

COST EFFECTIVE / LEVEL 4 CITIZEN MONITORING

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Biographical Sketch of Author

Phil Emmling has an M.S. in Zoology from the Center for Great Lakes Studies at the University of Wisconsin-Milwaukee. Phil has worked as a bench chemist and laboratory manager at the Environmental Chemistry and Technology Program for the last 25 years. He currently volunteers as the Vice-President of Conservation for the Wisconsin Council of the Federation of Fly Fishers. He has an interest in citizen science in aquatic ecosystems.

Abstract

Citizen monitoring programs can provide data for a wide range of educational, stewardship, advocacy, and scientific objectives. The acceptance of citizen monitoring data into agency databases and the transfer of conclusions into public policy have been highly variable from state to state and at the federal level. Water quality professionals have been concerned about the QA/QC of the data. Citizen monitoring programs often minimize the QA/QC concern by limiting data collection to elementary biological surveys, elementary chemical testing, and subjective habitat assessments. This paper presents a low cost, water quality monitoring study combining volunteer labor, limited volunteer testing, and certified laboratory testing.

The results provided a high quality data set for basic water chemistry parameters, total suspended solids (TSS), nutrient concentrations, bacteria numbers (TFC), and benthic macroinvertebrates in Castle Rock Creek, WI. Seasonal and runoff event trends were shown for all of the chemical and bacteria data. Strong correlations were found between turbidity and TSS, total phosphorus and TSS, Kjeldahl nitrogen and TSS, and TFC and BOD_{5d}. Volunteer data for “simple parameters” collected on 22 dates at 7 sites provided additional support for the conclusions and recommendations developed from a limited number of certified laboratory tests. Inexpensive water quality testing kits did not provide acceptable data for ortho phosphorus, ammonium, chloride, and free CO₂. Volunteers did not attempt to perform total nitrogen, total phosphorus, or total fecal coliform and *E. coli* analyses. Biomonitoring results indicated that the stream was generally in good to very good condition with regard to organic pollution. In spite of the assessment provided by biomonitoring indices, Castle Rock Creek would seem to be impacted with regard to organic pollution during runoff events.

INTRODUCTION

Castle Rock Creek is a coldwater trout stream, however, most anglers avoid fishing the creek in spring and summer after a rain event because of the “muddy” water quality. A major fish kill occurred in 1987 after a heavy rain event. Nonpoint pollution sources were the most likely cause of the fish kill. Nonpoint source pollution was considered the primary cause of water quality problems in the Castle Rock Creek watershed (WDNR, 1994). The threat of nonpoint source pollution comes from grazing, the trampling of stream banks, cattle access to the stream, runoff from nearby barnyards and cultivated fields, and improper manure storage and handling. In 1999, water quality fisheries monitoring surveys were conducted (WDNR) to document fish community health prior to a stream stabilization project. In July, the survey found fish community health to be poor and few coldwater indicator species were present. Poor habitat was part of the reason. In August and September, water quality surveys found fluctuating dissolved oxygen and pH levels that are typically an indication of excessive algal growth. Temperature levels were found not to be optimal for trout streams.

The Castle Rock Watershed Committee (CRCWC) was formed to improve the water quality and in-stream habitat of Castle Rock Creek. The CRCWC and the Grant County (WI) Land and Water Conservation District received a \$10,000 State of Wisconsin, River Protection Planning Grant in October 2000. About \$5,300 was provided to complete a volunteer water quality assessment of Castle Rock Creek. It was hoped that increased local awareness of local nonpoint pollution problems in Castle Rock Creek could assist the CRCWC enhance the capacity building of the organization in order to protect and restore the spring creek ecosystem.

MONITORING STRATEGY

Agencies and universities develop and implement rigorous monitoring strategies lasting several years and costing hundreds of thousands or millions of dollars in order to assess the impact of land-use practices on selected stream segments (USGS, 1999; Lombardo et al., 2000). Volunteer monitoring often lacks strategy, experience, and cash. Often the educational experience and “just being out there” can be worthy goals for the novice aquatic ecologist, but of little interest to the professional resource manager or academic aquatic ecologist.

The goal at Castle Rock Creek was to design a monitoring network for assessing the impact of land-use practices on water and habitat quality that would be more similar to a professional monitoring program than an educational experience. A sampling plan was developed to provide temporal (14 monthly, 2 base flow, and 4 runoff event sampling dates) and spatial (7 sampling sites) data. Physical, chemical, and biological parameters were selected that were similar to the parameters that professionals would use to characterize the impact of agricultural runoff on the stream. The sampling and analytical protocols needed to provide representative samples and reliable data and have a minimum of QA/QC concerns. The Wisconsin Department of Natural Resources (WDNR), the University of Wisconsin-Stevens Point, Environmental Task Force Laboratory (UWSP-ETFL) and College of Natural Resources (UWSP-CNR), the Wisconsin State Laboratory of Hygiene (WSLH), and the University of Wisconsin-Madison, Environmental Chemistry and Technology Program (EC&T) were contacted concerning physical, chemical, and biological sampling and analytical procedures. Professionals completed protocols and procedures considered too difficult for volunteers. Professional testing services were kept to a minimum in order to remain within the limited monitoring budget of the grant (\$5,300). The Internet was searched for climate and other useful physical data at no cost to the project.

METHODS

Sample Site Locations

The main channel of Castle Rock Creek is a third order stream draining three sub-watersheds and one spring tributary. The drainage area is about 40 mi² or 100 km². The land-use in the watershed (aerial photos 1993) was 8.34% corn, 6.42% other row crops, 41.87% forage crops, 13.57% grassland, 26.52% mixed deciduous forest, 2.37% conifer forest, and <1% high and low density urban. The monitoring network consisted of 5 main channel and 2 tributary sampling sites distributed along approximately 2 ½ miles of stream (Figure 1). Site 5 was the furthest upstream location and coincided with a WDNR Total Maximum Daily Load (TMDL) development site draining the Fennimore Branch and the Gunderson Valley Branch. The stream sections are located upstream from Site 5 and are listed as 303 (d) Impaired Water. Site 4 receives a mixture of water from Site 5 (~1-3cfs) and small bubbling springs (~8-10cfs). Site 3 contains a mixture of spring tributary water (Site 7) and water from Site 4. Site 2 was chosen to assess the downstream impact of the Doc Smith Branch tributary (Site 6). Site 1 was selected as the furthest downstream sampling location and the end of the special regulation trout fishing water. Tributary Site 7 monitors a spring channel that provides very good quality ground water to the system. Site 7 provides a reference area or benchmark for the monitoring network. A USGS real-time stage height gauging station was established downstream from Site 5 during July 2001. The sample sites were monitored on 22 dates from November 3, 2000 until December 8, 2001.

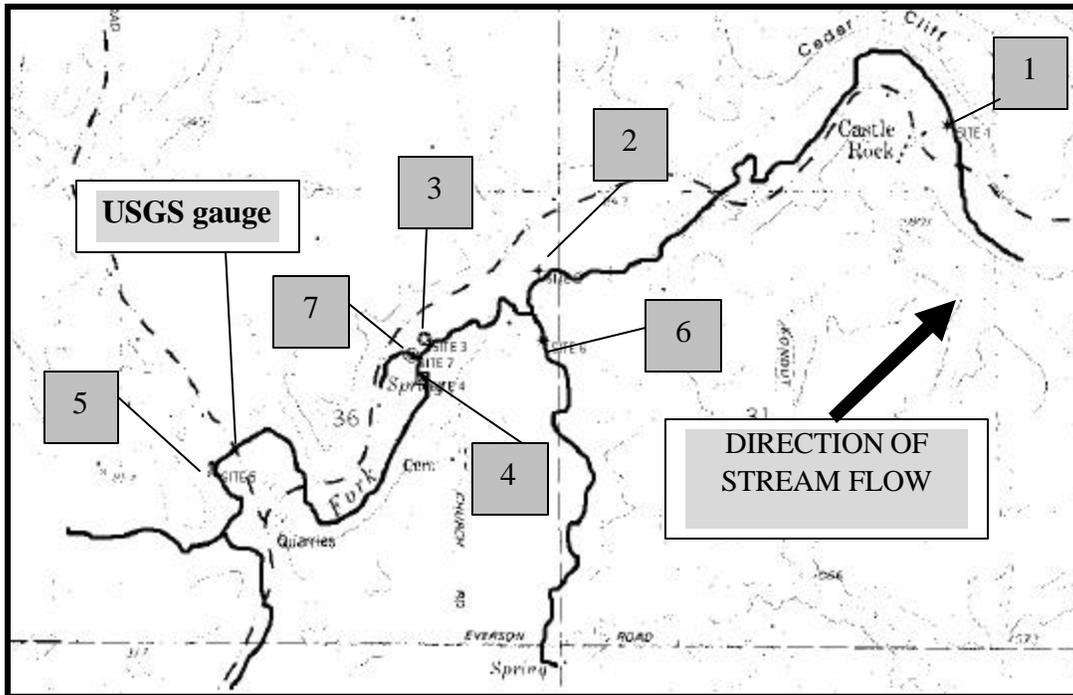


Figure 1. Location of Castle Rock Creek sample sites and U.S.G.S. stage height and discharge gauge.

Physical Parameters

Physical data were measured at the sampling sites and obtained from several sources on the Internet. On-site data included stream velocity, transect width and depth, stage height, rainfall, and air and water temperature. Internet data included real-time stage height, area rainfall, historical rainfall, and historical average monthly temperature.

The stream velocity data were measured with a Price Pygmy current meter (Buchanan and Somers, 1984). The meter was borrowed from the EC&T program. Stream width was measured with a fiberglass tape reel. Stream depth was measured with a meter stick.

Stage height (water level) was read on each sampling date from white, porcelain, calibrated, stage height boards (Forestry Suppliers, Inc.). The stage height boards measure the water height variation between 0.00 and 3.30 feet. The boards were placed next to shore and positioned at 1.00 foot regardless of water depth on March 20, 2001.

A real-time, stage height recording station was installed by WDNR and USGS in July 2001. The PS-2 pressure sensor gauge is accurate to within 0.01 foot.

Ambient air and water temperatures were recorded at all 7 sites and on all 22 sampling dates. Alcohol-filled thermometers were used to measure water temperature. Mercury-filled thermometers were used to measure air temperature. All thermometers were calibrated against a certified (NIST) thermometer placed in a constant temperature water bath at EC&T.

Weather data were obtained from the State of Wisconsin, Midwest, and University of Illinois-Champaign Climatologic Centers. The climate data were collected at Wisconsin stations located near the sample sites

(Lancaster, Muscoda, Dodgeville, and Platteville, WI). Volunteers maintained three rain gauges that were installed at their homes located within the watershed.

Chemical Sampling and Analyses

Water chemistry parameters were measured in the field and on water samples collected monthly (14) and during base flow (2) and runoff events (4). Water samples were collected as grab samples. A flow chart of the sample collection and handling procedures for chemical and bacteriological testing is provided in Figure 2.

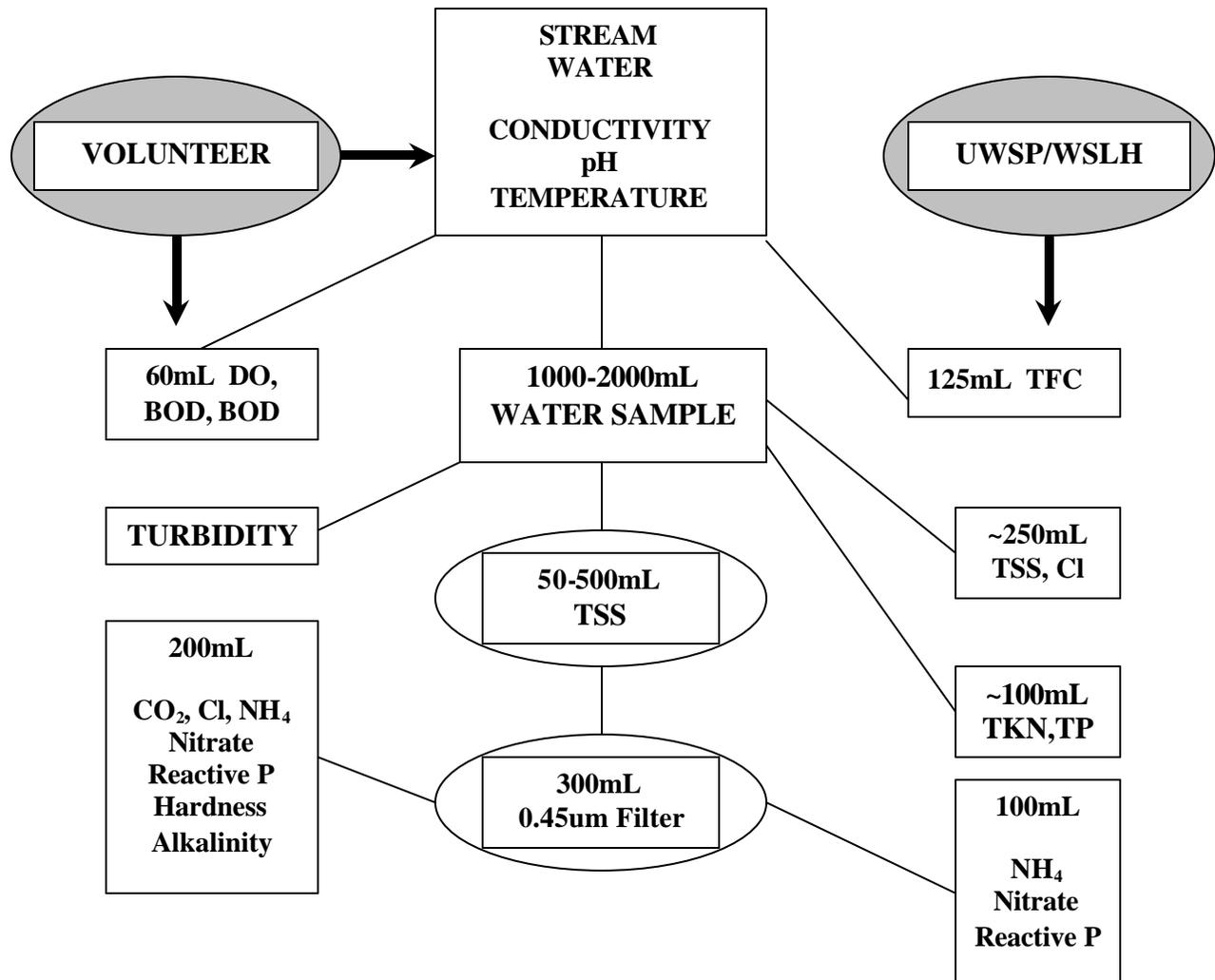


Figure 2. Field sampling and sample handling.

Water quality data collected at the time of sampling were hydrogen ion concentration (pH), specific conductivity, and temperature. The pH probe was calibrated with buffered test solutions at pH 4, 7, and 10 on the night before each sampling trip. The conductivity tester was calibrated with conductivity standards at 445 and 718uS on the night before each sampling trip. Standards and extra batteries were included on every sampling trip.

Bulk water grab samples were collected in 1 clear and 2 amber tinted 60mL glass bottles with polypropylene Polyseal® caps for dissolved oxygen (DO-1 clear bottle) and biochemical oxygen demand (BOD-2 amber

bottles). The percent saturation of dissolved oxygen was calculated from tabulated data for the solubility of oxygen in water at the temperature of the stream during DO and BOD sampling.

Bulk water, grab samples were collected in clean, brown polyethylene, wide-mouth 1000 or 2000mL containers. A 200-250mL aliquot was refrigerated, shipped on ice to the UWSP-ETFL, and tested for TSS and chloride. A 100mL aliquot was acidified with 1:1 sulfuric acid to pH<2 (3 drops), refrigerated, shipped on ice to the UWSP-ETFL, and tested for total Kjeldahl nitrogen (TKN) and total phosphorus. A 50-500mL aliquot was filtered through a 934/AH glass fiber filter (1.5um pore). When the filter became clogged with solids, additional filters were used until 300ml of filtrate was obtained. The 300mL of filtrate were filtered through a nylon filter (0.45 um pore) and the filtrate was split into a 100mL UWSP-ETFL (2 base flow and 4 event dates) and a 200mL volunteer (22 sampling dates) dissolved fraction. The UWSP-ETFL fraction was acidified with 1:1 sulfuric acid to pH<2 (3 drops), refrigerated, shipped on ice, and analyzed for ammonium-nitrogen, nitrite+nitrate-nitrogen, and reactive phosphorus. The volunteer dissolved fraction was refrigerated and analyzed within 24 hours for free carbon dioxide, chloride, ammonium- nitrogen, nitrite+nitrate- nitrogen, reactive phosphorus, total alkalinity, and total hardness.

Turbidity measurements were made at home on bulk water samples and within 12 hours of sampling. A Hach 2100P portable turbidimeter was used to measure turbidity in nephelometer turbidity units (NTU). The unit was borrowed from EC&T. Turbidity was not measured in the field because the measurement cell could not be kept free of condensation moisture and dirt.

The UWSP-ETFL chemical testing was performed on 2 base flow and 4 runoff event samples. The UWSP parameters included chloride, ammonium-nitrogen, nitrite + nitrate-nitrogen, total Kjeldahl nitrogen (TKN), reactive phosphorus, total phosphorus, and total suspended solids (TSS). The UWSP-ETFL charge for the analyses was \$50 per sample or \$350-400 per event. The methods and detection limits are listed in Table 1.

Volunteer chemical testing was performed on 14 monthly, 2 base flow, and 6 runoff event samples. The volunteer chemistry methods and detection limits are listed in Table 2.

Biochemical oxygen demand (BOD) sampling has been described in this report. Three replicate water samples were obtained at all sites during every sampling trip. One sample was “fixed” for DO at the sampling site. DO was determined on the sample within 12 hours of acid “fixing” the sample. The two additional samples were incubated in a volunteer’s basement in the dark at 20°C for 5 days. After 5 days, the BOD test was completed. Two DO tests were performed on each replicate BOD sample. Comparable BOD tests were performed at the Fennimore Sewerage Treatment plant on creek water and sediment suspensions collected on May 4, 2001.

Bacteria Sampling and Testing

Bulk water grab samples (125mL) were taken on 2 base flow and 4 runoff event dates in order to determine the number of total fecal coliform (TFC) bacteria in the creek water. Additional testing for *E. coli* bacteria was performed on a summer runoff sample (August 2, 2001) and a summer base flow sample (August 21, 2001). The Wisconsin State Laboratory of Hygiene (WSLH) provided 150mL, custody sealed, sterile plastic, wide-mouthed sample bottles, shipping supplies, and instructions. TFC and *E. coli* bacteria numbers are expressed as colonies per 100mL of water sample. The tests for TFC (9215 B.) and *E. coli* bacteria (9221 F.) are described in Standard Methods for the Examination of Water and Wastewater (APHA, 1995). The charge per test was about \$9-12.

Biomonitoring

Macroinvertebrate organisms were kick-sampled with a D-frame net at 7 sites on November 4, 2000, April 3, 2001, and November 3, 2001. Macroinvertebrate sampling followed the WDNR guidelines (WDNR, 2000). All samples were taken from riffle areas. Volunteers picked all the organisms (20,912) contained in the 21 samples.

| Analyses | Method | Method Detection Limit |
|-----------------------------|---|-------------------------------|
| Chloride | Automated Ferricyanide 4500 C1 E | 0.2 mg/L |
| Nitrogen, Ammonia | Automated Salicylate 4500-NH ₃ G | 0.01 mg/L |
| Nitrogen, Nitrite + Nitrate | Automated Cadmium Reduction 4500-NO ₃ F | 0.021 mg/L |
| Nitrogen, Total Kjeldahl | Block Digester; Auto Salicylate 4500-NH ₃ G | 0.08 mg/L |
| Phosphorus, Reactive | Automated Colorimetric 4500 P F | 0.003 mg/L |
| Phosphorus, Total | Block Digester, Automated 4500 P F | 0.012 mg/L |
| Total Suspended Solids | Gravimetric 2540 D | 2.0 mg/L |

Table 1. UWSP-ETFL water chemistry analytical methods.

| | | |
|-----------------------------|--|--------------------------------------|
| Chloride | La Motte 4503-DR Direct Reading Titrator | 0-200 ppm/ 4ppm |
| Nitrogen, Ammonia | La Motte 3351-01 Octa-Slide Nessler Method | 0.2-3.0 ppm |
| Nitrogen, Nitrate + Nitrite | La Motte 3519 NCR-2 Octet Comparator | 0.25-10 ppm |
| Phosphorus, Reactive | LaMotte 3119 NPL Octet Comparator | 0.2-0.8 ppm/ 0.2ppm |
| Total Suspended Solids | Gravimetric 2540 D Drying 24 hrs. @ 60C | 0.2 mg/L |
| Dissolved Oxygen | La Motte 5860 Winkler Titration | 0.2 mg/L |
| Biochemical Oxygen Demand | La Motte 5860 Winkler Titration | 0.2 mg/L |
| Free Carbon Dioxide | La Motte 7297-DR Direct Reading Titrator | 0-50 ppm/1ppm |
| Total Alkalinity | La Motte 4491-DR Direct Reading Titrator | 0-200 ppm/ 4ppm as CaCO ₃ |
| Total Hardness | La Motte 4482 DR-LT Direct Reading Titrator | 0-200 ppm/ 4ppm as CaCO ₃ |
| pH | Oakton pH Testr™ 2 | 0.1 pH unit |
| Specific Conductivity | Oakton TDS Testr™3 | 0-1990 uS/ 10 uS |

Table 2. Volunteer water chemistry analytical methods.

The time required to pick each sample containing arthropods and aquatic vegetation was about 3 hours. A 2x magnifying lamp was used for a final inspection in each sample aliquot.

Samples collected on November 4, 2000 from sites 3, 5, and 7 (3171 organisms) were sent to the UWSP-CNR for identification, calculation of several biotic water quality indices, and discussion of results. Sites 3, 5, and 7 were chosen for detailed processing because these samples contained approximately 69% of the total number of arthropods and 98% of the arthropod taxa collected at all 7 sites. The reports provided a “short list” of arthropod families, genera, and species living in the entire sampling area. The “short list” helped volunteers process biomonitoring samples from Sites 1, 2, 4, and 6. Samples collected on April 3 and November 3, 2001 were picked and sub-sampled according to the UWSP-CNR protocols (UWSP-CNR, 1999). A total of 5-10 sub-samples were obtained from each April 3 and November 3, 2001 sample. A volunteer processed 3 sub-samples from each of the 14 samples in order to calculate a Family Biotic Index (Hilsenhoff, 1988) value for each sub-sample and a mean FBI for the composite sample. An additional sub-sample from the April 3 and November 4, 2001 sampling at Sites 3,5,and 7 was sent to UWSP-CNR for identification, calculation of several water quality biotic indices, and discussion of results.

RESULTS AND DISCUSSION

Physical Data

Stream velocity, width, and cross sectional area measurements were made at all 7 sites in November and December 2000 and January 2001. Site 7 had a hard gravel bottom and a rectangular shaped channel. The mean velocity was 1.20fps and the calculated mean discharge was about 8-10cfs. Site 4 located upstream had a base flow discharge of about 15cfs. Site location was found to be critical to obtaining these measurements and calculating stream discharge. Stream discharge at Castle Rock Creek was difficult to measure due to fine sediments near the shore, numerous back eddies, large mats of vegetation, and random boulders in the streambed. The Price Pygmy meter had an accuracy of 0.1fps, however, the minimum velocity required to consistently turn the cups (0.3fps) was difficult to find during winter base flow. In addition, the time required to complete the measurements (~30 minutes per site) was too long to allow for the other sampling tasks. No additional discharge measurements were performed after January 6, 2001. Volunteers generally measure stream velocity using a float (orange, rubber ball, etc.), however, the mean velocity for the water column at a given point may be 15% greater than the surface velocity measurement (Buchanan and Somers, 1984).

Stream stage height measurements were taken at Sites 1,2,3, and 7 after March 20, 2001. The mean stage height values for Sites 1,2,3,and 7 for 17 dates were 1.16, 1.15, 1.14, and 1.14 feet respectively. The mean values were 0.16, 0.15, 0.14, and 0.14 foot above the initial set point of 1.00 foot. The average creek level was about 0.15 foot higher than level recorded on March 20, 2001. There are no long-term USGS monitoring wells in this watershed. If the stage height boards remain in place at the creek, future stage height monitoring may describe the impact of additional high capacity water use in the watershed.

The WDNR and USGS placed a real-time stream flow recording station about 200 yards downstream of Site 5 in July 2001. The gauge provided discharge data for a sediment and nutrient TMDL development study. The TMDL study was the first indication that the preliminary results of the volunteer monitoring effort were attracting agency attention to Castle Rock Creek. The real-time gauge provided highly valuable information about the magnitude and duration of runoff events at the creek (Figure 3).

Water temperature was measured on each sampling date (22) at all 7 sites. The water temperature of the spring tributary (Site 7) ranged between 9° and 10° C (Figure 4). Site 3 was located about 200 yards downstream of Site 7 and had the next smallest range of temperature values (7-16° C) due to the high percentage (40%) of discharge coming from Site 7. Site 5 was the furthest upstream location and had the largest range of temperatures (0-21.5° C). Data collected by the USGS discharge gauge in December 2001 showed that stream flow at Site 5 was being

reduced and increased daily by the diurnal freezing and thawing cycle. The mean water temperature of all 154 measurements was nearly 10°C. The Wisconsin State Climatology Center provided mean monthly air temperature data and a summary for about 100 years at four stations located near the sampling area. The mean monthly air temperature of the four stations was plotted with the water temperature data (Figure 4). Mean ambient air temperature controlled the water temperature of Sites 1,2,4,5, and 6. Ground water temperature controlled the water temperature at Site 7. A mixture of water from Site 7 and Sites 4-5 moderated the water temperature at Site 3.

Castle Rock Creek temperature data were entered into a fish bioenergetics model (Hanson et al., 1995). The model was run for steelhead trout and suggested that a coldwater fish would lose weight from the middle of June through September due to high specific respiration rates produced by higher than optimum water temperatures. The bioenergetics model was run without data for brown and brook trout and using a hypothetical initial weight of 200 grams and weight gain of 50 grams in 365 days.

Ambient air temperature was recorded on each sampling date (22) at all 7 sites. These data were not used for further analysis.

Water Chemistry Data

Water Chemistry Method Evaluation

Volunteer probe measurements for temperature, pH and specific conductance produced accurate, precise, and reproducible data.

Volunteer, water chemistry, titration methods produced positive measurement errors because the true concentrations were usually exceeded at the titration end point (color change). Using a smaller drop of titrant or increasing the amount of sample can increase the accuracy of titration tests. The procedure for chloride testing had an end point that was difficult to determine and generally produced values 10-20% higher than the UWSP-ETFL values. The procedure for free CO₂ had an end point (faint pink) that was difficult to determine. Volunteer chloride and CO₂ data were not used in this report. Volunteer titration measurements for dissolved oxygen, biochemical oxygen demand, total alkalinity and total hardness produced very useful data.

Volunteer, water chemistry, color comparator tests add reagents to a measured volume of sample and produce a colored reactant in a specific amount of time (1-10 minutes). The values for analytical nitrate standards obtained with the La Motte Co. color comparator test were found to agree well with the values obtained using a Varian DMS 80, UV-VIS Spectrophotometer (540 nm). The volunteer chemistry nitrate nitrogen data were not reported because more accurate data were obtained from the certified laboratory (UWSP-ETFL). The limits of detection for ammonium-nitrogen (0.200-0.500mg/L) and reactive phosphorus (0.200-0.500mg/L) color comparator tests were determined to be too high for monitoring the water quality of Castle Rock Creek.

Hydrogen Ion – pH

The pH was measured at each site on every sampling trip. The measurements were made during daylight hours between 630 and 1730 hours. The spring tributary (Site 7) had a range of 7.4-7.6. The pH range at Sites 1-6 was generally 8.0-8.9 except on June 18, August 2, and October 23, 2001 when the ranges were 7.8-8.2, 7.6-7.7, and 7.8-8.1 respectively. Photosynthetic activity probably raised the pH at Sites 1-6 above pH 8.0 during base flow conditions. Rainwater entering the system during the runoff events on June 18, August 2, and October 23, 2001 lowered the pH below 8.0. Rainwater samples collected by volunteers on April 5-7, April 9-12, and August 1-2, 2001 recorded pH values of 5.7, 6.3, and 5.4 respectively.

Specific Conductivity, Total Hardness, and Total Alkalinity

Specific conductivity, total hardness, and total alkalinity were measured at each site on every sampling date. Base flow conductivity (550-750uS) and total hardness concentrations (300-350ppm) were produced by dissolved concentrations of calcium (72-82ppm), magnesium (35-42ppm), sodium (4.5-9.5ppm), and potassium (2.8-6.7ppm) characteristic of the regional limestone and sandstone soils and aquifers. Major cations were determined by ICP analysis at EC&T. Alkalinity values were generally 320-360ppm as CO_3^{2-} . The largest range for all three parameters was reported at Site 5 and the smallest range was reported at Site 7. Conductivity data for each site and sampling date are illustrated in Figure 5. The lowest values for conductivity were recorded during the August 2, 2001 runoff event. The conductivity of rainwater was about 30uS. Conductivity values for Sites 1-6 on August 2 were about 70% (435uS) of the base flow average value (~600uS) and suggest that 25-30% of the sample contained runoff water. Conductivity data could be used to estimate the increase in discharge during runoff sampling.

Dissolved Oxygen and Percent Saturation of Dissolved Oxygen

Dissolved oxygen (DO) and temperature were measured at each site on every sampling trip. The DO values, measured between 630 and 1730 hours, were above the WDNR recommended lower limit for coldwater fishes (6.0mg/L) except at Sites 4,5, and 6 during the August 2, 2001 runoff event (5.7, 5.6, and 5.6mg/L). DO % saturation values less than the 10th percentile of the data at Sites 1-6 occurred on June 18 and August 2, 2001 (Figure 6). On August 2, 2001 the combined effects of a late evening, bimodal rain event, night hours, and very high turbidity during the daylight hours prevented oxygen production by photosynthesis and extended the diurnal respiration period in the creek.

Total Suspended Solids

The most noticeable characteristic of the water quality at Castle Rock Creek was that it was very “muddy” during and after a snowmelt or rainfall runoff event. Total suspended solids (TSS) measurements quantified “muddy” on each of the sampling dates. The terms total suspended solids and total suspended sediments (inorganic and organic) can be considered synonyms for this data set. TSS values ranged from 0-1196 mg/L (Figure 7). Monthly and winter and summer base flow TSS values were generally <10mg/L from mid August through February. The highest TSS values for Sites 1-6 were recorded on the two largest runoff events (June 18 and August 2, 2001). The spring tributary (Site 7) and Site 5 averaged 0.4mg/L and 18.4mg/L for 14 low flow dates and 0.4mg/L and 362.5mg/L for 8 higher or event flow dates. TSS measurements were strongly correlated ($r^2 = 0.986$) to turbidity values measured with a portable turbidimeter (Figure 8).

Chloride

Chloride was measured in 2 base flow and 7 runoff event samples. Site 5 had the largest range of chloride values and a mean chloride concentration of 26.1 mg/L. Site 7 has the smallest range of chloride concentrations and a mean chloride level of 8.3 mg/L. The tributary sites, Site 6 and Site 7, dilute the chloride concentrations above Site 2 and Site 3 respectively. Chloride concentration decreased downstream. Perhaps Site 5 represented a “point” source and the concentration was diluted as the channel volume increased. Chloride may be useful as a conservative tracer for overland runoff from cattle operations and domestic sewerage systems.

Nitrogen

Nitrogen was analyzed at the UWSP-ETFL as nitrite+nitrate, ammonia/ammonium, and total Kjeldahl nitrogen. Nitrate concentrations ranged between 4-6 mg/L. Site 7 had a mean concentration of 4.0mg/L nitrate. Site 5 had a mean concentration of 5.8mg/L nitrate. Nitrate values decreased during runoff events indicating that ground water was the major source of nitrate and the rain and runoff water diluted the base flow concentrations.

Ammonium nitrogen was present in low concentrations in Castle Rock Creek. Base flow ammonium nitrogen values on December 4, 2000 and August 21, 2001 were below the limit of detection (0.01mg/L) at all sites. The highest ammonium values were measured during the August 2 and October 23, 2001 runoff events. Ammonium values at Site 7 were less than the detection limit (0.01mg/L) except on August 2, 2001 (0.02mg/L). The mean ammonium concentration measured on five runoff dates was 0.40 at Site 5.

Total Kjeldahl nitrogen (TKN) analyses measure organic and ammonium nitrogen in bulk water samples. TKN was measured at 7 sites on 7 sampling dates. TKN values were less than 0.50 mg/L at all sites in the winter and summer base flow samples. TKN values at the spring tributary (Site 7) were not significantly higher during runoff events (0.10mg/L) than during base flow (0.08mg/L). The mean TKN concentration measured on five runoff dates at Site 5 was 4.94mg/L. TKN levels were positively correlated ($r^2 = 0.87$) to total suspended solids at Castle Rock Creek (Figure 9). These data suggest that overland runoff supplies TKN to the creek.

Phosphorus

The phosphorus species measured in Castle Rock Creek samples included reactive and total phosphorus. Reactive phosphorus values had a spatial and temporal distribution similar to ammonium nitrogen. The highest reactive phosphorus values were measured during the August 2 and October 23, 2001 runoff events. The range of values at Site 7 was 0.027-0.035mg/L. The mean concentration of reactive phosphorus at Sites 1-6 was 0.038 and 0.069mg/L at winter and summer base flow. The mean concentrations at Sites 1-6 were 0.143 and 0.208mg/L on two snowmelt runoff events (April 2001) and 0.207, 0.309, and 0.252mg/L on three rain runoff events (June 18, August 2, and October 23, 2001).

Total phosphorus concentrations were approximately 2-30 times higher than the reactive phosphorus concentrations at Sites 1-6 during runoff events. The total phosphorus concentration range at Site 5 was 0.066 mg/L on December 2, 2000 to 3.040 mg/L on August 2, 2001. The spring tributary (Site 7) had consistently low values for total phosphorus (0.039-0.051 mg/L). Total phosphorus values had a spatial and temporal distribution similar to ammonium, TKN, and reactive phosphorus. Total phosphorus data were positively correlated ($r^2 = 0.94$) to total suspended solids data at Castle Rock Creek (Figure 10). This is consistent with the general tendency of phosphorus to attach to soil particles and move with runoff to surface water (USGS, 1999). These data suggest that overland flow supplies total phosphorus to the creek. Excessive aquatic plant growth and eutrophication in freshwater generally result from elevated (total) phosphorus concentrations (typically greater than 0.1 mg/L). Every runoff event measurement at Sites 1-6 exceeded 0.1 mg/L at Castle Rock Creek. On August 2, 2001, the spring tributary (Site 7) recorded a total phosphorus value of 0.165 mg/L.

Biochemical Oxygen Demand

The biochemical oxygen demand (BOD) determination is an empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters, effluents, and polluted waters (APHA, 1995). BOD measurements >8 mg/l were probably an underestimate of the BOD because these samples should have been diluted with a standard BOD dilution "cocktail." The Fennimore Sewerage Treatment Plant diluted a May 4, 2001 sample from Site 5 and reported a BOD level of 20.4 mg/L. The volunteer BOD level at Site 5 on May 4, 2001 was 8.9 mg/L or the entire initial DO in the BOD bottles. The Fennimore staff reported a BOD level of 5.6 mg/L for Site 4 and the volunteer BOD level was 4.9 mg/L. A valid BOD agency measurement requires that the final DO should be >2 mg/L.

There were 154 volunteer BOD determinations performed on the monthly, base flow, and runoff event samples at Castle Rock Creek (Figure 11). The spring tributary (Site 7) never recorded a BOD > 0.8 mg/L. BOD values at Site 5 indicate a much greater oxygen-demanding load than at Site 7. Every runoff event produced a measurable BOD response at Sites 1-6. BOD spatial and temporal response provided the most sensitive analytical indication that runoff water and organic pollution were entering the creek.

It is probable that the BOD test responded to increased aerobic respiration from bacteria and other microbial organisms entering the creek. A graph of the BOD response to numbers of total fecal coliform (TFC) bacteria on 8 sampling dates at all 7 stations indicated a linear relationship ($r^2 = 0.726$) between BOD and the natural log of TFC counts (Figure 12). The correlation would probably improve if the BOD test were performed according to USEPA protocols (APHA, 1995).

Mitchell and Stapp (1997) suggest a water quality index for the volunteer assessment of surface water using BOD measurements. The index rates the water quality with respect to BOD as excellent ($<2.0\text{mg/L } /5_d$), good ($2.0\text{-}4.0\text{mg/L } /5_d$), fair ($4.1\text{-}10.0\text{mg/L } /5_d$), and poor ($>10.0\text{mg/L } /5_d$). The Castle Rock Creek data, however, would not have a BOD >10.0 because the initial DO from mid April through October would seldom be 10.0 mg/L and the BOD tests were not diluted before incubation. Nevertheless, the BOD index could be a very useful tool to determine the presence and degree of organic pollution in streams.

Bacteria Data

TFC bacteria colonies per 100mL of water ranged from <10 to 670,000. TFC values at the spring tributary (Site 7) were three to four orders of magnitude lower than the Doc Smith Branch (Site 6) and the main channel locations (Sites 1-5). TFC values at the spring tributary (Site 7) were 10-30/100mL except on June 18, 2001 (160 /100mL) and August 2, 2001 (290 /100mL). The mean TFC /100mL value for Sites 1-6 during 2 summer and 1 fall runoff events (June 18, August 2, and October 23, 2001) was 378,017.

TFC bacteria represent a significant water quality problem in the main channel (Sites 1-5) and Doc Smith Branch (Site 6) during spring, summer, and fall runoff events. It should be noted that the August 2, 2001 specific conductivity and total hardness data suggest that 25-30% of the creek water was runoff or 75-70% creek water was base flow having a low TFC. Therefore, the TFC runoff stream at Sites 1-6 may contain 4 to 3.3 times the number measured in the creek. The overland runoff flow at Site 5 on August 2, 2001 could have brought 2,560,000 to 2,112,000 TFC /100mL to Castle Rock Creek.

TFC and *E.coli* bacteria counts were compared during a summer runoff event (August 2, 2001) and summer base flow (August 21, 2001). TFC counts were similar to *E.coli* counts for 13 of 14 paired tests. The sample collected on August 2, 2001 at Site 5 contained 640,000 TFC/100mL, however, only 74,000 *E.coli*/ 100mL. Site 5 was the only sampling location having any canopy cover (25%), leaf litter and woody debris in the streambed. The unidentified bacteria may belong to the genus *Klebsiella* that is common in woody debris and can test positive in a TFC test.

Biochemical oxygen demand data were positively correlated to the log of TFC counts at Castle Rock Creek. Neither TFC counts nor BOD values, however, were linearly correlated to TSS. The data suggest that TFC and TSS enter Castle Rock Creek during runoff events but the bacteria are not attached to the inorganic fraction of the suspended sediment. In addition, bacteria and inorganic soil particles composed of silica have negatively charged surfaces at a $\text{pH} >3$ implying that these particles may repel each other. The higher density inorganic soil particles quickly drop out of the water column, because of the flashy hydrograph, however, the low-density bacteria and organic matter may be transported long distances in the creek. The BOD impact on the stream can remain high in spite of a return to relatively clear water transparency. For example, samples collected near the end of the runoff event on October 23, 2001 at Sites 1-6 had a low mean value for TSS (52.9mg/L), a very high mean value for TFC ($212,000 /100\text{mL}$), and a high mean value for BOD ($4.7\text{mg/L}/5_d$).

Biomonitoring Data

Twenty-one families of aquatic arthropods were identified from samples collected at all 7 sites on November 4, 2000, April 4, 2001, and November 3, 2001. Ten families contained over 99% of the organisms (Figure 14). Crustaceans and caddisflies were the most abundant arthropods within the monitored area.

Macroinvertebrates, and especially arthropods, are an important component of the aquatic ecosystem and have long been used to evaluate the water quality of streams. Hilsenhoff reviewed the literature and produced a biotic index (HBI) to evaluate water quality in Wisconsin streams (Hilsenhoff, 1987). Hilsenhoff developed a Family Biotic Index (FBI) as a rapid field assessment of organic pollution (Hilsenhoff, 1988). The HBI and FBI indices were calculated and used to characterize the water quality of Castle Rock Creek. The HBI and FBI simply represent the average weighted pollution tolerance value of all arthropods present in a sample, excluding those organisms either too immature or damaged to allow correct identification, and those organisms that have not been assigned a pollution tolerance value.

HBI values were calculated at the UWSP-CNR for Sites 3,5, and 7 on the three collection dates. Site 7 had an initial score of 6.14 and a water quality rating of “fair” or having fairly significant organic pollution. One species of arthropod (Isopoda, Asellidae, *Caecidotea brevicauda brevicauda*) was assigned an HBI tolerance value of 8.00 (very significant organic pollution) and was so numerous (62%) that an incorrect HBI value was calculated for Site 7. The HBI was 3.15 without the isopod score. The isopod data were excluded from the FBI and HBI calculations because the organism has no species tolerance value and the family value of 8.00 is too high.

The FBI criteria for 21 samples (Sites 1-7) imply that 8 scored excellent, 9 scored very good, and 4 scored in the range of good water quality. The HBI criteria for 9 samples (Sites 3,5,and 7) imply that 4 scored excellent, 1 scored very good, 3 scored good, and 1 scored fair. The HBI and FBI calculations generally support the conclusion that the water quality of the main channel (Sites 1-5) and Doc Smith Branch are good to very good and the water quality of the spring tributary (Site 7) is excellent with respect to the degree of organic pollution.

Lillie et al. (2002) explain that there are no strict rules to assign qualitative designations to a sample metric. According to the authors, it is extremely important to emphasize the fact that the HBI and FBI are indices of **organic** pollution and are based on a community’s response to the combination of high organic loading and decreased dissolved oxygen levels. Generally, the FBI underestimates the severity of pollution in highly polluted streams and overestimates the degree of impact in clean streams. Sampling in sites not meeting established criteria (e.g., inadequate flows velocities, snags or pools rather than riffles) seriously limit the use of the HBI and FBI. Species richness and diversity indices generally vary directly with water quality and low diversity may indicate an unstable community. However, cold, clean, headwater streams (Site 7) may have low species richness and diversity and still represent excellent water quality.

SUMMARY

Volunteer monitoring can provide quality rapid assessment data to agencies and preliminary data to academic researchers at a modest cost. The Castle Rock Creek case study provided numerous examples of the benefits of advanced citizen monitoring.

Most stream sections in the United States have little or no water quality and habitat data. The Castle Rock Creek data set represents the most complete set of physical, chemical, and biological measurements ever compiled for the stream. The data set is being added to the USEPA STORET database. The data have been sent to the volunteer stream monitoring program in Montana and will be used as an educational database representative of a Midwest trout stream. The Castle Rock Creek monitoring program was featured in the Winter, 2002 issue of the Federation of Fly Fisher’s quarterly magazine. The author has become a resource to volunteer monitoring groups in Wisconsin, other states, and the USEPA Web-site listserver.

The monitoring program has provided information to resource management agencies. The TFC and *E. coli* data persuaded WDNR to monitor bacteria in the TMDL work. The % DO saturation data indicate that high amounts of nutrients are being retained in the creek. Specific conductivity, total hardness, and total alkalinity data suggest a method to estimate the volume of runoff and the pollutant load entering the creek. The biomonitoring phase defined the distribution of 20, 912 arthropods at 7 sites in spring and in fall samples. The spring tributary (Site 7)

data suggest the water quality potential of Castle Rock Creek. The main channel (Sites 1-5) and Doc Smith Branch (Site 6) data describe the consequences of land-use practices in the watershed on the water quality of the creek. The temperature data suggest that the stream restoration goals should consider making the stream narrower and deeper in order to maintain optimum temperatures for a coldwater sport fishery.

Volunteer Mr. Michael Smith encouraged the USEPA to fund WDNR to develop a sediment and nutrient TMDL. The TMDL study produced a GIS land-use map of the watershed. The TMDL study installed a real-time stage height and discharge gauge with Internet access. Preliminary monitoring data helped the Castle Rock Creek Watershed Committee and Grant County obtain a second \$150,000 Targeted Runoff Management grant for cost-shared BMP work. The nutrient and bacteria data indicated that a significant BMP effort should be directed toward barnyard and manure handling practices.

The spatial and temporal trends in the data and correlations between parameters suggest additional nonpoint source pollution and fishery bioenergetics questions that are worthy of academic interest. What are the chronic effects of high respiration and photosynthetic activity on the biology and chemistry of streams? How far downstream does a barnyard affect the BOD load? Can chloride be used as a conservative chemical tracer for nutrient inputs to streams from manure? How does the temperature cycle at Castle Rock Creek affect the growth rates of brown and brook trout? What is the tolerance value of individual isopod species?

These data have been useful for educators, agencies, advocates, and academics because of the professional design of the network, rigor of the methods, dedication of the volunteers, and a modest amount of State funding. Professional water quality monitors need to define the monitoring question, design the program, store the data, and interpret the results. Volunteers can act as surrogate field technicians, LTEs, and student hourly help.

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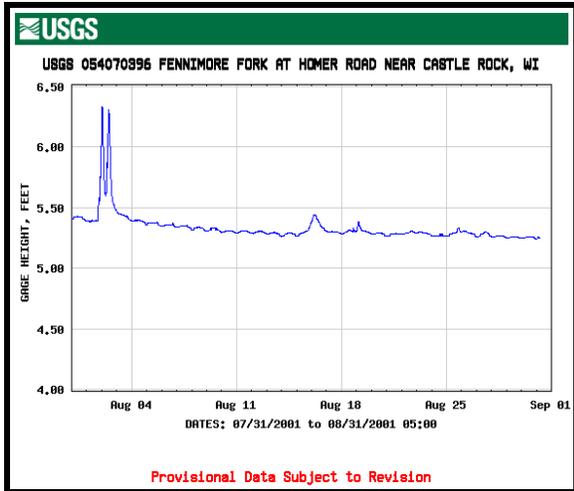


Figure 3. August 2001 stage height.

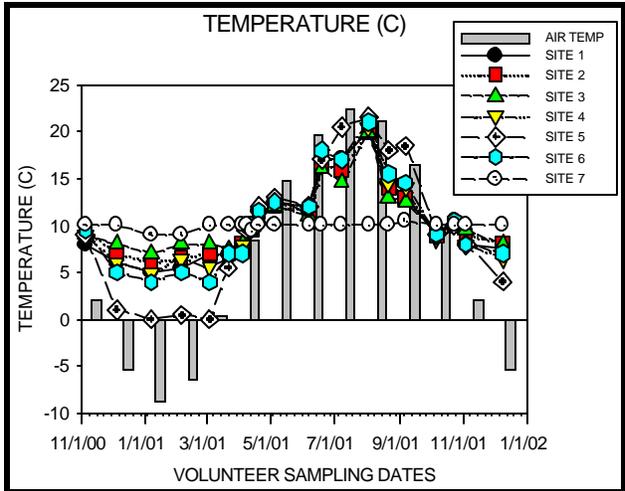


Figure 4. Water temperature and average monthly air temperature.

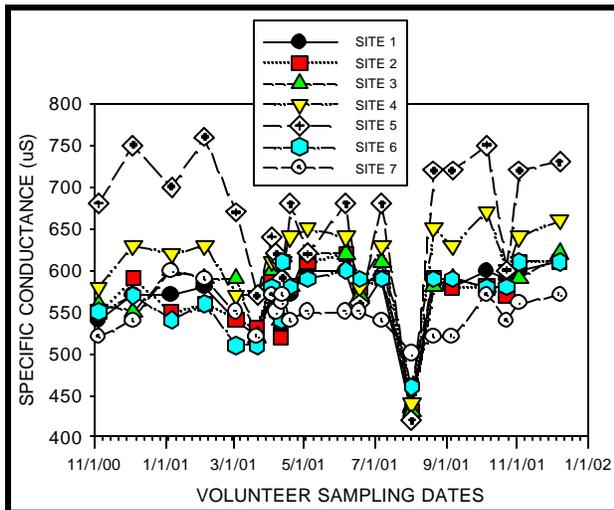


Figure 5. Conductivity on the sampling dates.

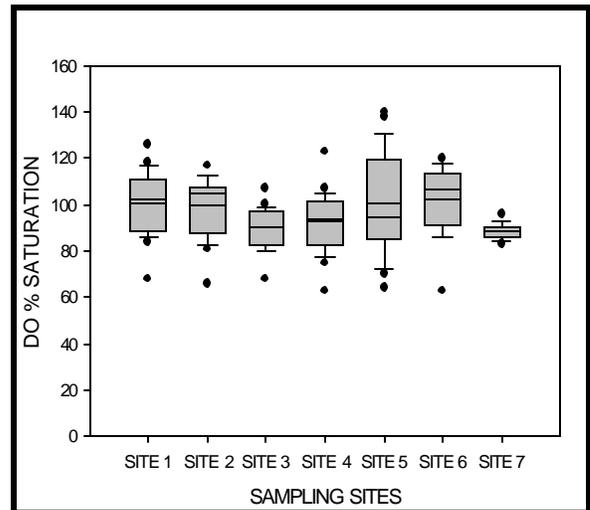


Figure 6. % DO SAT at sampling sites.

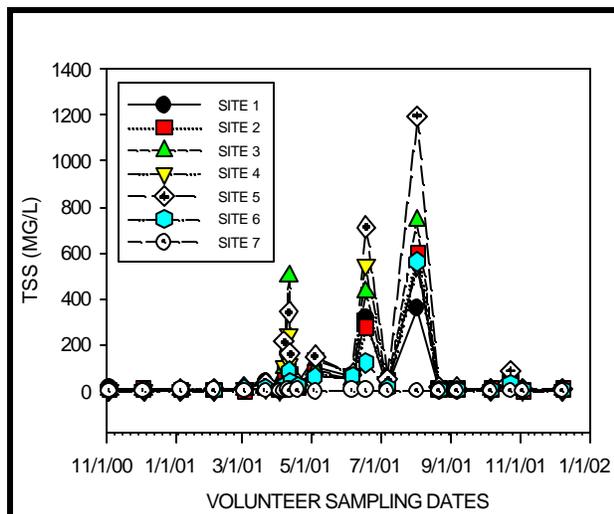


Figure 7. TSS on the sampling dates.

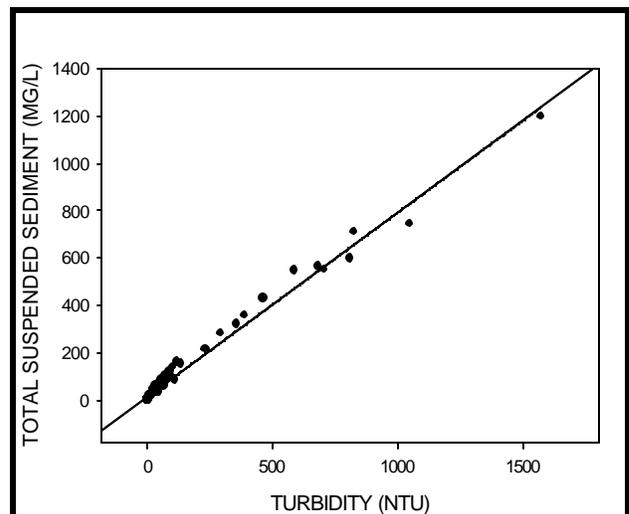


Figure 8. TSS as a function of turbidity.

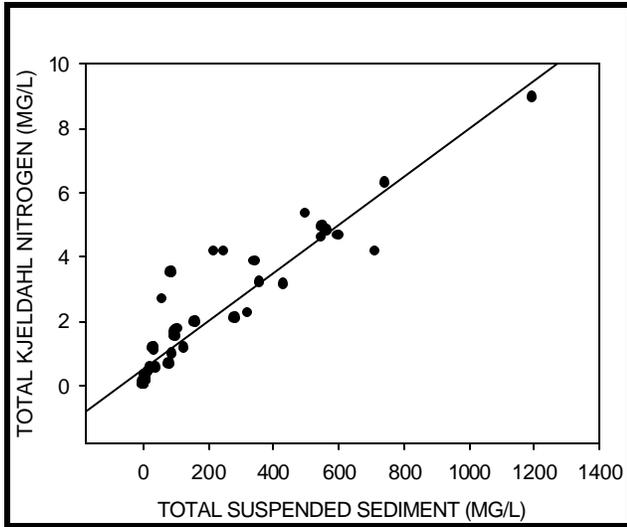


Figure 9. TKN and TSS at Castle Rock Creek.

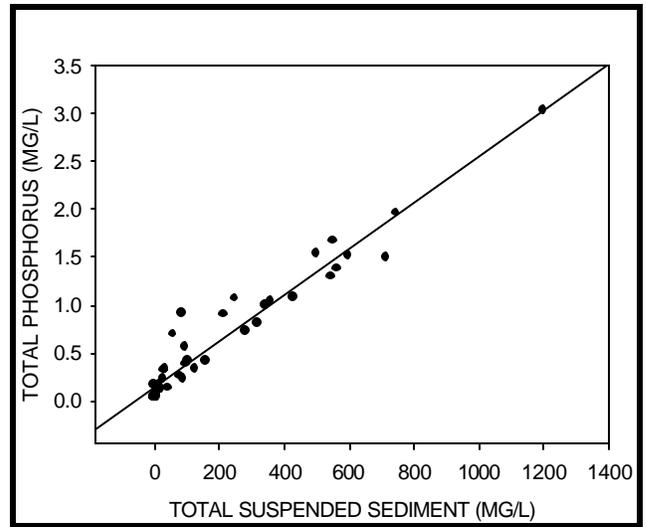


Figure 10. Total phosphorus and TSS.

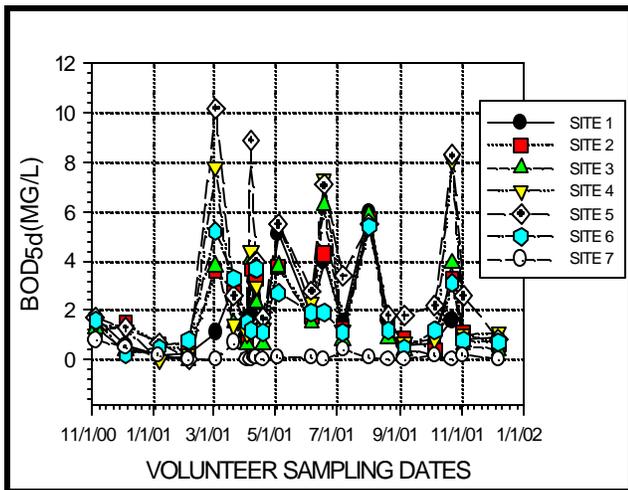


Figure 11. BOD on volunteer sampling dates.

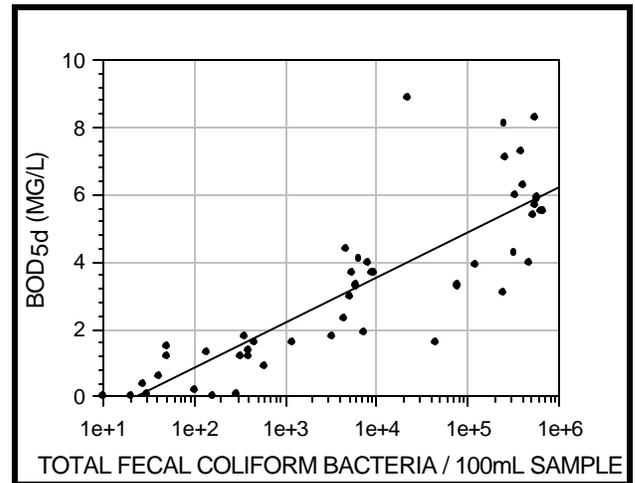


Figure 12. BOD and TFC at Castle Rock Creek.

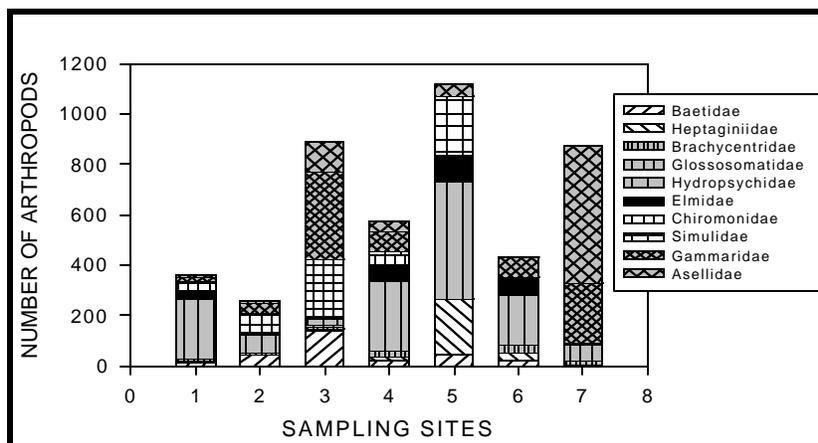


Figure 13. Relative number of arthropods on November 3, 2000.