottles contained within the automatic sampler. A data logger was used to control the automatic sampler. The data logger was programmed to read the stage, compute a discharge, and compute the volume of water that passed the monitoring station during 15-minute increments. Each time a designated volume of water passed the monitoring station the data logger would send a voltage pulse to the sampler causing it to activate and take a sample. With this setup, the sampler would take a flow-weighted composite sample throughout the storm hydrograph. The hydrograph and hyetograph in figure 4 show a typical sampled storm with rainfall intensity, instantaneous discharge, and sample activations plotted against time.

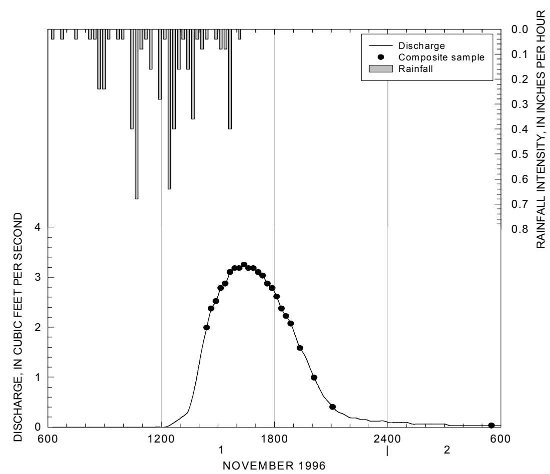

Figure 4. Hydrograph and hyetograph showing discharge and rainfall record of storm at the cotton field site 07369654 Coon Bayou Tributary near Tillar, Arkansas, November 1-2, 1996.

At the cotton field site, the entire storm-runoff hydrographs were sampled with the automatic sampler for every storm event. Because of the length of the storm runoff events at the forested site, the entire hydrograph was sampled only once. During the other sampled events, samples were taken at least until the peak of the hydrograph had passed.

Water-quality analyses were performed on the flow-weighted composite samples from both storm runoff sites between January 1995 and December 1996 for specific conductance, pH, turbidity, suspended solids, sulfate, chloride, fluoride, nutrients, and fecal coliform and fecal streptococcus bacteria. Bacteria concentrations were determined at the USGS laboratory in Little Rock, Arkansas. Specific conductance and pH were determined on-site for the composite sample. Other constituents were analyzed at the USGS Water Quality Laboratory in Ocala, Florida.

The catfish pond site was in central Chicot County. The pond is used to raise fingerling catfish. It is a levee type pond that drains into the Main Ditch Canal of the Boeuf River when the drainpipe valve is open. Samples were collected from the pond effluent as the pond was being drained between April 17 and May 7, 1995. The volume of water in the pond before draining was approximately 10.8 acre-feet. Effluent samples were collected using a polyethylene churn splitter at the drainpipe. Two samples were collected on April 17 after the drainpipe valve was opened and one sample was collected on April 18. The catfish-pond manager closed the valve on April 19 through April 25 to allow for time to seine the fish out of the pond. After the valve was reopened, samples were collected daily from April 26 through April 28. The valve was closed again from April 29 through May 3. After the valve was reopened, daily samples were collected from May 4 through May 7 when the pond completed draining. Ten samples were collected as the pond drained.

The pond water-surface level was flagged on the side of the levee before the drain valve was initially opened and each time a sample was collected. A total station surveying instrument was used to collect data to calculate the pond areas and volumes that corresponded with the water-surface level initially and at the time each sample was collected.

Biological and Habitat Data

During an initial reconnaissance conducted in early November 1994, 40 sites within the study area were evaluated based on absence or presence of stream discharge and recent anthropogenic disturbances. Twenty-five sites were selected for bioassessment using the U.S. Environmental Protection Agency (USEPA) Rapid Bioassessment Protocol II (Plafkin and others, 1989). The selected sites had discharges of at least 0.5 cubic feet per second (ft^3/s) and no evidence of recent bank, substrate, or channelization disturbances. Homogeneous dispersal of sites throughout the study area was limited by a lack of sites meeting these criteria in some areas.

During November and December 1994, macroinvertebrate communities were qualitatively sampled using a D-frame kick net with a mesh size of 425 microns. A reach length of 25 to 50 meters (82 to 164 feet) typically was sampled for 60 minutes. Reaches were sampled for less than 60 minutes (sample collection time) when the stream reach had a very homogeneous habitat and all available habitat within the reach could be adequately sampled in less than 60 minutes. In these situations, sample collection time was reduced to a minimum of 30 minutes. Samples were collected by kick netting, dipping, and hand picking from bottom substrates, vegetation, and rip rap.

Samples were sorted and organisms were enumerated at the site. The original sample was dispensed into a 5-gallon container and mixed until contents were judged homogeneous. Then a small aliquot was transferred into a white picking pan measuring approximately 15 × 20 inches. Organisms in the subsample pan were removed, labeled, and preserved in a container of 10 percent formalin. If the first aliquot contained at least 100 invertebrates the subsample was complete. However, if a minimum of 100 invertebrates was not found in the first aliquot, the sample again was mixed and a second aliquot was processed. Subsample aliquots were processed until at least 100 organisms were removed or the sample was completely processed. At two sites (sites 12 and 16), the sample in the 5-gallon container was thoroughly mixed and then split into two subsamples. Comparison of the results of these duplicate samples provided some measure of the variability of the processing steps following sample collection.

Stream habitat was assessed using methods described in Plafkin and others (1989). Habitat parameters (bottom substrate or available cover, substrate embeddedness, flow, channel alteration, bottom scouring and deposition, run-to-bend ratio, bank stability, bank vegetative stability, and streamside cover) were given a rating score according to qualitative parameter descriptions. All parameter scores were then summed to calculate a total score.

DATA ANALYSIS METHODS

At the cotton field site, forest site, and catfish pond, water-quality and discharge data were used to compute constituent loads associated with storms (cotton field and forest sites) or the draining of the pond. Boxplots and the Wilcoxon rank sum test (Helsel and Hirsch, 1992) were used to summarize and compare the water-quality data. USEPA Rapid Bioassessment Protocol II data-analysis methods (Plafkin and others, 1989) were used for an assessment of biological conditions at the 25 ambient sites.

Water Quality

Data from the flow-weighted composite water-quality samples provided the mean concentrations of constituents for the sampled event. At the cotton field site, the entire storms were sampled; therefore, the sample event-mean concentrations were the same as the storm event-mean concentrations.

Loads for the cotton field site were computed using the flow-weighted composite samples for dissolved chloride, suspended solids, total nitrogen, total ammonia plus organic nitrogen, total phosphorus, and dissolved orthophosphorus. The loads were computed using the sampled event-mean concentrations (EMCs) and the runoff volumes (RVs). The RVs were computed for each event by multiplying the event-mean discharges by the length of time each event occurred. A load for a given sampling event (i) is computed by the equation

$$LOAD_i = EMC_i \times RV_i \times (6.245 \times 10^{-5}) \qquad (1)$$

where

$LOAD_i$ is constituent load (in pounds) for event i;

EMC_i is event-mean concentration of constituent (in milligrams per liter) for event i;

RV_i is runoff volume (in cubic feet) for event i, and;

6.245×10^{-5} is the conversion from milligrams per liter to pounds per cubic foot.

Because the EMCs sampled at the cotton field site represent the entire storms sampled, the computed loads at this site are considered storm loads.

Constituent loads computed for the forested site are for the sampled event and not the complete storm event except for the one complete storm event that was sampled at the forested site. The sampled event was subdivided and used to develop relations between percent storm load for a constituent and percent runoff volume, which then were used for estimating storm loads. The relations developed were second-order polynomial regression equations in the form of:

$$PERCLOAD_i = b_0 + b_1 \times PERCRV_i + b_2 \times PERCRV^2_i \qquad (2)$$

where

$PERCLOAD_i$ is percent of storm load computed for storm i;

b_0, b_1, b_2 are regression coefficients; and

$PERCRV_i$ is percent of storm runoff-volume sampled for storm i.

Storm loads for the forested site for each constituent were computed by dividing the sampled event loads by the estimated PERCLOAD for each storm.

The standard error of estimates (SE) and the coefficient of determination (R^2) were computed for each equation. The SE is a measure of the error about the regression. A smaller SE indicates a more precise prediction. The R^2 is the proportion of the variation in the response variable explained by the explanatory variables. A greater R^2 indicates a better fit.

The EMCs for the forested site were computed using the estimated storm-load and the storm-runoff volumes. A storm EMC for a given storm (i) is computed by the equation

$$EMC_i = \frac{LOAD_i}{RV_i} \times (1.601 \times 10^4) \qquad (3)$$

where

EMC_i is event-mean concentration of constituent (in milligrams per liter) for storm i;

$LOAD_i$ is pollutant load (in pounds) for storm i;

RV_i is runoff volume (in cubic feet) for storm i, and;

1.601×10^4 is the conversion from pounds per cubic foot to milligrams per liter.

Mean EMCs of all the storm samples combined, were computed for dissolved chloride, suspended solids, total nitrogen, total ammonia plus organic nitrogen, total phosphorus, and dissolved orthophosphorus at both sites. Three methods were used to compute the mean EMCs: volume-weighted, logarithmic-transformed, and arithmetic. The volume-weighted mean EMC was computed using the equation

$$VWMEMC = \frac{\Sigma(EMC_i \times RV_i)}{\Sigma RV_i} \quad (4)$$

where

VWMEMC is volume-weighted mean EMC of a constituent (in milligrams per liter) for a site.

The logarithmic-transformed mean EMCs were computed by transforming the EMCs to base-10 logarithms, summing the values, dividing by the number of storms, and retransforming the value. The arithmetic mean was computed by summing EMCs and dividing by the number of storms.

Regression equations were developed to estimate storm loads for unsampled storms for suspended solids, total nitrogen, total ammonia plus organic nitrogen, total phosphorus, and dissolved orthophosphorus at both sites. Size of the data set limited the number of explanatory variables that could be used in the regression analysis. Explanatory variables used were RV and a seasonal factor for the cotton field site, and RV for the forested site. The seasonal factor was used to explain the agricultural condition of the cotton field. Regression equations were not developed for estimating storm loads for dissolved chloride because there is not a good correlation between the dissolved chloride storm loads and the RVs.

For the cotton field and forested sites the regression equations, using a logarithmic transformation (log base-10) of the response and explanatory variables are in the following form:

$$\log(LOAD) = b_0 + b_1\log(RV) + b_2\log\ (SEASON) \quad (5)$$

where

SEASON is 0 for storms occurring March 1 through July 15, and 1 for storms occurring July 16 through February 28.

When equation 5 is retransformed it becomes

$$LOAD = b_0{}' \times (RV)^{b_1} \times (SEASON)^{b_2} \quad (6)$$

where

$b_0{}'$ is 10^b.

The retransformation of a log-transformed regression model provides a consistent estimator of median response but systematically underestimates the mean response (Miller, 1984). Therefore, a bias-correction factor (BCF) needs to be included in the retransformed regression equation if an unbiased estimate of the mean is to be obtained. A BCF was computed for each equation by using a smearing estimate that is a nonparametric method based on the average residuals in original units (Duan, 1983). After applying the BCF to equation 6, the form of the equation becomes

$$LOAD = b_0{}' \times (RV)^{b_1} \times (SEASON)^{b_2} \times BCF \quad (7)$$

To estimate annual loads at both sites for the 1996 calendar year, the appropriate storm load equations were applied to all of the unsampled runoff-producing storms during the year. Base-flow samples collected at the forested site were used to estimate the base-flow loads that occurred during the year at that site. Annual loads were estimated by summing the sampled loads, the estimated unsampled loads, and at the forested site the base flow loads that occurred during the year.

The constituent loads released during the draining of the catfish pond were determined by multiplying the concentrations by the change in volume of water that occurred between samples. The total loads from the drainage were determined by summing the individual sampled loads.

Selected water-quality data were graphically summarized and compared using boxplots. The Wilcoxon rank sum test (a non-parametric test comparing ranked data) was used to compare selected water-quality data from storms at the cotton field and forest sites.

Bioassessment

The USEPA Rapid Bioassessment Protocol II data-analysis methods (Plafkin and others, 1989) require comparisons to a reference site. No suitable bioassessment reference sites representative of relatively undisturbed conditions were found in the Boeuf River Basin. All sites evaluated were affected by land clearing, channelization, and bank disturbances. Boat Gunwale Slash, a least-disturbed reference stream for the Mississippi Alluvial Plain (Delta) ecoregion (Bennett and others, 1987), was used in this assessment as the reference stream for rapid bioassessment comparisons.

Benthic macroinvertebrate data for Boat Gunwale Slash were obtained directly from Bennett and others (1987). The habitat parameter and total scores for the reference site were calculated based upon interpretation of the physical description presented in Bennett and others (1987).

Organisms from the Boeuf River Basin samples were identified to the family level using dichotomous keys (Merritt and Cummins, 1984; Pennak, 1989), enumerated, categorized by tolerance value and functional feeding group (Plafkin and others, 1989; Merritt and Cummins, 1984; and Lenat, 1993), and entered (along with data from the reference site) into a rapid bioassessment protocol metric calculation spreadsheet template provided by the USEPA (Howell, 1989). The spreadsheet subsequently was modified by the USGS to add some families that were present in the study area samples but not included in the provided spreadsheet. Taxa richness, family biotic index, ratio of scraper to filtering collector abundance, ratio of EPT (Ephemeroptera, Plecoptera, and Trichoptera) to Chironomidae abundances, percent contribution of dominant family, EPT index, ratio of shredder to total abundance, and the community loss index are the seven metrics used in the benthic invertebrate Rapid Bioassessment Protocol II (Plafkin and others, 1989). The spreadsheet provided by the USEPA calculated these seven metrics except that, for this study:

(1) ratio of scraper to filterer plus scraper abundance replaced scraper to filtering collector abundance, and

(2) ratio of EPT (Ephemeroptera, Plecoptera, and Trichoptera) to Chironomidae plus EPT abundance replaced ratio of EPT (Ephemeroptera, Plecoptera, and Trichoptera) to Chironomidae abundance.

A metric value "normalized" to the reference site metric value then was calculated for most metrics at each of the Boeuf River Basin sites. The normalized metrics were calculated as a ratio of the metric value at the reference site and the metric value at the Boeuf River Basin site; except the biological condition score for the percent contribution of dominant family was expressed as the actual percent contribution and the community loss index was not compared to the reference station, because a comparison to the reference station is incorporated into the index. Each metric value obtained was given a metric score of 0, 3, or 6, based on criteria given in Plafkin and others (1989). For each site, a biological condition score was calculated by summing the metric scores. Biological condition scores were compared to the biological condition score for the reference site. A biological condition category then was assigned to each bioassessment site based on the comparison of biological condition scores at the bioassessment site to the reference site score and criteria in Plafkin and others (1989).

Relations between benthic macroinvertebrate communities, physical habitat, and water quality were examined using the Spearman’s correlation test (Helsel and Hirsch, 1992). Biological community scores were tested for correlation with physical habitat scores and with water-quality values. The strongest correlations also were examined using x-y plots.

Metrics and scores for duplicate samples from sites 12 and 16 were compared using relative percent difference. Relative percent difference was calculated using the formula

$$RPD = \frac{|a-b|}{(a+b) \div 2} \times 100 \qquad (8)$$

where RPD is relative percent difference (percent), and a and b are the values associated with the duplicate samples from a site.

WATER-QUALITY, BIOLOGICAL, AND HABITAT ASSESSMENT

Concentrations, loads, and other water-quality associated results for the ambient, cotton field, forest, and catfish pond sites are described in this section. Benthic macroinvertebrate and habitat results also are discussed.

Water Quality

Water-quality samples from the 25 ambient sites (which were at locations where recent bank, substrate, or channelization disturbances were not evident) indicate that streams in the Boeuf River Basin typically are turbid and nutrient enriched during the late fall during periods of relatively low flow (fig. 5, table 2). Most suspended solids concentrations (residue at 105 degrees Celsius) ranged from about 50 to 200 mg/L. Most total nitrogen concentrations ranged from about 1.1 to 1.8 mg/L. Much of the nitrogen was ammonia plus organic nitrogen, which typically ranged from about 0.8 to 1.5

mg/L. Total phosphorus and dissolved orthophosphorus typically ranged from about 0.25 to 0.40 mg/L and 0.10 to 0.25 mg/L, respectively.

Data from previous investigations suggest that concentrations of suspended solids and some nutrients in the Boeuf River Basin are higher than in much of the Mississippi Alluvial Plain in Arkansas. Median concentrations of total suspended solids, total phosphorus, and dissolved phosphorus from samples collected during all seasons at several sites in the Mississippi Alluvial Plain (Petersen, 1988; Petersen, 1992) usually were lower than 50 mg/L, 0.25 mg/L, and 0.10 mg/L, respectively. Median concentrations of total ammonia plus organic nitrogen and total nitrogen for the sites in the Boeuf River Basin were similar to medians reported by Petersen (1988, 1992). Total suspended solids and nutrient concentrations for the sites in the Boeuf River Basin generally were similar to concentrations for sites sampled in previous USGS investigations (Bryant and others, 1978; Lamb, 1979; Petersen, 1981). However, in two basins, suspended solids (Flat Bayou) or total phosphorus (L'Anguille) concentrations were substantially lower than concentrations from the Boeuf River Basin. Data collected as part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program (Coupe, 2002) in the Mississippi Embayment study unit (an area primarily containing the Mississippi Alluvial Plain of Arkansas, Louisiana, Mississippi, and nearby states) indicate that the November-December sample concentrations of total nitrogen, total phosphorus, and dissolved orthophosphorus from the Boeuf River Basin are slightly higher than November-December sample concentrations from several other streams in the Mississippi Alluvial Plain.

Values listed as water-quality standards or guidelines by the Arkansas Pollution Control and Ecology Commission (1998) occasionally were exceeded (or, in the case of dissolved oxygen were less than the standard) in samples from the ambient sites (table 2). However, conditions listed in the standards sometimes provided exceptions or specific sampling criteria that must be met to legally apply the standard. For example, the numeric turbidity standard only applies to turbidities resulting from "waste discharges or instream activity", the total phosphorus guideline does not apply in waters "highly laden with natural silts...which reduce the penetration of sunlight needed for plant photosynthesis...", and the chloride and sulfate standards are based on multiple samples collected over 30 to 360 days. Therefore, the following comparisons to the standards and guidelines are for general comparison and do not necessarily imply violation. The standard for turbidity in channel-altered Delta (Mississippi Alluvial Plain) streams (75 nephelometric turbidity units) was exceeded at about half of the sites. The total phosphorus guideline (0.1 mg/L) was exceeded at all but one site. Chloride (160 mg/L) and sulfate (30 mg/L) standards for the Boeuf River Basin were exceeded at one and two sites, respectively. The primary season dissolved oxygen standard (5 mg/L) was not met at two sites.

Typically the suspended solids and nutrient concentrations from the ambient sites (sampled during a period of relatively low streamflow) were lower than concentrations in runoff from the cotton field but higher than concentrations in runoff from the forest area. These differences indicate that suspended solids and nutrient concentrations in the Boeuf River Basin are affected by streamflow and land use.

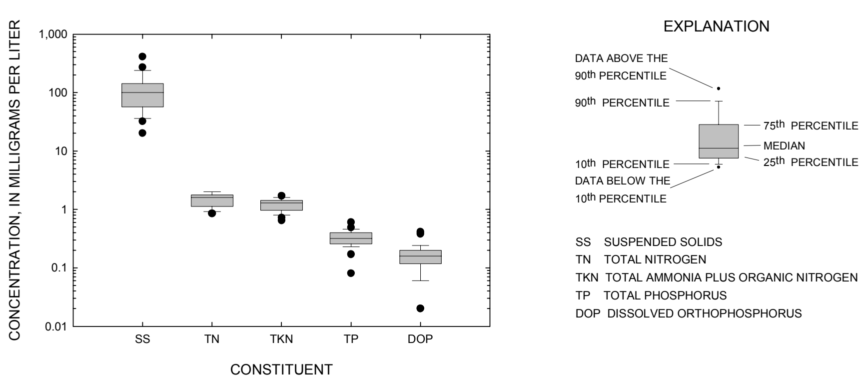

Figure 5. Ranges and distributions of suspended solids and nutrient concentrations at 25 ambient sites sampled during a period of relatively low streamflow in November and December 1994.

Table 2. Water quality of samples from the 25 ambient sites

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; NTU, nephelometric turbidity units; five-digit numbers in parentheses are water-quality parameter codes; --, no data; <, less than]

Site number	Date	Specific conductance (μS/cm) (00095)	pH water whole field (standard units) (00400)	Temperature water (deg C) (00010)	Oxygen, dissolved (mg/L) (00300)	Oxygen, dissolved (percent saturation) (00301)	Turbidity (NTU) (00076)	Residue total at 105 deg.C, suspended (mg/L) (00530)	Sulfate dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, dissolved (mg/L as F) (00950)
1	11/29/1994	201	7.4	10.8	9.6	86	150	90	8.3	17	0.3
2	11/23/1994	340	8.1	11.3	10.9	98	35	36	15	43	0.5
3	11/07/1994	345	8.2	18.6	10.5	111	140	150	10	26	0.2
4	11/21/1994	269	7.5	16.6	7.4	76	73	88	10	23	0.2
5	11/21/1994	303	8.1	16.1	9.3	94	82	120	12	32	0.4
6	11/22/1994	340	7.0	17.5	10.7	111	78	120	15	32	0.4
7	11/09/1994	150	6.6	20.3	5.3	59	96	100	7.4	19	0.1
8	11/08/1994	161	6.5	18.3	3.9	42	7.7	20	3.6	16	<.1
10	11/30/1994	153	7.1	13.1	10.1	95	--	240	8.5	13	0.1
11	11/30/1994	156	7.1	13.4	10.3	97	--	210	8.6	14	0.2
12	12/07/1994	717	7.4	14.6	9.2	90	110	120	24	160	0.2
13	12/02/1994	182	7.1	11.8	10.1	93	--	190	9.8	19	0.1
14	11/22/1994	270	6.9	12.2	8.8	81	41	52	5.9	36	0.1
15	11/22/1994	320	6.9	12.7	7.9	74	42	84	7.7	38	0.3
16	11/09/1994	312	6.9	17.5	2.9	31	100	120	7.0	43	0.2
17	11/09/1994	224	6.9	17.7	6.7	70	--	32	--	--	--
18	12/07/1994	281	7.1	13.6	8.8	85	140	140	11	44	0.2
19	12/06/1994	125	6.5	12.5	4.5	42	87	52	6.2	12	<.1
20	12/06/1994	221	7.3	13.6	10.0	96	54	36	3.9	19	0.2
21	11/29/1994	497	7.6	11.8	8.6	79	140	100	24	51	0.2
22	12/01/1994	366	7.5	8.3	8.4	71	190	90	27	39	0.2
23	12/01/1994	389	7.4	8.7	7.6	65	160	270	47	37	0.1
24	11/07/1994	640	7.8	19.3	8.9	96	42	58	31	100	0.2
25	11/29/1994	514	7.6	11.2	9.2	83	120	100	24	66	0.2
27	12/01/1994	225	7.0	12.4	8.8	82	--	410	17	27	0.1

Table 2. Water quality of samples from the 25 ambient sites—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; NTU, nephelometric turbidity units; five-digit numbers in parentheses are water-quality parameter codes; --, no data; <, less than]

Site number	Date	Nitrogen nitrate dissolved (mg/L as N) (00618)	Nitrogen nitrite dissolved (mg/L as N) (00613)	Nitrogen NO_2+NO_3 dissolved (mg/L as N) (00631)	Nitrogen ammonia dissolved (mg/L as N) (00608)	Nitrogen organic total (mg/L as N) (00605)	Nitrogen ammonia+organic total (mg/L as N) (00625)	Nitrogen, total (mg/L as N) (00600)	Phosphorus total (mg/L as P) (00665)	Phosphorus dissolved (mg/L as P) (00666)	Phosphorus ortho, dissolved (mg/L as P) (00671)
1	11/29/1994	0.37	0.01	0.38	0.08	1.2	1.3	1.7	0.60	0.43	0.41
2	11/23/1994	0.22	0.01	0.23	0.04	0.89	0.93	1.2	0.34	0.28	0.24
3	11/07/1994	0.38	0.03	0.41	0.16	1.2	1.4	1.8	0.38	0.19	0.19
4	11/21/1994	0.14	0.01	0.15	0.07	0.90	0.97	1.1	0.30	0.19	0.18
5	11/21/1994	0.19	0.02	0.21	0.02	0.62	0.64	0.85	0.26	0.13	0.11
6	11/22/1994	0.27	0.02	0.29	0.04	1.1	1.1	1.4	0.28	0.07	0.06
7	11/09/1994	0.04	0.01	0.05	0.04	0.76	0.80	0.85	0.32	0.17	0.16
8	11/08/1994	--	0.01	<.02	0.01	1.3	1.3	--	0.17	0.14	0.12
10	11/30/1994	0.27	0.01	0.28	0.09	1.3	1.4	1.7	0.40	0.19	0.17
11	11/30/1994	0.27	0.01	0.28	0.08	1.4	1.5	1.8	0.40	0.22	0.20
12	12/07/1994	0.07	0.01	0.08	0.02	1.6	1.6	1.7	0.24	0.04	0.02
13	12/02/1994	0.23	0.06	0.29	0.15	1.2	1.4	1.7	0.33	0.15	0.16
14	11/22/1994	0.09	0.01	0.10	0.07	0.92	0.99	1.1	0.23	0.14	0.13
15	11/22/1994	0.25	0.04	0.29	0.19	1.5	1.7	2.0	0.39	0.25	0.24
16	11/09/1994	0.24	0.04	0.28	0.17	1.5	1.7	2.0	0.30	0.10	0.08
17	11/09/1994	0.37	0.04	0.41	0.16	1.3	1.5	1.9	0.43	0.20	0.20
18	12/07/1994	0.26	0.01	0.27	0.06	1.1	1.2	1.5	0.32	0.13	0.09
19	12/06/1994	0.11	0.01	0.12	0.08	1.2	1.3	1.4	0.40	0.26	0.15
20	12/06/1994	0.11	0.01	0.12	0.02	0.80	0.82	0.94	0.25	0.18	0.14
21	11/29/1994	0.46	0.02	0.48	0.03	1.1	1.1	1.6	0.26	0.16	0.17
22	12/01/1994	0.41	0.01	0.42	0.07	1.1	1.2	1.6	0.46	0.24	0.23
23	12/01/1994	0.20	0.01	0.21	0.10	1.2	1.3	1.5	0.49	0.38	0.38
24	11/07/1994	--	<.01	<.02	0.01	0.71	0.72	--	0.08	0.02	0.02
25	11/29/1994	--	<.01	0.16	0.03	0.93	0.96	1.1	0.23	0.12	0.13
27	12/01/1994	0.36	0.01	0.37	0.10	1.5	1.6	2.0	0.37	0.14	0.14

Eleven storm events were sampled at the cotton field and forested sites. The rainfall amounts for the storms sampled ranged from 0.54 to 1.74 inches. at the cotton field site and from 1.14 to 4.31 inches at the forested site (table 3). The runoff volumes varied with each event depending upon the rainfall amount, intensity and antecedent conditions, time of the year, and agricultural condition of the field. Water-quality data associated with these storm events are listed in tables 4 and 5.

Table 3. Storm events sampled

Site	Storm number	Date	Rainfall (inches)	Runoff volume (thousand cubic feet)
Cotton field	1	March 4-5, 1995	0.54	100
	2	March 14-15, 1995	1.74	172
	3	July 5, 1995	1.53	72.2
	4	April 21, 1996	1.22	7.58
	5	April 22-23, 1996	1.30	88.9
	6	April 29, 1996	1.07	12.3
	7	July 20-21, 1996	0.57	22.2
	8	July 24-25, 1996	1.40	57.2
	9	November 1-2, 1996	1.26	62.6
	10	November 7-8, 1996	1.10	89.7
	11	December 16-18, 1996	1.41	100
Forested	1	January 5-11, 1995	1.19	1,678
	2	March 3-6, 1995	1.16	1,421
	3	March 7-11, 1995	2.10	4,071
	4	July 5-8, 1995	4.31	571
	5	March 24-29, 1996	1.14	853
	6	April 22-24, 1996	0.76	305
	7	July 28-30, 1996	1.79	237
	8	October 25-28, 1996	2.77	447
	9	November 1-5, 1996	2.36	856
	10	November 7-12, 1996	1.45	846
	11	December 16-20, 1996	3.10	1,982

Table 4. Water quality of composited storm runoff samples from the cotton field site

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; mg/L, milligrams per liter; cols./100 mL, colonies per 100 milliliters; --, no data; Five digit numbers in parentheses are water-quality parameter codes; K, results based on colony count outside the acceptance range (non-ideal colony count)]

Date	Specific conductance (μS/cm) (00095)	pH water whole field (standard units) (00400)	Turbidity (NTU) (00076)	Residue total at 105 deg.C, suspended (mg/L) (00530)	Sulfate dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, dissolved (mg/L as F) (00950)	Nitrogen nitrate dissolved (mg/L as N) (00618)	Nitrogen nitrite dissolved (mg/L as N) (00613)
March 4-5, 1995	69	7.0	2,300	1,700	3.9	10	0.1	0.41	0.01
March 14-15, 1995	36	6.9	4,300	90	1.6	3.6	0.1	0.12	0.01
July 5, 1995	16	7.1	960	1,300	0.3	0.3	0.1	0.24	0.02
April 21, 1996	94	6.5	1,600	1,500	4.5	8.0	0.3	1.36	0.04
April 22-23, 1996	61	6.9	1,500	1,800	2.5	6.1	0.2	0.55	0.01
April 29, 1996	60	6.2	1,200	1,300	4.2	4.2	0.2	0.46	0.01
July 20-21, 1996	212	7.9	31	130	8.0	9.4	0.2	0.11	0.04
July 24-25, 1996	52	6.5	77	120	2.0	2.0	0.1	--	<0.01
November 1-2, 1996	62	6.4	19	27	1.7	0.8	<0.1	0.15	0.01
November 7-8, 1996	54	6.6	75	65	1.1	0.8	<0.1	--	<0.01
December 16-18, 1996	39	8.0	18	18	1.2	0.6	<0.1	--	<0.01

Date	Nitrogen NO_2+ NO_3 dissolved (mg/L as N) (00631)	Nitrogen ammonia dissolved (mg/L as N) (00608)	Nitrogen organic total (mg/L as N) (00605)	Nitrogen ammonia+ organic total (mg/L as N) (00625)	Nitrogen, total (mg/L as N) (00600)	Phosphorus total (mg/L as P) (00665)	Phosphorus dissolved (mg/L as P) (00666)	Phosphorus ortho, dissolved (mg/L as P) (00671)	Coliform, fecal, 0.7 um-mf (cols./100 mL) (31625)	Streptococci fecal, kf agar (cols./100 mL) (31673)
March 4-5, 1995	0.42	0.15	6.6	6.7	7.1	3.5	0.81	0.80	520	10,000
March 14-15, 1995	0.13	0.05	3.5	3.6	3.7	1.9	0.45	0.47	K1,600	11,000
July 5, 1995	0.26	0.46	2.4	2.9	3.2	1.0	0.28	0.24	>6,000	20,000
April 21, 1996	1.4	0.65	6.7	7.3	8.7	3.8	0.65	0.69	K18,000	K16,000
April 22-23, 1996	0.56	0.10	7.9	8.0	8.6	3.9	0.61	0.61	K1,300	K2,000
April 29, 1996	0.47	0.05	5.2	5.2	5.7	2.3	0.29	0.30	41,000	>100,000
July 20-21, 1996	0.15	0.54	1.6	2.1	2.2	0.87	0.06	0.06	2,000	K270
July 24-25, 1996	0.36	0.01	1.3	1.3	1.7	0.40	0.15	0.14	32,000	57,000
November 1-2, 1996	0.16	0.09	1.2	1.3	1.5	1.2	1.0	0.98	31,000	>100,000
November 7-8, 1996	0.08	0.05	0.36	0.41	0.49	0.98	0.59	0.58	K7,000	86,000
December 16-18, 1996	0.07	0.05	0.59	0.64	0.71	0.48	0.35	0.38	K64,000	67,000

Table 5. Water quality of composited storm runoff samples from the forest site

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; mg/L, milligrams per liter; cols./100 mL, colonies per 100 milliliters; --, no data; Five digit numbers in parentheses are water-quality parameter codes; K, results based on colony count outside the acceptance range (non-ideal colony count)]

Date	Specific conductance (µS/cm) (00095)	pH water whole field (standard units) (00400)	Turbidity (NTU) (00076)	Residue total at 105 deg.C, suspended (mg/L) (00530)	Sulfate dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, dissolved (mg/L as F) (00950)	Nitrogen nitrate dissolved (mg/L as N) (00618)	Nitrogen nitrite dissolved (mg/L as N) (00613)
January 5-11, 1995	60	6.7	40	32	1.8	5.1	<.1	0.06	0.01
March 3-6, 1995	56	6.9	22	18	1.2	2.5	<.1	--	0.01
March 7-11, 1995	47	6.6	22	18	0.7	1.7	<.1	--	0.01
July 5-8, 1995	80	6.9	290	350	9.0	4.3	<.1	0.05	0.03
March 24-29, 1996	70	7.0	28	21	5.1	2.9	<.1	0.05	0.02
April 22-24, 1996	113	7.1	22	14	1.5	2.1	<.1	--	0.01
July 28-30, 1996	815	7.3	5.3	11	35	120	0.2	0.06	0.02
October 25-28, 1996	161	6.4	71	43	11	17	<.1	--	<.01
November 1-5, 1996	165	6.1	30	28	8.3	20	<.1	--	<.01
November 7-12, 1996	160	6.8	41	37	6.5	17	<.1	--	<.01
[1]December 16, 1996	79	7.4	34	30	2.2	6.2	<.1	--	<.01
[1]December 17, 1996	76	7.3	22	20	1.9	5.3	<.1	--	<.01
[1]December 18, 1996	76	--	17	11	2.2	6.2	<.1	--	<.01
[1]December 19, 1996	75	8.0	15	8	2.3	6.7	<.1	--	<.01
[1]December 20, 1996	82	7.5	12	8	2.2	6.3	<.1	--	<.01

Date	Nitrogen NO_2+NO_3 dissolved (mg/L as N) (00631)	Nitrogen ammonia dissolved (mg/L as N) (00608)	Nitrogen organic total (mg/L as N) (00605)	Nitrogen ammonia+ organic total (mg/L as N) (00625)	Nitrogen, total (mg/L as N) (00600)	Phosphorus total (mg/L as P) (00665)	Phosphorus dissolved (mg/L as P) (00666)	Phosphorus ortho, dissolved (mg/L as P) (00671)	Coliform, fecal, 0.7 um-mf (cols./ 100 mL) (31625)	Streptococci fecal, kf agar (cols./ 100 mL) (31673)
January 5-11, 1995	0.07	0.02	1.1	1.1	1.2	0.15	0.10	0.10	--	--
March 3-6, 1995	<.02	0.02	1.1	1.1	--	0.12	0.11	0.06	K190	480
March 7-11, 1995	<.02	0.02	0.84	0.86	--	0.14	0.12	0.09	460	K1,300
July 5-8, 1995	0.08	0.03	3.3	3.3	3.4	0.51	0.08	0.07	>1,200	>10,000
March 24-29, 1996	0.07	0.04	1.5	1.5	1.6	0.17	0.12	0.09	720	K470
April 22-24, 1996	<.02	0.06	1.5	1.6	--	0.32	0.18	0.18	380	2,700
July 28-30, 1996	0.08	0.06	0.73	0.79	0.87	0.07	0.03	0.05	K450	K990
October 25-28, 1996	<.02	0.03	1.1	1.1	--	0.23	0.14	0.16	K730	K610
November 1-5, 1996	0.02	<.01	--	1.0	1.0	0.24	0.14	0.08	5,400	7,800
November 7-12, 1996	<.02	<.01	--	1.4	--	0.22	0.16	0.10	K1,900	K2,900
[1]December 16, 1996	0.03	0.02	1.1	1.1	1.1	0.23	0.14	0.13	K7,100	K15,000
[1]December 17, 1996	<.02	<.01	--	0.88	--	0.18	0.13	0.12	K6,200	K12,000
[1]December 18, 1996	<.02	<.01	--	0.99	--	0.16	0.12	0.11	2,500	5,700
[1]December 19, 1996	<.02	<.01	--	1.0	--	0.14	0.10	0.10	600	1,900
[1]December 20, 1996	<.02	0.02	1.2	1.2	--	0.29	0.11	0.10	120	250

[1]Composite samples collected during storm event of December 16-20, 1996.

The median of the event-mean concentrations of dissolved chloride in samples from the cotton field site was significantly ($p<0.05$) less than the median of the event-mean concentrations in samples from the forested site (fig. 6). The median of the event-mean concentrations of suspended solids in samples from the cotton field site (130 mg/L) was significantly ($p<0.05$) greater than the median of the event-mean concentrations in samples from the forested site (fig. 6). The higher suspended solids concentrations in the cotton field site are expected because of the tilled soil of the cotton field compared to the soil of the forested site that was densely vegetated.

Median nutrient event-mean concentrations of total nitrogen, total ammonia plus organic nitrogen, total phosphorus, and dissolved orthophosphorus were all significantly ($p<0.05$) higher in samples from the cotton field than in the forested site (fig. 6). The higher nutrient concentrations may result from fertilizer applications to the cotton field.

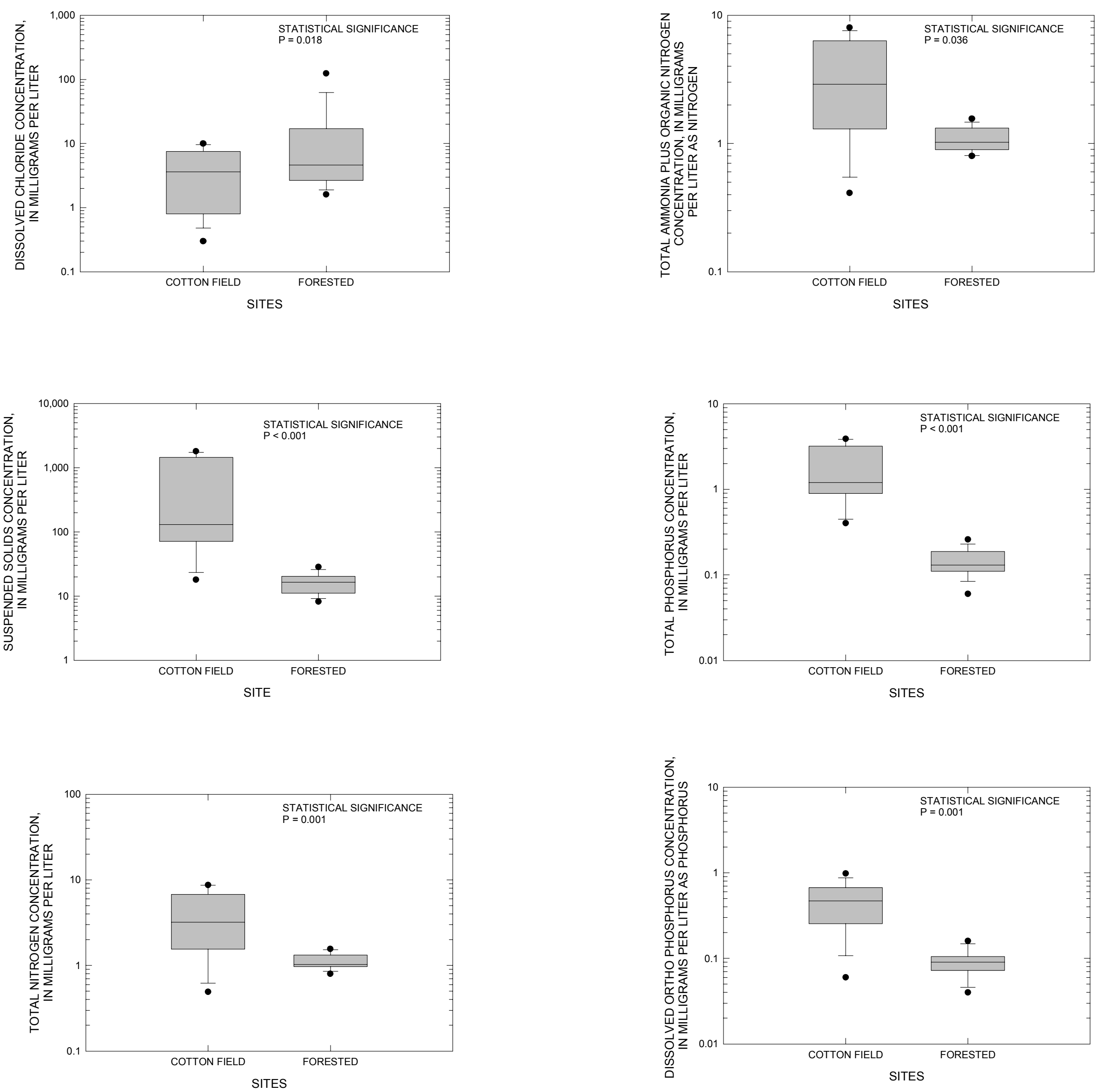

Figure 6. Ranges and distributions of dissolved chloride, suspended solids, and nutrient event-mean concentrations at cotton field and forested sites.

The computed mean EMCs using the volume-weighted, logarithmic-transformed, and arithmetic methods are shown in table 6. The median also is shown for the constituents by site in table 6.

Event-mean concentrations for all but two of the constituents were normally distributed. The EMCs for dissolved chloride at the forested site and suspended solids at the cotton field site are not normally distributed. Because the EMCs for these sites are not normally distributed, the median and the log-transformed mean were better estimators of the central tendency of the data than the arithmetic mean and the volume-weighted mean.

Regression coefficients and error statistics for regression equations used to calculate loads are listed in tables 7-9. Standard errors for the load regression equations ranged from 54 to 135 percent for the cotton field site (table 8) and 21 to 48 percent for the forested site (table 9). The coefficients of determination ranged from 0.75 to 0.86 for the cotton field site and 0.80 to 0.94 for the forested site. No coefficient for the seasonal explanatory variable was included in the load regression equation for the forested site (table 9) because the seasonal variable was not significantly correlated to loads at this site. An example of the estimated loads plotted against the measured loads for total nitrogen is shown in figure 7 for all sampled storms at both sites.

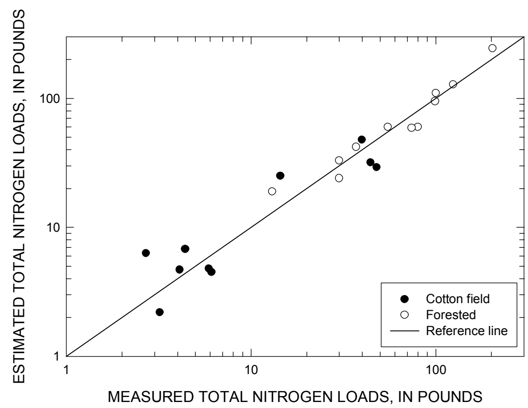

Figure 7. Measured and estimated total nitrogen storm loads.

Table 6. Mean and median event-mean concentrations by sites

Constituent, in mg/L	Site	Event-mean concentrations (milligrams per liter): Volume-weighted mean	Log-transformed mean	Arithmetic mean	Median
Dissolved chloride	Cotton field	3.6	2.4	4.2	3.6
	Forested	7.8	7.1	18	4.6
Suspended solids	Cotton field	619	258	732	130
	Forested	15.2	15.2	16.3	16.4
Total nitrogen	Cotton field	3.6	2.8	4.0	3.2
	Forested	1.0	1.1	1.1	1.0
Total ammonia plus organic nitrogen as nitrogen	Cotton field	3.4	2.5	3.6	2.9
	Forested	1.0	1.1	1.1	1.0
Total phosphorus	Cotton field	1.8	1.4	1.8	1.2
	Forested	.14	.14	.15	.13
Dissolved orthophosphorus	Cotton field	.51	.38	.48	.47
	Forested	.09	.08	.09	.09

Table 7. Regression coefficients and error statistics for percent load regression equations at the forested site

[b, regression coefficient; R^2, coefficient of determination; SE, standard error of estimate in percent; equation form is $PERCLOAD_i = b_0 + b_1 \times PERCRV_i + b_2 \times PERCRV^2_i$]

Constituent	Regression coefficients			Error statistics	
	b_0	b_1	b_2	R^2	SE
Dissolved chloride	0.073	0.714	0.214	1.00	0.2
Suspended solids	.071	1.645	-.727	1.00	3.7
Total nitrogen	.078	.746	.172	1.00	1.8
Total ammonia plus organic nitrogen	.078	.746	.172	1.00	1.8
Total phosphorus	.049	1.179	-.230	1.00	.7
Dissolved orthophosphorus	-.017	1.235	-.222	1.00	1.4

Table 8. Regression coefficients and error statistics for load regression equations at the cotton field site

[b, regression coefficient; R^2, coefficient of determination; SE, standard error of estimate in percent; equation form is $LOAD = b_0' \times (RV)^{b_1} \times (SEASON)^{b_2} \times BCF, b_0' = 10^{b_0}$]

Constituent	Regression coefficients				Error statistics	
	b_0	b_1	b_2	BCF	R^2	SE
Suspended solids	1.137	0.493	-1.184	1.321	0.77	135
Total nitrogen	-2.230	.740	-.671	1.081	.85	54
Total ammonia plus organic nitrogen	-2.386	.765	-.704	1.087	.86	54
Total phosphorus	-3.268	.884	-.522	1.087	.83	57
Dissolved orthophosphorus	-5.658	1.242	-.253	1.278	.75	111

Table 9. Regression coefficients and error statistics for load regression equations at the forested site

[b, regression coefficient; R^2, coefficient of determination; SE, standard error of estimate in percent; equation form is $LOAD = b_0' \times (RV)^{b_1} \times BCF, b_0' = 10^{b_0}$]

Constituent	Regression coefficients			Error statistics	
	b_0	b_1	BCF	R^2	SE
Suspended solids	-3.276	1.043	1.073	0.84	44
Total nitrogen	-3.570	.900	1.019	.94	21
Total ammonia plus organic nitrogen	-3.655	.912	1.021	.93	23
Total phosphorus	-4.880	.969	1.079	.80	48
Dissolved orthophosphorus	-5.219	.992	1.068	.85	42

The 1996 annual flow volumes and loads were divided by the drainage areas to calculate annual yields for the sites (table 10). The basin yields for the five constituents ranged from about 2 to 27 times greater at the cotton field site, although the flow volume per acre and rainfall were greater at the forested site. Fifty-three percent of the flow was sampled at the cotton field site and 23 percent of the flow was sampled at the forested site.

Water released from the catfish pond (fig. 8, table 11) generally had high (relative to concentrations in forest and cotton field runoff and in low flow samples from ambient sites) concentrations of sulfate, chloride, suspended solids, and some nutrients. Sulfate and chloride concentrations from the catfish pond were typically substantially higher than concentrations in cotton field or forested runoff samples (fig. 6, tables 2 and 3) and somewhat higher than concentrations from the low flow samples from ambient sites (table 2). Suspended solids concentrations from the catfish pond samples typically were higher than concentrations in samples from the ambient sites (table 2) and in runoff samples from the forested site (fig. 6, table 5), but often were lower than concentrations in samples from the cotton field runoff (fig. 6, table 4). Concentrations of nitrogen species (total ammonia plus organic nitrogen, nitrite plus nitrate, and total nitrogen) typically were higher in samples from the catfish pond than in samples from any of the other types of sites (fig. 6, tables 2, 4, and 5).

Table 10. Estimated annual yields for 1996 calendar year

[RV, runoff volume per acre; ft^3/acre, cubic feet per acre; SS, suspended solids; TN, total nitrogen; TKN, total ammonia plus organic nitrogen; TP, total phosphorus; DOP, dissolved orthophosphorus; ( ), percent of volume of yield sampled]

Site	Rain (inches)	RV (ft^3/acre)	Yield, in pounds per acre				
			SS	TN	TKN	TP	DOP
Cotton field	41.14	16,750	496	2.97	2.67	1.49	0.51
		(53)	(52)	(53)	(54)	(57)	(57)
Forested	52.56	19,190	18.1	1.31	1.29	.18	.11
		(23)	(29)	(25)	(25)	(28)	(27)

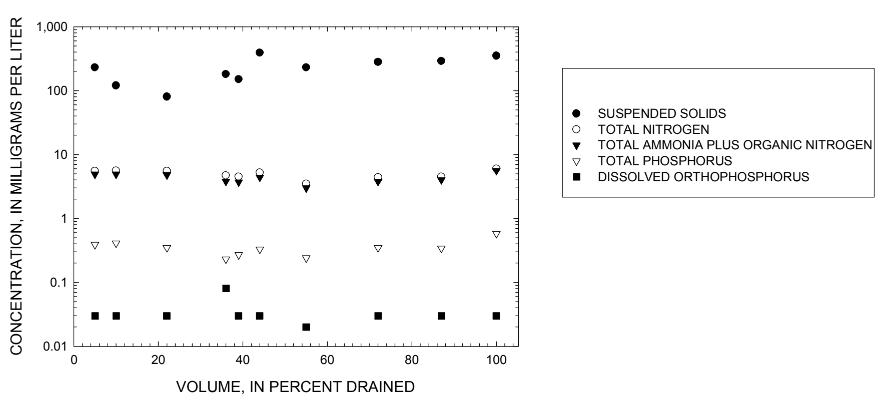

Figure 8. Sampled concentrations with percent volume of catfish pond drained.

Table 11. Water quality of grab samples collected during draining of the catfish pond

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; cols./100 mL, colonies per 100 milliliters; five-digit numbers in parentheses are water-quality parameter codes; --, no data]

Date	Time	Specific conductance (µS/cm) (00095)	pH water whole field (standard units) (00400)	Temperature water (deg C) (00010)	Turbidity (NTU) (00076)	Residue total at 105 deg.C, suspended (mg/L) (00530)	Sulfate dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, dissolved (mg/L as F) (00950)	Nitrogen nitrate dissolved (mg/L as N) (00618)	Nitrogen nitrite dissolved (mg/L as N) (00613)
4/17/1995	1115	685	7.8	24	180	230	26	96	0.5	0.48	0.17
4/17/1995	1500	710	7.7	--	120	120	26	96	0.5	0.50	0.17
4/18/1995	1045	690	7.9	22	180	80	27	96	0.5	0.48	0.17
4/26/1995	1115	610	8.1	20	130	180	28	87	0.4	0.70	0.15
4/27/1995	945	600	8.0	18	120	150	28	86	0.4	0.70	0.14
4/28/1995	915	630	7.6	18	450	390	29	85	0.4	0.67	0.12
5/04/1995	1100	660	7.9	19	140	230	31	87	0.4	0.42	0.07
5/05/1995	1015	650	7.9	21	180	280	31	88	0.4	0.52	0.10
5/06/1995	1020	647	7.9	21	170	290	31	88	0.4	0.42	0.09
5/07/1995	1015	690	8.0	21	400	350	31	87	0.4	0.37	0.05

Date	Time	Nitrogen NO_2+ NO_3 dissolved (mg/L as N) (00631)	Nitrogen ammonia dissolved (mg/L as N) (00608)	Nitrogen organic total (mg/L as N) (00605)	Nitrogen ammonia+ organic total (mg/L as N) (00625)	Nitrogen, total (mg/L as N) (00600)	Phosphorus total (mg/L as P) (00665)	Phosphorus dissolved (mg/L as P) (00666)	Phosphorus ortho, dissolved (mg/L as P) (00671)	Coliform, fecal, 0.7 um-mf (cols./ 100 mL) (31625)	Streptococci fecal, kf agar (cols./ 100 mL) (31673)
4/17/1995	1115	0.65	1.6	3.3	4.9	5.6	0.39	0.08	0.03	K27	980
4/17/1995	1500	0.67	1.6	3.3	4.9	5.6	0.41	0.09	0.03	K27	K960
4/18/1995	1045	0.65	1.6	3.2	4.8	5.4	0.35	0.06	0.03	K17	>500
4/26/1995	1115	0.85	1.5	2.3	3.8	4.7	0.23	0.07	0.08	100	K7,600
4/27/1995	945	0.84	1.5	2.2	3.7	4.5	0.27	0.05	0.03	92	4600
4/28/1995	915	0.79	1.6	2.8	4.4	5.2	0.33	0.03	0.03	89	K6,500
5/04/1995	1100	0.49	0.81	2.2	3.0	3.5	0.24	0.04	0.02	K350	3,500
5/05/1995	1015	0.62	1.1	2.7	3.8	4.4	0.35	0.04	0.03	150	2,100
5/06/1995	1020	0.51	0.92	3.1	4.0	4.5	0.34	0.05	0.03	K68	930
5/07/1995	1015	0.42	0.08	5.5	5.6	6.0	0.58	0.04	0.03	67	K1,500

Concentrations of total phosphorus and orthophosphorus generally were lower in samples from the catfish pond (table 11) than in samples from the cotton field runoff, forest runoff, or ambient site low flow (fig. 6, tables 2, 4, and 5). Fecal coliform bacteria concentrations from the catfish pond samples (table 11) almost always were lower than concentrations in the forest or cotton field runoff samples (tables 4 and 5).

Concentrations of suspended solids, total nitrogen, total ammonia plus organic nitrogen, total phosphorus, and dissolved orthophosphorus were relatively constant throughout the draining of the pond (fig. 8). However, there were rather substantial fluctuations of suspended solids and dissolved orthophosphorus in samples collected on April 26 through April 28 (table 11, fig. 8), which were collected after rains on April 18 and April 26 (table 12). Concentrations of all four constituents increased slightly as the percent volume of the pond drained increased from 70 to 100 percent (fig. 8).

The loads (pounds) of suspended solids, nitrogen, and phosphorus released from the catfish varied substantially (table 12). The suspended solids load was 8,050 pounds, while 166 pounds of total nitrogen and 12.0 pounds of total phosphorus were released.

Table 12. Selected constituent loads from catfish pond drainage, April-May 1995

[ft^3/acre, cubic feet per acre; SS, suspended solids; TN, total nitrogen; TKN, total ammonia plus organic nitrogen; TP, total phosphorus; DOP, dissolved orthophosphorus; lbs, pounds]

Sample		Rainfall volume (ft^3)[1]	Sampled volume (ft^3)	Load				
Date	Time			SS (lbs)	TN (lbs)	TKN (lbs)	TP (lbs)	DOP (lbs)
4/17/1995	11:15	--	27,700	400	9.5	8.5	0.67	0.052
4/17/1995	15:00	--	27,550	210	9.6	8.4	.71	.052
4/18/1995	10:45	28,200	64,800	320	22	19	1.4	.12
4/26/1995	11:15	34,800	75,000	840	22	18	1.1	.37
4/27/1995	09:45	--	21,500	200	6.0	5.0	.36	.040
4/28/1995	09:15	1,080	23,130	560	7.5	6.4	.48	.043
5/04/1995	11:00	9,700	63,800	920	14	12	.96	.080
5/05/1995	10:15	--	90,440	1,600	25	21	2.0	.17
5/06/1995	10:20	3,080	84,800	1,500	24	21	1.8	.16
5/07/1995	10:15	--	69,950	1,500	26	24	2.5	.13
Totals		76,860	548,670	8,050	166	145	12.0	1.22

[1]4.99 inches of rain fell during the draining of the pond. Volume was calculated by multiplying rainfall by drainage area of pond.

Benthic Macroinvertebrate Communities and Physical Habitat

Taxa abundances for a reference site (Bennett and others, 1987) and 25 sites in the Boeuf River Basin are listed in table 13. Associated tolerance values and feeding groups also are listed.

Because no reference sites were found in the Boeuf River Basin, a site at Boat Gunwale Slash was used as a reference site for comparison with sites in the Boeuf River Basin. Three major factors that should be considered when comparing the Boeuf River Basin sites and benthic macroinvertebrate communities to the Boat Gunwale Slash site and its community are that (1) Boat Gunwale Slash has a drainage area (23 square miles) that is substantially smaller or larger than many of the Boeuf River Basin sites, (2) the Boat Gunwale Slash macroinvertebrate and habitat information was collected in August 1983 (rather than in November or December), and (3) sampling methods differed (one notable difference is that all organisms were enumerated and identified in the Boat Gunwale Slash sample).

Family richness (number of taxa, table 14) was substantially higher at the reference site (29 families) than at the sites in the Boeuf River Basin (8 to 18 families). Samples from most sites had about 31 to 62 percent the family richness of the reference site (table 15). Some difference in richness may be attributable to the larger number of individuals sampled at the reference site.

The family biotic index (which is a family-abundance weighted measure of tolerance) (table 14) generally was substantially lower at the reference site (6.1) than at the sites in the Boeuf River Basin (5.3 to 8.6), indicating that the community from the reference site was composed of a smaller proportion of tolerant individuals than were the communities from the sites in the Boeuf River Basin. Samples from the Boeuf River Basin sites had family biotic index values that were 71 to 107 percent of the index value for the reference site (table 15).

Samples from the Boeuf River Basin sites generally contained a greater proportion of scrapers (relative to filterers) than did the sample from the reference site (table 14). The scraper to filterer plus scraper ratio was 0.74 at the reference site and ranged from 0.20 to 1.00 at Boeuf River Basin sites (table 14). Samples from the Boeuf River Basin sites had ratios that were 27 to 135 percent of the ratio at the reference site; ratios at most Boeuf River Basin sites were 105 to 135 percent of the ratio at the reference site (table 15). This indicates that at the Boeuf River Basin sites a greater proportion of macroinvertebrates were grazing on periphyton than were filtering fine particulate organic matter (FPOM).

Two tolerance-related metrics that are based on numbers of individuals and families of the generally intolerant Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) generally indicated those Boeuf River Basin sites that were organically enriched or otherwise stressed. Ratios of EPT to EPT plus Chironomidae (a generally tolerant family of true flies) abundance at Boeuf River Basin sites varied substantially among sites (ranging from 0.00 to 1.00); the ratio at the reference site was 0.55 (table 14). The EPT index (richness of EPT families) for the reference site (3 families) was higher than at almost all of the Boeuf River Basin sites (range 0 to 4 families, but exceeding 1 family in only 11 of 27 samples).

Macroinvertebrate samples from the Boeuf River Basin sites generally were composed of a greater percentage of individuals from a single family (percent contribution of dominant family) than was the sample from the reference site. The largest percentage of individuals from a single family at the reference site was 16 percent (table 14). Largest single-family percentages from the Boeuf River Basin sites ranged from 15 to 87 percent and in most cases were at least twice the percentage from the reference site. Presence of families that are extremely numerically dominant indicate environmental stress (Plafkin and others, 1989).

Community loss index (Courtemanch and Davies, 1987) values, which measure the loss of taxa between a reference site and another site, ranged from 1.0 to 3.3 at Boeuf River Basin sites (table 14). Plafkin and others (1989) place all of these values in the middle category (values from 0.5 to 4.0) of biological condition scoring criteria.

Ratios of shredder to total abundance generally did not exceed 0.06 (table 14), indicating that shredders of coarse particulate organic matter are not an important component of the macroinvertebrate community during the late fall. Shredder abundance has been suggested to be linked to abundance of coarse particulate organic matter (leaf litter for example) (Lamberti and Moore, 1984; Merritt and Cummins, 1996). Low abundance of shredders probably is related to the absence of a well established riparian vegetation zone (see streamside cover score in table 18). The ratio for the reference site was slightly higher than most sites in the Boeuf River Basin, possibly because of the presence of a well established riparian zone.

Table 13. Abundance, tolerance values, and feeding groups of macroinvertebrate taxa collected from 25 sites in the Boeuf River Basin and a reference site

[Reference site data from Bennett and others, 1987]

Order	Tolerance value	Feeding group	Family	Abundance at site													
				Reference	1	2	3	4	5	6	7	8	10	11	12	12 (duplicate)	13
Oligochaeta	10	Collectors	Oligochaeta	2	1	2							2				
Hirudinea	8	Predators	Erpobdellidae	2			1	1									
	9	Predators	Hirudinidae	1													
	8	Predators	Glossiphoniidae	1													
	8	Predators	Piscicolidae				1										
Gastropoda	9	Scrapers	Physidae	4													
	6	Scrapers	Viviparidae	11	15	12	20	2	5	16	1	2	4	1	3	1	1
	6	Scrapers	Planorbidae	1		1		3			1	4					
	6	Scrapers	Ancylidae	1								2					
Pelecypoda	8	Filterer collectors	Sphaeriidae	6	3	6	1										
Decapoda	8	Collectors	Cambaridae			1	1	2		2	1		1	2			1
	9	Collectors	Palaemonidae	19				6	7		2		62	105	22	19	103
Amphipoda	7	Collectors	Talitridae	2							31	2	4		61	50	
Ephemeroptera	4	Collectors	Baetidae	15							4						
	7	Collectors	Caenidae	19	17	9		39	6	4	14		1	1	20	24	1
	4	Collectors	Ephemeridae	4													
	4	Scrapers	Heptageniidae			1											
	2	Collectors	Leptophlebiidae														
Plecoptera	1	Shredders	Leuctridae														
Trichoptera	4	Filterer collectors	Hydropsychidae		1	1								1	2	8	
	4	Collectors	Hydroptilidae		1	3											
Anisoptera	1	Predators	Gomphidae	1					1		2	2		1			2
	9	Predators	Libellulidae	1								4		1	4	1	
	5	Predators	Protoneuridae	6													
	9	Predators	Coenagrionidae		27	21	9	43	37	50	9		8	2	81	44	5
Hemiptera	9	Piercers	Corixidae		28	5		2	7	3			1	11			
	5	Piercers	Veliidae				1										
	5	Predators	Pleidae	15													
	5	Predators	Gelastocoridae	2						4							
	5	Predators	Gerridae	1													

Table 13. Abundance, tolerance values, and feeding groups of macroinvertebrate taxa collected from 25 sites in the Boeuf River Basin and a reference site--Continued

[Reference site data from Bennett and others, 1987]

Order	Tolerance value	Feeding group	Family	Abundance at site													
				Reference	1	2	3	4	5	6	7	8	10	11	12	12 (duplicate)	13
	5	Predators	Mesoveliidae	1													
	5	Predators	Hydrometridae					1									
	5	Predators	Belostomatidae								2		1				
	5	Predators	Notonectidae														1
	5	Predators	Nepidae	1													
Coleoptera	5	Predators	Dytiscidae	7													
	5	Scrapers	Elmidae												4	1	
	5	Shredders	Haliplidae	10	2			4	1		12						
	5	Predators	Hydrophilidae	5				2			2	1					
	6	Predators	Gyrinidae		1				1				1				
	4	Collectors	Scirtidae										1				
	4	Scrapers	Hydroscaphidae														
	4	Predators	Carabidae				1			1							
	4	Predators	Noteridae			1		1			1						
	4	Shredders	Curculionidae									1		1			
Diptera	5	Predators	Ceratopogonidae	1			3										
	3	Shredders	Tipulidae														
	4	Collectors	Chironomidae	31	18	68	49	5	40	18	23	4	9	5	2	6	4
	8	Collectors	Stratiomyidae														
	8	Collectors	Culicidae														
	8	Collectors	Sarcophagidae				3										
Nematomorpha	8	Predators	Parachordodidae				1		1					2	2		1
	8	Predators	Chordodidae														
Isopoda	7	Collectors	Asellidae	35								4				2	
Megaloptera	8	Predators	Sialidae	8													
Total number of individuals				213	114	131	91	111	106	98	105	26	95	133	201	156	119

Table 13. Abundances, tolerance values, and feeding groups of macroinvertebrate taxa collected from 25 sites in the Boeuf River Basin and a reference site--Continued

[Reference site data from Bennett and others, 1987]

Order	Tolerance value	Feeding group	Family	Reference	Site 14	15	16	16 (duplicate)	17	18	19	20	21	22	23	24	25	27
Oligochaeta	10	Collectors	Oligochaeta	2						2							2	
Hirudinea	8	Predators	Erpobdellidae	2		1			2			2			1			1
	9	Predators	Hirudinidae	1														
	8	Predators	Glossiphoniidae	1														
	8	Predators	Piscicolidae									2						
Gastropoda	9	Scrapers	Physidae	4														
	6	Scrapers	Viviparidae	11	3	1	1		3	1	3	5	15	14	4	2	3	10
	6	Scrapers	Planorbidae	1	1							1	3	6			1	
	6	Scrapers	Ancylidae	1				1	9									
Pelecypoda	8	Filterer collectors	Sphaeriidae	6	1							2						2
Decapoda	8	Collectors	Cambaridae		1	2	8	6	13	1			1		1	1	2	
	9	Collectors	Palaemonidae	19	1			2	62	22			30		37	77	20	
Amphipoda	7	Collectors	Talitridae	2	4		41	31		12	30				4			
Ephemeroptera	4	Collectors	Baetidae	15	1								3		1			
	7	Collectors	Caenidae	19	35	28		2	1	48	18	120	6	37	9	4	9	7
	4	Collectors	Ephemeridae	4														
	4	Scrapers	Heptageniidae														1	
	2	Collectors	Leptophlebiidae														3	
Plecoptera	1	Shredders	Leuctridae															
Trichoptera	4	Filterer collectors	Hydropsychidae		1													
	4	Collectors	Hydroptilidae														1	3
Anisoptera	1	Predators	Gomphidae	1			1	1	1	1					1			
	9	Predators	Libellulidae	1	1		6	6		1								
	5	Predators	Protoneuridae	6														
	9	Predators	Coenagrionidae		16	48	24	21	36	28	41	1	1	75	8	12	13	14
Hemiptera	9	Piercers	Corixidae		3	3				4	1		15	27	11			55
	5	Piercers	Veliidae															
	5	Predators	Pleidae	15														
	5	Predators	Gelastocoridae	2									1		4			
	5	Predators	Gerridae	1														

Table 13. Abundances, tolerance values, and feeding groups of macroinvertebrate taxa collected from 25 sites in the Boeuf River Basin and a reference site--Continued

[Reference site data from Bennett and others, 1987]

Order	Tolerance value	Feeding group	Family	Reference	Site 14	15	16	16 (duplicate)	17	18	19	20	21	22	23	24	25	27
	5	Predators	Mesoveliidae	1														
	5	Predators	Hydrometridae		2						1		1		16	3	3	
	5	Predators	Belostomatidae		4				2		1		9	1			1	
	5	Predators	Notonectidae															
	5	Predators	Nepidae	1														
Coleoptera	5	Predators	Dytiscidae	7											1			
	5	Scrapers	Elmidae					2						1				1
	5	Shredders	Haliplidae	10	8	6		6	4				59		6	1	9	3
	5	Predators	Hydrophilidae	5														
	6	Predators	Gyrinidae							6			2				27	5
	4	Collectors	Scirtidae					2										1
	4	Scrapers	Hydroscaphidae															
	4	Predators	Carabidae															
	4	Predators	Noteridae					1	1				5		8			1
	4	Shredders	Curculionidae				1											
Diptera	5	Predators	Ceratopogonidae	1														
	3	Shredders	Tipulidae												3			
	4	Collectors	Chironomidae	31	11	33	6	1	1	11	6	14	9		6	2	8	6
	8	Collectors	Stratiomyidae															
	8	Collectors	Culicidae												1			
	8	Collectors	Sarcophagidae					1										
Nematomorpha	8	Predators	Parachordodidae		5	1		1		1	4	1		1		1		1
	8	Predators	Chordodidae															
Isopoda	7	Collectors	Asellidae	35			13	24	2		1							
Megaloptera	8	Predators	Sialidae	8														
Total number of individuals				213	98	123	101	108	137	138	106	148	160	162	122	103	103	110

Table 14. Bioassessment metrics for samples collected from sites in the Boeuf River Basin and a reference site

[EPT, Ephemeroptera, Plecoptera, and Trichoptera; N/A, not applicable]

Rapid bioassessment metrics	Site													
	Reference	1	2	3	4	5	6	7	8	10	11	12	12 (duplicate)	13
Number of taxa (family richness)	29	11	13	12	13	10	8	14	10	12	12	10	10	9
Family biotic index	6.1	7.3	5.7	5.3	7.6	6.7	7.3	6.0	5.9	8.2	8.6	8.0	7.5	8.6
Scraper/(filterer + scraper) abundances	0.74	0.79	0.67	0.95	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.78	0.20	1.00
EPT/(Chironomidae + EPT) abundances	0.55	0.51	0.17	0.00	0.89	0.13	0.18	0.44	0.00	0.10	0.29	0.92	0.84	0.20
Percent contribution of dominant family	16	25	52	54	39	38	51	30	15	65	79	40	32	87
EPT index (family)	3	3	4	0	1	1	1	2	0	1	2	2	2	1
Community loss index	N/A	2.1	1.8	2.0	1.6	2.3	3.1	1.4	2.0	1.9	1.9	2.3	2.2	2.7
Shredder/total abundance	0.05	0.02	0.00	0.00	0.04	0.01	0.00	0.11	0.04	0.00	0.01	0.00	0.00	0.00

Rapid bioassessment metrics	Site														
	Reference	14	15	16	16 (duplicate)	17	18	19	20	21	22	23	24	25	27
Number of taxa (family richness)	29	17	9	9	16	13	13	10	9	15	8	18	9	15	14
Family biotic index	6.1	6.8	7.0	7.4	7.3	8.3	7.5	7.6	6.7	6.3	8.1	7.0	8.6	6.7	7.8
Scraper/(filterer + scraper) abundances	0.74	0.67	1.00	1.00	1.00	1.00	1.00	1.00	0.75	1.00	1.00	1.00	1.00	1.00	0.85
EPT/(Chironomidae + EPT) abundances	0.55	0.77	0.46	0.00	0.67	0.50	0.81	0.75	0.90	0.50	1.00	0.63	0.67	0.64	0.63
Percent contribution of dominant family	16	36	39	41	29	45	35	39	81	37	46	30	75	26	50
EPT index (family)	3	3	1	0	1	1	1	1	1	2	1	2	1	4	2
Community loss index	N/A	1.1	2.7	2.6	1.3	1.5	1.6	2.4	2.6	1.4	3.3	1.0	2.7	1.5	1.6
Shredder/total abundance	0.05	0.08	0.05	0.01	0.06	0.03	0.00	0.00	0.00	0.37	0.00	0.07	0.01	0.09	0.03

Table 15. Comparison of bioassessment metrics for samples collected from sites in the Boeuf River Basin to a reference site

[EPT is Ephemeroptera, Plecoptera, and Trichoptera]

	Site											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**10**	**11**	**12**	**12 (duplicate)**
Number of taxa (family richness)[1]	38	45	41	45	34	28	48	34	41	41	34	34
Family biotic index[2]	83	107	114	80	91	84	102	103	74	71	76	81
Scraper/(filterer + scraper) abundances[1]	107	90	129	135	135	135	135	135	135	68	105	27
EPT/(Chironomidae + EPT) abundances[1]	93	31	0	161	24	33	80	0	18	52	166	153
Contribution of dominant family[1]	149	316	328	236	230	310	180	94	397	480	245	195
EPT index[1]	100	133	0	33	33	33	67	0	33	67	67	67
Community loss index[3]	2.1	1.8	2.0	1.6	2.3	3.1	1.4	2.0	1.9	1.9	2.3	2.2
Shredder/total abundances[1]	37	0	0	77	20	0	243	82	0	16	0	0

	Site														
	13	**14**	**15**	**16**	**16 (duplicate)**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**27**
Number of taxa (family richness)[1]	31	59	31	31	55	45	45	34	31	52	28	62	31	52	48
Family biotic index[2]	71	90	88	82	84	74	81	80	90	97	75	88	71	91	78
Scraper/(filterer + scraper) abundances[1]	135	90	135	135	135	135	135	135	101	135	135	135	135	135	114
EPT/(Chironomidae + EPT) abundances[1]	36	140	83	0	121	91	148	136	163	91	182	113	121	116	113
Contribution of dominant family[1]	527	217	237	247	175	275	212	235	493	224	282	185	455	160	304
EPT index[1]	33	100	33	0	33	33	33	33	33	67	33	67	33	133	67
Community loss index[3]	2.7	1.1	2.7	2.6	1.2	1.5	1.6	2.4	2.6	1.4	3.3	1.0	2.7	1.5	1.6
Shredder/total abundances[1]	0	174	104	21	118	62	0	0	0	785	0	157	21	186	58

[1]Ratio of the study site to the reference site expressed as a percentage.

[2]Ratio of the reference site to the study site expressed as a percentage.

[3]Raw value (not compared to reference site as a ratio).

Biological condition scores for the Boeuf River Basin sites ranged from 15 to 42, compared to 48 for the reference site (table 16). Scores normalized to the reference score (ratios of Boeuf River Basin scores to the reference score) ranged from 31 to 88 percent. Based on these scores most Boeuf River Basin sites would be in the "moderately impaired" category and two sites would be classified in the "non-impaired" category (Plafkin and others, 1989). However, substantial uncertainty exists in the biological condition category rating because of differing drainage areas, sampling methods, and sampling season between the reference site and sites in the Boeuf River Basin. The biological condition categories presented provide a general and relative assessment of the macroinvertebrate communities at the Boeuf River Basin sites.

A comparison of individual metrics, biological condition scores, normalized total scores, and the biological condition category for the duplicate samples indicated that substantial differences could occur between duplicate samples. However, these differences did not result in differences in the biological condition category (table 16). The results for the duplicates from site 12 generally were similar, but results for the duplicates from site 16 often were substantially different (table 17). Relative percent differences between metrics and scores for samples from site 12 ranged from 0 to 118 percent, and usually were less than 20 percent. Relative percent differences for samples from site 16 ranged from 0 to 200 percent and usually were greater than 50 percent. The greater similarity of the duplicates from site 12 relative to the duplicates from site 16 may be a function of the larger number of individuals counted and identified at site 12 (201 and 156) than at site 16 (101 and 108) (table 13).

Physical habitat scores for Boeuf River Basin sites ranged from 14 to 83 out of the possible 135 points (table 18). Most sites were considered to have poor habitat related to bottom substrate available cover, embeddedness, and flow and were considered to have poor or fair habitat related to most other factors. The score for the reference site as rated from documented data (Bennett and others, 1987) was 92. Most habitat factors at the reference site were considered good to excellent; only embeddedness was considered poor. Scores for the Boeuf River Basin sites ranged from 15 to 90 percent of the reference site score (table 18).

Physical habitat can have a strong influence on biological communities. Part of the variation in biological condition scores for the Boeuf River Basin sites and the reference site was explained by the physical habitat scores (Spearmans rho=0.31, one-sided p-value = 0.051; fig. 9). In general, sites with the lowest habitat scores had the lowest biological condition scores (for example, sites 5, 6, 13, and 24). However, a considerable amount of variability in the biological condition scores was not explained by the habitat scores and some sites with low habitat scores were among those with the highest biological condition score totals (for example, sites 1, 25, and 27).

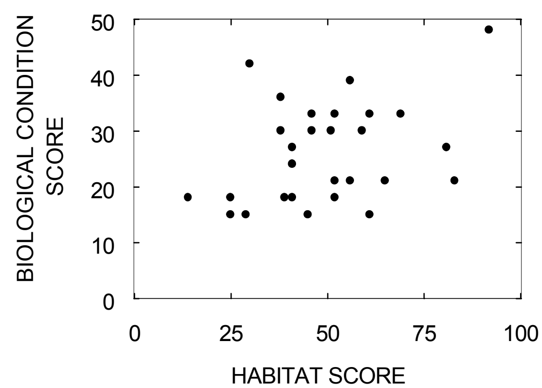

Figure 9. Relation of biological condition score to habitat score.

Table 16. Comparison of biological condition scores for samples collected from sites in the Boeuf River Basin to a reference site

[EPT is Ephemeroptera, Plecoptera, and Trichoptera; N/A is not applicable; NI is non-impaired; MI is moderately impaired]

	Site													
	Reference	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**10**	**11**	**12**	**12 (duplicate)**	**13**
Number of taxa (family richness)	6	0	3	3	3	0	0	3	0	3	3	0	0	0
Family biotic index	6	3	6	6	3	6	3	6	6	3	3	3	3	3
Scraper/(filterer + scraper) abundances	6	6	6	6	6	6	6	6	6	6	6	6	3	6
EPT/(Chironomidae + EPT) abundances	6	6	3	0	6	0	3	6	0	0	3	6	6	3
Contribution of dominant family	6	6	0	0	3	3	0	3	6	0	0	3	3	0
EPT index	6	6	6	0	0	0	0	0	0	0	0	0	0	0
Community loss index	6	3	3	3	3	3	3	3	3	3	3	3	3	3
Shredder/total abundances	6	6	0	0	6	0	0	6	6	0	0	0	0	0
Biological condition score (total)	48	36	27	18	30	18	15	33	27	15	18	21	18	15
Normalized total score (percent of reference score)	N/A	75	56	38	63	38	31	69	56	31	38	44	38	31
Biological condition category	NI	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI

	Site														
	Reference	**14**	**15**	**16**	**16 (duplicate)**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**27**
Number of taxa (family richness)	6	3	0	0	3	3	3	0	0	3	0	3	0	3	3
Family biotic index	6	6	6	3	3	3	3	3	6	6	3	6	3	6	3
Scraper/(filterer + scraper) abundances	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
EPT/(Chironomidae + EPT) abundances	6	6	6	0	6	6	6	6	6	6	6	6	6	6	6
Contribution of dominant family	6	3	3	3	6	3	3	3	0	3	3	3	0	6	3
EPT index	6	6	0	0	0	0	0	0	0	0	0	0	0	6	0
Community loss index	6	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Shredder/total abundances	6	6	6	0	6	6	0	0	0	6	0	6	0	6	6
Biological condition score (total)	48	39	30	15	33	30	24	21	21	33	21	33	18	42	30
Normalized total score (percent of reference score)	N/A	81	63	31	69	63	50	44	44	69	44	69	38	88	63
Biological condition category	NI	NI	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI	MI	NI	MI

Table 17. Relative percent difference values for metrics and scores associated with duplicate samples

[EPT is Ephemeroptera, Plecoptera, and Trichoptera]

	Site 12	Site 16
Number of taxa (family richness)	0	56
Family biotic index	6	1
Scraper /(filterer + scraper) abundances	118	0
EPT/(Chironomidae + EPT) abundances	9	200
Percent contribution of dominant family	22	34
EPT index (family)	0	200
Community loss index	4	67
Shredder/total abundance	0	143
Biological condition score (total)	15	75
Normalized total score	15	76

Table 18. Physical habitat score assessment of the Boeuf River and its tributaries

Site number	Bottom sub-strate avail-able cover score (0-20)	Embed-ded-ness score (0-20)	Flow score (0-20)	Channel alter-ation score (0-15)	Bottom scouring and deposi-tion score (0-15)	Run/ bend ratio score (0-15)	Bank stabil-ity score (0-10)	Bank veg-eta-tive stabil-ity score (0-10)	Stream-side cover score (0-10)	Habi-tat score (0-135)	Ratio of habitat score at site to refer-ence site score (per-cent)
Reference	13	5	15	15	14	7	10	5	8	92	100
1	3	3	6	3	3	4	5	6	5	38	41
2	3	6	4	3	2	6	6	6	5	41	45
3	6	2	8	2	2	2	5	9	5	41	45
4	12	12	5	5	5	2	1	4	5	51	55
5	1	2	1	1	1	2	1	2	3	14	15
6	2	1	3	1	2	4	5	6	5	29	32
7	4	3	4	8	8	2	6	9	8	52	57
8	16	16	5	10	10	3	5	8	8	81	88
10	3	3	6	6	6	6	2	8	5	45	49
11	4	5	5	3	4	4	3	6	5	39	42
12	4	5	5	7	4	3	8	8	8	52	57
13	2	2	2	2	2	4	4	3	4	25	27
14	12	6	4	4	4	4	5	8	9	56	61
15	8	10	4	6	7	5	5	8	6	59	64
16	5	10	5	8	12	3	5	5	8	61	66
17	10	10	2	5	5	4	2	2	6	46	50
18	4	2	3	6	3	3	5	6	9	41	45
19	10	1	2	11	11	3	9	10	8	65	71
20	5	5	11	3	4	7	8	8	5	56	61
21	5	3	5	8	8	3	2	6	6	46	50
22	18	12	8	10	10	8	4	8	5	83	90
23	14	8	5	8	8	6	5	6	9	69	75
24	2	1	1	1	1	1	3	9	6	25	27
25	3	2	3	3	4	3	2	5	5	30	33
27	4	4	5	4	6	3	2	5	5	38	41

Table 19. Correlations between water quality and biological condition scores

[Spearman's rho correlation values can range from 0 to 1 or 0 to -1. Negative values indicate an inverse relation. A value of 0 would indicate no correlation between the water-quality factor and the biological condition score, whereas a value of 1 or -1 would indicate perfect correlation. p is one-sided probability value from a t-test]

	Spearman's rho	p
Specific conductance	0.03	0.44
Dissolved oxygen	-0.40	0.02
Turbidity	-0.15	0.22
Suspended solids	-0.34	0.04
Dissolved nitrite plus nitrate	-0.10	0.32
Total ammonia	-0.03	0.44
Total ammonia plus organic nitrogen	-0.21	0.15
Total phosphorus	-0.29	0.14
Dissolved orthophosphorus	0.25	0.11

Water quality (table 2) also can influence biological communities. Biological condition scores were correlated most strongly (table 19) with dissolved oxygen concentrations (Spearmans rho = -0.40, one-sided p-value = 0.02) and suspended solids concentrations (Spearmans rho = -0.34, one-sided p-value = 0.04). There does not appear to be a meaningful and consistent relation between dissolved-oxygen concentration and the biological condition scores for these data (fig. 10); in general, relatively low and relatively high biological condition scores are found through much of the range of dissolved-oxygen concentrations. However, many of the lowest scores are associated with sites that had the highest dissolved-oxygen concentrations and many of the highest scores are associated with sites that had slightly lower oxygen concentrations. At sites where suspended solids concentrations were less than about 125 mg/L biological condition scores were quite variable, ranging from 15 to 42 (fig. 11). At sites where suspended solids concentrations were greater than about 125 mg/L biological condition scores were less variable, typically ranging from 15 to 24. Two sites had suspended solids concentrations exceeding 250 mg/L and biological condition scores exceeding 29. Other water-quality characteristics (specific conductance, turbidity, nitrite plus nitrate, ammonia, ammonia plus organic nitrogen, total phosphorus, and orthophosphorus) compared with biological condition scores were less strongly correlated (absolute values of rho ranged from 0.03 to 0.29) with the scores.

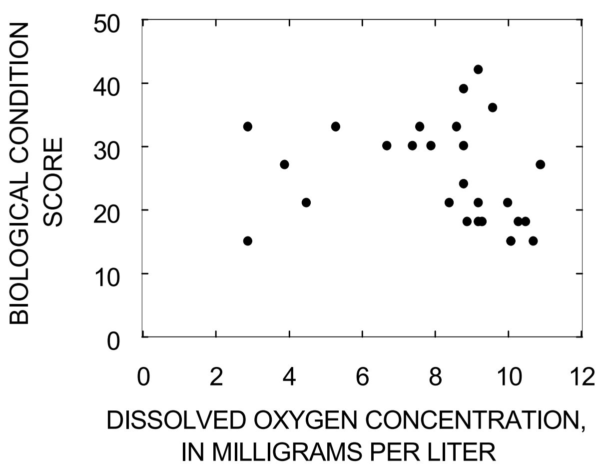

Figure 10. Relation of biological condition score to dissolved oxygen concentration.

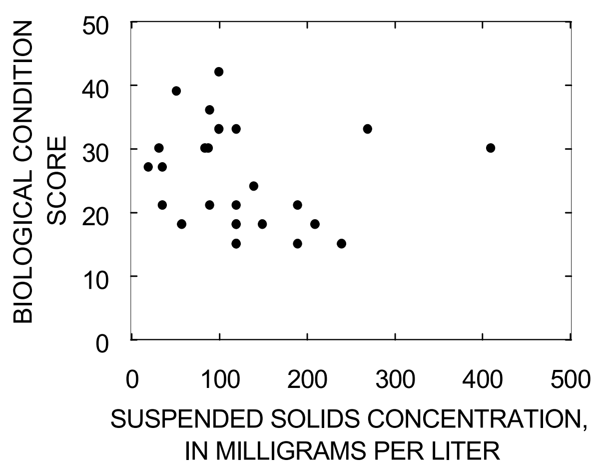

Figure 11. Relation of biological condition score to suspended solids concentration.

SUMMARY

Water-quality and biological samples were collected at 27 sites in the Boeuf River Basin between November 1994 and December 1996. Single water-quality samples were collected at 25 ambient monitoring sites during periods of seasonal low flow; one of these sites was the same site sampled downstream from a forested area during storm events. Storm runoff samples were collected at two sites (one draining a cotton field, one draining a forested area) using automatic samplers during 11 storm events. Ten water-quality samples were collected at one site during the draining of a catfish pond. Benthic macroinvertebrate community samples were collected and habitat was measured at the 25 ambient sites. Collection and measurement occurred on the same date that the water-quality samples were collected.

Water-quality samples from the 25 ambient sites (which were at locations where recent bank, substrate, or channelization disturbances were not evident) indicate that streams in the Boeuf River Basin typically are turbid and nutrient enriched during the late fall during periods of relatively low flow. For example, most suspended solids concentrations ranged from about 50 to 200 mg/L, most total nitrogen concentrations ranged from about 1.1 to 1.8 mg/L, total phosphorus typically ranged from about 0.25 to 0.40 mg/L. These concentrations appear to be slightly higher than typical spring and summer sample concentrations from the Mississippi Alluvial Plain.

Typically the suspended solids and nutrient concentrations from the ambient sites were lower than concentrations in runoff from the cotton field but higher than concentrations in runoff from the forest area. This indicates that suspended solids and nutrient concentration in the Boeuf River Basin are affected by streamflow and land use.

Samples collected during the storm events at the sites downstream from the cotton field and the forested area indicate that suspended solids, total nitrogen, total ammonia plus organic nitrogen, total phosphorus, dissolved orthophosphorus, and dissolved chloride concentrations were significantly different ($p<0.05$) during runoff events at the two sites. Dissolved chloride concentrations typically were higher at the site downstream from the forested area. Concentrations of the other constituents typically were higher downstream from the cotton field. The higher suspended solids and nutrient concentrations may result from soil tillage and fertilizer application at the cotton field. Concentrations of sulfate, chloride, suspended solids and some nutrients in samples from the catfish pond generally were greater than concentrations in samples from the cotton field and forest runoff sites and the ambient sites. Total phosphorus, orthophosphorus, and fecal coliform bacteria concentrations from the catfish pond generally were lower than concentrations in the cotton field or forest runoff and ambient-site samples.

Estimated annual yields of suspended solids, nitrogen, and phosphorus were substantially higher from the cotton field than from the forested area. Yields ranged from about 2 to 27 times greater at the cotton field site than at the forested site.

Biological condition scores for the Boeuf River Basin sites ranged from 15 to 42, compared to 48 for the reference site (table 16). Scores normalized to the reference score (ratios of Basin scores to the reference score) ranged from 31 to 88 percent. Based on these scores most Boeuf River Basin sites would be in the "moderately impaired" category and two sites would be in the "non-impaired" category (Plafkin and others, 1989). However, substantial uncertainty exists in the biological condition category rating because of differing drainage areas, sampling methods, and sampling season between the reference site and sites in the Boeuf River Basin. The biological condition categories presented provide a general and relative assessment of the macroinvertebrate communities at the Boeuf River Basin sites.

Several metrics that are measurements of the tolerance of individuals and taxa in the benthic macroinvertebrate community and that are used in calculating the biological condition scores indicate that the communities at most sites are composed of more tolerant macroinvertebrates than the community at the reference site. Family biotic index values generally were substantially lower at the reference site than at most sites in the Boeuf River Basin, indicating a less tolerant community at the reference site. Two tolerance related metrics (Ratio of EPT to EPT plus Chironomidae, EPT Index) also indicated a less tolerant community at the reference site. The indication of more tolerant communities suggests that sites are organically enriched or otherwise stressed.

Physical habitat scores for Boeuf River Basin sites indicated that most sites had poor habitat related to bottom substrate available cover, embeddedness, and flow and were considered to have poor or fair habitat related to most other factors. Most habitat factors at the reference site were considered good to excellent; only

embeddedness was considered poor. Scores for the Boeuf River Basin sites ranged from 15 to 90 percent of the reference site score.

Physical habitat has a strong influence on biological communities. Part of the variation in biological condition scores for the Boeuf River Basin sites and the reference site was explained by the physical habitat scores. In general, sites with the lowest habitat scores had the lowest biological condition scores. However, a considerable amount of variability in the biological condition scores is not explained by the habitat scores and some sites with low habitat scores are among those with the highest biological condition score totals.

Biological condition scores also were significantly correlated with dissolved oxygen concentrations and suspended solids concentrations. However, in neither case does there appear to be a meaningful and consistent relation between the water-quality characteristic and the biological condition scores; in general, relatively low and relatively high biological condition scores are found through much of the range of dissolved oxygen and total suspended solids concentrations. However, many of the lowest scores are associated with sites that had the highest dissolved oxygen concentrations and many of the highest scores are associated with sites that had slightly lower oxygen concentrations. Also, many of the sites with the highest scores had lower suspended solids concentrations, while many of the lowest scores are at sites with higher suspended solids concentrations. Other water-quality characteristics (specific conductance, turbidity, nitrite plus nitrate, ammonia, ammonia plus organic nitrogen, total phosphorus, and orthophosphorus) compared with Biological Condition Scores were less strongly correlated with the scores.

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