Permitted Concentrated Animal Feeding Operation Assessment

Buffalo National River, Arkansas

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November 2016

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Cover: The karstic Boone Formation looms over campers and fishermen at Buffalo National River.

Acknowledgements

This assessment was funded by the National Park Service Water Resources Division through the efforts of Bill Hansen, former Chief of the Water Rights Branch, with additional financial, administrative, and computer support from Buffalo National River (BNR). Data and studies reviewed in this report were provided by organizations, universities, and government agencies that in some cases have spent decades studying the geohydrology and water quality of the Buffalo River and the Ozarks. The water quality monitoring database developed at BNR over the last 30-years has established a critical baseline rarely available. The foresight of those who established this program, and the work of the individuals who carry it on to this day, is greatly appreciated. Dr. David Peterson, a retired math professor from the University of Central Arkansas, helped with data organization and analyses, and James Petersen, retired USGS hydrologist, reviewed the data analysis and interpretations and suggested valuable improvements. Martin Maner, who worked for ADEQ for 35-years and served as the Chief of the Water Section, provided critical insights to Arkansas's water quality standards and permitting regulations. Chuck Bitting with BNR produced most of the maps and provided additional guidance, and Faron Usrey provided data and results from special project water quality studies. Dr. Andrew Sharpley with the University of Arkansas Department of Crop, Soil, and Environmental Sciences provided site-specific water quality data in electronic format, patiently answered questions, and reviewed water quality related sections of this report. Dr. Van Brahana with the University of Arkansas Geoscience Department and his associates provided insights and publications related to their ongoing karst hydrology and water quality studies. Dr. Mark Hudson and Mr. Kenzie Turner, USGS employees who have conducted or coordinated recent geologic mapping of the entire Buffalo River watershed, assisted the author with a geologic field reconnaissance of the Big Creek Valley in October 2016. This field review helped with development of a conceptual framework for ground water and surface water interactions at and between the numerous water quality sampling sites on Big Creek. Dr. Joe Nix, his associates, and the water quality laboratory at Ouachita Baptist University, provided additional water quality data. U.S. Geological Survey stream flow gaging combined with continuously recording water quality monitors allowed for data analysis, comparisons, and interpretations that otherwise would not have been possible. Several additional sources of information related to the water quality and karst interactions in the Big Creek watershed are available, but there was insufficient time to assess all sources.

Executive Summary

Nonpoint source runoff and groundwater infiltration are recognized as long-term water quality concerns at Buffalo National River (BNR), a unit of the National Park Service (NPS) tasked by Congressional legislation to preserve the Buffalo River for present and future generations. This report assesses Concentrated (often referred to as Confined) Animal Feeding Operations (CAFO) utilizing liquid waste management systems. It reviews the permitting of C and H Hog Farms' swine facility constructed in 2013. This permitted CAFO is the largest in the Buffalo River watershed. For context, the estimated nitrogen output is equivalent to a human population of 7,000, and the phosphorus output is equivalent to 23,000 humans, in a watershed with a total human population of approximately 17,000 (Holland, 2016). The report is primarily intended for National Park Service (NPS) technical staff and management, and was funded by the NPS Water Resources Division.

The Clean Water Act (CWA) requires all point source discharges to obtain a permit prior to discharging to surface streams. CAFOs utilizing liquid waste management systems currently are designated as point sources, dry waste CAFOs such as poultry operations may or may not be required to obtain a permit depending on their location relative to designated nutrient surplus areas of Arkansas. All CAFOs in Arkansas are required to develop a nutrient management plan. In Arkansas, Clean Water Act authority is administered by the Arkansas Pollution Control and Ecology Commission (APC&EC) and implemented by the Arkansas Department of Environmental Quality (ADEQ), with U.S. Environmental Protection Agency (EPA) oversight. The Buffalo River is designated an Outstanding Resource Water, and the associated anti-degradation policy states "existing water quality will be maintained and protected."

Nonpoint surface runoff and ground water infiltration are the primary sources of bacteria and nutrients in the Buffalo River and correlate with conversion of lands from forest to pasture and with karst geology. The Buffalo River's unique geomorphology and hydrogeology, with its large shallow pools, makes it more susceptible to nuisance algae production than other, more consistently spring-fed, Ozark streams. Nuisance algal conditions likely will increase without water quality conservation actions. Ultimately, the Buffalo River's future water quality will be best served by changes in land use practices that avoid the introduction of nutrients, and include improved communication and understanding of the causal factors and a focused effort by state and federal agencies and institutions to develop and implement guidance, science, and regulations to address key threats to the system.

Buffalo National River implemented a water quality monitoring program in 1985, and conducted dye tracing studies to track ground water flow and contaminant transport in karst geologic settings. These studies helped provide the justification for a 1992 moratorium on permitted CAFOs in the Buffalo River Watershed, and an ADEQ led study of CAFO operating conditions. ADEQ investigations at 16 of the 21 permitted operations in 1992 revealed problems related to management and design of the waste disposal system. Fifty percent of the farms had excess solid waste build-up in the storage ponds, and at four of the farms, waste flowed continuously over the bank of the storage pond and off-site. From this study, ADEQ concluded that the current system by which CAFOs are designed, permitted, and regulated was failing to curtail discharges from the waste storage and disposal systems.

These results prompted ADEQ to initiate a study of CAFOs in the Buffalo River watershed intended to collect site-specific waste quality information, review operational issues, and make recommendations for on the ground improvements and permitting considerations. The study addressed some elements and unknowns as initially envisioned, but significant information gaps remained and it is unclear how ADEQ used the study results to improve permitting requirements and decisions (ADEQ, 2002).

In 2012, ADEQ (with EPA oversight) developed a general permit to cover regulated CAFOs under the National Pollutant Discharge Elimination System (NPDES). This state-wide permit would allow new CAFOs to receive coverage under the permit by filing a Notice of Intent, which ADEQ would post to their website as public notice. In 2013, ADEQ approved their first and only Notice of Intent under this general permit, and issued a "sub-permit" to C and H Hog Farms.

Of primary concern to the NPS and others were:

- ADEQ's public notice and communication procedures.
- The karst setting and lack of assessment of geohydrologic conditions and known hazards.
- The scale of the operation and volume of nutrients and bacteria produced.
- No review of previous studies or presentation of new information or regulatory adjustments that made it appropriate to lift the 1992 moratorium.
- Limited consideration of modeling potential water quality impacts to the Buffalo River in determining the impacts and whether it would conform to meet anti-degradation requirements of the CWA.
- Limited baseline data for Big Creek, tributaries, springs, or ground water near the facility.
- Limited information on application of wastes on spreading fields near streams and on floodplains prone to inundation and in excess of plant uptake rates and soil test recommendations.
- Vulnerabilities of clay-lined waste storage ponds and little information concerning sludge management. Sludge accumulation in waste holding ponds was a significant problem identified in the previous ADEQ CAFO study.

In response to these concerns, the governor and state legislature passed an act requiring a temporary moratorium on CAFO permits in the Buffalo River watershed, and expanded public notice requirements. A commission was appointed to draft changes to Arkansas' CAFO permitting regulations concerning public notice. The APC&EC enacted the improved public notice requirements and formally incorporated a moratorium on similar CAFOs, lasting at least 5 years, into state regulations. The governor and legislature funded an extensive study of the CAFO, currently being conducted by the University of Arkansas Division of Agricultural and Cooperative Extension Service (Big Creek Research and Extension Team - BCRET), with assistance from other well-qualified regional water quality and agronomy experts. The study does not characterize the karst hydrogeology of Big Creek, and does not measure storm-driven runoff water quality responses in Big Creek.

ADEQ has decided not to re-issue the NPDES general permit because only one facility has requested coverage under this permit in its 5-year term, which expired October 31, 2016. C and H Hog Farms submitted a new permit application under Regulation No. 5, no discharge, permitting authority. Regulation No. 5 currently covers all other permitted CAFOs in Arkansas utilizing liquid waste management systems. This new permit application is considered by ADEQ to be administratively complete, and C and H Hog Farms can continue operation under their current general permit until such time as the ADEQ Director makes a final decision on the new permit. Regulation No. 5 may be a more restrictive permit because it provides protection to all waters of the state from any discharge of pollutants. Another permitting option includes the use of an individual permit under the NPDES program which would provide direct EPA oversight and long-term operational management.

An appeal process exists under APC&EC Regulation No. 8 to challenge ADEQ permitting decisions. This venue was utilized by the NPS in response to the permitting of the Pindall Landfill in the 1980s. The opportunity to challenge the permit or its conditions will be forfeited if a new permit is issued and no appeal is submitted through the formal adjudicatory process. Formal comments on the basis of the agency concerns on the permit must first be submitted prior to the appeal.

As part of this assessment, existing water quality and discharge data, along with previous studies, were analyzed and reviewed. Data from the Big Creek Research and Extension Team (BCRET were analyzed and results showed:

- Samples collected from Big Creek downstream of the C and H Hog Farms (and all other potential sources of nonpoint source pollution in the contributing watershed) are higher in nitrate and total nitrogen, total coliform bacteria, chloride, specific conductance, alkalinity and total dissolved solids than at the Big Creek sampling site upstream of the C and H Hog Farms operation. Higher nitrate levels at the downstream sampling site occur under hydrologic conditions dominated by ground water input.
- State water quality numeric limits were exceeded for *E. coli* at both the upstream and downstream sampling sites in 2014, and the upstream site in 2015. ADEQ is the agency responsible for making determinations of exceedance and stream impairment, and employs broader guidance when making such decisions.
- Trend over time plots at the downstream site indicated base flow concentrations of total phosphorus, total suspended solids, nitrate, and total nitrogen increased over the BCRET sampling period. However, total phosphorus and total suspended solids also increased at similar levels at the upstream site. Total nitrogen increased little at the upstream site compared to the downstream site, and nitrate declined at the upstream site during the same period that it increased at the downstream site. Differences in flow conditions between years may have contributed to the increasing trends. Future trend assessment at the downstream site will benefit from using flow-weighted values, but the upstream site lacks discharge data.
- Trend analysis was useful in determining that many of the base flow water quality patterns in Big Creek are related to the geologic setting, legacy nonpoint source constituents contributed by sources prior to and concurrent with C and H Farms, and the effects of hydrologic conditions and seasonality.

- Sufficient data were not available to analyze storm runoff concentration and load patterns in Big Creek. However, BCRET uses ISCO automated samplers to collect storm runoff samples from Big Creek and may provide the necessary storm flow concentrations with time. Comparison of upstream and downstream loads is hampered by the lack of stream discharge information at the upstream site.

Water quality and stream discharge information were analyzed from the in-park monitoring station on Big Creek at Carver, located 4-miles downstream from the BCRET sampling site below the CAFO and ½ mile above the confluence with the Buffalo River. These data came from BNR, USGS, and special studies being conducted by the University of Arkansas Geosciences Department and Ouachita Baptist University. Results showed:

- Nitrate concentrations for samples collected during base flow have not increased significantly over the 30 years of BNR data collection at Big Creek at Carver.
- Nitrate concentrations were typically 57 percent lower at the Big Creek at Carver site than at the BCRET downstream sampling station.
- Dissolved oxygen values below the state's numeric water quality criteria occur in summer and early fall during low flow conditions.
- During late summer and early fall low-flow conditions, nitrate concentrations increased at the BCRET sampling site downstream of the CAFO, but decreased at Big Creek at Carver over the same period.
- Discharge data from the USGS gaging stations at Big Creek near Mt. Judea and Big Creek at Carver revealed the intervening reach is a losing stream segment. It is likely that water entering the subsurface karst conduits in this losing reach of Big Creek resurfaces in the Buffalo River channel in a previously identified gaining reach below the confluence of Big Creek and the Buffalo River.
- Karst ground water and surface water interactions appear to be significant in both the Boone Formation and the underlying Ordovician aged formations.
- Turbidity has not increased at Big Creek at Carver during base flow conditions, but recent data and field observations indicate summer phytoplankton blooms and other suspended solids may be affecting water clarity.
- Fecal coliform bacteria counts have not increased at Big Creek at Carver based on statistical significance tests of BNR data. In some hydrologic conditions, elevated Buffalo River *E. coli* geometric mean values have been linked to relatively high bacteria counts discharging from Big Creek.
- Nitrate values in the Buffalo River at Woolum, below the gaining reach likely fed by Big Creek, were determined to be increasing. However, eight out of nine sampling stations on the Buffalo River mainstem monitored by BNR over the last 30 years show similar increases in nitrate concentrations, with only the most upstream site above Boxley unchanged.
- Nitrate concentrations in ground water issuing from the park's largest spring, Mitch Hill Spring, have increased 360 percent during 30 years of BNR monitoring.

Currently, ADEQ is analyzing results from a borehole drilled near the C and H Hog Farms' waste storage ponds to investigate an electrical resistivity anomaly detected by Oklahoma State University researchers. Recommendations based on this assessment include:

- Implement recommendations contained in BNR's Water Resources Management Plan, the highest priority being development of a watershed-based **voluntary** water quality conservation program.
- Conduct an assessment of impacts to water quality at NPS units associated with CAFOs.
- Conduct a low-flow discharge and water quality investigation along the length of Big Creek to map and quantify gaining and losing reaches and track water quality changes associated with these reaches.
- Conduct ground water investigations of the Big Creek karst ground water flow system utilizing tracer dyes.
- Conduct storm event water quality studies and use tracer dyes to "tag" runoff from waste management areas to determine when it arrives at water quality sample collection sites within the park.
- Update BNR's Water Quality Monitoring Plan.
- Conduct a dissolved oxygen and nutrient assimilation study in the stream reach above Big Creek at Carver.
- Formalize meetings between the NPS and ADEQ to improve communications between the agencies.
- Request NPS Heartland Network Inventory and Monitoring Program assistance with water quality monitoring efforts at Buffalo National River.
- Intensify science and educational dialogue and initiatives with the U.S. Geological Survey to address data gaps.
- Work with APC&EC to evaluate alternative rulemaking processes for the protection of the Buffalo National River.

On September 30, 2016 The Beautiful Buffalo River Action Committee, headed by five state agency directors, was formed and was tasked with developing a water quality conservation plan and implementation strategy for the Buffalo River watershed. The state's description of the conservation effort is similar to BNR's number one priority recommendation from the park's Water Resources Management Plan, and the committee's efforts should be fully supported by the National Park Service. Because 89 percent of the Buffalo River watershed lies outside the park's boundaries, this is a historic announcement with potentially long-term positive consequences.

Background

Establishment of a National River

Formal recognition of the Buffalo River's outstanding scenic and recreational qualities began with the establishment of Buffalo River State Park in 1935, and culminated in the creation of Buffalo National River (BNR) 37 years later. Public Law 92-237 of March 1, 1972 (86 Stat. 44) established BNR as a part of the National Park System:

> "...for the purposes of conserving and interpreting an area containing unique scenic and scientific features, and preserving as a free flowing stream an important segment of the Buffalo River in Arkansas for the benefit and enjoyment of present and future generations."

The U.S. House of Representatives Committee Report (1972) explained the basis for establishing BNR:

> "Because it is a pure, free-flowing stream which has not been significantly altered by industry or man, it is considered to be one of the country's last significant natural rivers. It is not one single quality, but the combination of its size, its completeness, its wild qualities, and its associated natural, scenic, and historic resources that makes the Buffalo River worthy of national recognition". (Public Law 92-237)

The Buffalo River thus became America's first National River, and Congress made clear the river is to be maintained as a pure, free-flowing stream. Congress intended the establishment of BNR to achieve that end. However, the park boundary encompasses only a narrow corridor comprising eleven percent of the surface watershed (Figure 1), and the National Park Service has a limited ability to influence changing water quality conditions. Private landowners control 60 percent of the watershed and they, along with state and local agencies and elected officials, will collectively decide the river's water quality future (Mott and Laurans, 2004).

Buffalo National River had 1,093,083 visitors in 2012 (NPS, 2012) generating almost $44 million for the local economy and creating 610 jobs in various sectors such as canoe liveries, hotels, cabin rentals, restaurants, and river management.

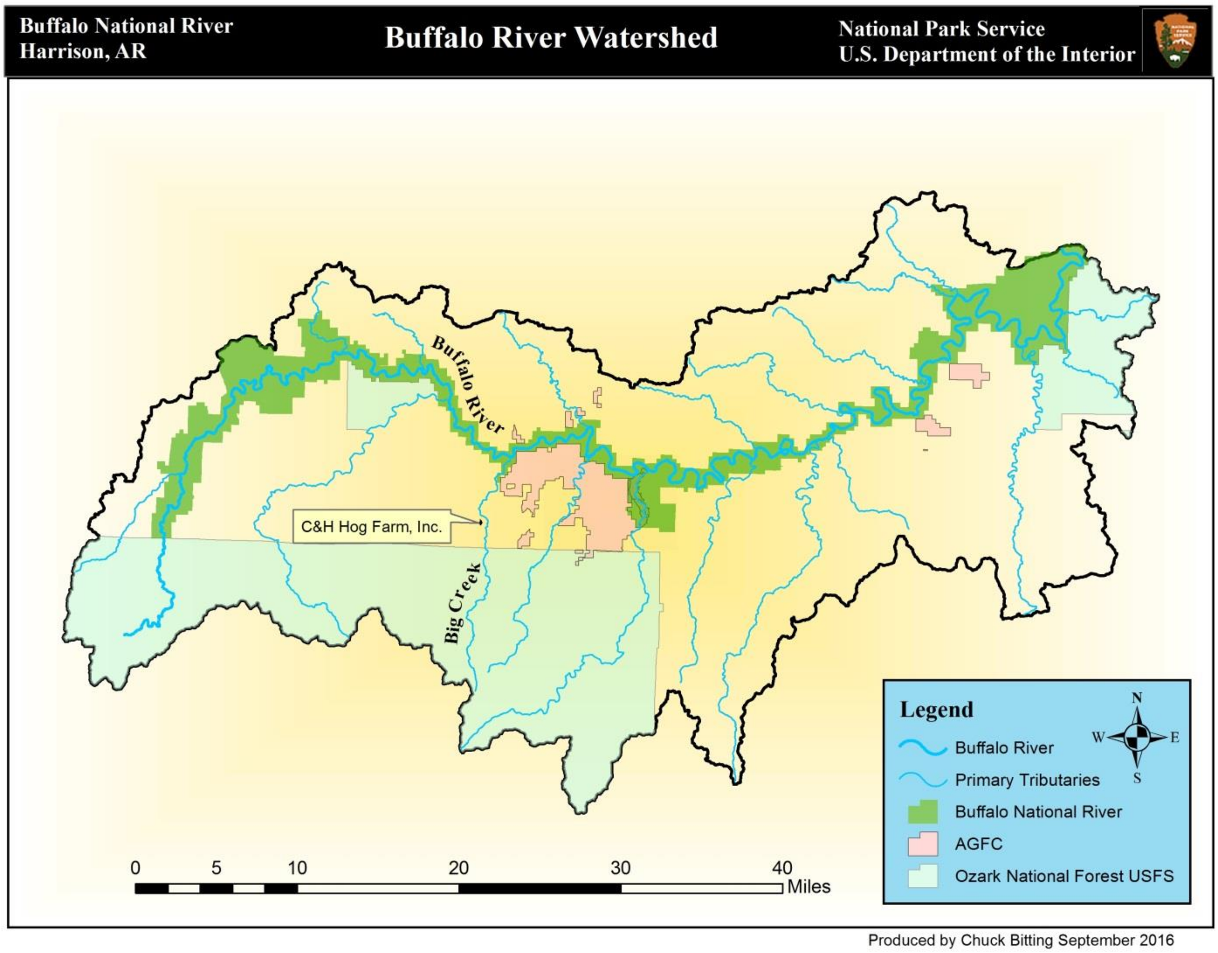


Figure 1: Buffalo National River and contributing watershed.

Clean Water Act

The Clean Water Act (CWA) was passed in 1972, the same year BNR was established. According to the U.S. Environmental Protection Agency (EPA):

> The Clean Water Act establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972.

Congress directed the EPA to restore and maintain the chemical, physical, and biological integrity of the nation's waters (EPA, undated). Along with establishing federal water quality standards for "all contaminants in surface waters," the CWA also "made it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained. EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls discharges" (EPA, 2015). Arkansas has been granted authority to administer the NPDES program and issue permits because it has established a permitting program and water quality criteria substantially equivalent to the federal program (EPA, 2016a). The CWA specified that Confined Animal Feeding Operations (technically referred to as "Concentrated" Animal Feeding Operations) were to be treated as point sources and regulated following provisions of the NPDES permit system.

Another important approach used in the CWA was to establish "Designated Uses" and an "Antidegradation Policy" for waterbodies. Designated uses include such categories as Public Water Supply, Fishable/Swimmable, and Outstanding National Resource Waters; water quality standards are established based on designated use. Under the Antidegradation Policy, waterbodies will not be degraded with pollutants such that they no longer meet their most restrictive designated use. CFR 40 § 131.12 states:

> ***(a)*** *The State shall develop and adopt a statewide antidegradation policy. The antidegradation policy shall, at a minimum, be consistent with the following:*
> ***(1)*** *Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.*
> ***(2)*** *Where the quality of the waters exceeds levels necessary to support the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water, that quality shall be maintained and protected unless the State finds, after full satisfaction of the intergovernmental coordination and public participation provisions of the State's continuing planning process, that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. In allowing such degradation or lower water quality, the State shall assure water quality adequate to protect existing uses fully. Further, the State shall assure that there shall be achieved the highest statutory and regulatory requirements for all new and existing point sources and all cost-effective and reasonable best management practices for nonpoint source control.*
> ***(i)*** *The State may identify waters for the protections described in paragraph (a)(2) of this section on a parameter-by-parameter basis or on a water body-by-water body basis. Where the State identifies waters for antidegradation protection on a water body-by-water body basis, the State shall provide an opportunity for public involvement in any decisions about whether the protections described in paragraph (a)(2) of this section will be afforded to a water body, and the factors considered when making those decisions. Further, the State shall not exclude a water body from the protections described in paragraph (a)(2) of this section solely because water quality does not exceed levels necessary to support all of the uses specified in section 101(a)(2) of the Act.*
> ***(ii)*** *Before allowing any lowering of high water quality, pursuant to paragraph (a)(2) of this section, the State shall find, after an analysis of alternatives, that such a lowering is necessary to accommodate important economic or social development in the area in which the waters are located. The analysis of alternatives shall evaluate a range of practicable alternatives that would prevent or lessen the degradation associated with the proposed activity. When the analysis of alternatives identifies one or more practicable alternatives, the State shall only find that a lowering is necessary if one such alternative is selected for implementation.*
> ***(3) Where high quality waters constitute an outstanding National resource, such as waters of National and State parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected.***
> ***(b)*** *The State shall develop methods for implementing the antidegradation policy that are, at a minimum, consistent with the State's policy and with paragraph (a) of this section. The State*

shall provide an opportunity for public involvement during the development and any subsequent revisions of the implementation methods, and shall make the methods available to the public. [48 FR 51405, Nov. 8, 1983, as amended at 80 FR 51047, Aug. 21, 2015]

Also included in the CWA were provisions for public notice of permit actions and public comment periods for draft permits and hearings, among others. Public notice of the preparation of a draft permit decision (including a notice of intent to deny a permit application) shall allow at least 30 days for public comment. Some requirements of the public notice process include:

- Mailing draft permit notices to the applicant; Federal and State agencies with jurisdiction over fish, shellfish, and wildlife resources; persons on any relevant mailing list; participants in past permit proceedings in that area.
- Notifying the public of the opportunity to be put on the mailing list through periodic publication in the public press and in such publications as Regional and State funded newsletters, environmental bulletins, or State law journals.
- When the program is being administered by an approved State, in a manner constituting legal notice to the public under State law.
- Any other method reasonably calculated to give actual notice of the action in question to the persons potentially affected by it, including press releases or any other forum or medium to elicit public participation.

Arkansas Pollution Control and Ecology Commission

Established in 1949 as part of the Arkansas Water Pollution Control Act (Act 472 of 1949), the Arkansas Pollution Control and Ecology Commission (APC&EC) makes environmental policy for Arkansas. Guidance is provided by the Governor, the Legislature, the EPA and others, and the Arkansas Department of Environmental Quality implements those policies (APC&EC, undated). The Commission also provides permit appeal oversight and adjudicatory hearings, and can override a permit decision of the ADEQ Director. After passage of the CWA, it was this Commission that crafted, and continues to modify, regulations that provide Arkansas with EPA's authority to implement sections of the CWA.

Arkansas Department of Environmental Quality

The Arkansas Department of Environmental Quality (ADEQ) is the State agency responsible for implementing the APC&EC Regulations and EPA promulgated elements of the CWA. They do this by examining thousands of permits each year, conducting facility inspections, providing compliance assistance, enforcement, and response to oil spills or chemical releases, for example. ADEQ staff also collects water samples as part of ongoing compliance inspections, and the agency maintains an on-site water quality laboratory. ADEQ communicates directly with EPA regarding specific policies and actions related to implementing the various details of the CWA, CFR 40, and APC&EC Regulations (ADEQ, 2016). ADEQ has a complex mission and often is at the center of critically important and sometimes controversial economic, environmental, and regulatory issues.

Federal Water Quality Standards

The three major components of the CWA Water Quality Standards Program are: (1) antidegradation, (2) designated use, and (3) water quality criteria. Water Quality Criteria can be chemical, physical, or biological and are intended to protect the designated use(s) of a waterbody. Only scientific considerations are employed when determining criteria supporting a given designated use (EPA, undated).

Most state Water Quality Standards include subjective narrative criteria such as "all surface waters will be free from undesirable or nuisance aquatic life," (i.e. algal blooms responding to nutrient enrichment). Numeric criteria are quantitative and define parameter-specific limits for such things as dissolved oxygen, temperature, turbidity, heavy metals, etc. Numeric criteria also specify the span of time (duration) over which conditions must be met. APC&EC has not set numeric nutrient criteria for waterbodies in Arkansas, but does have narrative criteria. EPA has issued technical guidance that can be used to help set criteria for nutrients (EPA, 2016b). Antidegradation regulations help to ensure the following: (1) all waters continue to support their designated uses; (2) waters with higher quality than the minimum are protected, unless there are important benefits associated with carefully considered actions that could cause additional degradation; and (3) highly valued, high-quality waters are "not degraded at all" (EPA, undated).

Under EPA and State regulations, the Buffalo River is referred to as an Outstanding National Resource Water (ONRW). The Buffalo River has two designated uses under this classification as specified by the APC&EC: Extraordinary Resource Water (ERW) and Natural and Scenic Waterway. Some minor, temporary degradation in ONRWs might occur; however, such degradation is to be minimized with water quality returning to the previous level after the activity is completed. Antidegradation reviews apply to permits issued under the CWA. The step-by-step process is intended to assess water quality impacts, consider alternatives, and coordinate with other agencies and the public.

Water quality standards are not directly enforceable under the CWA. When standards are not being met, there is no legal requirement for pollution sources to take specific actions. States administering the CWA are obligated to:

- Place the water body on the state's 303(d) list (list of impaired waters)
- Develop Total Maximum Daily Loads (TMDLs) for each pollutant exceeding criteria
- Reduce effluent limits in NPDES permits for regulated facilities and activities

Only permittees that fail to meet effluent limits or other conditions of their permit are subject to enforcement actions. Nonpoint sources are not subject to enforcement action because they are exempt from CWA regulations. Nonpoint source pollution represents the most significant source of pollution overall in the United States. More than 40 percent of all impaired waters were affected solely by nonpoint sources, while less than 10 percent of water quality criteria exceedances were caused by point source discharges alone (EPA, undated).

The APC&EC has developed water quality standards for Arkansas which are published in Regulation No. 2, and will be discussed as they pertain to BNR later in this report. Water quality standards are complicated and it is ultimately up to ADEQ, in coordination with others such as the EPA if necessary, to determine if exceedances have occurred or are ongoing. Other parties can petition the agency to review submitted data and other sources of pertinent information, and request a determination as to exceedance, loss of designated use(s), and the need to add a waterbody to the state's 303(d) list of impaired waters.

Ozarks Karst Hydrology and Water Quality

The rock layers comprising the Ozarks are sedimentary deposits with thick intervals of limestone formed in coral reef and associated environments. Coral reefs form where concentrations of calcium and carbonate in sea water are near saturation, allowing calcareous organisms to secrete shells, or become oversaturated resulting in precipitation of calcium carbonate ($CaCO_3$). This secretion or precipitation process can be reversed, even millions of years later. Through both dissolution and physical erosion, limestone interacts with low pH rainwater and/or percolating soil water over millions of years to form karst landscapes. Karst landscapes are characterized by caves, sinkholes, springs, losing streams, underground drainage networks, and other unique physical and hydrologic features.

The Buffalo River is in the southern Ozarks, and its main karst unit is the 400 foot thick Boone Formation. The Boone Formation was deposited around 340 million years ago, and over the eons has weathered to form extensive karst, including subsurface drainage networks capable of transporting groundwater quickly and from one surface basin to another (Mott, Hudson and Aley, 2000; Soto, 2014). While the Boone Formation underlies much of the Arkansas Ozarks, it is completely dissected and has extensively developed karst subsurface drainage networks in the Buffalo River valley. Therefore much of the limestone is rapidly drained following precipitation events.

The Buffalo River's unique hydrology and channel dimensions make it more susceptible to nutrient stimulation of periphyton (algae and cyanobacteria and other aquatic organisms that cling to substrate) and free-floating algal communities. Because the Buffalo River dissects the Boone Formation along most of its length, during rainstorms the caves and conduits forming the subsurface drainage network within the Boone rapidly transport much of the infiltrating rainwater to the river (Brahana, et al., 2016). This subsurface water meets with the overland storm runoff, especially from the Boston Mountains, and produces huge floods on the Buffalo River (Neely, 1985). Yearly high volume bankfull flows and occasional extreme floods carve and maintain very large pools (McKenney, 1997; Panfil and Jacobson, 2001).

Under low flow conditions the river's velocity slows, and in summer the Buffalo River can become relatively warm because of the open canopy, clear water, and sunlight warming the large, clear, open pools (Mott, 1997). Warm water temperatures, low flows, clear water, and plenty of sunlight combine to make the Buffalo more susceptible to nuisance aquatic vegetation growth than cooler, faster-flowing Ozark streams. During some summers the river can become aesthetically degraded (Figure 2) due to aquatic plant production (Meyer and Rippey, 1976). Meyer and Rippey found that orthophosphate concentrations (the soluble form of phosphorous taken up by algae) was very low in the river, indicating it is quickly processed by the algal population, suggesting it could be a limiting nutrient. They further hypothesized that increased levels of phosphorous could increase the density of algae and frequency of algal blooms present in the river. These algal blooms are the most common water quality related complaint of park visitors.

Figure 2: Filamentous algae in the Buffalo River during low-flow conditions in 2016 (source: Carol Bitting).

Ozarks soil is relatively poor quality, and often contains rock fragments known as chert. As a result, agriculture in the Ozarks is predominated by pasture and hay land. In the last half century, Ozarks farmers have effectively utilized confined animal feeding operations, and the concentrated manure they produce, to supplement fertilizer requirements of hayfields and pastures. In northwest Arkansas, excessive application of fertilizer, primarily in the form of dry poultry manure, has contributed to streams no longer meeting their designated uses and being placed on the 303(d) list of impaired waters. Because the Buffalo River is in a rugged and remote setting, agricultural development has lagged, and the water quality of the Buffalo River has remained mostly excellent during base-flow conditions (Mott, 1997; Watershed Conservation Resource Center, 2016).

Pindall Landfill Permit Rescission

In 1984, a solid waste disposal permit application was submitted to ADEQ (then known as Arkansas Department of Pollution Control and Ecology) under Arkansas' Solid Waste Management Code for a proposed landfill near Pindall, Arkansas just north of the Buffalo River's surface watershed divide. In 1985, a preliminary hydrogeologic report and initial design and operation narrative was submitted to ADEQ. The public had become aware of the pre-application, and Congressman John Paul Hammerschmidt requested more information about the proposal. This initial application was considered deficient by ADEQ, and the applicant continued to refine their permit application.

There was concern that this landfill, which would be located in the karstic Boone limestone formation, might present a risk of groundwater contamination. Local citizens were also concerned and formed a group called Citizens Against the Land-Fill (CALF). CALF hired geohydrologist Tom Aley with Ozark Underground Laboratory to evaluate the groundwater system using dye-tracing techniques. Tracing demonstrated that groundwater from the proposed landfill site, which is located within the Crooked Creek topographic watershed, can flow to Mitch Hill Spring, the park's largest spring. ADEQ refuted these results, but asked the landfill proponent to install a leachate collection and monitoring system and propose a method of leachate disposal. This prompted the permittee to file for a NPDES permit to discharge the treated leachate to the City of Marshall's Sewage Treatment Plant.

Based primarily on the dye-tracing results and their implications, the Superintendent of BNR stated the agency's position in April 1986:

> "As part of the National Park System, the Buffalo River is a National treasure. This proposed landfill represents a significant threat to the integrity of this resource and should therefore not be permitted."

National Park Service legal counsel and technical experts were assigned to the project and the NPS presented oral positions at public meetings and submitted written comments for the record. Governor Bill Clinton asked ADEQ if this was a wise location and requested careful consideration of the permit application. On August 20, 1986, the ADEQ Director notified the park superintendent that a decision had been made to issue the permit.

Within the 30-day window prescribed by Regulation 8, attorneys for both the National Park Service and CALF filed formal appeal documents and a request for an adjudicatory hearing to the Arkansas Pollution Control and Ecology Commission (APC&EC). The objective of the appeal was to request that APC&EC, which oversees the Department, rescind the permit.

National Park Service experts were brought in from Mammoth Cave National Park and elsewhere to testify before the APC&EC, along with park staff, including the Superintendent. This testimony was coordinated with the expert opinion of consultants hired by CALF. Presentation of evidence and testimony took place over the course of seven Commission meetings. On May 22, 1987, the landfill permit was rescinded by order of the APC&EC.

Water Quality Monitoring Program

The Pindall Landfill issue prompted concern about the potential for external developments to cause alteration of the Buffalo River's water quality, and in 1985 Resource Managers at BNR reached out to the National Park Service's Water Resources Division to establish a water quality monitoring program. A Water Quality Monitoring Plan was developed and sampling started in 1985 (Thornton and Nix, 1985) and continues today. Originally, the NPS conducted all of the sampling, and Ouachita Baptist University's water quality lab performed analyses. In 1990, the park established a hydrologist position to oversee the water quality monitoring program, among other tasks. Soon after, BNR and ADEQ began to cooperate in the water quality monitoring program and undertook special studies where water quality monitoring detected potential problems.

Nutrient samples collected by BNR staff are analyzed in ADEQ's water quality lab, and ADEQ staff uploads the data to EPA's national water quality database. Fecal coliform, turbidity, and E. coli samples are analyzed in BNR's Water Quality Lab. BNR also manages a copy of the water quality database, which now has over 30 years of monthly and quarterly samples for 9 river sites, 20 tributaries, and 3 springs (see Figure 3 and Table 1). The sampling design and parameters collected were designed with consideration in assessing impacts from external development as a priority issue, and one of the tributaries sampled was Big Creek near Carver (T6). A scientifically credible baseline has been established over the last 30 years for many key parameters and these results will be discussed later in the report. For more details on the water quality monitoring program and some of its results and accomplishments, see BNR Water Quality Monitoring Plan and Water Resources Management Plan (Mott, 1993; Mott and Laurans, 2004).

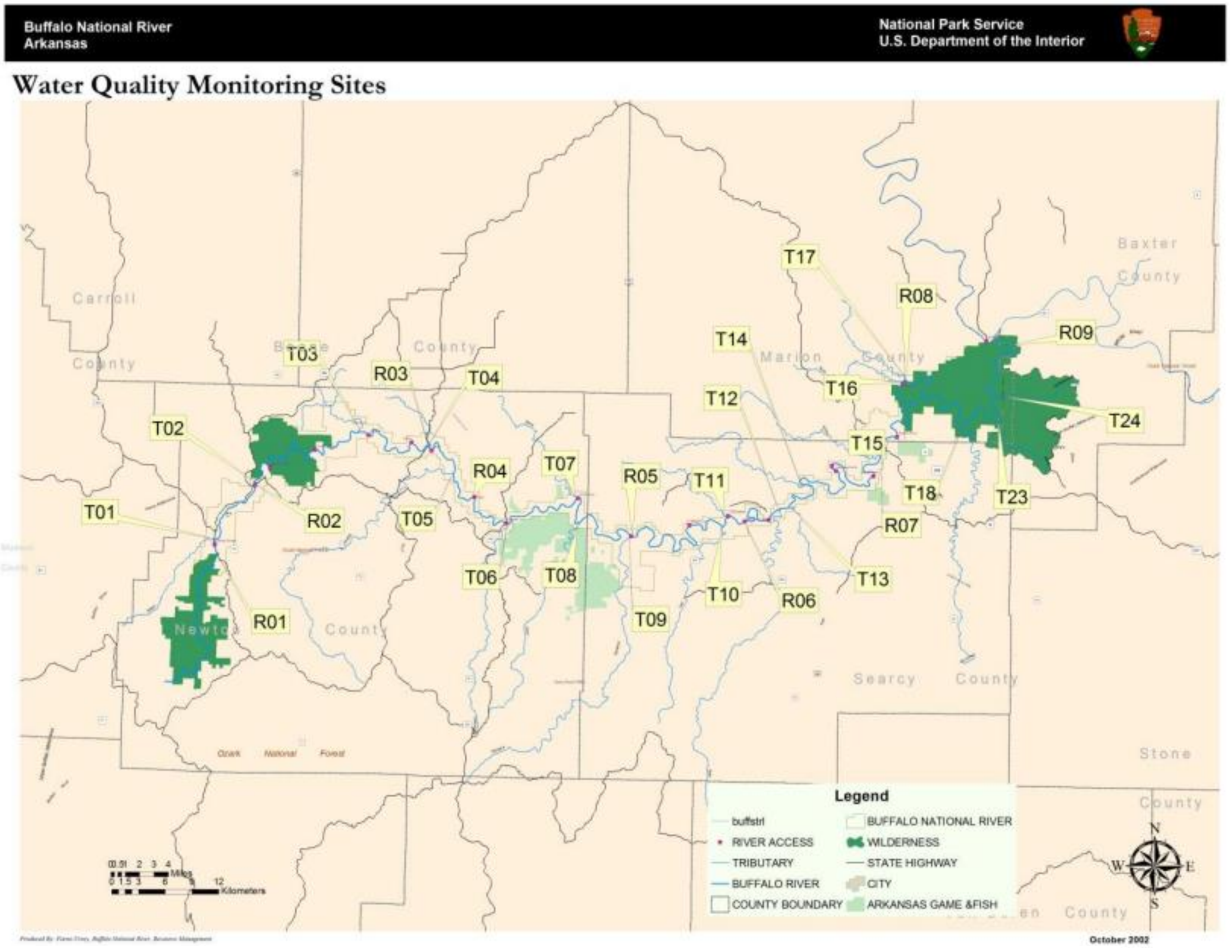


Figure 3: Buffalo National River Water Quality Monitoring Program sampling sites (source Usrey, 2013)

Table 1: Buffalo National River Water Quality Monitoring Program sample collection sites.

Springs	
S2	Luallen Spring
S33	Mitch Hill Spring
S41	Gilbert Spring

River Sites	
R1	Wilderness Boundary
R2	Ponca
R3	Pruitt
R4	Hasty
R5	Woolum
R6	Gilbert
R7	Hwy 14
R8	Rush
R9	Mouth

Tributaries	
T1	Beech Creek
T2	Ponca Creek
T3	Cecil Creek
T4	Mill Creek
T5	Little Buffalo River
T6	Big Creek/M
T7	Davis Creek
T8	Cave Creek
T9	Richland Creek
T10	Calf Creek
T11	Mill Creek/M
T12	Bear Creek
T13	Brush Creek
T14	Tomahawk Creek
T15	Water Creek
T16	Rush Creek
T17	Clabber Creek
T18	Big Creek/L
T23	Middle Creek
T24	Leatherwood Creek

Dye Tracing

One of the special studies conducted in cooperation with ADEQ examined the source of high nutrient concentrations coming into the river from Mill Creek (T4 on Figure 2). During that study, it was determined that 96 percent of the nitrate load carried by the Buffalo River downstream of its confluence with Mill Creek originated from Mill Creek. The study revealed the majority of the nutrient source was a large spring near the head of Mill Creek (Maner and Mott, 1990). Because this spring had an unusually high volume of discharge relative to the size of its surface basin, investigators suspected ground water was being supplied from the adjacent Crooked Creek watershed. Dye tracing studies were initiated and the results indicated that 80 percent of the land area draining to the spring lies across the surface water divide in the Crooked Creek basin. Detailed geologic mapping combined with 3D modelling of the aquifer revealed the Mill Creek springs lie in a structural low, and the spring was the outlet for water draining from the base of the Boone Formation. The water quality results better matched land use in the interbasin recharge area of Crooked Creek, which has a greater percentage of cleared land (Mott et al., 2000).

Several other dye-tracing studies were conducted in an attempt to fully characterize the interbasin recharge area contributing groundwater to the Buffalo River. Detailed geologic mapping and aquifer modelling continued as well. One trace resulted in dye going to springs in both the Crooked Creek and the Buffalo River watershed. Other traces linked Davis Creek to Mitch Hill Spring significantly increasing the recharge area estimated for this spring during the Pindall studies. Geologic mapping revealed Mitch Hill Spring is in the Everton Formation, a karst unit below the Boone Formation. Through faulting and other structural controls, Mitch Hill Spring integrates ground water from the Boone and underlying strata from an area 14 times larger than its surface water drainage area (Soto, 2014; Hudson, 1998).

1992 Moratorium on CAFOs in the Buffalo River watershed

Data collected as part of the water quality monitoring program indicated a general loading of nutrients and bacteria into the river from its tributaries, with extreme spikes during rain events (Mott and Laurans, 2004). In 1992, ADEQ received a permit application for a 480 sow/2100 pig farrowing operation to be sited less than 1-mile from the park boundary near Piercetown, AR. Field investigations of the proposed site showed karst bedrock, sinkholes, and poor soils not considered suitable for land application of liquid waste. Water quality modelling results predicted that leakage from the waste ponds into the karst strata: "would result in Buffalo River NO3-N concentrations 1.7 – 56 times greater than current background concentrations" (Kresse, 1992).

During public review, letters from the NPS, FWS, and the public expressed two main concerns; (1) the short distance from the Buffalo River, and (2) the direct conduits to ground water characteristic of the karstic Boone Formation. In response to these concerns, ADEQ initiated "an investigative study to assess if a hog operation in this location would be an immediate or future threat to the water quality of the Buffalo River" (Arkansas Soil and Water Conservation Commission (ASWCC), 1994).

Concurrently, ADEQ inspections of permitted CAFOs in the watershed indicated multiple concerns including the finding that 52 percent had excessive solid waste built up in the manure holding ponds, and at 25 percent of the inspected farms, waste flowed continuously over the bank of the storage pond and off site. ADEQ staff concluded "the current system by which confined animal operations are designed, permitted, and regulated is failing to curtail discharges from the waste storage and disposal systems" (ADEQ, 1993). Based on these results, ADEQ staff recommended a moratorium on any new CAFOs, while a more detailed study and assessment was conducted. Recommendations also would be made concerning improvements to CAFO operations and the permits used to regulate them. ADEQ Director Randall Mathis signed the moratorium on October 12, 1992 (see Appendix A).

1994 – 2002 ADEQ Confined Animal Feeding Operation Study

As discussed, the Director of ADEQ implemented a moratorium on permitted CAFOs in the Buffalo River watershed, while studies were performed and recommendations made and implemented to improve water quality conditions and runoff. In the proposal for these studies, ADEQ summarized the issue as:

> "The greatest threat to surface and ground water quality in northwest Arkansas is nonpoint source pollution from confined animal operations. Northwest Arkansas has the greatest percentage of broiler houses, hog farms, and dairies than any other area of the State. In conjunction with having some of the highest production rates in the United States, northwest Arkansas is also listed as one of the most vulnerable areas of the State to potential ground water pollution (ASWCC, 1991). Practically all of the waste generated from these animal production facilities is land applied and, as a result, nitrate levels measured from this region are atypically high" (Arkansas Department of Pollution Control & Ecology, 1992).

Also included in the proposal was a discussion of the site investigation that helped justify the 1992 moratorium. Investigation of 16 of the 21 permitted CAFO operations in the Buffalo River watershed "revealed numerous problems related to the design and/or management of the waste disposal system." Discussions with the permittees revealed that often "he did not understand or was not familiar with his site management plan, including the sections of his land available for land application of waste, the proper pond to pump from in a two-stage system, and other aspects of the waste storage and disposal system" (ADEQ, 1993).

Review of previous ADEQ inspection reports indicated these problems had persisted for many years, and ADEQ efforts to bring operators into compliance with their permit requirement had been mostly unsuccessful (ADEQ, 1993). As of 2005, ADEQ was responsible for permitting 2,100 CAFOs in Arkansas, with 108 of these utilizing liquid waste disposal systems. According to an EPA review conducted in 2005, ADEQ inspects 100% of CAFOs once a year. CAFO enforcement priorities are (1) release discharges and (2) repeat discharges. Enforcement actions on a "paperwork" violation are not issued unless it is a repeat violation. A draft formal enforcement action, with or without a penalty, is sent to the facility for review, comment, and/or signature. If the facility is known to be recalcitrant, ADEQ can go directly to a notice of violation (NOV). Enforcement actions are tracked by an internal tracking system (EPA, 2005).

ADEQ issues many formal enforcement actions; however, during past audits of ADEQ's program, it was determined that "approximately 30% of the actions were not addressed in a timely manner and did not have appropriate escalation when violations continued over a long period" (EPA, 2005).

ADEQ coordinated with the Arkansas Soil and Water Conservation Commission to access EPA 319 (h) funds, requesting $300,000 in federal funds to be matched with $220,000 in non-federal funds (ASWCC, 1994). The 4-year study began in 1994, and the following are highlights from the goals:

- Monitor and evaluate the effectiveness of the Waste Management System Best Management Practices including design, training, and management;
- Evaluate water quality at various locations;
- Reduce waste loads from the study sites and reduce permit violations; and,
- Demonstrate that CAFOs can be operated without significant impacts to water quality.

Study sites were located in the Little Buffalo, Big Creek, and Cave Creek watersheds within the Buffalo River basin in Newton County. Objectives associated with this study were directly applicable to concerns related to the C and H Hog Farms operation. Five or six hog farms and one pristine site were to be selected for an evaluation of waste management systems and associated BMPS, and to conduct:

1. Sampling and analysis of surface water runoff (collection of samples by automatic sampling devices, grab, and/or rainfall simulation events); sampling and analysis of the shallow perched interflow (collection by shallow trench and/or suction lysimeters); sampling and analysis of shallow ground water (collection by shallow upgradient and downgradient monitoring wells); sampling of the soils at various locations; sampling of a tributary at upgradient and downgradient locations from one farm site.
2. Nutrient and bacteria loads leaving one farm site will be determined by measuring flow and concentration of runoff.
3. Identification of the on-site sources contributing to the greatest impact to the surface and/or ground water. Creation of a new BMP or modification of existing BMPs for reducing waste loss from each of these sources.
4. Implementation of these BMPs with continued monitoring to evaluate the effect of the modified BMP. This may include improving the Waste Management System to meet the standards set in the SCS[1] Field Office Technical Guide and any other standards required by ADPC&E.
5. Review and summarize water quality data from ongoing, joint ADPC&E/Park Service Buffalo River and major tributaries sampling program.
6. Assessment of surface/subsurface water interactions such as quantity and quality of total ground water contributions to the stream.
7. Work directly with SCS to modify state permit standards based on the results of this project.
8. ADPC&E will survey the other swine farms in the watershed and use the results of the demonstration farms along with these surveys to estimate the load reductions.

[1] Soil Conservation Service now referred to as the Natural Resources Conservation Service (NRCS)

This proposal was supported by BNR. Implementation funding included 75% cost share to cooperating farmers installing recommended Best Management Practices (BMPs). BNR staff assisted ADEQ with installation of some of the more complicated flumes and automated sampling and recording instrumentation needed to sample storm generated runoff, and contributed all data from the Water Quality Monitoring Program and other sources.

As with many large studies, problems evolve and priorities change. Based on review of published documents that could be located, ADEQ efforts in this study ultimately focused on developing better means of storing, retrieving, and spreading waste from storage ponds. Sludge accumulation was a significant concern because it contained higher than anticipated phosphorus concentrations and was difficult to extract and apply in conformance with the nutrient management plan. The close-out report to EPA for this project was titled “Land Application of Accumulated Solids From Liquid Waste Systems Demonstration Project” dated September 30, 2002. This report provided little information or data that could be linked back to the original water quality data collection and evaluation objectives. For example, there was no reporting or data presented on any of the objectives listed above with the exception of some aspects of #4 and a general reference to reducing off-site nutrient loads (Formica et al., 2001, ADEQ, 2002).

One of the side projects spun out of this work involved using rainfall simulators to estimate runoff concentrations of nitrogen and phosphorus from controlled application plots located near Jasper, AR on the Boone Formation. Runoff from these plots ranged from 45.2 to 146 mg/L of total phosphorus (P). Even under the best of controlled conditions where manure application rates were minimized, ground cover was good, and aluminum chloride was added to bind phosphorus, depending on soil types “1.8 – 6.2 percent of the nitrogen and 2 to 9.6 percent of the phosphorus that was land applied was lost to storm water runoff” (Smith et al., 2001; Formica et al., 2001). In a review of separate rainfall simulator and other studies, Sharpley, (1993), concluded, soil P content, volume of runoff, and erosion are the major factors determining P transport from waste application sites.

Another documented concern was the build-up of phosphorus in soils. Soil phosphorus commonly exceeded 300 pounds per acre on the permitted land application fields sampled, which is considered by agronomists to be the cutoff for additional manure application (Coblentz et al., undated). A statewide sampling of swine facility waste ponds concluded the need to clean out accumulated solids was a widespread issue, and that these solids were very high in nutrients, especially P, much higher than anticipated in the nutrient management plan (Van Epps et al., 1998). ADEQ staff determined that mixing the solids with an agitator was critical prior to removing waste from the storage pond. However, the cost of agitation and spreading ($3,000 to $30,000) was typically more than a producer could afford. Also, once accommodations were made for the actual build-up of nutrients in fields previously used to receive waste, most operators did not have enough acreage to dispose of the pond sludge clean out wastes even one time.

This project was successful in getting producers, integrators, academics, cooperating agencies and regulators to focus on waste management environmental issues related to liquid waste management systems. Several ideas for better waste management were developed, tested, and demonstrated

(ADEQ, 2002). The report failed to provide the off-farm environmental sampling, results, and analysis as called for in the study objectives.

It is unknown and undocumented as to what elements of this study were used to inform permitting requirements and/or decisions. ADEQ did not announce the conclusion of the study or provide a report detailing their findings, and the 1992 Buffalo River watershed CAFO moratorium was subsequently lifted (Formica et al., 2001; Van Epps et al., 1998).

C and H Hog Farms, Incorporated

The first swine CAFO permitted in the Buffalo River watershed since the 1992 moratorium is C and H Hog Farms, Inc., located in the Big Creek watershed near Mt. Judea (pronounced Mt. Judy), AR. Big Creek is the fifth largest watershed contributing to the Buffalo River with a drainage area of 84 mi sq. (53,460 acres)(Panfil and Jacobson, 2001). Mt. Judea is within Newton County, and as with most of the county, the population is sparse and the median incomes are low. The facility (Figure 4) was designed in a similar manner to the previous swine CAFOs studied by ADEQ from 1994 – 2002, but is at a much larger scale. The waste storage ponds and land application sites are predominantly underlain by the Boone Formation; therefore, karst geohydrology. This karst environment governs how the operation interacts with the basin's ground and surface water resources. At nearly 50 percent of the acreage available for land application, alluvial material covers the Boone Formation. Under these stream deposits, dissolution and erosion has formed a "cutter and pinnacle" bedrock surface (Halihan and Fields, 2015). Combined with secondary porosity, contaminant transport and fate could include conduit routes to the subsurface drainage system, a surface stream, or both. During summer low-flow conditions, Big Creek is dry near C and H Hog Farms, which means the stream is flowing through the valley's underground karst drainage network developed in the Boone Formation.

In 2012, C and H Hog Farms submitted a Notice of Intent (NOI) to construct a swine gestation and farrowing operation housing 6,503 head weighing an average of 150 pounds, which is classified as a large CAFO under EPA regulations. The almost one million pounds of swine would generate an estimated 1.5 million gallons of waste annually. Pit recharge, wash water, and precipitation add approximately 2.2 million gallons, to yield the total volume of 3.7 million gallons of liquid to be land applied on 630 acres (Henson, 2012).. The two holding ponds have a capacity of 2,735,922 gallons, with under barn concrete pits adding an additional 759,542 gallons. Factoring in the 25-year, 24-hour rainfall event, engineering calculations estimate 270 days of storage, fifty percent more than ADEQ's required minimum of 180 days. The NOI contained an engineering firm prepared report titled "Major Construction Approval Application" (DeHaan, Grabs and Associates, 2012) with two purposes selected on NPDES Permit Application Form: 1.) Initial Permit Application for New Construction and 2.) Construction Permit. ADEQ approved the NPDES General Permit for this operation on August 3, 2012.

Figure 4: Aerial photo of the C and H Hog Farms farrowing and gestation buildings and waste storage ponds looking south. For scale, the large building is 441 feet long by 138 feet wide, and the area of the ponds totals 1.3 acres (photo source: Carol Bitting).

During operation, waste is flushed through slats to shallow (2 feet deep) concrete pits, and then drained to the first pond which, upon filling, overflows to pond 2. Sludge will mainly accumulate in pond 1. Pond 2 water is reused along with fresh water to flush the barns. Two of the three owners of C and H Hog Farms were owners of C and C Hog Barn near Vendor, AR (now referred to as EC Hog Farm), which was a 325 head gestation and farrowing facility that closed once C and H Hog Farms became operational.

Holding pond liners were constructed of "Fat Clay" found on site and identified in two of three exploratory boreholes at depths of 7 – 11 feet. Boreholes also showed chert gravel and chert layers, and variable depths to auger refusal, which are indicative of karst regolith, and dissolution forming cutter and pinnacle bedrock surface topography. Total surface area of the two ponds is 1.3 acres and engineers state "seepage rates will be less than ADEQ maximum allowed seepage rates of up to 5,000 gallons per acre per day" (DeHaan, Grabs and Associates, 2012). 5,000 gallons per acre per day equates to a permitted loss of 2,372,500 gallons per year, more than half the C and H Hog Farms' estimated waste production, wash water, and precipitation volume. In a letter to the Ozark Society, ADEQ personnel state (ADEQ, 2013):

> “Permeability, or seepage, is the quantity of fluid that has passed through the pond liner and **into the soils**. The design calculations for anticipated seepage are based on USDA NRCS Part 651 -Agricultural Waste Management Field Handbook - Chapter 10 Agricultural Waste Management System Component Design which states, NRCS guidance considers an acceptable initial seepage rate to be 5,000 gallons per acre per day. This higher value used for design assumes that manure sealing will result in at least a half order of magnitude reduction in the initial seepage."

Natural Resources Conservation Service (NRCS, 2012) Agricultural Waste Management Field Handbook chapter 7 discusses the issues, siting considerations, and specific problems associated with karst geology (NRCS, 2012). This discussion is consistent with general karst concerns and water quality considerations commonly accepted by the scientific and resource management community.

> “Fractures in bedrock may convey contaminants directly from the site to the well and significantly affect water quality in a local aquifer. Although karst topography is well known as a problem because of its wide, interconnected fractures and open conduits, almost any near-surface rock type will have fractures that can be problematic unless **treated in design**. Fractures have relatively little surface area for attenuation of contaminants. In fact, many fractures are wide enough to allow rapid flow. Pathogens may survive the passage from the site to the well and thereby cause a health problem.”

The NRCS manual discusses the need for additional site investigations in karst areas and provides several engineering approaches to mitigate known concerns and presents alternative design considerations. In summary, *Table 10-4 Criteria for siting, investigation, and design of liquid manure storage facilities* within the NRCS manual states that where the vulnerability of the site is very high, such as in karst locations, the recommendation of NRCS is to “Evaluate other storage alternatives” other than clay-lined ponds (Appendix B). The NRCS manual also includes specific examples for how to manage liquid waste where it is deemed pond storage is unadvisable.

Figure 5 shows erosion rills in the clay liner on the sides of one of the C and H Hog Farms’ storage ponds and gravel and cobbles mixed in the clay liner. Figure 6 shows the design drawings for one of the storage ponds. ADEQ inspectors and others are concerned that the erosion and desiccation cracks may have damaged the liner, and the mixed size fraction of particles within the liner could increase hydraulic conductance in excess of stated design specifications (Morris, 2013).

Figure 5: Erosion rills and gravel to cobble size fraction within one of the waste storage ponds (from Morris, 2013).

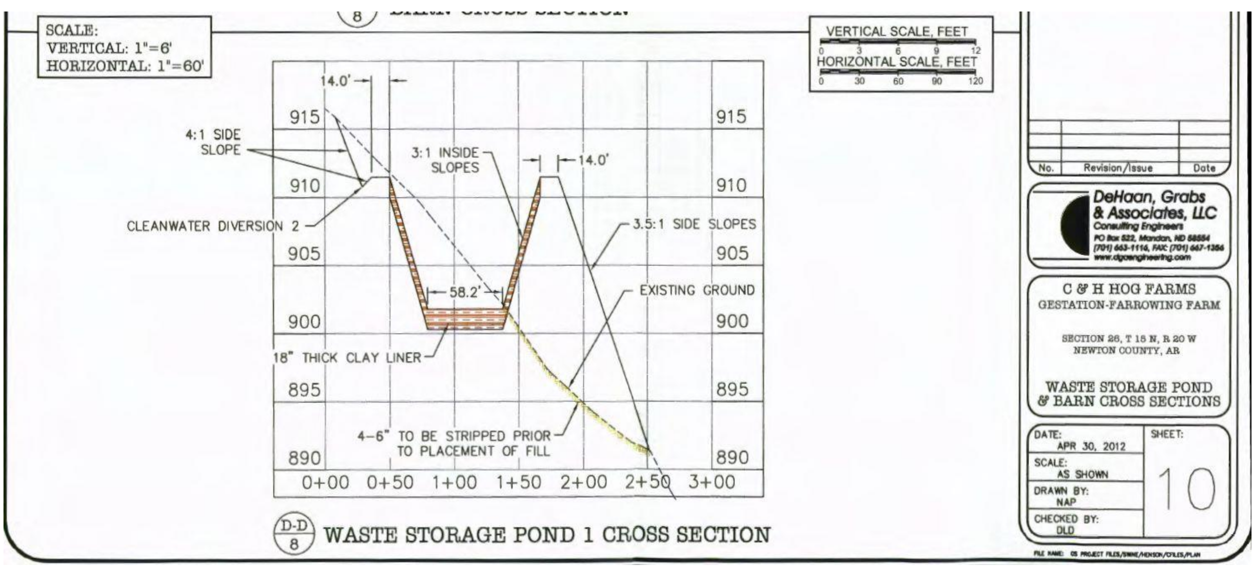


Figure 6: Waste storage pond 1 cross-section showing the 18-inch clay liner (source DeHaan, Grabs, and Associates, 2012).

Nutrient Management Plan

The NOI includes a Nutrient Management Plan (NMP) to describe plans for land application of the estimated 3.7 million gallons of liquid waste, wash water, and precipitation produced annually on seventeen application fields totaling 630 acres. The Nutrient Management Plan was prepared by DeHaan, Grabs & Associates, LLC, based in Mandan, ND in May 2012, and was stamped approved by a registered Arkansas Engineer. This section specifically evaluates the following statement in the NOI:

> "The area will be used to produce hay and pasture, **thereby consuming the nutrients in a full cycle system**. All land application areas will receive application of waste at rates consistent with infiltration capabilities of the native soils such that there is **no runoff** to surrounding areas."

The amount of nutrients produced at C and H Hog Farms is estimated in the NMP. The nutrients to be focused on in this report are nitrogen and phosphorus. Nitrogen is available for plant uptake primary in the form of ammonium (NH4) and nitrate (NO3), and for phosphorus in the form of orthophosphate (OPO_4). According to the NMP, 92,611 pounds of nitrogen and 31,091 pounds of phosphorus would be generated annually from C and H Hog Farms.

One useful comparison is how large of a human population would be required to produce the same volume of nutrients produced by C and H Hog Farms? According to Spellman and Whiting, 1996, the mass of nitrogen and phosphorus per 1000 animal units (AU) per day for humans is 0.2 and 0.02 pounds per day, respectively. The average weight of a human in North America is currently estimated at 178 pounds (Walpole et al., 2012). Calculations derived from these sources and the NMP reveal more than 7,000 humans are required to produce the same mass of nitrogen as the C and H Hog Farms operation, and more than 23,000 humans would be required to produce the 31,000 pounds of phosphorus. The population of Newton County was only 8,064 in 2013, according to census data. These calculations indicate that C and H Hog Farms has a significant nutrient load to be managed, far in excess of a typical Buffalo River watershed farming operation. The NMP uses buffer strips and slope avoidance as mitigation measures.

Phosphorus Considerations

Soil phosphorus can be a potential source of contamination to surface water for both sediment-attached and soluble phosphorus in runoff (NRCS, 2012; Sharpley, 1993). Table 3 was prepared from soil sample results contained in the NMP prepared for the NOI submitted prior to C and H Hog Farms conducting land application activities. Guidance from University of Arkansas states that fields are considered to be above the optimum level for phosphorus (P) when values exceed 50 pounds per acre (Espinoza et al., 2007). Only fields 12 and 15 were recommended by the University of Arkansas as needing additonal phosphorus. All other fields were recommended to receive zero pounds per acre for a "full-cycle system" (DeHann, Grabs, and Associates, 2012). Based on the soil test recommendations, out of the 630 acres permitted to receive land application, only 85 acres actually required additional P, and the total recommended P for these 85 acres equates to 3,391 pounds. Furthermore, when the acres are looked at in total, these 17 fields contain an above optimum surplus of 21,815 pounds of phosphorus already existing on the landscape.

Field Number	Usable Acres	Phosphous level	P_2O_5 lbs/field Recommended by University of AR	Concentration ppm (mg/L P_2O_5)	Existing lbs/acre P_2O_5	Excess P_2O_5 on landscape (pounds)*
1	15.6	Above Optimum	0	83	166	1810
2	17	Above Optimum	0	72	144	1598
3	13.6	Optimum	0	42	84	462
4	8.8	Optimum	0	50	100	440
5	23.8	Above Optimum	0	65	130	1904
6	34.5	Above Optimum	0	76	152	3519
7	74.3	Above Optimum	0	178	356	22736
8	15.5	Optimum	0	46	92	651
9	41.2	Above Optimum	0	52	104	2225
10	33.2	Above Optimum	0	69	138	2922
11	20.7	Above Optimum	0	57	114	1325
12	23.7	Low	1,659	19	38	-284
13	61.6	Optimum	0	48	96	2834
14	18	Above Optimum	0	52	104	972
15	61	Very Low	6,100	15	30	-1220
16	79.6	Optimum	0	48	96	3662
17	88.7	Optimum	0	50	100	4435
Total	630		7,759 (**3,391 lb P**)			49,989 **(21,815 lb P)**
* Calculated by: (Existing lb/ac – 50 pounds optimum) * # acres; P_2O_5 * 0.4364 = P						

Table 2: Soil test phosphorus results from the C and H Hog Farms nutrient management plan, analyzed in 2012 prior to application of swine waste.

Long-term applications of organic P at rates that exceed the uptake rate of plants can result in saturation of the adsorption sites near the soil surface. This results in increased concentrations of both soluble and labile (easily altered) P. The excess soluble P can either leach downward to a zone that has more attachment sites, and then be converted to labile P or fixed P, or in karst environments, it could infiltrate conduits and subsurface drainage networks. Excess phosphorus can also be carried off the land in runoff water. If soils that have high labile P concentrations reach surface water as sediment, sediment particles will continuously desorb (release P in the soluble form) until equilibrium is attained. Therefore, sediment from land receiving animal waste at high rates or over a long period of time will have a high potential to pollute surface water (NRCS, 2012).

Sandy soils, such as those common to alluvial deposits in the Big Creek floodplain, may not effectively retain phosphorus (NRCS, 2012). If the ground water table is close to the surface, the application of waste at excessive rates, or at nitrogen-based rates, will likely contaminate the ground water beneath those soils. However, ground water that is below deep, clay soils is not likely to be contaminated by phosphorus because of the adsorptive capacity of the clay minerals. Almost half (291 acres) of the application fields used by C and H Hog Farms have alluvial soils, which commonly have a higher sand content than in-situ developed soils.

Because northwest Arkansas has a substantial CAFO industry, high phosphorus readings in pasture soils receiving animal waste is a common occurrence. Vast areas of the landscape could not accept phosphorus if soil test results and plant uptake requirements were the only criteria applied. To assist landowners and regulators with estimating the potential for phosphorus to impact waters of the State, Arkansas has developed the Arkansas Phosphorus Index (API) (Sharpley et al., 2010). This index uses various factors to estimate likelihood of phosphorus mobilization. However, this Index is not referenced in the NRCS (2012) guidance manual. Rather, the NRCS states "Waste must be applied in a manner that:

- Prevents runoff or excessive deep percolation of the wastewater,
- Applies nutrients in amounts that do not exceed the needs of the crop, and
- Minimizes odors from the waste being applied"

This approach would provide for long-term viability for agricultural producers and the environment, especially in sensitive karst settings upstream from one of the State's most renowned Extraordinary Resource Waters.

Estimated total waste water production was approximately 2.6 million gallons per year according to the 2014 and 2015 annual reports filed by C and H Hog Farms. The ongoing test results from the waste storage ponds and soils, and results from recalculations of the Arkansas Nutrient Management Planner with 2009 Phosphorus Index, confirm earlier projections that phosphorus is being applied at rates in excess of annual plant consumption. Several scientific papers are accessible at the BCRET website detailing how long-term application of excessive phosphorus in watersheds results in a slow but steady build-up of legacy phosphorus in soils and ground water. Once phosphorus outmigration from the watershed becomes measurable, it can continue for a long time with lasting environmental consequences (www.bigcreekresearch.org).

Nitrogen Considerations

Nitrogen (N) is one of the most important major plant nutrients contained in animal manure and is readily dissolved in water. According to the NRCS, even when application rates target plant consumption levels, nitrogen is the most difficult nutrient to manage because of the many pathways it can follow to get into ground and surface waters (NRCS, 2012). NRCS reviewed study results comparing dissolved nitrogen concentration in runoff from grass with and without applied manure, and determined dissolved nitrogen was typically 370 percent higher from fields with manure application. Negatively charged nitrate also remains in the soil solution and readily moves with infiltrating water. Generally, nitrate has the greatest pollution potential of the three nutrients and can limit the amount of organic waste that can be safely applied on the land.

A study by Daniel, et al. (1991), compared nitrate concentrations in groundwater between areas with large amounts of cattle/poultry production, and forested areas. Thin soils, fractures, and solutionally enlarged openings in the Boone-St. Joe limestone aquifers were shown to make them susceptible to contamination. The study found that cattle/poultry areas had significantly higher nitrate concentrations than forested areas. Another study, (Steele et. al., 1990) compared wells in the Everton and Boone formations and also compared control wells in mostly forested areas to experimental wells in pasture areas. Nitrate levels were significantly higher for wells in pasture dominated areas compared to control wells, and were higher in the shallower wells (Steele et. al., 1990). Also, during rain events, springs in pasture dominated areas showed minor increases in nitrate concentrations but large increases in fecal coliform colonies.

Bacteria Considerations

The excreta from warm-blooded animals have countless micro-organisms, including bacteria, viruses, parasites, and fungi. Some of the organisms are pathogenic (disease causing), and many of the diseases carried by animals are transmittable to humans, and vice versa. Table 3 (NRCS, 2012) lists some of the diseases and parasites transmittable to humans from animal manure. Many states, including Arkansas, use fecal coliform and/or *Escherichia coli* (*E. coli*) bacteria as indicators of pollution from warm-blooded animals, including humans. The fecal coliform and *E. coli* groups represent a part of the total coliforms, and are easily differentiated from the total coliforms during testing. A positive test for fecal coliform bacteria is a clear indication that pollution from warm-blooded animals exists. A high count indicates a greater probability that pathogenic organisms will be present (McCabe, 1997).

Disease	Responsible organism	Disease	Responsible organism
Bacterial		Viral	
Salmonella	Salmonella sp.	New Castle	Virus
Leptospirosis	Leptospiral pomona	Hog Cholera	Virus
Anthrax	Bacillus anthracis	Foot and Mouth	Virus
Tuberculosis	Mycobacterium tuberculosis	Psittacosis	Virus
	Mycobacterium avium		
Johnes disease	Mycobacterium paratuberculosis	Fungal	
		Coccidioidomycosis	Coccidoides immitus
Brucellosis	Brucella abortus	Histoplasmosis	Histoplasma capsulatum
	Brucella melitensis	Ringworm	Various microsporum and trichophyton
	Brucella suis		
Listerosis	Listeria monocytogenes	Protozoal	
Tetanus	Clostridium tetani	Coccidiosis	Eimeria sp.
Tularemia	Pasturella tularensis	Balantidiasis	Balatidium coli.
Erysipelas	Erysipelothrix rhusiopathiae	Toxoplasmosis	Toxoplasma sp.
Colibacilosis	E. coli (some serotypes)		
Coliform mastitis-metritis	E. coli (some serotypes)	Parasitic	
		Ascariasis	Ascaris lumbricoides
		Sarcocystiasis	Sarcocystis sp.
Rickettsial			
Q fever	Coxiella burneti		

Table 3: Diseases and organisms spread by animal manure (source NRCS, 2012).

In more recent years, EPA and the State of Arkansas have established criteria for using *E. coli* in regulatory standards for surface waters along with fecal coliform bacteria (see Water Quality Standards section). The EPA reports that a direct relationship between the density of *E. coli* in water and the occurrence of swimming-associated gastroenteritis has been established, resulting in numeric criteria defining recreational water standards (EPA, 2012; NRCS, 2012). There is no estimate of bacteria production or attenuation in the NMP as there is for nutrients (DeHaan, Grabs, and Associates, 2012). In a letter to ADEQ, the Arkansas Department of Health expressed their concern for potential pathogen risk for park visitors stating "…we have concerns that water borne pathogens – including E-coli and Cryptosporidium - from the proposed land application sites may pose a risk for full-body contact on the BNR, a popular recreational destination" (Arkansas Department of Health, 2013). Arkansas Department of Health staff is currently working with BNR to better assess potential concerns related to recreational activity throughout the river as hundreds of thousands of visitors are recreating on and in the river each year.

ADEQ Permitting Action

General Permit

When Congress passed the CWA, it specifically included the term "concentrated animal feeding operation" in the definition of point sources (CWA § 502(14), EPA, 2015). C and H Hog Farms was authorized to construct and operate their CAFO through the use of a general permit. EPA created this permitting approach because it allows permitting authorities to issue a single NPDES permit containing a common set of conditions applicable to a potentially large number of applicants (Gaba, 2007). The general permit itself is issued following a notice and comment process, and individuals become eligible for coverage under the permit after submitting a "Notice of Intent" (NOI). Following submission of the NOI and ADEQ approval, these point sources are authorized to discharge subject to the conditions of the permit.

Because ADEQ did not grant C and H Hog Farms an individual permit to operate its swine facility, it was not subject to the traditional public notification, review, and appeal requirements defined in the CWA and APC&EC regulations. A state-wide general permit already existed (NPDES General Permit No. ARG590000 approved 2012), and through it, ADEQ had established a process whereby an applicant could file a Notice of Intent (NOI) and Nutrient Management Plan (NMP) to operate under its conditions. The application must be in conformance with the Best Management Practices and other stipulations of the general permit. Because the general permit ARG590000 had already gone through the EPA and APC&EC permit review process, the level of public notice was reduced to a 30-day notice and public comment period for the NOI, posted to the ADEQ website (ADEQ, undated).

One of the actions then-Governor Mike Beebe and the State legislature mandated was additional public notice requirements under Act 1511. This was a temporary act instructing ADEQ to not grant any new CAFO permits under the general permitting process without publishing a public notice in a major statewide and county-level paper twice a week for six consecutive weeks (Arkansas State Legislature, 2013). The legislature called for a committee to look into the problems with general permit public notice clauses and recommend changes to Regulation No. 6 (NPDES permits) as appropriate. The committee recommended requiring the same level of public review for CAFOs submitting a NOI under the general permit process as required by EPA, APC&EC, and the CWA for individual permits. The APC&EC promulgated these recommendations into Regulation #6 on September 26, 2014. Additionally, APC&EC placed a new moratorium on CAFOs in the Buffalo River watershed which is discussed in more detail later in the document.

Another issue to which the governor responded was the lack of site-specific assessments or field investigations that normally provide some level of assurance a permit is being approved in compliance with water quality standards, especially the anti-degradation provisions applicable to ONRW waters such as the Buffalo River. Following requests by the C and H Hog Farms owners for assistance from the University of Arkansas Cooperative Extension Service, Governor Beebe requested an allocation from the legislature to fund a significant water quality monitoring program near the C and H Hog Farms facility. This study is being completed by a team led by an agronomy professor, Dr. Andrew Sharpley, with lengthy experience in CAFO nutrient management (Hovis, 2014). That work will be described and examined in more detail under the water quality section.

Individual Permits

Individual permits can be issued to CAFOs in Arkansas under either Regulation 5 (no discharge permit) or Regulation 6 (NPDES). Individual permits are arguably more appropriate for CAFOs that have the potential to garner significant public interest and are located in sensitive environments. Large CAFOs sited in ONRW watersheds dominated by karst landscapes merit a higher level of public scrutiny and site-specific assessments. The individual permit process also allows concerned citizens and agencies to examine the various technical considerations, calculations, and assumptions contained in the permit, and how these considerations, calculations and assumptions led to a final decision by ADEQ. Where these decisions are deemed to result in harm to concerned parties, Regulation 8 provides for administrative procedures to petition the APC&EC to review and potentially override the ADEQ Director's decision, as was the case in the Pindall Landfill permit rescission discussed earlier.

Arkansas Water Quality Standards

One of the requirements of the CWA was to establish water quality criteria and standards for the nation's surface waters. The APC&EC is the entity with responsibility for developing and maintaining water quality criteria and standards through *Regulation #2, Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas.* Based on the author's observations and experiences over the last 30 years, these regulations:

- Apply only to surface waters.
- Are primarily designed to regulate "end of pipe" point source discharges.
- Are sometimes interpreted to be inapplicable to storm event driven nonpoint source pollution (i.e. Reg. 2.401 and 2.501 "Waters may, on occasion, have natural background levels of certain substances outside the limits established by these criteria, in which case these criteria do not apply)."
- Do not set numeric standards for nutrients.
- Do not set numeric standards based on site-specific water quality data available for some ONRW streams that the CWA says must be "maintained and protected."

- Include an antidegradation policy to protect existing uses.
- Utilizes the State of Arkansas' Continuing Planning Process to permit lower water quality where necessary. In allowing such degradation or lower water quality, the State shall assure water quality adequate to protect existing uses.
- Implement the highest statutory and regulatory requirements for all new and existing point sources.
- Implement provisions of the Arkansas Water Quality Management Plan with regard to nonpoint sources.
- Contain a list of Extraordinary Resource Waters for which ONRW status applies.

Outstanding Resource Waters

Arkansas contains many beautiful streams and several have been officially recognized under EPA's ONRW designation, which is referred to in Arkansas as simply Outstanding Resource Waters (ORW). The Buffalo River is listed under two State ORW beneficial use categories; Extraordinary Resource Waters (ERW) and Natural and Scenic Waterways (NSW):

- Where high quality waters constitute an ORW, those uses and water quality for which the outstanding waterbody was designated shall be protected by (1) water quality controls, (2) maintenance of natural flow regime, (3) protection of instream habitat, and (4) encouragement of land management practices protective of the watershed.
- The Buffalo River and many of its tributaries are also primary contact recreation waters because their drainage areas are greater than 10 square miles.
- ERW Status can only be removed to build a reservoir serving a domestic need when no alternative is available.
- The State maintains a process whereby additional waterbodies can be nominated for ONR status.

General Standards

General standards are applicable to all waters at all times unless a waterbody is specifically excluded. Man-made pollution cannot produce undesirable aquatic biota or result in the dominance of nuisance species. These standards also discuss the use of biological integrity assessments to determine if a waterbody's ecological condition has declined relative to a reference waterbody or a list of key species. Other general standards are described for color, taste and odor, foreign materials, toxic substances, and oil and grease.

Specific Standards and Numeric Criteria

Under EPA guidance the APC&EC has promulgated specific numeric standards through Regulation No. 2, usually on an "ecoregion" basis. These regulations are complicated and will only be reviewed in a cursory manner as they pertain to the Buffalo River and tributaries. ADEQ is the agency charged with implementing standards through their various permitting processes, and monitoring and reporting programs to determine if an exceedance has occurred. Some of the most important standards are turbidity, bacteria, dissolved oxygen, toxic substances, and nutrients. As mentioned, there are no specific numeric standards for nutrients, but a narrative standard requiring avoidance of nuisance algae growths, and related dissolved oxygen fluctuations that could be damaging to aquatic communities is provided. Regulation No. 2 briefly explains the State's rationale for not establishing specific nutrient standards.

As a result of the ONRW (CWA, EPA) or ORW (APC&EC) status for the Buffalo River, the National Park Service may have a role in developing water quality standards that would serve as the baseline values. NPS has extensive water quality monitoring and special studies completed over the last 30 years that can inform these decisions. NPS' role is based on the EPA's antidegration policy for ONRWs:

> "Where high quality waters constitute an outstanding National resource, such as waters of National and State parks and wildlife refuges and waters of exceptional recreational or ecological significance, that **water quality shall be maintained and protected**."

Therefore, baseline water quality values determined through the BNR and ADEQ joint water quality monitoring program should not be degraded (for more on this program see Mott and Laurens,2004, Mott, 1997, or Watershed Conservation Resource Center, 2016). BNR has collected thousands of water quality samples with several important laboratory parameters analyzed in the EPA certified water quality laboratories at ADEQ headquarters in Little Rock, AR; BNR headquarters in Harrison, AR; and Ouachita Baptist University in Arkadelphia, AR. This is one of the best water quality databases in the NPS, and results in ADEQ having access to better water quality data from the Buffalo River watershed than almost any other watershed in Arkansas. NPS staff has discussed the opportunity to develop site-specific water quality standards for the Buffalo River with ADEQ staff, but efforts to formally implement such standards through third party rulemaking or other methods acceptable to APC&EC have not been undertaken.

Arkansas CAFO Permitting Regulations

As discussed in the CWA section, to become an authorized NPDES permitting authority, the requirements imposed under a State's NPDES program must be as stringent as the requirements imposed under the federal NPDES program. States may impose requirements that are broader in scope or more stringent than the requirements imposed under the federal NPDES program. Arkansas has administered EPA's NPDES permit authority since 1986.

As of 2005, ADEQ was responsible for permitting 2,100 CAFOs with 108 of these utilizing liquid waste disposal systems. Currently, ADEQ does not use NPDES Regulation No. 6 for CAFOs (the general permit issued to C and H Hog Farms was the only exception in the last 20 years), but instead uses Regulation No. 5. Given these circumstances, Regulation 6 will not be reviewed further in this document. However, Regulation No. 5 Part 5.105 contains the following exemption – "Any confined animal operation using a liquid waste disposal system shall be exempt from the requirements of this regulation if the owner or operator obtains and maintains active coverage under either a National Pollutant Discharge Elimination System individual or general permit for discharges from a concentrated animal feeding operation."

Regulation No. 5 "No Discharge" Permits

All CAFOs in Arkansas that utilize a liquid waste management system are required to acquire and maintain a State permit and nutrient management plan. Before the general NPDES permit ARG59000 was established in 2012, all regulated CAFOs were covered under APC&EC Regulation No. 5: *Liquid Animal Waste Management Systems*. Developed in 1992 pursuant to the Arkansas Water and Air Pollution Control Act (Act 472; Ark. Code Ann. § 8-4-101 et seq.), APC&EC adopted Regulation No. 5 following recommendations of then Governor Bill Clinton's Animal Waste Task Force. Regulation No. 5 provides more comprehensive coverage of the various CAFOs in the State than required by the NPDES program (Noble and Looney, 1994). In-depth comparisons of Regulation No. 5 requirements by Hovis, 2014, determined that they are more stringent and provide more environmental safeguards than the general NPDES permit issued to C and H Hog Farms.

An important coverage found in Regulation No. 5 requires ADEQ to protect all waters of the State which include:

> "all streams, lakes, marshes, ponds, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and all other bodies or accumulations of water, **surface and underground**, natural or artificial, public or private."

This broad applicability of protected waters is much more comprehensive than that afforded by the CWA NPDES program, which is limited to navigable surface waters and their tributaries. Under Regulation No. 5, Concentrated Animal Feeding Operation (CAFO) means an animal feeding operation (AFO) that is defined as a Large CAFO or as a Medium CAFO pursuant to 40 CFR 122.23, or that is designated as a CAFO in accordance with 40 CFR 122.23(c).

Dr. Karl VanDevender (2008) with the University of Arkansas Cooperative Extension Service has provided a detailed assessment of the requirements of Regulation No. 5, which was used extensively in the following text. Regulation No. 5 requires the development of a Waste Management Plan and a Site Management Plan (usually combined in a Nutrient Management Plan), and defines who is considered technically capable of preparing such plans. Most plans are written or approved by the Natural Resources Conservation Service, Arkansas Natural Resources Commission, or a professional engineer registered in the state of Arkansas. The plan includes maps showing land application areas, a description of the vegetative cover in the application area, a land use agreement if the land is not owned by the owner of the confined animal operation and non-application buffer areas.

Application for a Regulation No. 5 permit also follows requirements of Regulation No. 8, Administrative Procedures. One of the administrative procedures required is the full public notice requirements mentioned earlier. Regulation No. 5 also specifically includes a “good neighbor policy” which requires new, renewing, and existing operations that are making major modifications, to notify all adjacent landowners. The adjacent landowners have the right to comment to ADEQ. Following the public comment period, ADEQ may issue or deny the permit. Neighbors or any other concerned citizen who commented in the original public comment period can appeal a permitting decision within 30 calendar days of public notice of the decision. If the permit is denied, the applicant has 30 days to appeal.

A new facility must be certified before operation may begin. The certification is prepared by the same entities allowed to prepare the permit. Subsequent modifications are considered either minor or major, and major modifications require public notification and implementation of the good neighbor policy. Major modifications include a more than 10 percent increased wasteload, addition of land application sites, or changes in waste treatment, type, handling or disposal. Once in operation, Regulation No. 5 has two types of educational requirements, including an initial minimum four hours of training in operation requirements and ongoing education in the areas of waste management and odor control.

Regulation No. 5 states the Nutrient Management Plan must follow the standards and specifications of the Natural Resources Conservation Service (NRCS). It specifically states in Reg. 5.402 Design Requirements that:

> “Designs and waste management plans shall be in accordance with this Chapter and the following United States Department of Agriculture Natural Resource Conservation Service technical publications: (1) Field Office Technical Guide, as amended. (2) Agricultural Waste Management Field Handbook, as amended.”

This is an important requirement because, as discussed previously, many of the problems associated with Permit ARG590001 stem from the fact that the operation’s siting, construction, and waste application processes only referenced this guidance but did not appear to follow it, especially Chapter 7, Geologic and Groundwater Considerations.

The waste management plan covers:

- the management and disposal of liquid waste generated
- the design of earthen holding ponds and lagoons
- subsurface investigations to determine site suitability and liner requirements
- timing of land application to match nutrient uptake
- measures to minimize the off-site movement of offensive odors
- a site management plan for each field
- proof of ownership for land application sites or contractual land use agreements
- soils analysis for each application site

Some Best Management Practices required by Regulation No. 5 include:

- avoiding application of waste if the soil is saturated, frozen, covered with ice or snow or when significant precipitation is reasonably expected in the next 24 hours
- not applying waste on slopes greater than 15 percent
- not applying waste in any way that would allow it to enter the waters of the state or run onto adjacent landowner's property
- buffers of 100 feet for streams including intermittent streams, ponds, lakes, springs, sinkholes, rock outcrops, wells and water supplies, or within 300 feet of outstanding resource waters.
- additional buffer zones, if deemed necessary.
- avoiding areas prohibited by the Arkansas Department of Health for the protection of public water supplies

Once operational, many activities must be recorded such as:

- a daily log sheet recording application rates, volume applied and acreage covered
- representative samples of the waste/wastewater at least once a year including pH, total nitrogen, potassium, total phosphorus, soluble phosphorus and percent solids
- a soil sample from each field analyzed at least once every five years including pH, potassium, phosphorus and nitrates
- annual reports showing wastewater analysis, locations, volumes and nitrogen application rates; method of application; and type of crops grown on each application site

To close an operating CAFO, the owner/operator must submit a closure plan to ADEQ within 60 days of the last day of operation. After ADEQ approval, a final closure certification can be prepared by the Natural Resources Conservation Service, an Arkansas Natural Resources Commission water quality technician, a certified nutrient management planner or a professional engineer registered in the state of Arkansas. The permit itself will remain valid until it either expires or the operator sends a written request to void the permit.

In 2015, after the construction of C and H Hog Farms and the public response, a third-party rulemaking petition by the Ozark Society resulted in the following addition to Regulation No. 5 (and No. 6) stating in part:

> The Director shall not issue a permit pursuant to Regulation No. 5 for a Confined Animal Operation in the Buffalo National River Watershed with: (1) 750 or more swine weighing 55 pounds or more; or (2) 3,000 or more swine weighing less than 55 pounds. (C) Reg. 5.901(B) does not prohibit the Director from: (1) Issuing a permit renewal or modification for a Confined Animal Operation in the Buffalo National River Watershed with an active permit as of the effective date of this regulation; or (2) Issuing a new Regulation No. 5 permit for a facility which holds an active Regulation No. 6 permit or coverage as of the effective date of this regulation. (D) A permit renewal, permit modification, or new permit issued pursuant to Reg. 5.901(C) shall

not increase the number of swine permitted at a facility. (E) Five years from the effective date of this regulation the Director shall initiate rulemaking to either delete this paragraph, Reg. 5.901(E), or delete the entirety of Reg. 5.901.

Regulation No. 8: Administrative Procedures

Regulation No. 8 sets out procedures governing the APC&EC, ADEQ, permit applicants, and the public concerning any matters brought before APC&EC. Once again, these regulations are complicated and are best interpreted by a legal professional. However, a general understanding will be presented to provide a context for future interactions with APC&EC and ADEQ.

The opening part of Regulation No. 8 mostly pertains to the responsibility of an applicant to follow ADEQ requirements for obtaining a permit and includes a public notice requirement for an "administratively complete application." This notice provides only 10 business days for any interested person to request a public hearing in writing. ADEQ is provided discretion to hold the public hearing or not, unless otherwise required by law. A second public hearing period is required for draft permit decisions. Public notice of a permit decision must be published either in the largest newspaper in the county where the facility is located, or in a state-wide newspaper for a statewide permit. Any interested person may submit written comments during the 30-calendar day public comment period, which can be extended an additional 20 days at the discretion of the ADEQ Director. Only those individuals who submit formal comments on the record will have standing to appeal a permitting decision to the APC&EC. ADEQ has the discretion to hold a public hearing regarding the application and draft decision.

The ADEQ Director has the responsibility to make a final permit decision based on the application, the public comments of record, and any other information required by law or regulation. The Director has authority to impose special conditions when issuing a permit. The final decision will contain a response to each comment received detailing the legal, regulatory, technical, scientific, and/or engineering rationale that pertains to the individual comment and decision. ADEQ will send a copy of the final permit decision to the applicant and notify all individuals and groups that submitted public comments on the record. This notice will include a statement describing the process for requesting an adjudicatory hearing and APC&EC review of the final permitting decision. Any "person with standing" who desires to appeal the Director's decision must file a request for hearing within 30 days.

Hearing requests must include:

- A statement identifying the permit action being appealed
- Date of the final decision
- A request for issuance, modification, or termination
- Certification that the request has been appropriately served

Regulation 8 further prescribes the manner and means by which arguments are to be formatted and presented and how they are to be delivered. An Administrative Hearing Officer (AHO) will subsequently be assigned to preside over all adjudicatory hearings. The AHO will conduct preliminary and adjudicatory hearings and prepare and transmit a recommended decision to the Commission. The preliminary hearing will be held within 30 days of the date of filing the request. The AHO will attempt to have their ruling and recommended decision to the APC&EC within 120 days after the preliminary hearing. The APC&EC will next conduct an independent (de novo) review of the record compiled by the AHO and may request additional evidence. The APC&EC's decision will be by majority vote and shall be issued in the form of a "Minute Order." The decision may affirm, modify, or reverse the AHO's decision. APC&EC may also reverse or remand the decision to the ADEQ Director with specific instructions on how to proceed.

Any "party of record" may request that the APC&EC hear oral arguments on the recommended decision within 20 days of notification. The request shall include:

- Factual objections and alleged legal errors
- Arguments and supporting evidence related to the above
- The specific relief sought
- A proposed Minute Order setting forth the proposed findings of fact and conclusions of law
- Addendums from the record

Assuming a party makes it through all such procedures with the APC&EC and remains dissatisfied with the final decision, that person or entity may appeal that decision to the circuit court of the county in which the involved action is located.

Water Quality Analysis and Interpretation

Big Creek Research and Extension Team Data

Big Creek Research and Extension Team (BCRET) was established at the direction of Arkansas Governor Mike Beebe and funded with special appropriations from the Arkansas legislature. Agronomic, geophysical, and water quality data collection efforts started in 2013, with the first water quality sample collected on September 12th. Water quality collections are made by field technicians at a typical interval of every seven, but up to fourteen days. Samples are typically collected as "grab samples," with occasional collection of stream samples using an ISCO automated sampler when stage height increases above a pre-determined threshold. The ISCO samplers are also used to collect samples from three fields, listed in the Notice of Intent (NOI) as waste application fields, during periods of rain-storm generated runoff. Descriptions of sampling sites and locations, parameter collection methods, laboratory analysis and minimum detection limits, and quality control aspects of the study, are presented at the BCRET web site (http://www.bigcreekresearch.org/).

The Big Creek sampling strategy adopted by BCRET primarily utilizes an upstream/downstream approach to assessing potential declines in water quality occurring in the intervening reach where the production facility, swine excrement holding ponds, and swine excrement land application fields are located. As reported by BCRET (bigcreekresearch.org), the upstream watershed contains 17,471 acres, and the downstream watershed contains 26,168 acres. The intervening sub-watershed (8,745 acres) is where land application of swine waste is permitted on 630 acres, as guided by the Nutrient Management Plan, and will be referred to as the **Nutrient Management Watershed (NMW)** in this analysis (Figure 7). The NMW includes the Dry Creek watershed which encompasses 4,534 acres. The NMW also contains the typical nonpoint sources found in the area, such as beef cattle operations and pasture fertilization with poultry waste and conventional fertilizer, septic systems, and the small town of Mt. Judea, for example.

The upstream and downstream sites (Figure 8) are the most frequently and consistently sampled, with 129 samples collected at the upstream site, and 136 samples collected at the downstream site, between 9/12/13 and 5/26/16, available for this analysis. The U.S. Geological Survey (USGS) has established a stream discharge gaging station at the downstream sampling site (Big Creek near Mt. Judea with a USGS reported drainage area of 26,112 acres) with stage and discharge data available from April 23, 2014 to present. Discharge data were used to calculate instantaneous loads (flux) at both the upstream and downstream sites. To estimate discharge at the upstream site, the upstream watershed area ratio (17,470/26,112 = 0.67) was multiplied by the downstream discharge value. However, upon conducting a geohydrologic field review of water quality collection sites on Big Creek, and consulting with geologic experts and information (Dr. Mark Hudson, USGS, personal communication, 2016; Braden and Ausbrooks, 2003), it was determined the flow relationship between the BCRET upstream and downstream sites is affected by the karst hydrology of the Boone Formation at these two sampling sites. The probability that the watershed ratio approach would yield unrepresentative flow volumes is therefore high. Instantaneous discharge data were also unavailable for the upstream site; making it impossible to spot check watershed ratio estimates. Big Creek flows across the Boone Formation for 2 miles before reaching the BCRET upstream sampling site, and is known to go dry between the sampling sites. After further analysis, flux comparisons between the upper and lower site are not presented because of the uncertainty introduced in discharge relationships by the karst interactions. However, the watershed ratio method was used to derive concentrations for the NMW, and plot nitrate values as a function of discharge at the upstream and downstream sites as shown in Figure 23.

Other BCRET sampling sites include a spring discharging from the NMW, Dry Creek (4,534 acres), which confluences with Big Creek between the upstream and downstream sampling sites, and Left Fork of Big Creek (23,714 acres), which flows into Big Creek downstream of the NMW (Figure 8). Of these sites, the spring has a relatively large sample set containing 128 samples from the same time period as the Big Creek upstream and downstream site sampling. Discharge data were unavailable for the spring. Dry Creek was sampled only seven times between November, 2014, and May, 2015, and Left Fork of Big Creek was sampled 42 times between May, 2015, and May, 2016. These sites also lack discharge data.

Figure 7: Big Creek watershed with Nutrient Management Watershed (NMW) highlighted (source BCRET October – December, 2014, project report available at bigcreekresearch.org).

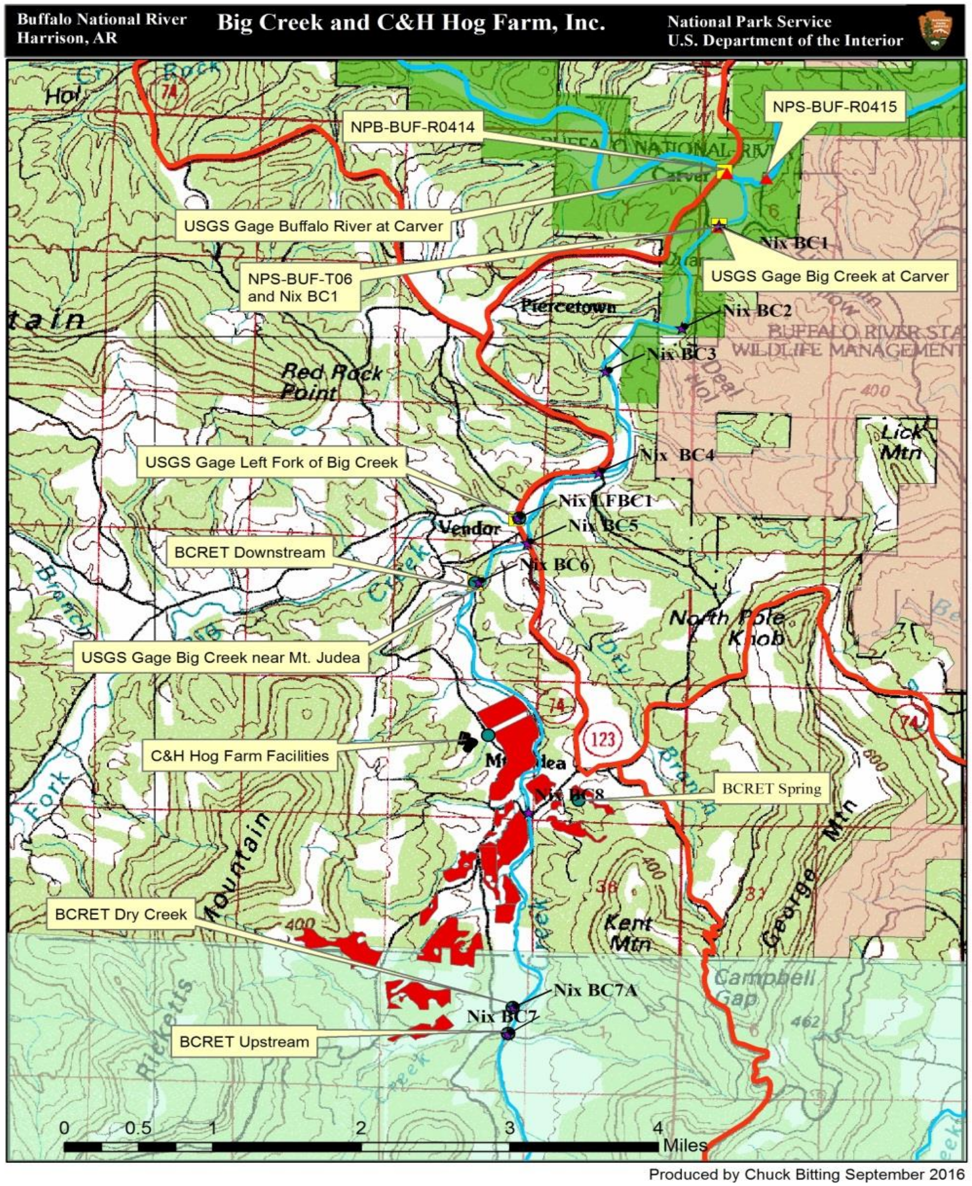
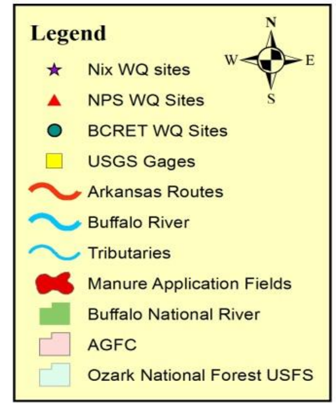
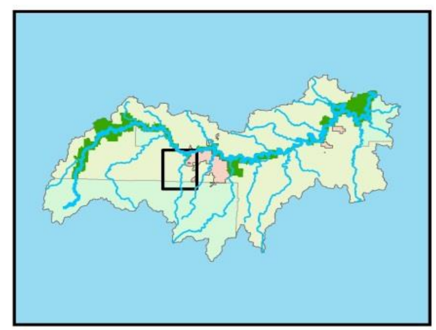


Figure 8: Water quality monitoring sites used in this assessment.



Water Monitoring Sites
(rows aligned where stations are shared)

Nix Stations	NPS Stations	BCRET Stations	USGS Stations
B1	BUF-R0415		
B2	BUF-RO414		Buffalo River at Carver
BC1	BUF-T-06		Big Creek at Carver
BC2			
BC3			
BC4			
BC5			
BC6		Dow nstream	Big Creek nr. Mt. Judea
BC7		Upstream	
LFBC1		Left Fork	Left Fork Big Creek
BC7A		Dry Creek	
		Spring	



The suite of collected parameters has been fairly consistent except that common field parameters, such as pH and conductance were not tested until 2015, and dissolved oxygen values were not available. Parameters consistently analyzed at the University of Arkansas Water Quality Lab include soluble reactive phosphorus, total phosphorus, nitrate, ammonium, total nitrate, total suspended solids, dissolved organic carbon, *Escherichia coli* and total coliform bacteria. In 2015, alkalinity, chloride, and total dissolved solids were added. BCRET notes the relative location on the hydrograph from which samples were collected (base or storm flow), but these notes do not always reflect the actual behavior of the Mt. Judea stream gage or parameters such as total suspended solids.

Because the BCRET sampling strategy was primarily designed as an upstream/downstream study, the data analysis provided herein also focuses on upstream/downstream comparisons. Water quality sampling started three months prior to the first slurry application. Baseline water quality that accounts for storm runoff, seasonal patterns, and inter-annual variation has not been quantitatively established for these sites. It is, therefore, difficult to attribute upstream and downstream differences to recent activities within the NMW. Issues associated with pre-C and H Hog Farms constituent loading, sample and constituent collection frequency and timing, duration, seasonal fluctuations, and unclear mixing of storm and base flow sampling, also makes trend analysis difficult at this time.

Analysis Methods

Data were analyzed using a suite of common water quality statistics including maximum, minimum, and quartile values. Zero values in the BCRET database were converted to the minimum detection limits (see BCRET quarterly reports for listing of detection limits- www.bigcreekresearch.org). Significance tests were performed using the nonparametric Wilcoxon signed rank sum test to evaluate the null hypothesis that the two distributions are the same. The null hypothesis was rejected if $p < 0.05$ for a one-tailed test. This translates to a > 95 percent confidence level that one set of the paired data (BCRET downstream sample results) has values that are systematically larger than the other set of paired data (BCRET upstream sample results).

A simple mixing model, as presented in Mott and Steele, 1991, was used to derive the concentration required from the NMW to add to the upstream concentration, to result in the measured concentration at the downstream site, and the median of those derived concentrations was calculated. These derived concentrations are estimates only, represent all possible natural and nonpoint sources in the NMW, and rely on the potentially erroneous watershed area ratio to calculate discharge at the upstream site. This adds an inherent level of uncertainty to the calculations as discussed above. Trend over time assessments were also analyzed and specific methods used for that analysis are presented in the source evaluation section.

In the following quartile graphs the top number above the box is the maximum concentration, the top line of the box is the 75th percentile, the middle line is the 50th percentile (median), the lower line is the 25th percentile, the lower whisker is the minimum value, and the n-value is the number of samples.

Phosphate

Phosphate is an important constituent because it sets waste application rates for several fields, is often elevated in soils and surface streams in basins where manure waste is applied, and is an important nutrient in aquatic ecosystems. Typical soluble reactive phosphorus (SRP) reported as phosphorus concentrations (those between the 25th and 75th percentile) were similar among the sites (Figure 9). The SRP median value is higher downstream of the NMW than upstream. Table 4 includes nonparametric Wilcoxon signed rank sum paired test results. The distribution of the sample concentrations was determined to be statistically different at the 95 percent confidence level, but the actual difference in median values was insignificant (0.002 mg/L). Derived median concentrations for the NMW were 44 percent higher than the Big Creek upstream site, but the actual change in concentration values were also small (0.004 mg/L).

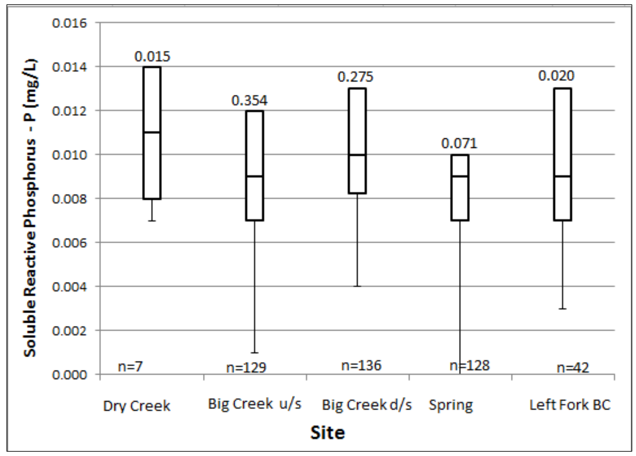


Figure 9: Quartile statistics for soluble reactive phosphorus (mg/L = milligrams per liter, u/s = upstream, d/s = downstream, BC = Big Creek).

Total phosphorus median concentrations were very consistent across the surface water sampling sites and there was no significant difference between the upstream and downstream sites (Figure 10). Total phosphorus quartile values were higher at the spring site. Derived median total phosphorus concentrations from the NMW were only 18% higher than at the Big Creek upstream site.

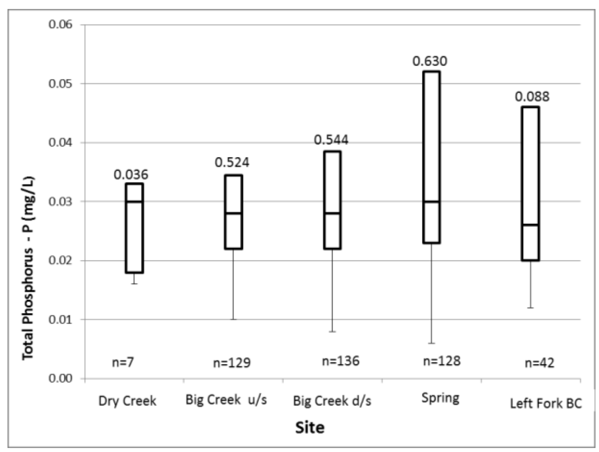


Figure 10: Quartile statistics for total phosphorus (mg/L = milligrams per liter, u/s = upstream, d/s = downstream, BC = Big Creek).

Parameter	Median U/S	Median D/S	Increase in Median D/S		Wilcoxon Results	Derived NMW median	Increase NMW compared U/S	
	mg/L	mg/L	mg/L	%	p<0.05	mg/L	mg/L	%
Soluble Reactive Phosphorus P, mg/L	0.009	0.011	0.002	**22**	**0.00010**	0.013	0.004	44.4
Total Phosphorus P, mg/L	0.027	0.027	0.000	0	0.09257	0.032	0.005	18.5
Nitrate N, mg/L	0.104	0.233	0.129	**124**	**<0.00001**	0.418	0.314	301.9
Total N, mg/L	0.190	0.320	0.130	**68**	**<0.00001**	0.999	0.809	425.8
Total Susp. Solids, mg/L	2.100	2.150	0.050	**2**	**0.00094**	2.718	0.618	29.4
Dissolved Organic C, mg/L	1.580	1.400	-0.180	**-11**	**0.00420**	1.074	-0.506	-32.0
E. coli, MPN/100 mL	88	66	-23	**-26**	**0.01040**	15.106	-73	-82.9
Total Coliform, MPN/100mL	2419	3310	891	**37**	**0.00019**	3998	1579	65.3
Chloride, mg/L	1.600	1.900	0.300	**19**	**<0.00001**	2.629	1.029	64.3
Specific Cond., uS/cm	110	158	48	**44**	**<0.00001**	NA	NA	NA
Alkalinity, mg/L $CACO_3$	44.00	68.00	24.00	**55**	**<0.00001**	119.8	75.8	172.3
Total Dissolved Solids, mg/L	65.00	90.00	25.00	**38**	**<0.00001**	152	87.0	133.8

Table 4: Comparison of BCRET upstream and downstream sampling sites showing median concentrations, increases downstream, statistical comparisons, and derived concentrations for the NMW (U/S = upstream, D/S = downstream, NMW = nutrient management watershed, mg/L - milligrams per liter, col/s = colonies per second, mg/s = milligrams per second, MPN = most probable number, mL = milliliters, uS = micro Seimens).

Nitrogen

Nitrogen is an important plant nutrient and water quality constituent, and nitrate easily dissolves in water. The Big Creek upstream site has lower nitrate values than any of the other sites (Figure 11). Median nitrate concentration increased by 124 percent at the downstream site, and this increase was statistically significant (Table 4). If the sampled spring represents some component of ground water in the NMW, nitrate is higher in ground water than in surface water. Derived median concentration of nitrate from the NMW was over 300 percent higher than the median at the Big Creek upstream site.

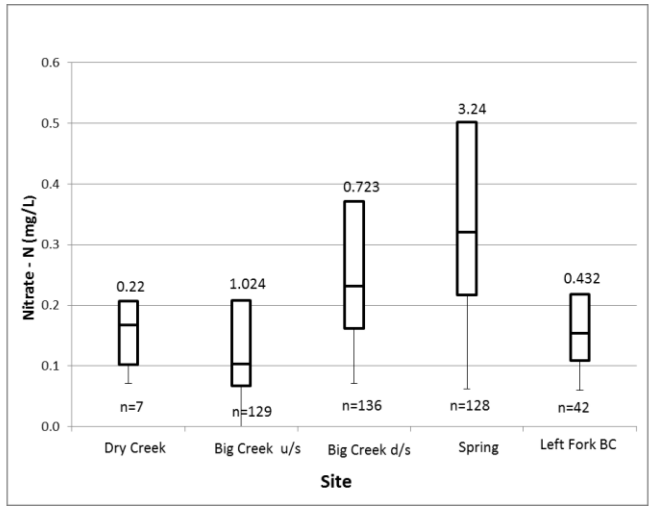


Figure 11: Quartile statistics for Nitrate (mg/L = milligrams per liter, u/s = upstream, d/s = downstream, BC = Big Creek).

Derived concentrations from the NMW were 426% higher for total nitrogen when compared to the upstream watershed (Table 4). Total nitrogen median values are again almost twice as high at the spring as the surface water sites, with dissolved nitrate on average comprising 58 percent of the total nitrogen measured at the spring.

The house well monitored by BCRET has a median nitrate concentration of 0.5 mg/L, higher than all other sampling sites. Higher nitrate values in karst ground water are expected where land use has been converted to pasture. Nitrate has been shown to migrate into the groundwater system, and once there, little assimilation occurs in the absence of sunlight and plant activity, rapid transport rates, and the presence of high levels of dissolved oxygen. For example, Mitch Hill Spring, BNR's largest spring, had a median nitrate concentration of 0.55 mg/L (Mott and Laurans, 2004).

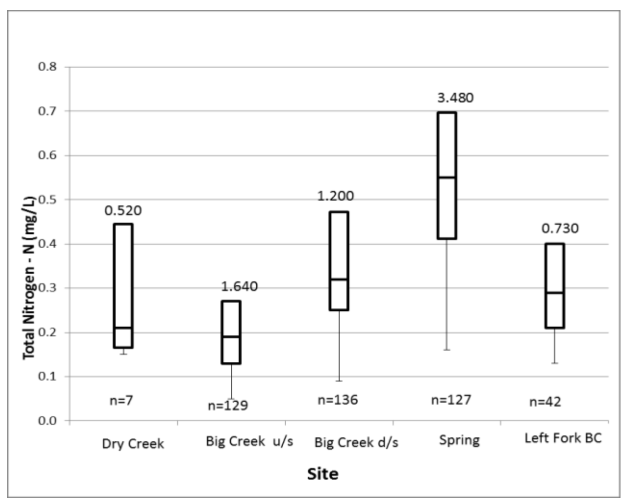


Figure 12: Quartile statistics for Total Nitrogen (mg/L = milligrams per liter, u/s = upstream, d/s = downstream, BC = Big Creek).

Total Nitrogen concentration patterns were similar to the patterns discussed for nitrate (Figure 12). Plant available nitrate comprises 73 percent of the total nitrogen in Big Creek at the downstream sampling site, but only 55 percent of the total nitrogen at the upstream site. Total nitrogen median concentration was 68 percent higher at the downstream site and this difference was statistically significant (Table 4).

Total Suspended Solids

Total suspended solids (TSS) measures how much sediment and organic material is being transported in the water column at the time of sampling. TSS are therefore related to water clarity (turbidity), and TSS can typically be used to determine the relative proportion of surface and ground water influencing a sample, making suspended solids a good indicator of storm runoff. Studies in the Buffalo River watershed have shown a strong positive correlation between total phosphorus with TSS, and bacteria with TSS (Mott and Steele, 1991; Steele and Mott, 1998; Galloway and Green, 2004).

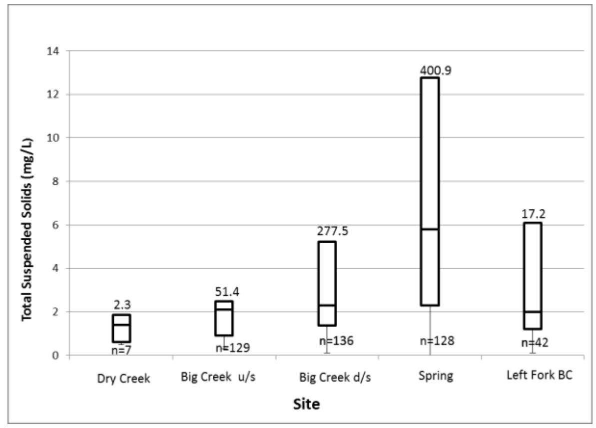


Figure 13: Quartile statistics for Total Suspended Solids (mg/L = milligrams per liter, u/s = upstream, d/s = downstream, BC = Big Creek).

The median value for TSS is higher downstream of the NMW than upstream (Figure 13). The spring has a median concentration nearly three times higher than the surface water sites, indicating that this spring is receiving unfiltered surface water. TSS medians were similar in Left Fork of Big Creek as compared to the upstream sampling site, but the 75th percentile was much higher in the Left Fork. However, Left Fork samples were not collected until the start of 2015, and there are 1/3 as many samples in the BCRET database compared to the upstream and downstream sites.

Median concentration values for TSS were only 2 percent higher at the downstream site than the upstream site as listed in Table 4, but the distribution of the data from the upstream and downstream site was determined to be statistically different as calculated by the Wilcoxon test and observed in the quartile statistics in Figure 13. The derived median concentration for the NMW was only 29 percent higher than the upstream median concentration for TSS.

Dissolved Organic Carbon

Dissolved Organic Carbon (DOC) is a measure of the organic molecules in a sample that will pass through a 0.45 micro-meter filter. Median DOC values were lowest in the upstream and downstream sampling sites, with the median being 11 percent lower at the Big Creek downstream site (Figure 14). The spring monitored by BCRET has a median value higher than the 75th percentile of any of the surface water sites, and a maximum concentration one to two orders of magnitude higher than the maximum values observed at the surface water sites.

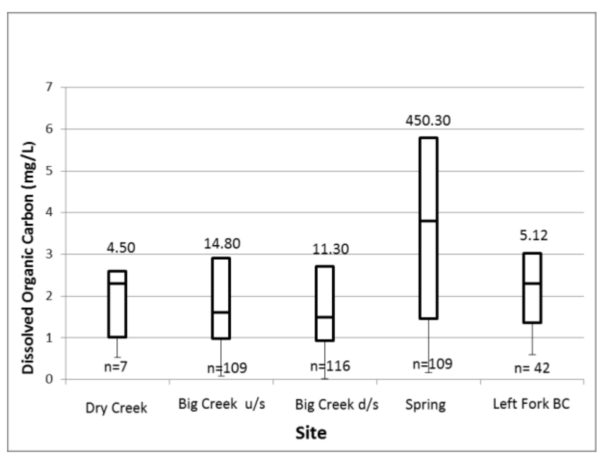


Figure 14: Quartile statistics for Dissolved Organic Carbon (mg/L = milligrams per liter, u/s = upstream, d/s = downstream, BC = Big Creek).

Escherichia coli and total coliform bacteria

Escherichia coli (*E. coli*) analysis is useful as an indicator of pathogens in recreational water. State standards have been developed for this indicator group and are applicable to Big Creek. Regulation No. 2 defines acceptable *E. coli* limits based on a primary (May 1 – Sept. 30) and a secondary (Oct. 1 – April 31) recreational water contact season. The primary contact standard is 410 colonies per 100 milliliters of sample in no more than 25 percent of eight samples collected during the primary contact season. Total coliform bacteria are a diverse group, not necessarily disease causing, and ubiquitous in the environment.

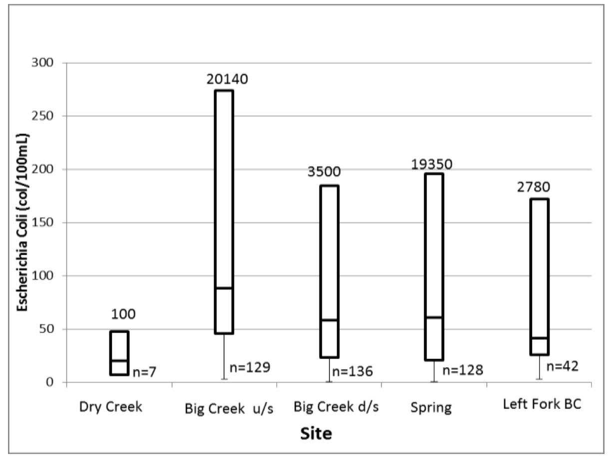


Figure 15: Quartile statistics for *Escherichia Coli* (col/100 mL = colonies per 100 milliliters, u/s = upstream, d/s = downstream, BC = Big Creek).

Median *E. coli* values were 88 colonies per 100 mL (col/100mL) at the upstream site and 66 col/100 mL at the downstream site, as shown in Figure 15. Both of these median values are considered high when compared to average values for the Buffalo River and tributaries, where median concentrations are typically between 5 and 30 col/100 mL (Galloway and Green, 2004; Usrey, 2013). *E. coli* counts varied widely, from near zero to over 20,000, with a large spread between the median and 75th percentile. *E. coli* results from the spring were higher than most of the surface water sites, and higher than other springs monitored in the Buffalo River watershed, with occasional very high readings as indicated by the maximum detected value of 19,350 col/100mL. These data provide a good example of why hydrologists refrain from drinking raw spring water from karst aquifers.

BCRET Upstream Site			BCRET Downstream Site		
Date	**E.Coli**		**Date**	**E. coli**	
5/1/2014	96.0		5/1/2014	62.4	
5/8/2014	57.3		5/8/2014	19.9	
5/13/2014	920.8		5/13/2014	1553.1	
5/19/2014	133.3		5/19/2014	53.7	
5/28/2014	290.9		5/28/2014	209.8	
6/5/2014	307.6		6/5/2014	201.4	
6/9/2014	410.6		6/9/2014	517.2	
6/19/2014	36.4		6/19/2014	61.3	
6/24/2014	980.4		6/24/2014	1046.2	
7/1/2014	238.2		7/1/2014	129.6	
7/7/2014	1732.9		7/7/2014	649.8	
7/15/2014	686.7		7/15/2014	816.4	
7/23/2013	142.1		7/23/2014	95.9	
7/31/2014	275.5		7/31/2014	224.7	
8/12/2014	98.8		8/12/2014	125.0	
8/20/2014	88.4		8/20/2014	69.7	
8/26/2014	3.1		8/26/2014	19.7	
9/3/2014	270.0		9/3/2014	65.7	
9/11/2014	2419.2		9/11/2014	980.4	
9/18/2014	365.4		9/18/2014	579.4	
9/23/2014	9.7		9/23/2014	47.1	
9/30/2014	5.2		9/30/2014	85.7	
	2015 Upstream		**2015**	**Downstream**	
5/14/2015	145.5				
5/18/2015	137.6				
5/26/2015	275.5		5/26/2015		
6/8/2015	866.4	exceed	6/8/2015	57.4	
6/17/2015	435.2	exceed	6/17/2015	344.8	
6/22/2015	78.0				
7/9/2015	201.4		7/9/2015	275.5	
7/16/2015	41.3		7/16/2015	11.8	No Exceedence
7/23/2015	93.3				
7/30/2015	27.2		7/30/2015	11.9	
8/6/2015	488.4	exceed			
8/13/2015	13.4		8/13/2015	24.0	
8/27/2015	104.6		8/27/2015	137.4	
9/2/2015	46.4		9/2/2015	20.3	
			9/10/2015	66.3	
9/16/2015	50.4		9/16/2015	6.2	
9/24/2015	17.1		9/24/2015	29.9	
			9/30/2015	31.7	

Figure 16: *E. Coli* samples collected by BCRET at the upstream and downstream sampling sites on Big Creek compared to ADEQ Regulation No. 2 water quality standards (applicable to the primary contact season and watershed > 10 square miles).

Table 4 shows median *E. coli* bacteria concentrations decreased at the downstream site as compared to the upstream site (-26%). Total coliform bacteria showed the opposite pattern, increasing at the downstream site. Both *E. coli* and total coliform decreases and increases were determined to be significant by the Wilcoxon test. Because *E. coli* medians are elevated, the samples were compared to Arkansas water quality numeric criteria during the primary contact season as presented in Figure 16. Red bars indicate time periods where *E. coli* values were greater than 410 colonies/100 mL in 25 percent of 8-samples. ADEQ is the agency with ultimate responsibility and authority for determining exceedances of State standards.

Chloride

Chloride (Cl) is a naturally occurring ion which can be elevated in surface and ground water receiving significant amounts of agricultural runoff or infiltration. It is considered to be a "conservative tracer" because it is not readily consumed by biota and is relatively inert. Figure 17 shows the downstream site, the spring, and Left Fork of Big Creek all demonstrate higher Cl medians than the upstream site.

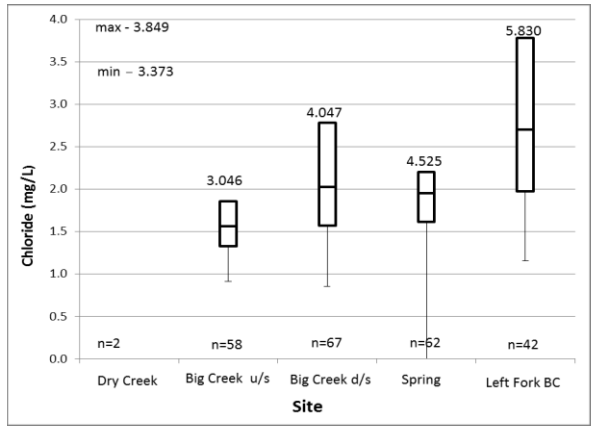


Figure 17: Quartile statistics for Chloride (mg/L - milligrams per liter, u/s - upstream, d/s = downstream, BC = Big Creek).

Table 4 shows median Cl concentrations increased by 19 percent at the downstream sampling site and this difference is statistically significant. Derived concentrations from the NMW were calculated to be 64 percent higher than concentrations measured at the upstream sampling site. For Cl, the median concentration from the spring was in between the concentration for the upstream and downstream sampling site, and the site with the highest median Cl concentration was the Left Fork of Big Creek.

Specific Conductance

Specific conductance (SC) is a measure of water's ability to conduct an electrical current, referenced to a standard solution at 25 degrees centigrade. Water's ability to conduct electricity is proportional to the amount of dissolved ions in the water. Because SC can be accurately measured in the field with a calibrated hand held instrument, it is an easy way to quantify the relative amount of ions in a solution. Ground water is typically higher in SC than surface water, and surface water is higher than rain water. SC is an effective way to characterize natural waters, and once characterized can be used as a screening tool to determine if concentrations of dissolved ions are increasing. If SC values are unnaturally high, other techniques such as laboratory analysis focused on common ions, are then employed to understand the reason for the elevated values.

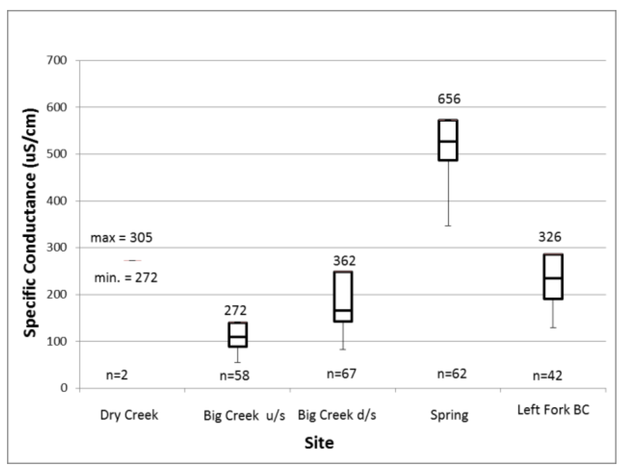


Figure 18: Quartile Statistics for Specific Conductance (uS/cm = micro Seimens per centimeter, u/s = upstream, d/s = downstream, BC = Big Creek).

Figure 18 shows a predictable pattern of SC increasing in the downstream direction and highest at the spring. Because the downstream sampling site is located in the soluble limestone of the Boone Formation, as is the spring, they have higher levels of dissolved ions resulting from the dissolution of the carbonate rock. SC values are also affected by increased Cl and nitrate ions, and other dissolved elements and compounds, as previously discussed. Table 4 shows the SC median increases by 44 percent at the downstream sampling site, and this increase is statistically significant.

Alkalinity and Total Dissolved Solids

Alkalinity and total dissolved solids (TDS) behavior mirrored that of specific conductance because both of these parameters measure part (alkalinity), or all (TDS), of the dissolved constituents in water that conduct an electrical current. Both of these parameters also increase in water with increased exposure to the soluble limestone bedrock of the Boone Formation.

Source Evaluation

Increasing medians and statistically significant differences were observed between the upstream and downstream sampling sites for SRP, nitrate, total nitrogen, total suspended solids, total coliforms, SC, alkalinity, and total dissolved solids (Table 4). It would be inappropriate; however, to affix cause and effect to the C and H Hog Farms operation for these increases without a scientifically valid collaborative line of reasoning. A collaborative line of reason could involve:

- Unique and increasing trends over time
- Increases from an established baseline
- A detection or observation uniquely attributed to swine waste
- In nonpoint source environments, storm-flow based assessments of contributed waste loads (nutrients, bacteria, suspended solids) during runoff events when pasture surfaces are flushed and ground water is infiltrated

At this time, there are insufficient data to effectively perform a collaborative analysis. BCRET has plotted concentrations over time in their quarterly reports, but the trend interpretations are observational only and trends were not detected. A problem encountered in conducting trend analyses of nonpoint source data is mixing of storm flow and base flow samples. As discussed in previous sections, storm events can produce parameter increases orders of magnitude higher than during base flow. Occasionally observed high results are important to understand the varied response to nonpoint runoff, but if used in trend analyses, storm data points can mask base flow trend observations because they can be disproportionately large.

Another approach to trend analysis in nonpoint source studies is to filter the storm flow data out of the database, and then perform the trend analysis only on samples collected during base flow conditions. This effectively results in determining trends predominantly reflecting ground water inputs that maintain stream flow during base flow conditions. To effectively analyze storm flow, data collected from several points in a storm hydrograph can be integrated, and the results summed to calculate storm event loading for individual storms. The USGS has also developed annual loading estimation techniques which include storm event loading.

Steele and Mott (1998) chose three middle river tributaries (Calf, Bear, and Tomahawk Creeks) to investigate storm flow water quality utilizing summed integration, and compared these results to a previous study of an undeveloped watershed within the Upper Buffalo Wilderness (Mott, 1990; Mott and Steele, 1991). These tributary streams were chosen because they provided a disproportionately large fecal bacteria (almost half of the fecal coliform load), nitrate, and phosphorous load to the Buffalo River despite comprising only 13% of the watershed. All three tributaries consistently had storm flow peak nutrient and bacteria concentrations and loads two to three orders of magnitude greater than during base flow. Peak fecal coliform bacteria counts during storm runoff events were 80 times higher in the tributaries (500 col/100 mL at the Wilderness Site versus greater than 40,000 col/100 mL from the three tributaries), peak nitrate values were 32 times higher (0.02 mg/L Wilderness Site and 0.65 mg/L Bear Creek), and peak total phosphorus was seven times higher (0.072 mg/L Wilderness Site and 0.7 mg/L peak concentrations for the tributaries)(Steele and Mott, 1998; Mott, 1997; Mott, 1990; Mott and Steele, 1991). The USGS has developed scientifically sound techniques whereby annual loads can be determined with targeted base and storm flow sampling, and the development of surrogate relationships between important parameters and hydrographs (Galloway and Green, 2004).

For this analysis, the BCRET database was filtered to remove storm event samples, and the resulting base flow samples were examined for increasing concentrations over time. The BCRET flags for storm and base flow did not always match the USGS hydrograph or behavior of TSS, and some further sorting of the BCRET data was required. Four parameters indicated an increasing trend using base flow samples only: total phosphorus, total suspended solids, nitrate, and total nitrogen. Figure 19 shows the scatter plot of all base flow data collected and analyzed for total phosphorus. Excel was used to draw a simple linear trend line through the plotted data. The trend line indicates average total phosphorus values increased from 0.021 mg/L to 0.033 mg/l, or 57 percent, in the two and one half years of sampling. This increasing trend was also observed at the upstream site (Figure 20).

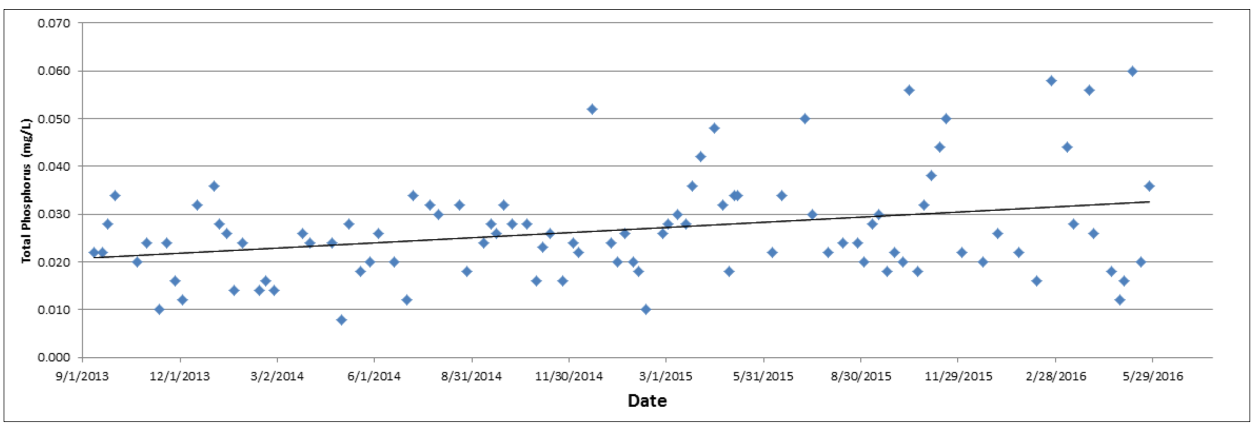


Figure 19: BCRET downstream site scatter plot of total phosphorus over time with computer drawn trend line (mg/L = milligram per liters).

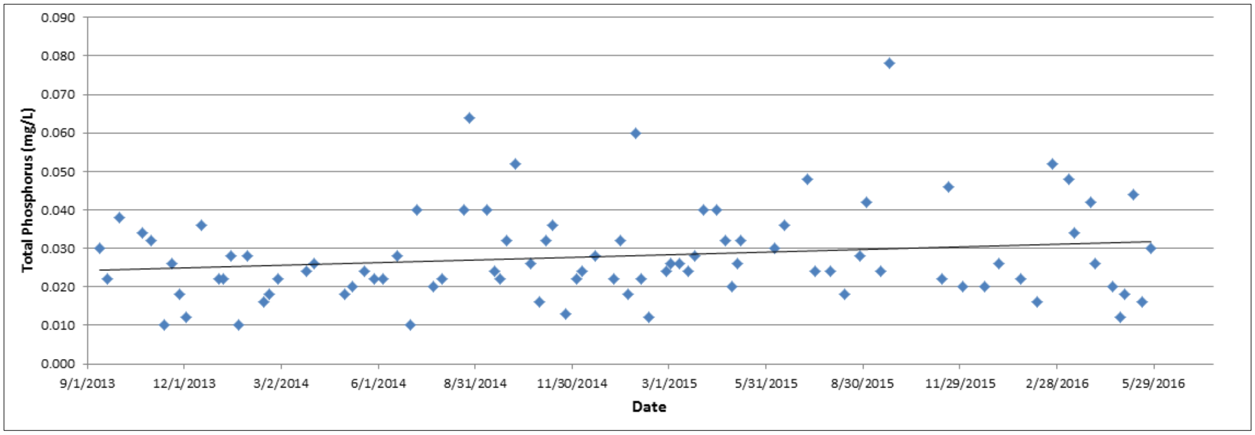


Figure 20: BCRET upstream sampling site scatter plot of total phosphorus over time with computer drawn trend line (mg/L = milligrams per liter).

Because total phosphorus is often adsorbed to sediment particles, Figure 21 shows a similar scatter plot relationship and increasing trend line for TSS as observed for total phosphorus. TSS concentrations increased from 1 mg/L in September, 2013, to 4 mg/L by May of 2016, or 300 percent. Figure 22 shows a similar increasing pattern and magnitude of increase for TSS at the upstream sampling site.

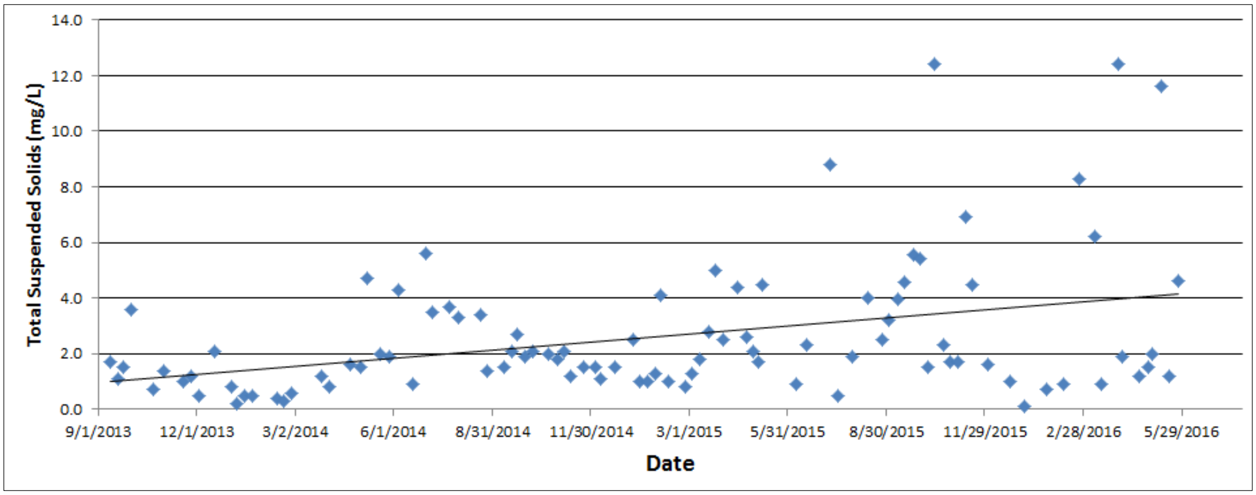


Figure 21: BCRET downstream sampling site scatter plot of base flow total suspended solids over time with computer drawn trend line (mg/L = milligrams per liter).

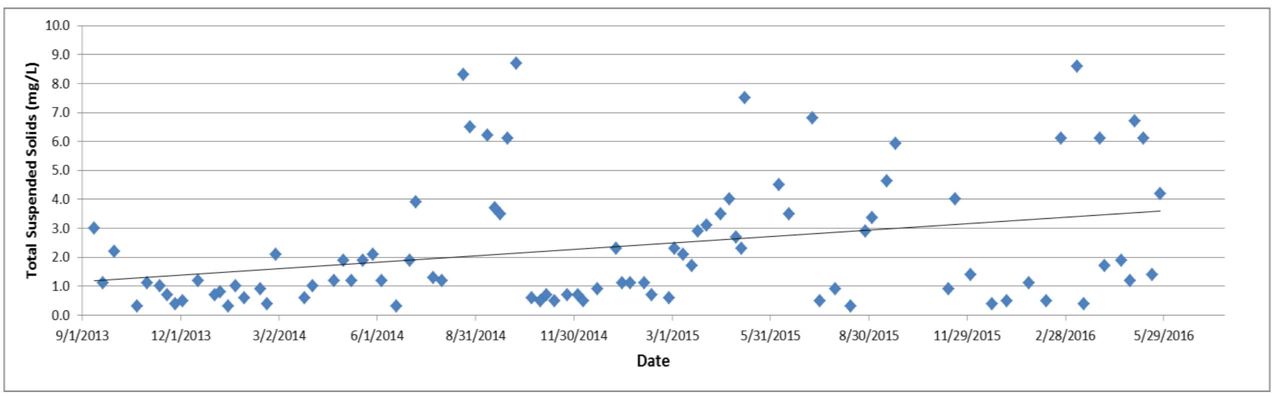


Figure 22: BCRET upstream sampling site scatter plot of base flow total suspended solids with computer drawn trend line (mg/L = milligrams per liter).

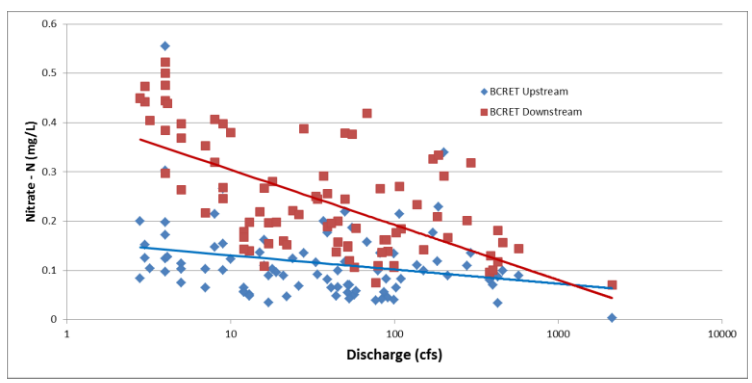


Figure 23: Scatter plot of nitrate concentrations as a function of discharge at the BCRET upstream and downstream sampling sites (mg/L = milligrams per liter, cfs = cubic feet per second).

Another pair of inter-related parameters with increasing trends at the downstream site is nitrate and total nitrogen. Nitrogen is a parameter of concern because it is significantly elevated at the downstream sampling site compared to the upstream sampling site, and nitrate was elevated in the spring and house well in comparison to the BCRET surface water sampling sites.

Nitrate can be especially problematic in trend with time analyses because it can display seasonal fluctuations, and in Big Creek the seasonal fluctuation are very pronounced as shown in Figure 24. These seasonal cycles were determined to be more related to flow than to other processes such as plant uptake. Specifically, as flow decreases at the downstream site, nitrate concentrations increase as shown in Figure 23. At the upstream site, this relationship is much less apparent. Because ground water input sustains stream flow during low flow conditions, this analysis provides additional evidence that ground water discharging to Big Creek from the NMW is elevated in nitrate compared to the streams. The watershed ratio method was used to calculate discharge at the upstream site to develop Figure 23, this analysis could be improved by collecting discharge at the upstream site when water quality samples are collected.

In Figures 24 through 27 the time interval has been reduced to two-years so that annual seasonal cycles observed in nitrate concentrations can run their course over both years. If the entire 2 and one half year record had been plotted, a bias could have been introduced. Because trend lines are disproportionally weighted by the results in the left and right tails of the data, a start date of January 1 was chosen. This insures the left tail of the graph is higher than the right tail of the graph, and any resulting increasing trend represents the most conservative trend estimate possible. Some error was introduced by the lack of seven samples at the upstream site from 9/20/15 to 11/6/15 because Big Creek was not flowing on the surface at the upstream location.

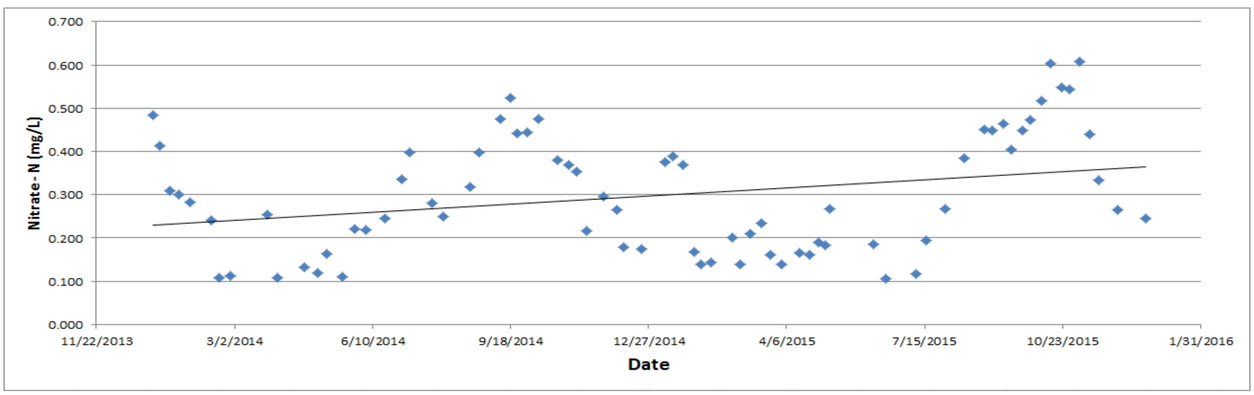


Figure 24: BCRET downstream sampling site scatter plot of base flow nitrate concentrations with computer drawn trend line (mg/L - milligrams per liter).

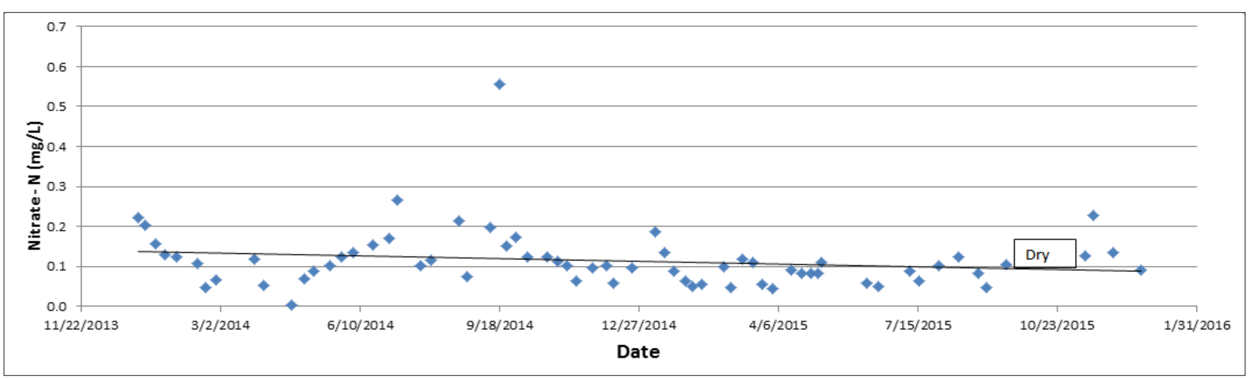


Figure 25: BCRET upstream sampling site scatter plot of base flow nitrate concentrations with computer drawn trend line (mg/L - milligrams per liter).

The linear trend line indicates nitrate increased from 0.23 mg/L to 0.37 mg/L, or 61 percent at the downstream site as shown in Figure 24. As observed in Figure 25, nitrate concentrations did not increase at the upstream site at the same time. This analysis is compromised by the 7 missing samples from the upstream site, but judging by nitrate concentrations during this same time period in 2014, they would not have accounted for the difference between the two sites. The nitrate data from 2014 was paired with nitrate data from 2015 from the downstream site. The median values were similar, but the mean value was 0.289 mg/L and 0.316 mg/L for 2014 and 2015, respectively, with no statistically significant difference (p-value of 0.102) according to the Wilcoxon rank sum test.

Total nitrogen seasonal fluctuations can be observed in Figure 26, but the response is dampened because total nitrogen includes organic and other forms of nitrogen along with nitrate. Total nitrogen appears to increase from 0.27 mg/L to 0.5 mg/L, or 85 percent, at the downstream site over two years. Figure 27 indicates total nitrogen increased from 0.19 mg/L to 0.22 mg/L, 16 percent, at the upstream site, and the seasonal pattern is less pronounced. The downstream data was again divided into 2014 and 2015 and paired. The median concentrations for the two-years were also similar but the mean concentrations were 0.35 mg/L for 2014, and 0.44 mg/L for 2015. For TN, the Wilcoxon rank sum p-value was 0.0033, indicating the 2015 data distribution was significantly different from 2014. Because

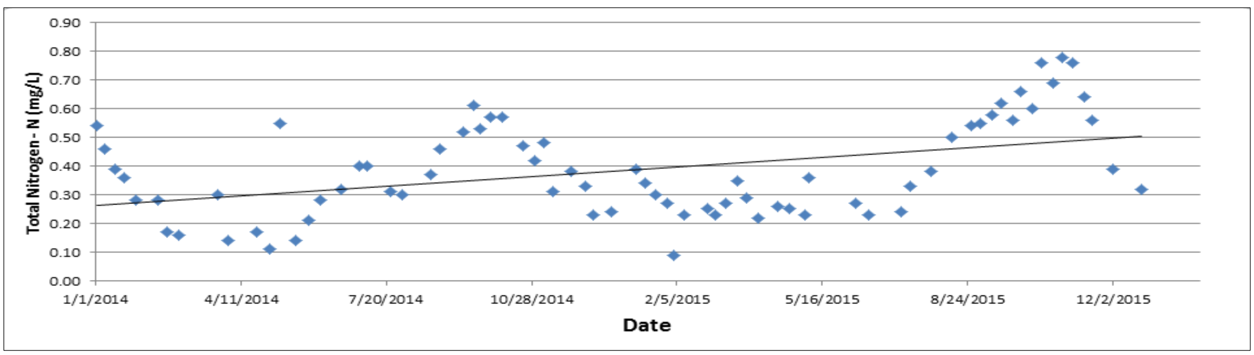


Figure 26: BCRET downstream sampling site scatter plot of base flow total nitrogen concentrations with computer drawn trend line (mg/L = milligrams per liter).

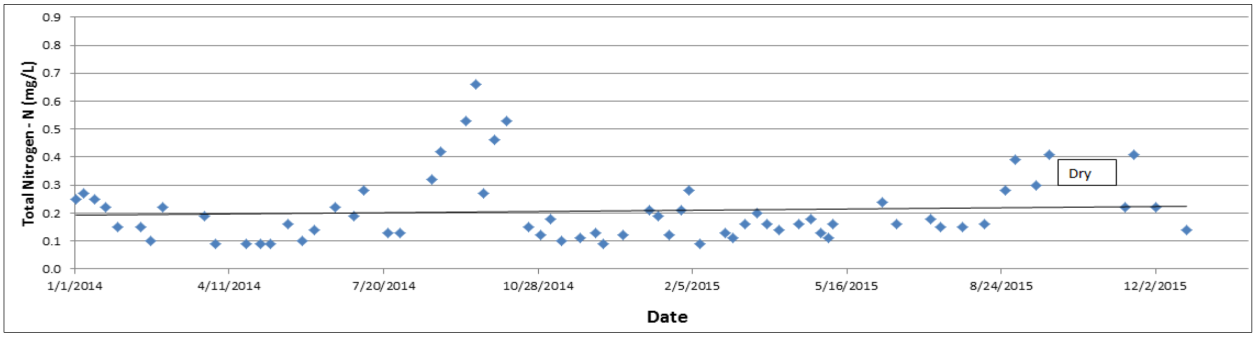


Figure 27: BCRET upstream sampling site scatter plot of base flow total nitrogen concentrations with computer drawn trend line (mg/L = milligrams per liter).

nitrate and total nitrogen are positively correlated with decreasing flow, the difference between the two-years could be explained by changes in discharge. However, it will be important for BCRET to examine this nitrogen pattern in the future as additional data becomes available.

Big Creek at Carver

BNR has collected water quality data within the park boundary at Big Creek at Carver (T06) since 1985 (Figures 3 and 8). The Big Creek at Carver site is approximately 4 river miles below the BCRET monitoring site downstream of the NMW and ½ mile upstream from the confluence with the Buffalo River. This section reviews the Big Creek at Carver data in relation to the BCRET data, and examines trends over time. Since the construction of C and H Hog Farms, additional special studies have been performed at this site by BNR, USGS, a professor emeritus from Ouachita Baptist University, Dr. Joe Nix, and his assistants, and by Dr. Van Brahana at the University of Arkansas Geosciences Department, and his associates.

BNR water quality measurements and lab analyses are made by trained professionals and technicians following documented procedures as required for ADEQ certification. For a complete description of BNR's Water Quality Monitoring Program see Mott (1993). The water quality database was designed with nonpoint source pollution as a concern, and samples are flagged based on their position in the hydrograph (base, rising, falling) coincident with sample collection. This allows the database to be easily filtered for base-flow samples, for example. Most sampling events involve meter calibration, measurement of basic field parameters on-site, discharge measurement or watershed ratio correlation to gages, and collection of grab samples from well mixed areas of the stream for laboratory analysis. Turbidity, fecal coliform, and since 2006, *Escherichia coli* are analyzed in the BNR lab. Nutrient samples are currently transported to the ADEQ Water Quality Lab for analysis.

The BNR WQMP data from the Big Creek at Carver site was compared to concentrations and patterns at the BCRET downstream site, and the BCRET Left Fork of Big Creek site. Because the BNR database spans approximately 30 years, trends at Big Creek near Carver are also examined. Data from USGS and BNR special studies focused on dissolved oxygen, turbidity, and E. coli are also presented.

The USGS installed a stream flow gaging station at the Big Creek at Carver site in October 2014 (Figure 8). Funded by the NPS, this site includes continuous temperature, specific conductance, dissolved oxygen, pH, nitrate plus nitrite, and turbidity sensors. The USGS plans to calculate loads for this site, and is currently collecting water quality data at the necessary points on the hydrograph to develop the relationships needed to model concentrations over time, and mathematically determine storm, base flow, and annual loads. Water-quality samples are collected using USGS stream-sampling protocol and submitted to the USGS National Water Quality Laboratory in Denver, Colorado for analysis. Loads will be determined for nitrate plus nitrite, ammonia, organic nitrogen, total nitrogen, orthophosphate and total phosphate. Continuous nitrate data is being collected with a Hach® Nitratax sensor.

Dr. Joe Nix's team is focused on collecting synoptic samples down the length of Big Creek from the BCRET upstream site to the Big Creek at Carver site (Figure 8), as well as two sites above and below the

Big Creek and Buffalo River confluence.   Dr. Van Brahana has recently published two papers based on his team's efforts in the area (see Murdoch et al., 2016; and Brahana et al., 2016). The publications describe the karst hydrogeology of the Boone Formation and geochemical processes and other factors affecting water quality. His team has collected numerous water quality samples and conducted dye-tracing, and they are working on additional publications.

Nitrate

In the BCRET study analysis, nitrate concentrations are elevated at the sampling site downstream of the waste application areas, or nutrient management watershed (NMW), relative to the site upstream of the NMW. Nitrate concentrations at the BCRET downstream site show a clear seasonal pattern and positive correlation with decreasing discharge, and were increasing with time during base flow. The average nitrate value based on 123 samples collected from 1988 to 2016 at Big Creek at Carver was 0.150 mg/L. This is 75 percent less than 0.263 mg/L average at the BCRET downstream sampling site, and similar to the 0.137 mg/L average at the BCRET upstream sampling site.

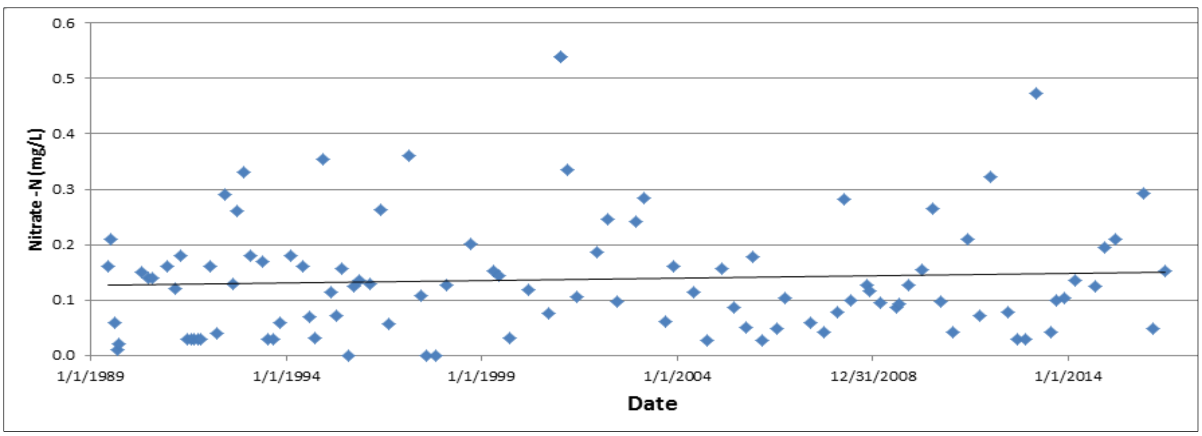


Figure 28: BNR Big Creek at Carver sampling site (T6) scatter plot of base flow nitrate concentrations over time with computer drawn trend line (mg/L = milligrams per liter).

The BNR data was reviewed to determine if any trends over time in nitrate base flow concentrations were apparent. Figure 28 displays a scatter plot of the base flow data for 104 samples. The average base flow nitrate concentration during this time period was 0.138 mg/L, with only a negligible increase (0.03 mg/L) over the 28 years. The BCRET nitrate data shows strong seasonal patterns at the downstream site. The Carver data were examined for seasonal fluctuations by calculating average seasonal values from all

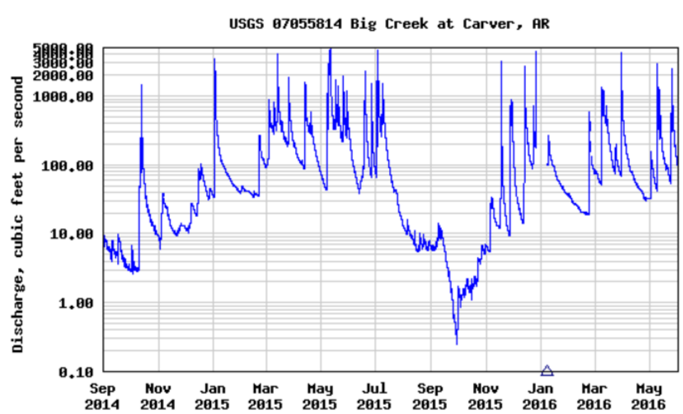


Figure 2629: USGS Hydrograph, Big Creek at Carver.

samples, which resulted in fall = 0.148, spring = 0.152, summer = 0.150, and winter 0.153. The seasonal variance is only 0.005 mg/L between fall and winter, and is insignificant at Big Creek at Carver.

BCRET data collected downstream from the NMW was compared to the continuous USGS nitrate data measured at Big Creek at Carver by pairing each BCRET data point with the corresponding daily mean nitrate value recorded by the USGS. The period of time was limited to the availability of USGS data, and spanned from September 2014 to December 2015 as shown in Figure 30. The graph starts on the left as the BCRET data are just beginning to slope down from a seasonal high in 2014, and the two point moving average lines converge from December 2014 to mid-July 2015. However, when low flow conditions arrive in mid-July, as shown in Figure 29, the data points in Figure 30 begin to diverge.

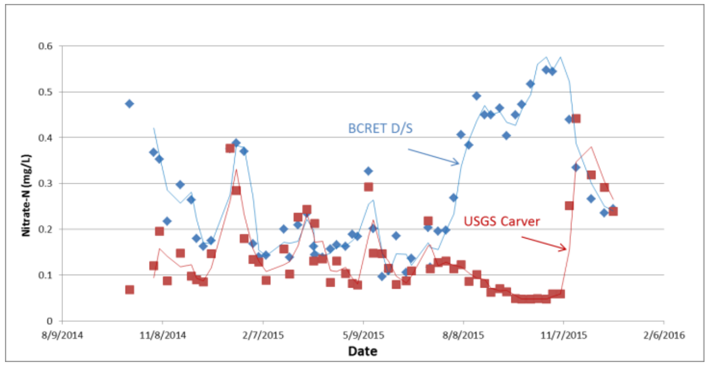


Figure 30: BCRET downstream and USGS at Carver sampling sites superimposed scatter plots of nitrate concentrations with 2-point moving average lines (mg/L = milligrams per liter, D/S = downstream).

Throughout the period of low-flow, nitrate concentrations at the BCRET sampling site downstream of the NMW were up to 1,000 percent higher than at the USGS Big Creek at Carver site, and this pattern continues until higher flows return on November 6th and 7th, 2015, breaking the period of divergence by decreasing nitrate concentrations at the site downstream of the NMW, and increasing nitrate values at Big Creek at Carver.

Figure 31 was created using data provided by Dr. Joe Nix with Ouachita Baptist University (OBU) and analyzed at the OBU laboratory in Arkadelphia, Arkansas. Sampling sites used by Nix include seven sites on the main stem of Big Creek, and the Left Fork of Big Creek where it enters the Big Creek mainstem. Data from one sampling interval, during the time period when low-flow conditions and nitrate divergence was occuring, were plotted to examine the pattern of nitrate decline between the BCRET sampling sites and the USGS Big Creek at Carver sampling site. During this September 15, 2015 sampling trip, about 50 percent of the decline occured in the reach confluencing with Left Fork of Big Creek.

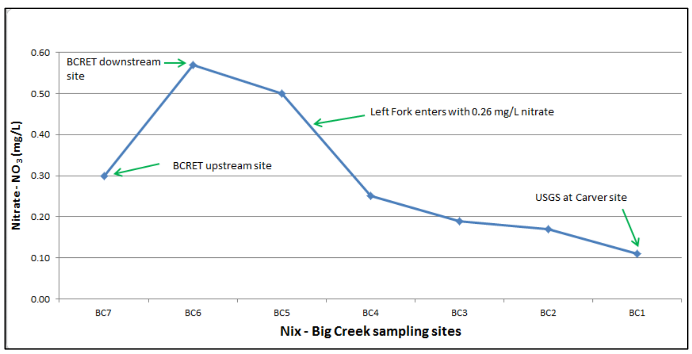


Figure 31: Big Creek sampling sites used by Nix to synoptically measure nitrate concentrations at 7 locations on September 15, 2015 (mg/L = milligrams per liter).

Figure 32 was developed to examine the possibility that changes in concentration were being caused by changes in discharge between the two sites. It is possible that even though concentrations of nitrate are lower at Big Creek at Carver, increases in discharge at Big Creek at Carver gage site could result in higher loads. In actuality, nitrate flux was higher, by up to 5,000 percent, at the BCRET site downstream of the CAFO. This results because the discharge at Big Creek at Carver was sometimes **less** than the discharge at the upstream USGS gage, Big Creek near Mt. Judea, AR (Figure 33). The drainage area at Big Creek near Mt. Judea is 26,112 acres, while the drainage area for Big Creek near Carver is 57,536 acres.

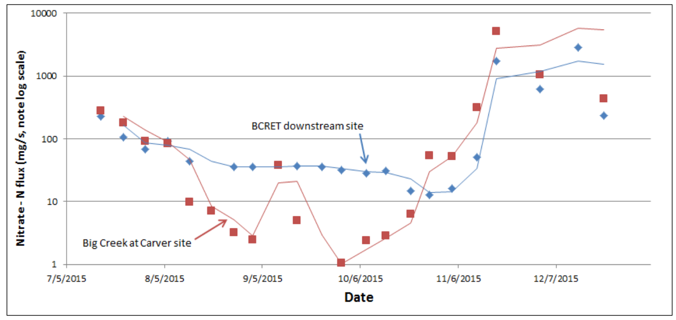


Figure 32: BCRET downstream and USGS at Carver sampling sites on Big Creek superimposed scatter plots of nitrate flux values with 2-point moving average lines (mg/L = milligrams per liter).

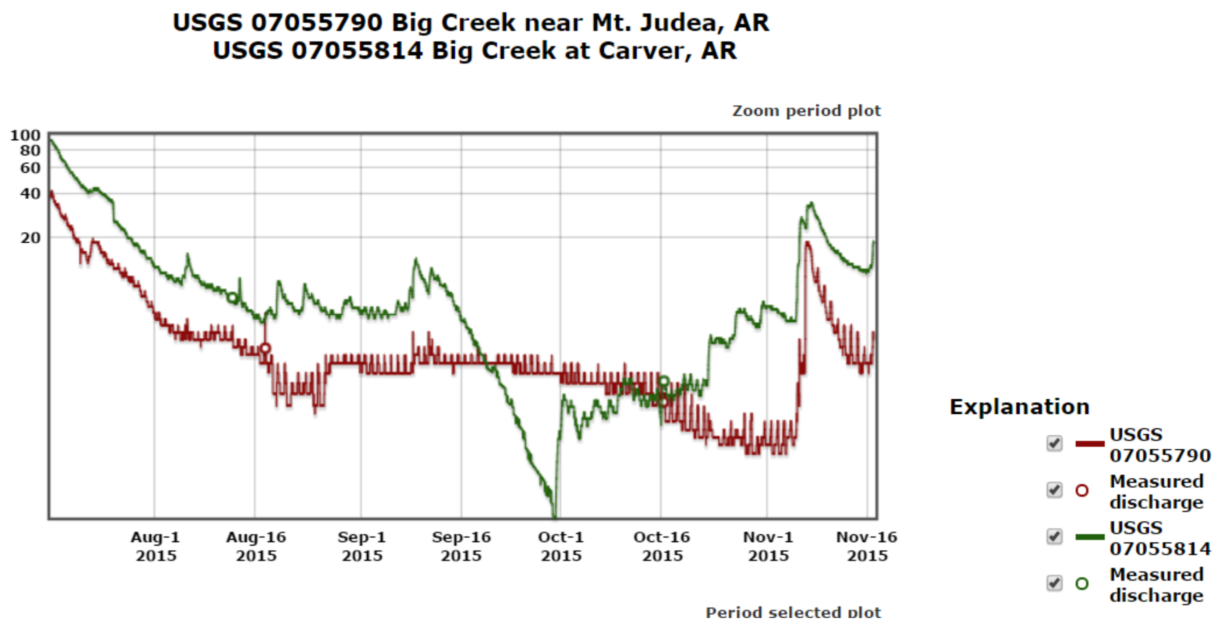


Figure 33: Screen capture of USGS discharge graph of Big Creek near Mt. Judea (aka BCRET downstream site) and Big Creek at Carver during low flow period in 2015.

In 2003 USGS staff conducted a flow gain and loss study and water quality sampling run along the length of the Buffalo River, including measuring flow and water quality at tributaries (Moix and Galloway, 2004). When examining flow patterns in the Buffalo River below Carver, USGS found discharge increased by 35 percent (7 cubic feet per second) in a 3-mile reach (Figure 34). Conductance also increased in this reach, and water temperature decreased, indicating ground water was discharging directly to the main channel of the Buffalo River. One possible source of this ground water recharge is the losing reach of Big Creek located between the two USGS gaging stations. This implies water with high nitrate concentration as observed at the BCRET sampling site downstream of the NMW could be entering the karst bedrock of either the Ordovician aged Fernvale/Plattin Limestone, or the Everton Formation, or both (Braden and Ausbrooks , 2003). Once in the subsurface drainage network, the water could travel through conduits and discharge directly to the Buffalo River main stem, bypassing the Big Creek at Carver sampling site. This could help explain why assimilation processes appear to be so effective in Big Creek, because some or all of the relatively high nitrate water is leaving the stream channel during low-flow conditions and entering the karstic formations. Further assessment is needed to confirm the presence, and quantify the significance, of this newly identified potential ground water flow route. Other hypotheses include loss of flow near the gage station as Big Creek enters the alluvial deposits of the Buffalo River floodplain, or irregularities in the USGS gage data at these rela installed gaging stations.

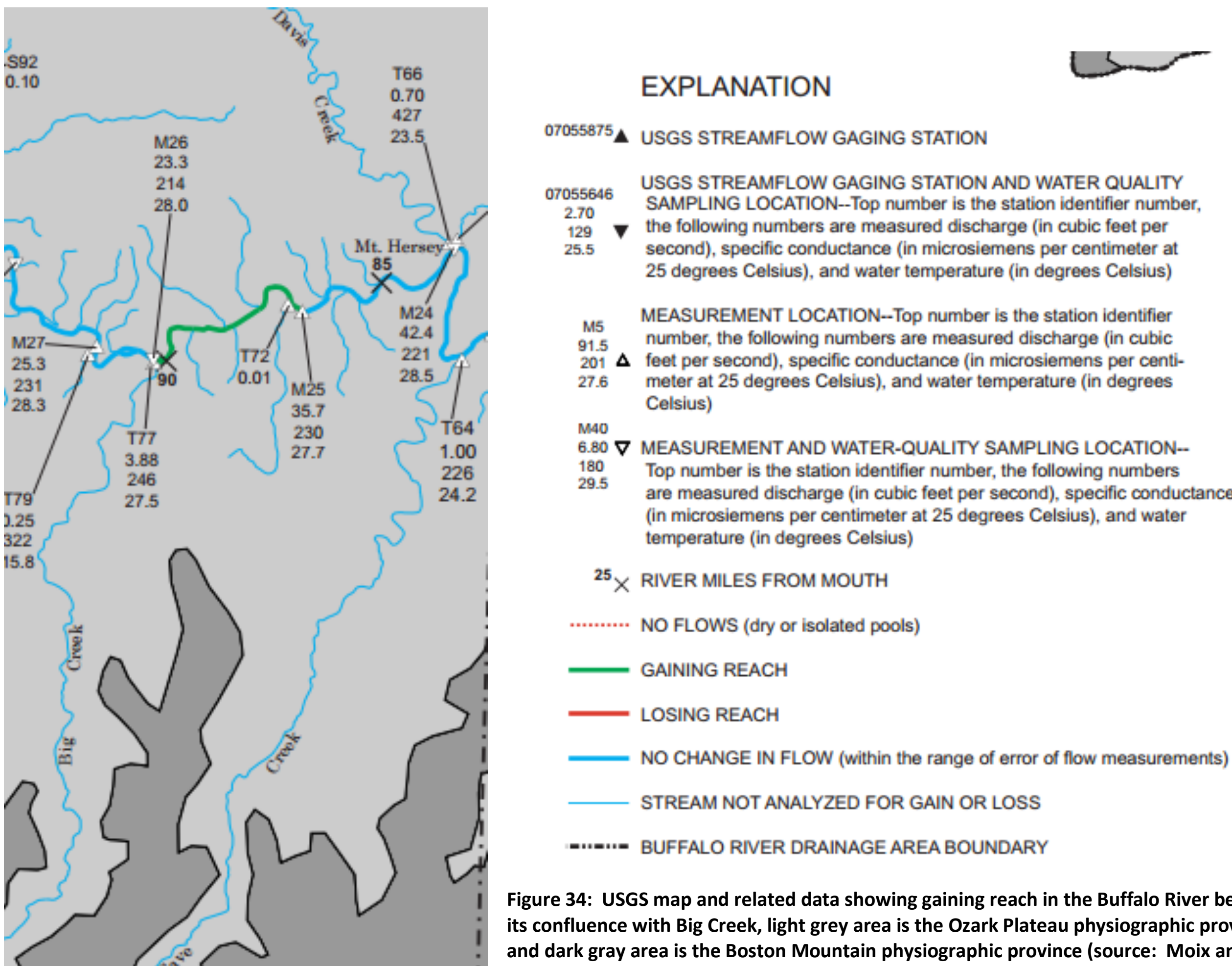


Figure 34: USGS map and related data showing gaining reach in the Buffalo River below its confluence with Big Creek, light grey area is the Ozark Plateau physiographic province and dark gray area is the Boston Mountain physiographic province (source: Moix and Galloway, 2004).

Dissolved Oxygen

Dissolved oxygen (DO) is a measure of how much oxygen is dissolved in the water column, and it is measured on-site at the time of sampling with a calibrated meter, or continuously monitored following specific sampling procedures such as those defined in Green and Usrey (2014). Dissolved oxygen is temperature dependent, with cooler waters holding more DO than warmer water. Diurnal variations are common because photosynthesis by plant communities during the day produces oxygen, while plant respiration, bacterial decomposition, and other processes consume oxygen at night. The USGS has installed a continuous dissolved oxygen probe at the Big Creek at Carver site to allow the variations in DO levels to be tracked at high temporal resolution throughout the day and night and over the course of years. The DO record shows that each summer during warm weather and low-flow conditions, the diurnally fluctuating dissolved oxygen values dip below the ADEQ Regulation #2 numeric standard of six milligrams per liter at the Big Creek at Carver site as shown in Figure 35.

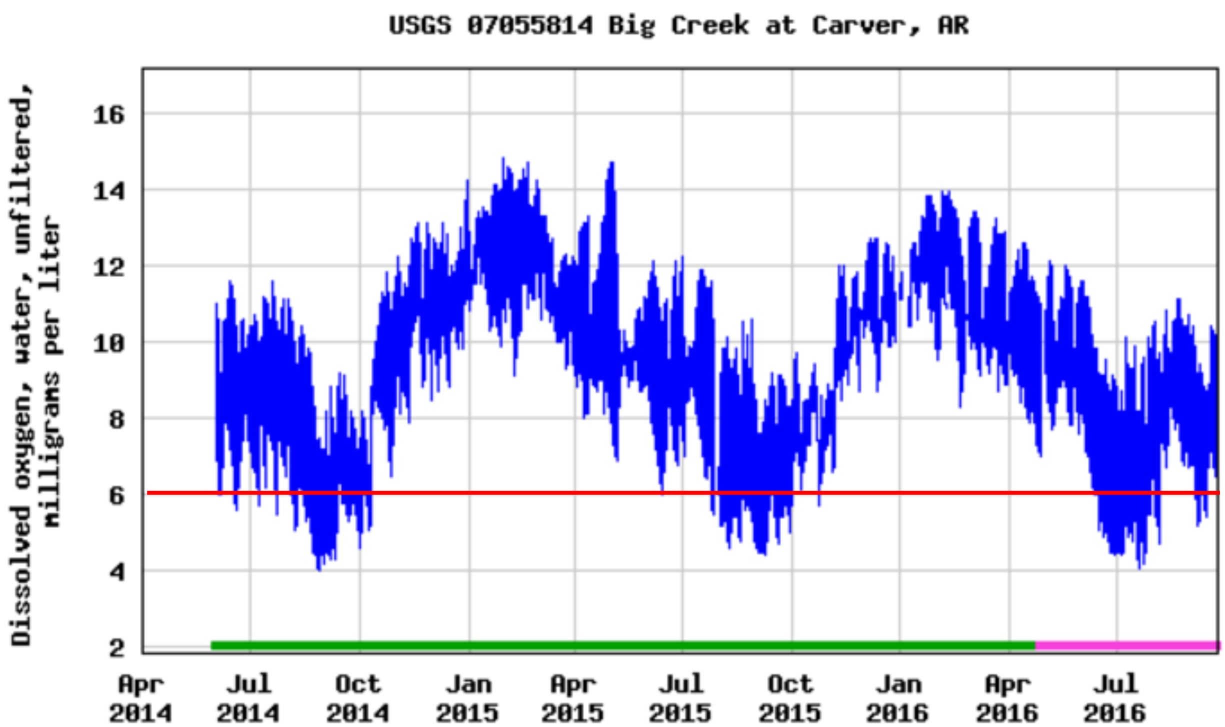


Figure 35: USGS at Carver dissolved oxygen values for the period of record from June, 2014 to September, 2016 (red line corresponds to state standard, green portion of lower bar denotes approved record, pink denotes provisional data subject to revision).

Dissolved oxygen values below 6 milligrams per liter are consistently recorded from late July through early October, the same time when discharge is at an annual low, nitrate is seasonally high at the BCRET sampling site downstream of the NMW, and nitrate is at its lowest at the Big Creek at Carver site. It is possible that algae production driven by increased nutrient concentrations and subsequent die-off is resulting in the overnight low dissolved oxygen levels, but this hypothesis has not been confirmed. Figure 36 shows dissolved oxygen behavior from a portion of June 2015, and from a portion of September 2015, when values are observed below 6 milligrams per liter. For the June period of record, mid-day percent saturation values exceed 100 percent, and the curve has a commonly observed sine wave pattern. In September, mid-day dissolved oxygen values rise to near 100 percent saturation, then level off for several hours, and the sine wave peaks flatten. The reason for these patterns is unknown, but they should be better understood as it has implications in assessing if a state standard is being violated in association with these conditions.

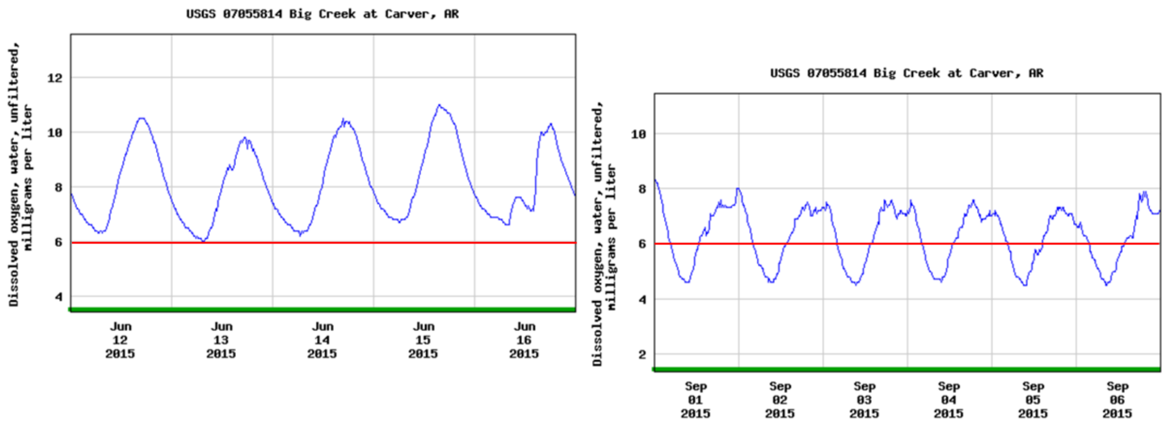


Figure 36: USGS at Carver dissolved oxygen diurnal fluctuation patterns in June, 2015, and September, 2015 (redline corresponds to state standard and green bar indicates approved record).

Turbidity

Turbidity is a measure of reflected light scattered by suspended particulates in a sample. Higher turbidity values are recorded when more suspended particles in water deflect the passage of light through the sample and into a light detector. Turbidity and total suspended solid readings are positively correlated. In the BCRET data, TSS values increased at the site downstream of the NMW.

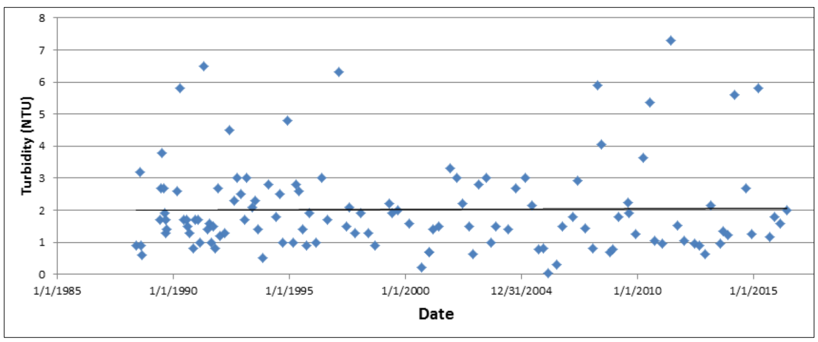


Figure 37: BNR Big Creek at Carver scatter plot of turbidity values with computer drawn trend line (NTU = nephelometric turbidity units).

Base-flow turbidity at Big Creek at Carver is plotted in Figure 37 based on samples collected from 1988 through 2016. The superimposed trend line does not show a notable increase in turbidity values, and the long-term average is consistently near 2.0 Nephelometric Turbidity Units (NTU).

Over the course of a year, the highest turbidity values are recorded in association with storm runoff when overland flow transports sediment and organic particles into the stream. Another pattern that can be observed with turbidity readings occurs in summer/fall low-flow conditions with increases in phytoplankton (microscopic plants) in the water column. This has been observed previously at Richland Creek when cattle had direct access to the stream during summer low-flows, and is observed in other Ozarks streams (Lohman and Jones, 1998). BNR staff has been sampling turbidity several times monthly, and has observed increasing high turbidity in the summer in Big Creek as compared to nearby streams. USGS is continually recording turbidity at Big Creek, but analysis of these data will involve statistical procedures beyond the scope of this effort.

Bacteria

Fecal coliform bacteria have been consistently sampled as part of the BNR water quality program since 1985. Figure 38 shows base flow fecal coliform results at Big Creek at Carver over this 30-year time-span, and the superimposed trend line indicates bacteria counts have increased from 10 colonies per 100 mL in the late 1980s, to nearly 30 colonies per 100 mL at present. To test this apparent trend the data were split into two time intervals (1985 – 1996, and 1997 – 2016) with 69 samples for each period. Median bacteria counts were seven colonies per 100 milliliters and six colonies per 100 milliliters for the two time periods, respectively, while the mean values were 14 colonies per 100 milliliters and 21 colonies per 100 milliliters. Both the Wilcoxon signed rank test and the Peoples T-test indicated that the difference between the two time periods were not statistically significant.

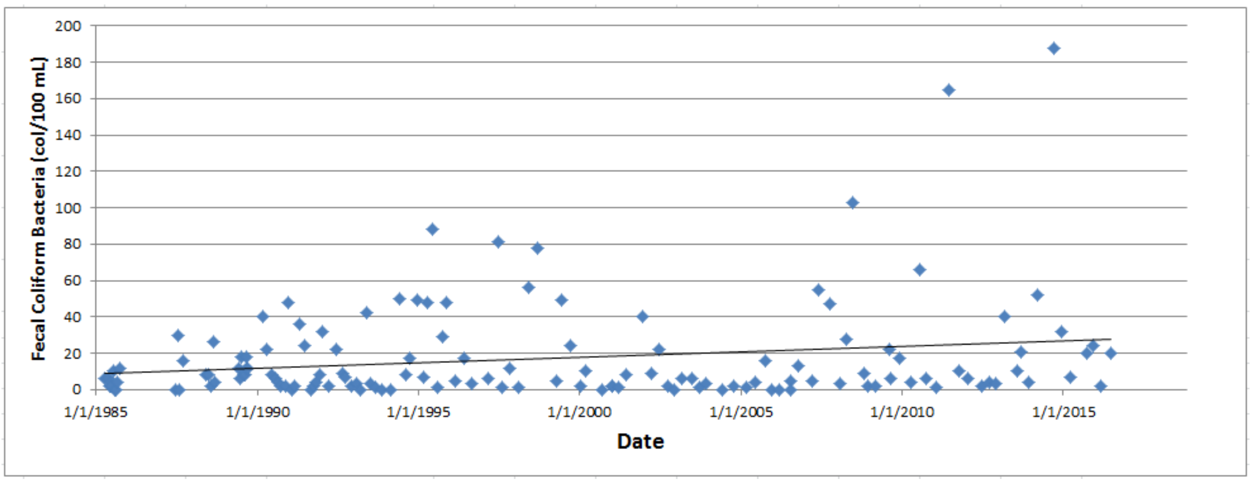


Figure 38: BNR Big Creek at Carver site base flow fecal coliform bacteria scatter plot with computer drawn trend line (col/100 mL = colonies per 100 milliliters).

BNR staff has noted the occasionally high bacteria levels at Big Creek at Carver and conducted intensive sampling of the Big Creek at Carver site, along with the Buffalo River upstream and downstream of the confluence with Big Creek, as shown in Figure 39. Each point in Figure 39 represents the geometric mean of 5 samples spaced evenly over a not more than 30-day period, as stated in ADEQ's Regulation #2. Observations in April 2014 include high geometric mean *E. coli* counts coming out of Big Creek that measurably elevate downstream bacteria counts in the Buffalo River, as compared to the upstream sampling site on the Buffalo River. Because Figure 39 includes high flow data, it is possible that surface runoff from the C and H Hog Farms application fields is contributing some portion of the observed geometric mean bacteria counts. There is very little, if any *E. coli* data from the BCRET sampling program that directly measures *E. coli* levels in the waste ponds, or in surface runoff from fields (Sharpley, personal communication, 2016).

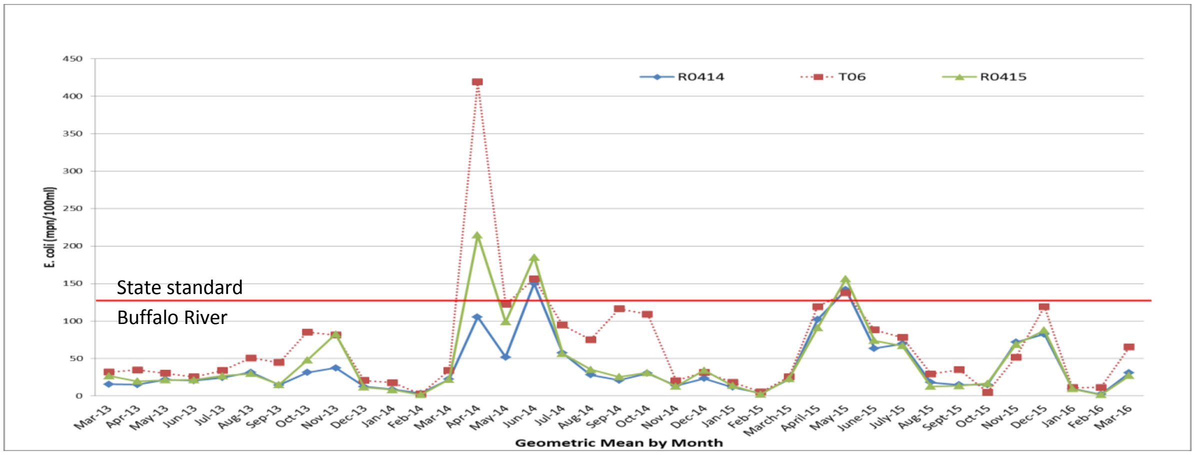


Figure 39: BNR Big Creek at Carver (T06), Buffalo River upstream of Carver (RO414), and Buffalo River downstream of Carver (RO415) Escherichia Coli geometric mean values from March 2013 to March 2016 (MPN/100 mL = most probable number per 100 milliliters).

Specific Conductance and Chloride

The BCRET data indicated both specific conductance and chloride increased at the site located downstream of the CAFO operation compared to the site upstream of the CAFO operation. Specific conductance has been routinely monitored by the BNR Water Quality Monitoring Program since 1985, and chloride since 2003. Review of the base flow scatter plots and trend lines at Big Creek at Carver indicated no increase in SC or chloride.

Nitrate in the Ordovician Aged Karst Formations

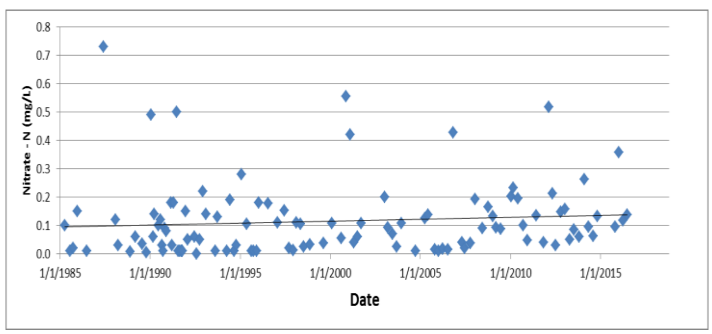


Figure 40: BNR Buffalo River at Woolum (R05) scatter plot of base flow nitrate concentrations over time with computer drawn trend line (mg/L - milligrams per liter).

After determining that some of the water and nutrient load in Big Creek could be migrating to conduits in the karst strata between the NMW and the Buffalo River, it was determined that a review of potential resurgence sites/zones was warranted. In the Big Creek vicinity of the Buffalo River watershed the Boone Formation and underlying karst rock units are in direct hydrologic connection. There is no confining shale unit, such as the Chattanooga Shale as described on the BCRET quarterly reports, or a thick sandstone such as the St. Peter sandstone, isolating one karst formation from the other (Mott et al., 2002; Aley and Aley, 1989; Braden and Ausbrooks, 2003; Murray and Hudson, 2002). One long-term monitoring site on the main channel of the Buffalo River is R05 - Woolum, located approximately 10 river miles below the gaining reach identified by Moix and Galloway (2004). Figure 40 shows the long-term base flow nitrate concentrations recorded at R05-Woolum from 1985 – 2016. The trend line indicates nitrate concentrations have risen only slightly from 0.1 mg/L to 0.14 mg/L during this time. This data record was also split, paired, and analyzed for two time periods from 1985 – 1998 and 1998 – 2016 with 55 samples per time period. Median concentrations for the two time periods were 0.060 mg/L for the first time period, and 0.094 mg/L for the second time period, and the average was 0.103 mg/L and 0.127 mg/L for the first and second time periods respectively. Wilcoxon signed rank test results indicated the difference between the two time periods was equal to the statistical significance cut-off with a p-value of 0.0505. River corridor sampling sites are affected by many potential nitrate inputs.

Another site of interest is the park's largest spring, Mitch Hill Spring. Mitch Hill Spring has a contributing surface/subsurface drainage area currently delineated at 31,774 acres, including inter-basin recharge from the Crooked Creek watershed to the north, as previously mapped by Aley and Aley, 1989; and Mott et al., 2002, using dye-tracing techniques. Mitch Hill Spring lies in a structural high dissected by the Buffalo River, exposing lower Everton Formation karst units at the land surface (Murray and Hudson, 2002). The recharge area is further complicated by a series of east-west trending faults and a graben structure which allow the spring's recharge area to vary with changing water table elevations (Aley and Aley, 1989). Recent dye-tracing studies conducted by Dr. Van Brahana (personal communication, 2016) indicates Mitch Hill Spring may be receiving ground water recharge from the Big Creek Valley. Because of this possibility, and because Mitch Hill Spring is a good indicator of ground water quality in the Everton Formation karst strata, it was examined for nitrate trends.

Figure 41 shows base flow nitrate concentrations at Mitch Hill Spring over the last 30 years as collected by the BNR water quality monitoring program, and since 1991, analyzed at the ADEQ laboratory. The computer drawn trend line indicates nitrate concentrations have increased by 360 percent, from 0.3 mg/L to 1.4 mg/L, during that time period. This data record was also split into two intervals (1991 - 2001 and 2002 – 2016) of 55 samples each and statistically compared. Median values increased from 0.620 mg/L to 1.160 mg/L, and the average increased from 0.618 mg/L to 1.179 mg/L, for the two time intervals. The Wilcoxon rank sum test indicated the increasing data values were statistically significant with p-value less than 0.0001.

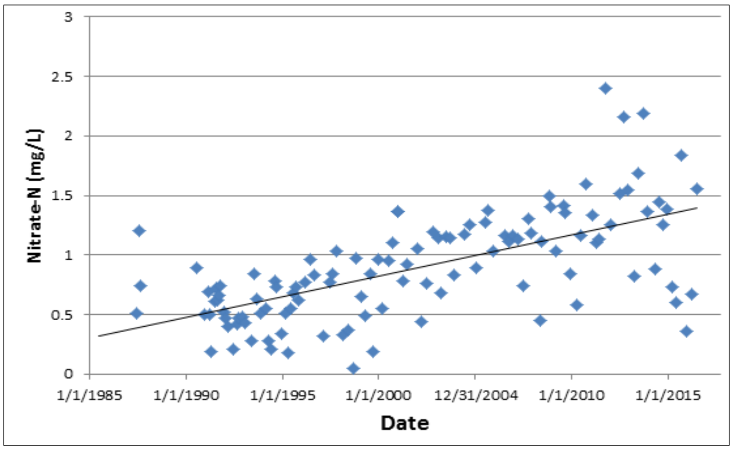


Figure 41: BNR Mitch Hill Spring (S33) sampling site scatter plot of base flow nitrate concentrations over time with computer drawn trend line (mg/L - milligrams per liter).

Mitch Hill Spring receives recharge mainly from the Springfield Plateau physiographic province where the Boone Formation is exposed at the land surface. Land use studies of the Buffalo River watershed (Scott and Hofer, 1995; Scott and Smith, 1994; Panfil and Jacobson, 2001; Stephenson and Mott, 1992) have shown that the Springfield Plateau region is being converted from forest to pasture at higher rates than the Boston or Salem Plateaus. Scott and Hofer (1995) digitized land use characterizations from four previous time periods (1965, 1972, 1974, and 1979) and used thirty meter resolution Landsat Thematic Mapper imagery to classify Land Use/Land Cover for 1992. These attributes were then overlain upon subwatershed, geology, topography, soils, land ownership, and physiographic province data layers to perform land use conversion analyses to answer specific questions. Major finding of this study include:

- Regression analyses indicate a loss of 3,619 acres of forest (converted mostly to pasture) per year. The area of pasture is projected to equal the area of forest by about 2050 in the Buffalo River watershed.
- The acreage in pasture increased by 445% (6,362 to 34,681 acres) for slopes greater than 14 degrees from 1965 to 1992.
- Newton and Searcy counties both lost about 40,000 acres of forest land over the 27 years of the study.
- The greatest loss of forest area occurred in the Springfield Plateau physiographic area and along the Highway 65 corridor.

Coupled with land conversion is additional agricultural development, mainly beef cattle pasture and confined poultry operations, with additional input from liquid waste management facilities such as swine and dairy operations. For example, NRCS (1995) used existing water quality, soils, slope, and land use data to conduct computer modeling, and determined 88 percent of the bacteria load in the middle section of the Buffalo River originates from agricultural operations. Agricultural input of nutrients to streams and ground water is well documented in the karst regions of the Ozarks (see USGS Ozarks Plateau National Ambient Water Quality Program studies available on-line).

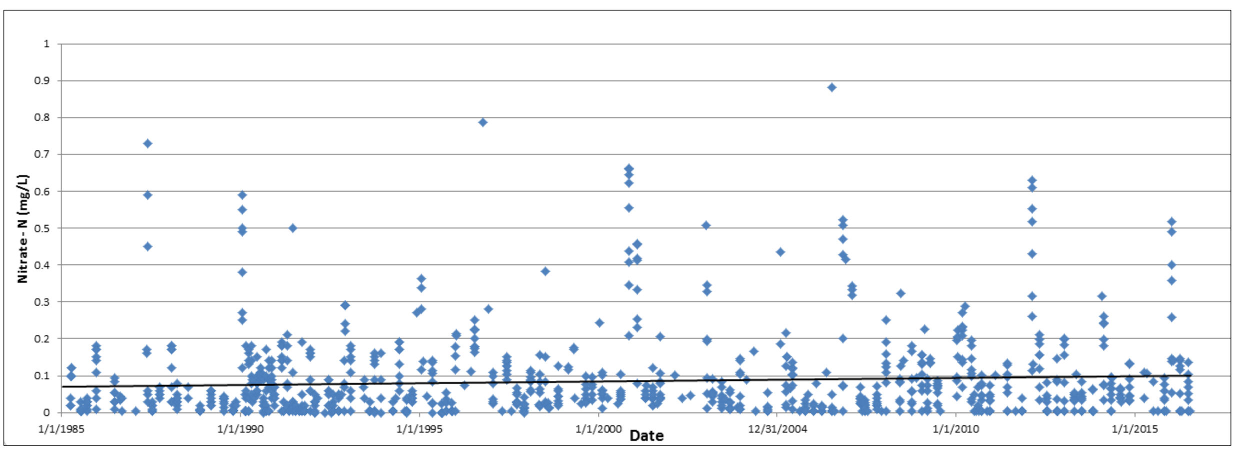


Figure 42: BNR all river corridor sampling sites (R01 - R09) scatter plot of base flow nitrate concentrations over time with computer drawn trend line (mg/L = milligrams per liter).

The Watershed Conservation Resource Center (2016) recently completed an analysis of Buffalo River water quality data collected over a 25-year period from 1985 – 2011. Statistical results from two time intervals, 1985 – 1994 and 1995 – 2011, were compared. Results showed that at eight out of nine river corridor monitoring sites, nitrate values have increased. At these eight sites, mean values increased from 25 to 55 percent, with only the most upstream site at Boxley unchanged. The scatter plot and trend line shown in Figure 42 also indicates that for all river corridor sites, nitrate concentrations were near 0.075 mg/L in 1985, and rose to 0.1 mg/L by 2016, or an increase of 33 percent.

Permitting Overview

C and H Hog Farms, Inc. is currently operating under NPDES Permit Number ARG590001 which, along with General Permit ARG59000, expired on October 31, 2016. The first major modification to the C and H Hog Farms General Permit requested the use of a "Vac Tanker" to apply swine waste to some of the fields originally permitted to receive waste through a pipeline/sprinkler system. BNR submitted comments on the modification and expressed concern on the appropriateness of assumptions made in the NMP regarding nutrient loading, especially phosphorus uptake. BNR also commented that the karst landscape upon which the facility is constructed and operating has never been addressed, and that water quality issues (high bacteria and low dissolved oxygen), had been identified in Big Creek within the park boundary. ADEQ responded that comments were to be limited to the modification only. The modification was approved by ADEQ in June 2014.

A second major modification request, to allow use of "Tank Wagon" to draft and spread excrement from Waste Storage Pond 2 as well as from Pond 1, was submitted by C and H Hog Farms on January 24, 2015. BNR also commented on this modification citing many of the same issues voiced in response to the first modification, and presented further water quality concerns. ADEQ approved this permit modification on May 12, 2015.

The third major modification requested by C and H Hog Farms was to install synthetic liners in both waste ponds, and a cover and gas flare system on Pond 1, dated May 7, 2015. Comments were not submitted by BNR for this modification, but other comments submitted expressed concern that the pump out of all "solid" manure from Pond 1 would yield more nutrients, especially phosphorus, than the limited spreading fields could assimilate. ADEQ approved this modification on March 21, 2016, but the liners and gas flare system have not been installed.

In August 2015, the recently closed C and C Hog Barn, discussed previously and now known as EC Farms, submitted a major modification request under their Regulation No. 5 permit, to accept and land apply waste from C and H Hog Farms. The EC Farms permit includes 550 acres within 36 fields, and would expand the C and H Hog Farms operation to the adjacent Little Buffalo River watershed (see T05 on Figure 3). BNR requested a public meeting be held on the application in a letter to ADEQ dated September 18, 2015. ADEQ issued a draft approval of this modification on March 9, 2016, and announced a public comment period until April 8, 2016, with a follow-up public meeting on April 11, 2016. BNR commented on this modification stating that it appeared to allow C and H Hog Farms to expand its production numbers in potential violation of the existing moratorium, and that the many issues identified in previous comments had not been addressed. ADEQ issued a final decision to approve the EC Farms modification in June, 2016, and BNR filed an appeal. This appeal was withdrawn in August 2016.

ADEQ initiated a public comment period to renew Regulation No. 6 NPDES General Permit ARG590000 on March 15, 2016. On April 20, 2016, C and H Hog Farms submitted a NOI and NMP and applied for a renewal of permit ARG590001 under the Regulation No. 6 general permit. This application included expanded acreages and field numbers for land application of swine waste. Soil test results indicate that phosphorus management will continue to be a challenge with most fields identified in the Regulation No. 5 permit application already at or above optimum phosphorus levels. All the newly identified fields are within the Big Creek and Buffalo River basin. On May 4, 2016, the ADEQ Director gave public notice that ADEQ would not be renewing General Permit ARG590000 after reviewing public comments on the permit. The Director noted that only one facility had received coverage during the 5-year term of the permit, and stated this limited use was inconsistent with the intent of a general permit.

In an undated letter, ADEQ Associate Director, Office of Water Quality, notified C and H Hog Farms of ADEQ's decision and stated "All facilities currently operating under the conditions of this permit will be asked to request coverage under an individual permit…An application for a liquid waste management system under APC&EC Regulation 5 was received on April 7, 2016. This application is currently under review for administrative completeness." C and H Hog Farms' current permit expired October 31, 2016, but APC&EC regulations allow a permitted operation to continue operating even if their permit is expired, so long as they have submitted a renewal application, or request for a new permit, that is considered administratively complete prior to the expiration date. ADEQ notified Mr. Jason Henson, the owner of C and H Hog Farms, Inc., and BNR on May 25, 2016 that the C and H Hog Farms Regulation No. 5 individual permit 5264-W had been reviewed and determined to be administratively complete.

On June 3, 2016, the BNR Superintendent requested that ADEQ hold a public hearing concerning the Regulation No. 5 permit application. Concerns identified by BNR focused on the "as constructed operation," and questioned how an NPDES discharge permitted facility could be converted to a "no discharge" Regulation No. 5 facility without physical alterations to the facility. BNR noted recent geophysical investigations conducted by Oklahoma State University (Halihan and Fields, 2015) appeared to show a waste contaminant plume under the clay lined holding ponds. If confirmed, such a plume would be considered a discharge to waters of the state, something specifically prohibited in Regulation No. 5. On September 2, 2016, ADEQ sent a "notice of technical incompleteness" to C and H Hog Farms stating that the Regulation No. 5 permit review is suspended pending completion of a drilling study to investigate the geophysical anomaly detected by Oklahoma State University scientists.

Electrical Resistivity and Drilling Study

In 2014 and 2015, researchers Dr. Todd Halihan and Jon Fields from Oklahoma State University (OSU) performed geophysical measurements of three application fields and near the waste storage ponds at C and H Hog Farms. Electrical resistivity transects were employed because these techniques can detect contrasts in soils, bedrock, and ground water. The surveys further characterized the karst nature of the study area and resolved dissolution features and fractures known to be characteristic of the Boone Formation. The final report, also available at the bigcreekresearch.org website (https://bigcreekresearch.org/related_material/2016_Fields%20and%20Halihan_ER%20Surveys%20of%20Applied%20Hog%20Manure%20Sites%20MTJ%20AR%2004....pdf), included geophysically interpreted transects of the field survey lines showing resistivity values of underlying strata. The transects completed near the waste storage ponds were not presented in the OSU report because interpretations of these data would need to be conducted in conjunction with directly acquired information concerning the soils, bedrock, and ground water.

Boreholes are typically employed in conjunction with geophysical surveys to allow comparison of indirectly acquired evidence (i.e. electrical signal penetration and return through subsurface strata) with directly acquired data and samples collected at locations of interest along the transect (i.e. auger or core drilling into the subsurface soils or bedrock and examination in the field and/or lab). The combination of direct and indirect evidence allows researchers to more accurately interpret the indirect geophysical results, and apply indirect results to a much larger spatial area than can be achieved through drilling at individual point locations. OSU did release transects associated with the waste storage ponds, but highly conductive zones identified in these transects could be caused by naturally occurring clay-rich soils, or highly conductive and possibly contaminated fluid within the strata.

Based on the possibility that the OSU results did detect leakage through the clay liner, BNR and other interested parties, most notably the Buffalo River Watershed Alliance, asked ADEQ to conduct the needed direct drilling at the waste storage pond. ADEQ subsequently developed a Site Investigation Plan (Harbor Environmental and Safety, 2016a) to collect samples from one borehole. The investigation's design does not address the objectives outlined in the parks request and thus will not resolve the unknowns associated with this issue. ADEQ changed the title of the investigation to a Drilling Study Work Plan (Harbor Environmental and Safety, 2016b). Results of the borehole investigation are anticipated no later than January 2017.

Summary of Ongoing Water Quality Investigations

Big Creek Research Extension Team

Dr. Andrew Sharpley provided BCRET data in electronic format for this analysis on August 26, 2016. Communications with Dr. Sharpley were very important to analyzing and reporting on the results of this study to date, as presented in the water quality section of this document. BCRET data collection activities are ongoing, and they release quarterly reports on their website showing ongoing data collection results, and other topics relevant to their investigation. Dr. Sharpley anticipates developing load calculations for the BCRET downstream sampling site in the future and is aware that better interpretations will result with additional time and data. BCRET is not planning to sample storm-event run off in Big Creek at intervals throughout the rising and falling limbs of a storm hydrograph(s). Such data could be useful in comparing storm loading between the upstream and downstream sites during maximum nonpoint runoff. The lack of discharge data for the upstream site is also a limiting factor. Given the karst setting and underground flow between the upstream and downstream sites, flow relationships between the two-sites should be further investigated. Other suggestions based on this review that might improve the BCRET study have been provided to Dr. Sharpley for his consideration.

Buffalo National River Water Quality Monitoring Data

BNR is continuing to collect seasonal water quality samples at Big Creek at Carver, along with 31 other sites in the park. These data are serving their intended purpose of providing a baseline and screening for significant water quality issues, but the seasonal sampling frequency is insufficient for the information currently needed at the Big Creek at Carver station. The Water Quality Monitoring Plan under which the water quality data activities are currently conducted requires updating to better conform to current technology, regulatory changes, laboratory procedures and detection limits, and other factors.

Buffalo National River Special Studies Data

When BNR became aware the C and H Hog Farms facility had been permitted and was under construction in the Big Creek basin, water quality sampling efforts were intensified at the Big Creek at Carver site and in the Buffalo River upstream and downstream of the confluence with Big Creek. These efforts have been briefly reviewed in this document as presented in the water quality section. Preliminary results of these studies have been transferred to ADEQ, and BNR has requested ADEQ examine the continuous dissolved oxygen results in comparison to State standards and decide if Big Creek is impaired. BNR water quality data was also used to inform the study plan for the USGS gage and water quality monitoring site located at Big Creek at Carver.

U. S. Geological Survey Discharge and Water Quality

The USGS collects the highest quality stream flow and water quality information. BNR and the State of Arkansas are benefiting from USGS data collection efforts at three sites on Big Creek: Big Creek near Mt. Judea (water quality and discharge), Left Fork Big Creek near Vendor (stage only), and Big Creek at Carver (discharge and intensive water quality monitoring and sample collection). This data collection program has been described previously in this report, and data from the USGS continuous nitrate and DO probes and stream discharge was used in the data analysis section. Of critical importance is the USGS plan to develop loading calculations for the Big Creek at Carver site. USGS also operates a stage only gage at the Buffalo River at Carver just upstream from the confluence with Big Creek. Development of a stage discharge rating curve, and collection of water quality information for this site, would allow for quantitative modeling of water quality concentrations in the Buffalo River downstream of the confluence with Big Creek.

University of Arkansas Geoscience Department, Dr. Van Brahana Karst Studies

Dr. Van Brahana is leading a group of trained volunteers who are conducting the most spatially encompassing water quality data collection effort in the area. Dr. Brahana has also led karst inventory and dye-tracing investigations in the Big Creek watershed, and nearby locations of hydrologic interest, and is a recognized regional expert in the field of karst hydrogeology. His team's efforts have already quantified the close hydrologic relationship of Boone Formation springs with precipitation events and area streams, and he has recently reported on preliminary water quality investigations. Water quality collection efforts continue, and Dr. Brahana is currently working on publishing his team's dye-tracing results.

Ouachita Baptist University, Dr. Joe Nix Big Creek Sampling and Analysis

Dr. Nix was instrumental in setting up the original water quality monitoring program at Buffalo National River. He is a chemist with extensive water quality experience. Dr. Nix established a water quality laboratory at Ouachita Baptist University, and this lab is certified by ADEQ. Dr. Nix is focused on collecting synoptic monthly water quality samples from nine sites on Big Creek, one site on the Left Fork of Big Creek, and from the Buffalo River upstream and downstream of its confluence with Big Creek. This data will be useful in interpreting assimilation of nutrients, and for other reasons, between the BCRET study sites and the NPS and USGS sampling sites at Big Creek at Carver.

Recommendations

1.) **Water Resource Management Plan** – Buffalo National River, Midwest Region, and the Water Resources Division need to make a long-term, concerted effort to implement the recommendations in Buffalo National River's Water Resources Management Plan. This plan was developed based on many years of resource management experience in the Buffalo River watershed. The most important recommendation in this plan is to develop a watershed based, voluntary, water quality conservation strategy. Positive actions such as funding and implementation of voluntary best management practices should be undertaken to offset negative trends elucidated in the water quality monitoring results discussed here and in other references. Governor Hutchinson's recent announcement to implement a watershed conservation effort for the Buffalo River should be enjoined and fully supported.
2.) **Examine CAFO permitting processes in other states** - The NPS should review CAFO permitting processes in other states where parks with important water resources are located. This review should determine if general permits are in place, public notice requirements, engineering standards, and the overall potential vulnerability of NPS units to state permitting actions, such as described in this assessment. Where vulnerabilities are identified, the NPS should work with States and the EPA to strengthen protection of park waters and improve communications regarding these decisions before facilities are permitted.
3.) **Flow gain and loss study** – During low-flow conditions, measure stream discharge in Big Creek at close intervals, and the discharge at any confluencing tributaries, to quantify increases or decreases in stream flow. Reaches where ground water is recharging the creek (gaining reach), or surface water is recharging ground water (losing reach), can then be quantified and mapped, as done by Moix and Galloway, 2004, for the Buffalo River. The gain and loss study should be conducted from where Big Creek leaves the Fayetteville Shale formation upstream of C and H Hog Farms, to Big Creek's confluence with the Buffalo River. Various field parameters (conductance, pH, dissolved oxygen, temperature) and water quality samples (nutrients, bacteria, turbidity, chloride) should be collected along with discharge. These flow and water quality data will be critical to understanding downstream effects of C and H Hog Farms on the water quality of Big Creek, assimilation processes, and the volume and quality of water being lost from the Big Creek channel and resurging in the gaining reach of the Buffalo River identified by the USGS below Carver.
4.) **Dye tracing studies** – Carefully planned and legally defensible dye-tracing studies should be completed in the Big Creek basin and surrounding karst environs. These traces should be conducted in the vicinity of current and proposed C and H Hog Farms waste spreading fields, to assist with determining karst subsurface ground water transport and resurgence to springs and surface streams. Currently, the BCRET sampling strategy is designed to detect changes in water quality above and below the C and H Hog Farms operation by measuring water quality in Big Creek, as discussed. However, it has been well documented in the Buffalo River watershed and elsewhere, that some or all of the water infiltrating into karst subsurface drainage networks can move out of one surface basin and discharge in another watershed. These inter-basin

movements have been shown to be driven by gradient, stratigraphic, and structural controls. Collection of dye-tracing information would reveal other areas that should be monitored, and help with interpreting results from areas currently being monitored. For example, water could be moving from outside the BCRET study basin and into the stream channel above the downstream sampling site and USGS gage near Mt. Judea, and complicating observed water quality differences between the BCRET upstream and BCRET downstream sampling sites. Another unknown is the volume of discharge lost to the Boone Formation upstream of BCRET's upstream sampling site. Dye tracing would also be employed within the losing reach identified by the USGS stream gages in lower Big Creek. Dye injection within the losing reach of Big Creek would be accompanied by dye sample collection and analysis in the gaining reach of the Buffalo River, to establish transport times and concentration recovery estimates. This work could also pinpoint the resurgence zone within the Buffalo River, and allow for special project sampling of water quality in the river near the flow gain point or reach.

5.) **Dye tagged storm flow study** – Because nonpoint source pollution is driven by land surface runoff and ground water infiltration during rain storms, several studies have documented substantial increases in concentration and loads of key constituents of interest (bacteria, phosphorus, sediment, total nitrogen) during rain events. One of the major short-coming of the current water quality sampling efforts in Big Creek is the general lack of intensive storm flow monitoring. Ongoing USGS sampling and plans to develop correlation curves between discharge and parameter concentrations will ultimately allow USGS to determine estimated annual loads, and parameter behavior during storm flows, at the Big Creek at Carver site. Dr. Sharpley (personal communication, 2016) states that his associates will also develop load estimates for the BCRET downstream site located at the USGS near Mt. Judea gage. It is unknown if both USGS and BCRET will use the same methods to calculate loads, but it is known that they are using different methods to collect and analyze water samples. The comparability of the USGS and BCRET data may therefore be limited. Development of load estimates for the upstream site is not being planned, and this will make data interpretations problematic. Furthermore, since most of the basin draining to Big Creek at Carver is downstream of the BCRET sampling station near Mt. Judea, it will be difficult to determine the direct contribution of storm flow runoff from the vicinity of the C and H Hog Farms operation. To address some of these uncertainties, a focused storm event sampling strategy such as that employed by Mott, 1990, and Steele and Mott, 1998, should be conducted at Big Creek at Carver. To assist with source tracking, methods employed by Ryan and Meiman, 1996, to inject dye into storm flow at the Big Creek near Mt. Judea sampling site (BCRET downstream) should also be employed. This would allow the storm runoff from the vicinity of C and H Hog Farms to be "tagged" with the dye and its arrival at the Big Creek at Carver site identified. Subsequent dye sample collection and direct analysis with a field fluorometer at the Big Creek at Carver site, would allow for the arrival of the upstream storm runoff to be detected, and intensive sampling and parameter concentrations to be correlated with arrival of the C and H Hog Farms runoff. Such a study would be expensive, and intensive in terms of staff, laboratory, and logistical considerations, but would be the most effective means of observing the actual storm runoff impacts from the C and H Hog Farms operation to Buffalo National River. Interpretations could be further improved if BCRET staff would sample the same storm event(s) at the Big Creek near Mt. Judea gage, and the upstream sampling site.

6.) **Update the Water Quality Monitoring Plan** – It has been 23 years since BNR's water quality monitoring plan was updated. Many changes to laboratory detection limits, addition of parameters and methods, and personnel have occurred in the intervening years. An update would also allow BNR to reflect on the current sampling strategy and what has and has not been useful in current efforts to respond to the C and H Hog Farms development and other concerns. Do parameters need to be added? Are the laboratory detection limits currently being used by ADEQ sufficient? Should additional monitoring sites be considered? Can the water quality database be better managed and archived?

7.) **Dissolved oxygen and nutrient assimilation study** – Big Creek at Carver is experiencing diel dissolved oxygen fluctuations whose minima fall below Arkansas Regulation No. 2 standards. The nutrient inputs from upstream, the newly identified losing stream reach, nuisance algal observations, respiration rates, and other factors, are interacting to potentially impair DO values and aquatic communities in Big Creek. This would be an opportunity for BNR to work with the USGS and/or an aquatic ecology professor and graduate student, for example, to design a study that might better define and quantify this phenomenon, and make interpretations regarding potential causes and solutions. A study could also investigate phytoplankton and periphyton density and community structure, aquatic macroinvertebrate assemblages, and chlorophyll concentrations. BNR should continue to request ADEQ and EPA to make a determination of impairment based on dissolved oxygen values recurrently below numeric criteria.

8.) **Communication with ADEQ** – Continue and improve management to management interactions with ADEQ that foster a relationship of open communication insuring that present and future ADEQ managers are fully aware of the National Park Service's mission and priorities at Buffalo National River. ADEQ and BNR could use such an opportunity to discuss important efforts in the Buffalo River watershed and any new developments. Both agencies need to have a better understanding of how the other agency views water quality concerns, for example, such as questions related to state standards and their interpretations.

9.) **Request assistance from the Inventory and Monitoring Program** - Request NPS Heartland Network Inventory and Monitoring Program provide additional assistance with water quality monitoring efforts at Buffalo National River. Water quality monitoring is the park's highest priority data collection need. One currently unmet need, for example, is a scientifically acceptable means of quantifying nuisance phytoplankton, periphyton, filamentous, and other algal growths in the Buffalo River, allowing these changes over time to be correlated with stream flow, season, water quality and land use development.

10.) **Science partnerships with USGS** – The Department of the Interior is fortunate to have the world's premier water science data collection and interpretation organization, the United States Geological Survey, as part of its bureau. The National Park Service should seek every opportunity to improve its understanding of Buffalo National River's geohydrology and water quality through consultation and study implementation with USGS hydrologists and geologists, who are widely recognized and respected experts. BNR could also benefit by turning scientific discoveries about the Buffalo River watershed into educational materials for park visitors and concerned citizens, so that they too can be enlightened by ongoing scientific discoveries.

11.) Organize a third-party rule-making committee – The APC&EC maintains a process whereby citizens and entities can petition the Commission to adopt rules and regulations. Referred to as "third-party rulemaking," a collaborative effort should be undertaken to develop and implement improvements to Regulations No. 5 and 6. This process should also be used to establish specific water quality standards for the Buffalo River in Regulation No. 2 that reflect as-measured water quality, and the ONRW anti-degradation policy requiring water quality to be maintained and protected.

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AppendixA

1992 ADEQ Buffalo River Moratorium

and Watershed Study Administrative Notice

ARKANSAS DEPARTMENT Of POLLUTION CONTROL &

ECOLOGY IN THE MATTER OF:

BASIN-WIDE INITIATIVE FOR
THE BUFFALO RIVER WATERSHED

ADMNISTRATIVE
NOTICE

This Administrative Notice constitutes a statement of policy which will be followed by the Department in exercise of its authorty under the Arkansas Water and Air Pollution Control Act,

A.C.A. §8-4-201 et seq.

FINDINGS

1. The Buffalo River is one of the state's and the nation's treasures. The Buffalo was the first stream to be designated as Natonal River. Arkansas Water Quality Standards classify the Buffalo as a Natural and Scenic Waterway and an Extraordinary Resource Water. Section 3(C) of the Regulation No. 2: Water Quality Standards directs the Department to protect such high quality waters using, among other means, "pursuit of land management protective of the watershed."

2. In general, the water quality of the Buffalo River is excellent. Recent data, however, indicates impairment of aquatic biota in tributaries to the Buffalo which could reasonably be expected to affect the Buffalo

in the future if the cause is not discovered and abated. In order to preserve the outstanding quality of the Buffalo, the Department has determined it necessary to invoke its authority under Section 3(C) of Regulation No. 2.

3. The Department will perform an extensive survey of the Buffalo River basin for the purpose of assessing the water quality of the Buffalo and its tributaries, identifying the cause of any impairment of waters in the basin, and determining a reasonably protective water quality management plan for all waters in the basin.

THESE PREMISES CONSIDERED, the Director hereby issues the following Notice:

NOTICE

1. During the pendency of the surveys and studies described above, the Department will not issue any permits for new sources to discharge wastes into any stream in the Buffalo River watershed, nor will the Department issue "no-discharge" permits for any facility or activity which would generate waste that could potentially impact the water quality of the Buffalo River or its tributaries.

2. The Department will perform surveys and inspections of all existing facilities and activities within PC&E's regulatory jurisdiction located in the Buffalo River basin. The purpose of these studies will be to catalog and assess what impact existing facilities may have on the Buffalo River or its tributaries.

3. Operators of confined animal facilities permitted by PC&E are strongly urged to consult with representatives from the Cooperative Extension Service to review the requirements of their permits and how their operations may be improved.

4. All persons and facilities subject to the regulatory jurisdiction of the Department shall cooperate with the surveys and studies described in this Administrative Notice, which includes allowing reasonable site access to Department personnel for the purpose of conducting inspections, collecting water samples and placing monitoring wells or other testing devices.

5. Nothing in this Administrative Notice shall preclude the Department from taking any form of enforcement action deemed appropriate to prevent or abate pollution of the waters of the Buffalo watershed.

6. The Department does not consider this Administrative Notice a final agency action subject to appeal or other adjudicatory review. However, any person adversely affected by subsequent actions by the Department in pursuance of the policy announced herein (e,g., through denial of a permit or initiation of an enforcement action) retains all rights of legal redress recognized by the Arkansas Water and Air Pollution Control Act.

Randall Mathis

RANDALL MATHIS, DIRECTOR

10/12/92
DATE

Appendix B

Criteria for citing, investigation, and design of liquid manure storage facilities

(source: NRCS, 2012)

Table 10–4 Criteria for siting, investigation, and design of liquid manure storage facilities

Risk → / Vulnerability ↓	**Very high** <1,500 ft from public drinking water supply wells; **OR** <100 ft from any domestic well or Class 1 stream	**High** Does not meet Very High Risk criteria; **AND** Recharge areas for Sole Source aquifers; **OR** 100 to 600 ft from unconfined domestic water supply well (or where degree of aquifer confinement is unknown) or Class 1 stream	**Moderate** Does not meet High Risk criteria; **AND** 600 to 1,000 ft from unconfined domestic well (or where degree of aquifer confinement is unknown) or Class 1 stream; **OR** <600 ft from unconfined nondomestic water supply well (or where degree of aquifer confinement is unknown) or Class 2 stream	**Slight** Does not meet Moderate Risk criteria; **AND** >1,000 ft from unconfined domestic well (or where degree of aquifer confinement is unknown) or Class 1 stream; **AND** >600 ft from unconfined nondomestic water supply well (or where degree of aquifer confinement is unknown) or Class 2 stream
Very high Large voids (e.g., karst, lava tubes, mine shafts); **OR** Highest anticipated ground water elevation within 5 ft of invert; **OR** <600 ft from improperly abandoned well*	**Evaluate other storage alternatives** * (or properly seal well and reevaluate vulnerability)	**Evaluate other storage alternatives** * (or properly seal well and reevaluate vulnerability)		
High Does not meet Very High Vulnerability criteria: **AND** Bedrock (assumed fractured) within 2 ft of invert; **OR** Coarse soils/parent material (Permeability Group I soils as defined in AWMFH, always including GP, GW, SP, SW); **OR** Highest anticipated groundwater elevation is between 5 to 20 ft below invert; **OR** 600 to 1,000 ft from improperly abandoned well*		**Synthetic liner required** * (or properly seal well and reevaluate vulnerability) No additional site characterization required	**Liner required** * (or properly seal well and reevaluate vulnerability) Specific discharge $\leq 1\times10^{-6}$ cm³/cm²/s No manure sealing credit Earthen liner design includes sampling and testing of liner material (Classification, Standard Proctor compaction, Permeability)	**Liner required** * (or properly seal well and reevaluate vulnerability). Specific Discharge $\leq 1\times10^{-6}$ cm³/cm²/s No manure sealing credit Earthen liner design includes sampling and classification testing of liner material Published permeability data and construction method specifications may be used
Moderate Does not meet High Vulnerability criteria; **AND** Medium soils/parent material (Permeability Group II soils as defined in AWMFH, usually including CL-ML, GM, SM, ML); **OR** Flocculated or blocky clays (typically associated with high Ca); **OR** Complex stratigraphy (discontinuous layering); **OR** Highest anticipated ground water elevation is between 21 to 50 ft below invert; **OR** 600–1,000 ft from improperly abondoned well*	**Evaluate other alternatives or synthetic liner as allowed** Local regulations may apply Consult with area engineer	**Further evaluate need for liner** Specific discharge $\leq 1\times10^{-6}$ cm³/m²/s No manure sealing credit Earthen liner/no liner design includes sampling and testing of liner/in-place material (Classification, Standard Proctor compaction/in-place density, Remolded/ Undisturbed sample Permeability)	**Further evaluate need for liner** Specific discharge $\leq 1\times10^{-6}$ cm³/cm²/s No manure sealing credit Earthen liner/no liner design includes sampling and testing of liner/in-place material (Classification, Standard Proctor compaction/ in-place density, Remolded/Undisturbed sample Permeability)	**Further evaluate need for liner** Specific discharge $\leq 1\times10^{-6}$ cm³/cm²/s No manure sealing credit Earthen liner/no liner design includes sampling and classification testing of liner/ in-place material + in-place density Published permeability data and construction method specifications may be used
Low Does not meet Moderate Vulnerability criteria; **AND** Fine soils/parent material (Permeability Group III and IV soils as defined in AWMFH, usually including GC, SC, MH, CL, CH); **AND** Highest anticipated ground water elevation is >50 ft below invert		**Further evaluate need for liner** Specific discharge $\leq 1\times10^{-6}$ cm³/cm²/s No manure sealing credit Earthen liner/no liner design includes sampling and testing of liner/ in-place material (Classification, Standard Proctor compaction/ in-place density, Remolded/ Undisturbed sample Permeability) Scarify and recompact surface to seal cracks and break down soil structure as appropriate	**Liner not required** Specific discharge ≤ 1 x 10^{-6} cm³/cm²/s Field classification and published permeability data may be used Construction method specifications may be used Scarify and recompact surface to seal cracks and break down soil structure as appropriate	

*See local regulations