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## Abstract

Contaminants in waterways continue to be a problem especially in watersheds dominated by land use changes such as agriculture. Clearing the land for agricultural use is needed to support the population; however, agricultural contaminants are cited as contributing the greatest input of suspended solids and nutrients to waterways. Quantifying various contaminants in surface water is useful in determining their origin, thus aiding in their mitigation. This study, focused on the Cache River Watershed, reports pH, dissolved oxygen (DO), conductivity, turbidity, total suspended solids (TSS), $NO_3^-$, $NO_2^-$, and $PO_4^{3-}$ in the lower sub watersheds. It was determined that in the Cache River, at these particular sites, TSS, $NO_3^-$, $NO_2^-$, and $PO_4^{3-}$ concentrations differ due to varying sources of input and land use.

## Introduction

Quality standards for water bodies are defined by three elements which include designated uses, water quality criteria, and the antidegradation policy (USEPA 2012). The first element, designated uses, defines the intended uses of the water. These uses may include drinking, recreational use, and aquatic life. Under the Clean Water Act, each state is accountable for the chemical, physical, and biological integrity of its waterways; every state is strongly encouraged to adopt both numeric and narrative criteria (USEPA 2012). Numeric criteria are important if a specific toxin is measured.

The antidegradation policy is set in place to protect the quality of the water. The antidegradation policy is divided into three tiers. Tier 1 protects the pre-existing uses of the water quality. Pre-existing uses can include fishing, swimming, or any type of water sport. As long as these events have occurred since November 28, 1975, the quality of the body of water is protected under this tier (USEPA 2012). Tier 2 protects the waters that have exceptional water quality and go beyond normal standards. Tier 3 protects the waters with the highest level of protection - known as the outstanding national resource waters. These waters are sometimes known for "exceptional ecological significance" (USEPA 2012). Dissolved nutrients are composed of both organic and inorganic materials. Total nitrogen and phosphorus also include organic matter that will eventually be decomposed or mineralized to inorganic form. The inorganic forms of nutrients are those used by primary producers (algae and plants). Their presence in different water locations or sites in a waterway helps to determine the concentration and locate the nonpoint source of contamination.

The Cache River Watershed (Figure 1) (HUC# 08020302) originates in the southeastern part of Missouri with greater than 90% of the watershed extending south through the Arkansas Delta Ecoregion. The watershed covers a total of 506,602 ha (AWIS 2006), land-use consists primarily of row crop agriculture (68%) and 19% of the watershed is forested (Arkansaswater.org 2012).

The Cache River is an ecologically important watershed as it, with the Lower White River watershed, forms the second largest continuous tract of bottomland hardwood forest in the US (AMWPT 2012). The Cache River is a tributary within the Mississippi River Basin and flows into the White River in eastern Arkansas. The Cache River is not used as a source of drinking water for humans, but is a source for agricultural water use and is ecologically important to the diversity of animals in the watershed (ADEQ 2008a). The Cache River is designated for the propagation of fish and wildlife, is an important migratory duck habitat, provides primary and secondary contact recreation, as well as domestic, agricultural, and industrial water supplies (ADEQ 2008a).

The Cache River Watershed was chosen as a target watershed for a Mississippi River Basin Initiative

(MRBI) project and cited as a source of nutrients and suspended solids contributing to the hypoxia in the Gulf of Mexico. Designated uses in the watershed include fisheries and the watershed above Cache Bayou – adjacent to natural areas has also been designated as an Extraordinary Resource Waterway (ADEQ 2008a).

Figure 1. The Cache River Watershed located in north east Arkansas (Arkansaswater.org 2012).

The major cause of impairment in the Cache River Watershed is from excessive turbidity, total dissolved solids and lead; lead is thought to originate either from mining activities in the headwaters or associated with clay in the watershed (ADEQ 2008b). Agricultural activities within the watershed are thought to be the major source of the contamination. The alluvial soil associated with the Delta Ecoregion is highly erodible, and soil disturbances as part of row-crop agriculture contribute to the suspended sediment in this watershed. In addition, silt and total suspended solid inputs during storm events from the unpaved farm roads, construction sites and other land disturbances are most likely adding significant loads and increasing in-stream turbidity concentrations during and following storm events (ADEQ 2008b).

Siltation or suspended sediment has been cited as causing direct and indirect biological effects to aquatic systems (Berry et al. 2003). Direct effects to aquatic invertebrates include abrasion, clogging of filtration mechanisms that interfere with ingestion and respiration, and habitat burial (Wilber and Clarke 2001). Indirect effects include decreased light attenuation and changes in stream bed morphology resulting in decreased suitable habitat (Berry et al. 2003). Deposition of suspended sediment on benthic invertebrates has been cited as one of the most important concerns of sediment pollution and also leads to decreased fisheries (Waters 1995). Substrate loss and change in composition and interstitial space were cited in that study as important relationships between sedimentation and benthic communities. Studies of freshwater mussels have also measured decreased feeding rates due to high levels of suspended sediment (Wilber and Clarke 2001).

In this study, we reported nutrient and suspended solids from seven subwatersheds in the lower Cache River (Figure 2, Table 1).

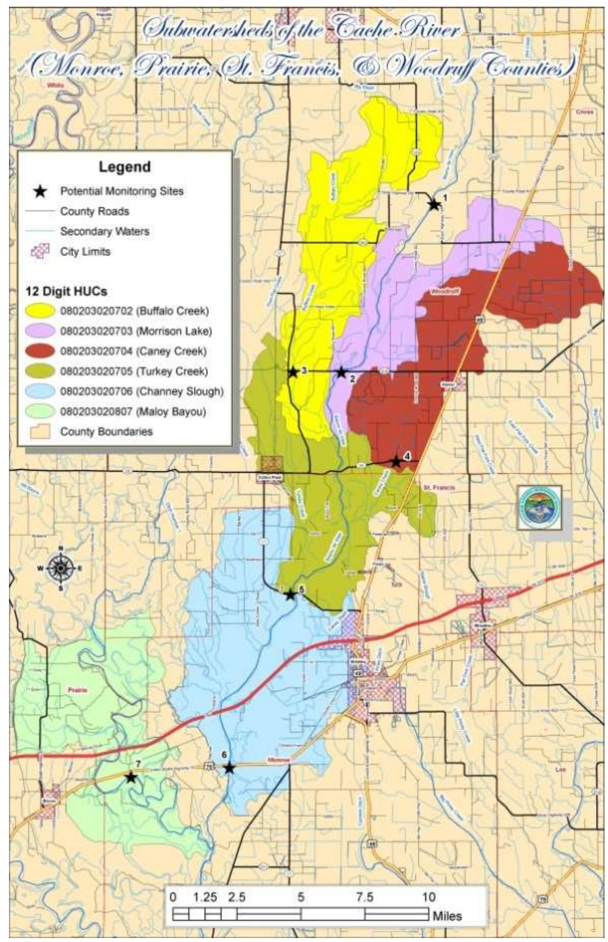


Figure 2. Sites in the Cache River Watershed sampled for water quality analyses from August – December, 2011 (map provided by ARNC 2011).

## Methods

The water collection sites were all located in the lower subwatersheds of the Cache River Watershed


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Table 1. Cache River Subwatershed sites sampled for water quality analyses. Hydrological Unit Code (HUC) and coordinates provided for each site. Area and land use data provided by AWIS (2006).

| Site | Subwatershed / HUC | Coordinates | Area (ha) | % Cropland | % Forest |
|---|---|---|---|---|---|
| 1 | Morrison Lake-Bayou De View HUC # 080203020703 | N 35 09.344' W 091 08.188' | 6,187 | 68 | 25 |
| 2 | Morrison Lake-Bayou De View HUC # 080203020703 | N 35 03.687' W 091 12.180' | | | |
| 3 | Buffalo Creek HUC # 080203020702 | N 35 00.596' W 091 14.189' | 8,775 | 67 | 25 |
| 4 | Caney Creek-Buffalo Creek HUC # 080203020704 | N 35 00.596' W 091 09.972' | 8,190 | 79 | 16 |
| 5 | Turkey Creek- Bayou De View HUC # 080203020705 | N 34 56.132' W 091 14.458' | 8,275 | 55 | 35 |
| 6 | Channey Slough-Bayou De View HUC # 080203020706 | N 34 50.378' W 091 16.981' | 14,082 | 43 | 43 |
| 7 | Maloy Bayou- Cache River HUC # 080203020807 | N 34 50.024' W 091 21.155' | 9,899 | 44 | 44 |

(Figure 2). At each site, water samples were collected weekly for 5 months (August-December, 2011). Grab samples from the water column were collected at each site from a bridge. Collected water was then transferred into acid-washed sample bottles (1-L and 250-mL Nalgene bottles) as recommended by the Arkansas State University Ecotoxicology Research Facility (ERF) Standard Operating Procedure (SOP) and based on American Public Health Association methods (APHA 2005). Samples were filtered at the site for nutrient analyses using a syringe and a 0.45 µm filter to fill two 15-mL centrifuge tubes; samples were placed immediately on ice and stored in a cooler for transportation back to the ERF. Dissolved oxygen (DO), pH, conductivity, and temperature were measured on site with a Thermo Scientific Orion Star A329 Portable pH/ISe/ Conductivity/RDO/DO Meter (Beverly, MA). All meters were calibrated prior to use and the results, date and time, initials, and observations were recorded in a field notebook.

Upon return to the ERF, samples were warmed to room temperature in preparation for TSS and turbidity analyses. The samples that were filtered for dissolved nutrients were placed in the freezer until analyzed. Using the filtration technique (method 2540D) and 100 mL of the sample, TSS were measured in triplicate for each site and turbidity was measured using the nephelometric method 2130B (APHA 2005) with a Hach 2100P turbidmeter (Loveland, CO). Nutrients were determined using an OI Analytical Model DA3500 (College Station, TX) nutrient analyzer. The method used for $NO_2^-$ and $NO_3^-$ was in accordance with APHA (2005) methods 4500- $NO_2$-B and 4500- $NO_3$-I. This procedure has a method detection limit (MDL) for $NO_3^-$ of 0.02 mg N/L with a range of 0.02 - 5.0 mg N/L. $NO_2^-$ has a MDL of 0.002 mg N/L with a range of 0.01 – 0.25 mg N/L (OI Analytical, 2007). The method used for $PO_4^{3-}$ is in accordance with USEPA Method 365.3 with a MDL of 0.01 mg/L with a range of 0.05 – 1.0 mg P/L (OI Analytical 2008).

In order to achieve quality assurance and quality control in this project, the Quality Assurance Project Plan and the ERF SOP was followed. The ERF is EPA certified (AR#00917) for TSS and nutrients ($NO_2^-$, $NO_3^-$, $PO_4^{3-}$) and bi-annual unknowns by the Arkansas Department of Environmental Quality (ADEQ) are required for certification.

## Results

Water quality analyses measured on-site were all within expected results for Delta streams (detailed data not shown). Mean pH values over the 5-month period ranged from 6.4 at Site 3 to 7.2 at Site 4. Mean conductivity values were lowest at Site 3 and greatest mean values were recorded at Site 1 (160 and 300 µs/cm, respectively).

The greatest differences in water quality among the sites were measured in TSS, turbidity, and dissolved nutrients. Greatest mean TSS and turbidity were measured from Sites 4 and 7 (Table 2). The highest individual TSS and turbidity measurements were from Site 4. Sites 5 and 6 had the lowest average turbidity as well as the lowest mean TSS. Turbidity, which measures the refractive nature of the suspended solids, had a moderately spread range among measured sites. The greatest range in TSS and turbidity was measured at Site 4.

Greatest mean $NO_3^-$ and $PO_4^{3-}$ values were measured in Site 1 as well as the greatest single value of $NO_2$ (1.02 mg/L) (Table 3). Lowest average $NO_3^-$ was measured in Site 3 and relatively low $PO_4^{3-}$ values

Table 2. Mean and ranges of TSS and turbidity from water collected at sites within the Cache River Watershed (n=18).

| | TSS (mg/L) | | Turbidity (NTU) | |
|---|---|---|---|---|
| Site | Mean | Range | Mean | Range |
| 1 | 22.3 | 6.3 - 41.6 | 32.1 | 12.5 - 61.2 |
| 2 | 12.4 | 2.2 - 36.2 | 22.3 | 6.4 - 56.9 |
| 3 | 13.5 | 0.2 - 48.8 | 18.1 | 6.1 - 75.6 |
| 4 | 25.4 | 5.1 - 123.6 | 45.3 | 2.2 - 264 |
| 5 | 12.2 | 4.2 -21.5 | 17.7 | 7.3 - 40.8 |
| 6 | 9.1 | 4.7 - 17.0 | 17.9 | 4.5 - 41.2 |
| 7 | 30.5 | 14.3 - 53.3 | 42.6 | 22.1 - 71.9 |

Table 3. Mean and ranges of $NO_3^-$, $NO_2^-$, and $PO_4^{3-}$ from water collected at sites on the Cache River. BDL = below detection limit (n=18).

| | $NO_3^-$ (mg/L) | | $NO_2^-$ (mg/L) | | $PO_4^{3-}$ (mg/L) | |
|---|---|---|---|---|---|---|
| Site | Mean | Range | Mean | Range | Mean | Range |
| 1 | 0.458 | 0.155- 1.420 | 0.025 | 0.003 - 0.102 | 0.119 | BDL - 0.389 |
| 2 | 0.277 | 0.062 - 0.712 | 0.017 | BDL - 0.085 | 0.101 | 0.003 - 0.432 |
| 3 | 0.181 | 0.022 - 0.460 | 0.016 | BDL - 0.056 | 0.066 | BDL - 0.276 |
| 4 | 0.296 | 0.124 - 1.128 | 0.015 | BDL - 0.049 | 0.087 | BDL - 0.248 |
| 5 | 0.229 | 0.044- 0.487 | 0.015 | BDL - 0.082 | 0.112 | BDL - 0.484 |
| 6 | 0.365 | 0.013 - 1.965 | 0.015 | BDL - 0.059 | 0.057 | BDL - 0.221 |
| 7 | 0.353 | 0.102 - 0.956 | 0.026 | 0.003 - 0.089 | 0.063 | BDL - 0.172 |

were also measured from this site. Site 6 had the greatest range of $NO_3^-$ values (0.013-1.965 mg/L).

## Discussion

Land use is directly linked with water quality as non-point source contamination contributes to pollutant loading within the waterway. Agricultural runoff is cited as the primary source that impacts surface waters of the US; it has been reported that 48% of US rivers and streams are contaminated (USEPA 2008). The ADEQ (2008a) includes excessive turbidity and TSS as major causes of impairment in the Cache River Watershed. Additionally, sediments are the leading cause of nonpoint source pollution (USEPA 2008) and chemicals associated with agricultural runoff can negatively impact water quality (Phillips et al. 2006).

Land use in the Cache River Watershed is primarily cropland (68%) and forest (19%) (Arkansaswater.org 2012). However, local land use contributes to the suspended sediment and nutrient concentrations measured at our sampling sites. Site 4 (79% cropland) had high mean TSS and turbidity as compared to the other sites with the exception of Site 7. The increased values of TSS and turbidity measured in Site 4 reflect the land use of this subwatershed. Agricultural activities contribute to nonpoint source contamination such as suspended sediments and increased nutrients. Low TSS and turbidity values measured in water from Site 6 may be attributed to land use in that subwatershed.

Highest average TSS and turbidity values recorded from Site 7 did not reflect increased cropland, as was noted for Site 4. In this subwatershed, forested buffer strips along the river may have more influence in water quality than overall land use. Upstream measurements from Site 7 are also not available for comparison as in sites 1-6. Forested buffer strips are efficient in removing sediment and nutrients from agricultural runoff and are recommended as a Best Management Practice (BMP) (Mosley 1979). Water storage and evapotranspiration by forested catchments have been shown to reduce surface flow into receiving systems (Mosley 1979, Fetter 2001) and grassed or forested buffer strips have been shown to reduce nutrient loading into agricultural drainage systems (Bouldin et al. 2004).

Site 1 had the greatest $NO_3^-$ and $PO_4^{3-}$ values and also high TSS and turbidity measurements. This uppermost site was chosen in the study to compare upstream input from the agriculturally-dominated upper Cache River Watershed. The decreasing nutrient values in downstream sampling sites (2,5,6) indicate an assimilative capacity of the river system to accrue sediment and nutrients from the water column. Associated wetlands, vegetation and decreased water velocity of the unchannelized lower Cache River may be responsible for the lower measured values at these downstream sites. It should be noted that sites 1-6 are hydrologically connected while Site 7 is located in an unconnected subwatershed (Figure 1). While sites 6 and 7 have similar land use, the measured sediment in the waterways was quite different. In these sampling sites, agricultural land in close proximity to the river and upstream inputs may contribute more to sediment input than overall subwatershed land use.

The single highest TSS and turbidity values for sites 2, 3, 4, 5 and 7 were measured on 16 Nov 2011. This sampling event also resulted in the greatest $NO_3^-$ and $PO_4^{3-}$ values measured for Site 4 and followed a 10.2cm storm event in the watershed (http://www.srh.weather.gov/lzk/?n=rain1111.htm)


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which increased surface runoff and river discharge (http://nwis.waterdata.usgs.gov/nwis). These measurements show that storm events lead to increased contaminant loading at the sites in this watershed during the non-production season. Typically following harvest, fields are bare of vegetation and overland flow will increase the movement of sediment and nutrients from the bare ground.

The measured water quality in the Cache River subwatersheds in this study is of interest as local land use and upstream inputs influence the cumulative water quality in a watershed. Ongoing grants dedicated to reducing the sediment and total nutrient loading in the Cache River are primarily focusing on agricultural BMPs and wetland protection. Wetlands located within the watershed are vital to remediating nutrients and sediments from the river.

This current data along with continued monitoring at these sites will provide evidence of the ability of BMPs and wetlands to mitigate effects of agricultural activities within the Cache River Watershed.

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## Literature Cited

**American Public Health Administration (APHA), American Water Works Association and Water Pollution Control Federation**. 2005. Standard Methods for the Examination of Water and Wastewater. 21st ed., Washington, D.C. 1288pp.

**Arkansas Department of Environmental Quality** (ADEQ). 2008a. Integrated Water Quality Monitoring and Assessment Report. Published by the Arkansas Department of Environmental Quality. 157pp.

**Arkansas Department of Environmental Quality** (ADEQ). 2008b. Arkansas' 2008 303(d) List of impaired water bodies. Published by Arkansas Department of Environmental Quality. 18pp.

**Arkansas Multiagency Wetland Planning Team** (AMWPT). http://www.mawpt.org/default.asp Accessed 4 Feb 2012.

**Arkansas Watershed Information System (AWIS) - 8-Digit: 08020302**. Arkansas Watershed Information System. Arkansas 85th General Assembly, 2006. <http://watersheds.cast.uark.edu/viewhuc.php?hucid=08020302>. Accessed 29 Mar. 2012.

**Arkansaswater.org**. 2012. Cache Watershed-08020302. <http://arkansaswater.org//index.php?option=com_content&task=view&id=127&Item>

**Berry W**, **N Rubinstein**, **B Melzian** and **B Hill**. 2003. The biological effects of suspended and bedded sediment (SABS) in aquatic systems: a review. US EPA, Duluth MN.

**Bouldin JL**, **JL Farris**, **MT Moore** and **CM Cooper**. 2004. Vegetative and structural characteristics of agricultural drainages in the Mississippi Delta landscape. Environmental Pollution 132:403-411.

**Fetter CW**. 2001. Applied Hydrology. 4th edition. Prentice Hall. Upper Saddle River, NJ.

**Mosley MP**. 1979. Streamflow generation in a forested watershed, New Zealand. Water Resource Research 15 (4):795-806.

**Phillips BM**, **BS Anderson**, **JW Hunt**, **SA Huntley**, **RS Tjeerdema**, **N Kapellas** and **K Worcester**. 2006. Solid-phase sediment toxicity identification evaluation in an agricultural stream. Environmental Toxicology and Chemistry 25:1671-1676.

**United States Environmental Protection Agency** (USEPA). 2008. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates. USEPA National Center for Environmental Publications (NSCEP), Cincinnati, OH. EPA 600/R-99/064.

**United States Environmental Protection Agency** (USEPA). 2012. Water Quality Standards | Region 7 | US EPA. *US Environmental Protection Agency*. <http://www.epa.gov/region07/water/wqs.htm>. Accessed 27 Jan. 2012.

**Waters TF.** 1995. Sediment in streams- sources, biological effects and control. American Fisheries Society Monograph 7. American Fisheries Society, Bethesda, MD.

**Wilber DH** and **DG Clarke**. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management. 121:855-875.