July 1, 2014

Mr. Doug Szenher
Arkansas Department of Environmental Quality
5301 Northshore Drive
North Little Rock, Arkansas 72118

Re: Public Comment—Regulation 5 and Regulation 6 Rulemaking

Subject: Geology of the Buffalo River Watershed

Dear Mr. Szenher:

We support the proposed amendments to the Arkansas Pollution Control and Ecology Commission's Regulation 5 and Regulation 6.

In this letter "CAFO" will be used to mean a medium or a large swine confined feeding operation as it relates to both Regulation 5 and Regulations 6.

I have attached several documents in support of this comment which I hereby incorporate by reference.

1. General Description

The Buffalo River Watershed in north-central Arkansas (Figure 1) is a region of uplifted, slightly deformed, Paleozoic-age sedimentary rocks. The uplift and concomitant tilting, which in general has less than several degrees of dip, were caused by farfield stresses along reactivated basement faults in response the Ouachita orogeny about 150 kilometers to the south. Although deformation in the area appears to be slight, and the rocks are nearly flat-lying, uplift has resulted in numerous fractures, joints and faults which facilitate vertical groundwater movement (Hudson, 2000; Hudson and Cox, 2003). Uplift is responsible for the downcutting of the rivers, resulting in the steep bluffs and vertical cave entrances for which the region is known.

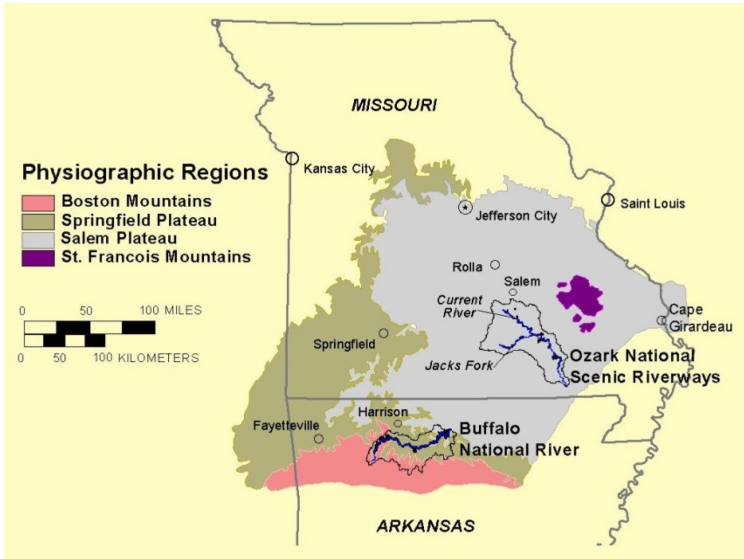

Figure 1.—Location of the Buffalo National River and its physiographic setting in north-central Arkansas.

Typical of the Ozarks region approximately 64 percent of the Watershed area is underlain by limestone and dolomite (also carbonate rock) formations. The Boone formation, a karstic, cherty limestone formation, occupies the largest part and underlies many tributaries and a substantial part of the mainstream Buffalo River (Scott and Smith, 1994).

Karst is formed in the following manner: Precipitation of relatively pure water (H_2O) gains carbon dioxide (CO_2) from the atmosphere as it falls as rain, but mostly from the soil zone where CO_2 partial pressures are higher because of decaying vegetation. Mixing H_2O with CO_2 yields carbonic acid (H^2CO_3), which dissociates into hydrogen ions (H^+) and bicarbonate ions (HCO_3^-). The H^+ reacts with the limestone ($CaCO_3$), generating calcium ions in solution (Ca^{+2}) ions in solution, and HCO_3^-. These are the dominant dissolved species we find in spring and well water that originates in the Boone and St. Joe Formations, and that create the karst over the huge time interval that these rocks have been exposed at the land surface. The limestone is being dissolved, creating void space where solid rock once existed.

The evidence that the Boone Formation is a mantled karst in the region has been well-established in the geologic literature (Adamski et al., 1995; Mott et al., 2000; Ting, 2002; Ting, 2005; Hobza, 2005; Hudson et al., 2005; Leh, 2006; Leh et al., 2008; Wagner, 2007; Brahana et al., 2009; Brahana, 2011; Brahana et al., 2014; Jarvie et al., 2014), as well as in field work by a diverse group of volunteers who have previously worked as professional scientists with Arkansas Department of Environmental Quality, University of Arkansas Division of Agriculture, U.S. Geological Survey, Tyson Foods, Inc., National Oceanographic and Atmospheric Administration, Ouachita Baptist University, and the University of Arkansas Department of Geosciences. This interpretation that the Boone is karstified is not speculation, but based on irrefutable scientific evidence that includes the following: strong interaction between surface water and groundwater; field observation of major springs and caves in the basin; rapid groundwater flow defined by dye-trace studies; field observation of conduits in the limestone between chert layers that has been intensively dissolved; dispersive groundwater flow along highly dissolved limestone layers that lie between impermeable chert layers, based on the distribution of dye retrieval during dye tracing; stream sections that are dry down-gradient from continuously flowing sections, indicating that these are losing reaches where all of the surface water discharge flows underground under low-flow conditions; the major-element geochemistry of water from the Boone Formation that is shown to be a predominantly calcium-bicarbonate type, which are the two dominant dissolved ions resulting from the dissolution of limestone by aggressive recharge water. If further evidence in needed it can be found in the number of caves, 360, conduits, pits, sinkholes, alcoves, karst aquifers, and springs—all karst features.

The uplands of the Buffalo River Watershed are primarily shale and sandstone. This steeper region is generally not suitable for agricultural activities. Over 45 percent of the Watershed has a slope ranging from 12.3 to24.9 percent steepness and over 30 percent has a slope of more than 24.9 percent steepness (Scott and Smith, 1994). Thus the area suitable for spray fields of a CAFO, that is limited both in Regulation 5 and 6 to having an average slope of 15 percent or less would almost certainly be less that 40% of the total area of the Watershed. This would be found primarily in the valleys along the tributaries and would be underlain by karst.

2. Example—Mt. Judea Valley and Big Creek

Examination of the Arkansas Geological Survey quadrangle maps of the Watershed area will show the areas with the topography that would meet the slope requirements for the spray fields of a CAFO. These can be found, for example, on the quadrangles for Parthenon, Eula, Snowball, Marshall, Hastay, Western Grove, and Mt. Judea. All of these show that the Boone formation is the underlying layer in areas that are flat enough for spray fields. On the other hand, if we look at the Boxley quadrangle, the top layer of rock is primarily shale and sandstone but the contour lines indicate that there is no area suitable for a CAFO. Since we have studied the Mt. Judea area intensively for the last few months, we will use Big Creek as an example to point out several factors as they related to suitability for CAFOs.

Big Creek, is one of the two largest tributaries to the Buffalo National River, encompassing about 8% of the total drainage of the entire Buffalo River drainage area. Physiographically, tributaries head in uplands on terrigenous sediments of Pennsyvanian age of the Boston Mountains Plateau (figure 1), and flow generally toward the north with relatively steep gradients. The stratigraphic unit of major concern is the Boone Formation (Figure 2), an impure limestone that contains as much as 70% chert (Braden and Ausbrooks, 2003). The upper and lower units of the Boone Formation have much less chert (typically less than 5%) than the middle part of the Boone. The upper and lower parts of the Boone Formation host significant caves in the region (figure 3). Intervening layers of limestone are karstified by smaller dissolution features (figure 4), with the chert acting as confining units above and below. The Boone Formation is a karst aquifer.

Stratigraphic Column

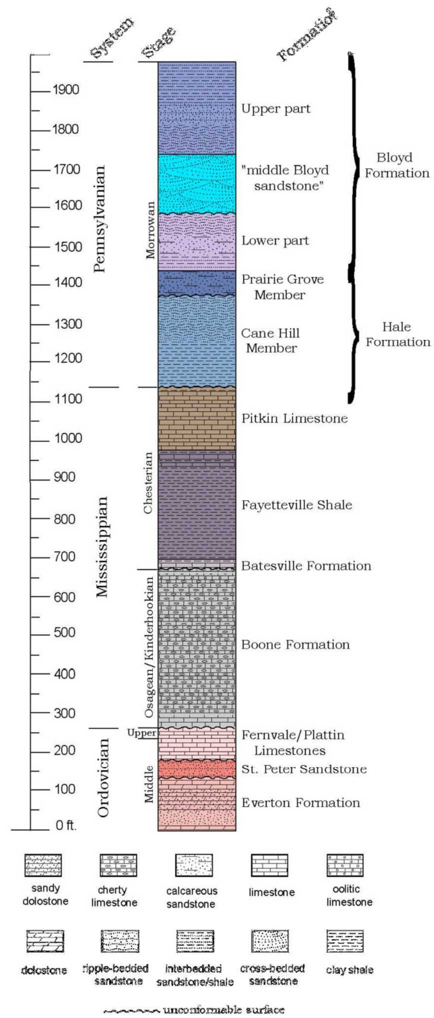

Figure 2.—Sequence of layers in Big Creek Basin, showing the relation of the Boone Formation to younger, overlying formations, and older, deeper lithologies.

Figure 3.—The thick sequence of interbedded limestone and chert of the Boone Formation is shown in this composite photograph near the town of Vendor, in the Big Creek drainage basin. Figure 4 shows the karst that develops in the limestone units in an enlarged scale.

3. Characteristics of karst geology.

Karst geology is described as any region of the earth's surface that is underlain by soluble rock that has been dissolved by dynamic groundwater flow. Areas of karst can take many forms, but they always have these attributes:

- surface water and ground water interact easily and quickly along dissolved fractures;
- groundwater is a much large percentage of the hydrologic budget than in non-karst;
- groundwater flows rapidly through conduits of enhanced permeability;
- dispersive flow is common, with flow spreading down-gradient along dissolution paths;
- contaminant migration through karst aquifers experiences little or no attenuation;
- springs are the dominant form of discharge in karst.

Many other landform features may be found in karst regions, such as sinkholes, internal drainage, uvalas, estavelles, sinkhole plains, sinking streams, and related voids, but their presence may be masked by a mantling veneer of overlying regolith covering the underlying

Figure 4. Karst dissolution features in limestone interbedded with chert from the middle Boone Formation. The chert acts as an insoluble confining unit for the karst, which develops in the soluble limestone layers. The scale of these voids typically ranges from 2 to more than 5 cm, and it is these voids which have developed over long geologic time which divert the groundwater flow from the input points shown on Figure 6 to the springs that lie along the creeks in the basin.

Figure 5. In regions of Big Creek basin at the top and bottom of the Boone Formation, where the limestone is thick and there is little chert, the size of the voids or conduits can be huge, large enough for humans to enter and explore the groundwater flow system. This figure shows John Eddings Cave, near the confluence of the Buffalo River, with dimensions of approximately 3 meters tall by 5 meters wide.

karst. The Boone Formation is a classic setting of mantled karst (Imes and Emmett, 1994; Brahana, 2011).

4. Potential problems relating to CAFOs in areas with karst geology.

There are multiple problems that can occur related to large swine operations, the most important of which are pathogen transport from the hog waste, nutrient transmission associated with organic and sediment transport through the open voids that underlie the land surface, and dissolved solutes transport in the flowing water. The fast flow of the groundwater facilitates turbulent flow in the voids, which makes karst particularly vulnerable compared to other underlying geologic conditions. Continuing dissolution increases the size of the voids over time, potentially weakening the roof support which may facilitate collapse, and the weight of water overlying clay-filled voids leading to large conduits also has been observed in the area. These can result in catastrophic "blow outs", in which the weight of the water forces the weak clay to be pushed into the underlying conduit, with the water from above draining rapidly and directly into the karst.

The existence of well-developed karst near a National River which has been designated as Extraordinary Resource Water definitely indicates a risk. The concentrated wastes from the CAFO between the medium to large size, including the calculated allowable leakage through the clay of the lagoon liner and the contribution to groundwater from spray fields represent the fecal matter and urine equivalent to a city of at least 35,000 people being spread untreated on less than one square mile of land (one mi^2 = 640 acres). The spreading fields are immediately proximate to a stream that provides major flow (8%) to the Buffalo National River and these are underdrained by groundwater flowing in the high-permeability voids of the Boone Formation. This setting puts the drainage basin downstream from the operation at risk, not only from the standpoint of ecology, but also from the standpoint of environmental integrity and water quality. This includes Big Creek, Left Fork of Big Creek, and the Buffalo National River, with its numerous canoers and swimmers that have primary and direct contact with the water.

5. Example: Study in Mt. Judea area.

The following results were obtained from our dye-tracing studies in the Mt. Judea area. We have been able to establish that we have very fast flow (1500 to 2500 feet per day for a straight-line distance, likely greater if we were able to ascertain the exact flow path), and we have diverse and heretofore unpredictable flow directions, based on the results of our dye injections.

Succinctly, we injected 3 dyes at three separate locations during spring 2014. Fluorescein dye was injected in dug well BS-39 (green circle on Figure 6), and recovered in BS-40 and the BS-02 springs that lie along and in the channel of Big Creek (shown at the end of the green arrows in Figure 6). This dye visibly appeared in Big Creek less than 30.5 hours after injection, indicating a flow velocity of at least 1500 feet per day. The spring from which it emerged was a limestone layer separated by two confining chert layers, essential the same as the karst in the Boone Formation shown in Figure 4. Flow was completely in the subsurface. Dye receptors downstream of the springs in Big Creek also indicated the presence of the dye, as did the spring itself. Dye was observed in the dye receptors for a period of more than two weeks.

Rhodamine WT was injected into BS-60, a losing section of stream along Sycamore Hollow (red circle on Figure 6) just prior to a rainstorm of approximately 2 inches, in anticipation of groundwater flow thought to be moving southeast and then northeast along Dry Creek into Big Creek. None of this dye was recovered in any receptors along this or any anticipated flowpath, although we input about 11 pounds. It is likely most of the dye moved north and west, based on the other two traces which showed dominant flow directions with northwest flow paths, but the density of dye-receptor coverage was not great enough in the main stem of Left Fork, and we did not have the results from the other tests at that time. We anticipate duplicating this test with many more dye receptors placed along Left Fork.

Eosin was injected in BS-36 (shown by orange circle on Figure 6), a dug well surrounded by spreading fields near the southern reaches of the C & H operation. Over the course of 8 days after injection we collected the first dye receptors, with positive traces to three nearby perched springs (BS-13, BS-14. BS-15, not identified on Figure 6, but close to the injection point in the rim of white around the orange circle on Figure 6), Dry Creek (BS-56, shown by the black arrow extending southeast from the injection point and a nearby seep in Figure 6)), the Sexton Cemetery -Mt. Judea bridge (BS-54, shown by the northward pointing black arrow from the previous arrow in figure 6—the black arrows signify travel in the surface streams), and the confluence of the Wheeler ephemeral stream with Big Creek (BS-59). Surprisingly, we also got very strong positive dye observations from five bedding-plane springs along Left Fork (BS-30, BS-30B, BS-30C, and BS-30E, orange arrow on the left from eosin injection point shown on Figure 6), the spring and well down-gradient from site BS-30 (BS-29 and BS-29 overflow, orange arrow on the right from eosin injection point shown on figure 6), and the site near the Vendor low water bridge over Left Fork (BS-42, near the head of the black arrow on Left Fork.

Sampling last summer, we were able to establish that background groundwater quality in the area was dominantly a calcium-bicarbonate type in the springs and wells of the Boone Formation, where it was exposed at land surface to allow infiltration of precipitation that served as recharge. Dissolution is greater in the valleys, based on faster flow, which is indicated by lower electrical conductivity when compared to the water from the Boone Formation beneath many hundreds of feet of overlying sedimentary rocks. Water from the overlying sedimentary rocks was a mixed type distinct and non-overlapping of water from the Boone Formation.

Sampling in Big Creek basin for more than one year at an average of one day per week by two crew members, we established a karst inventory that identified numerous caves, springs, sinkholes, bedding-plane anastomoses, epikarst dissolution features, sinking streams, dry stream reaches, and very fast groundwater velocities.

4.

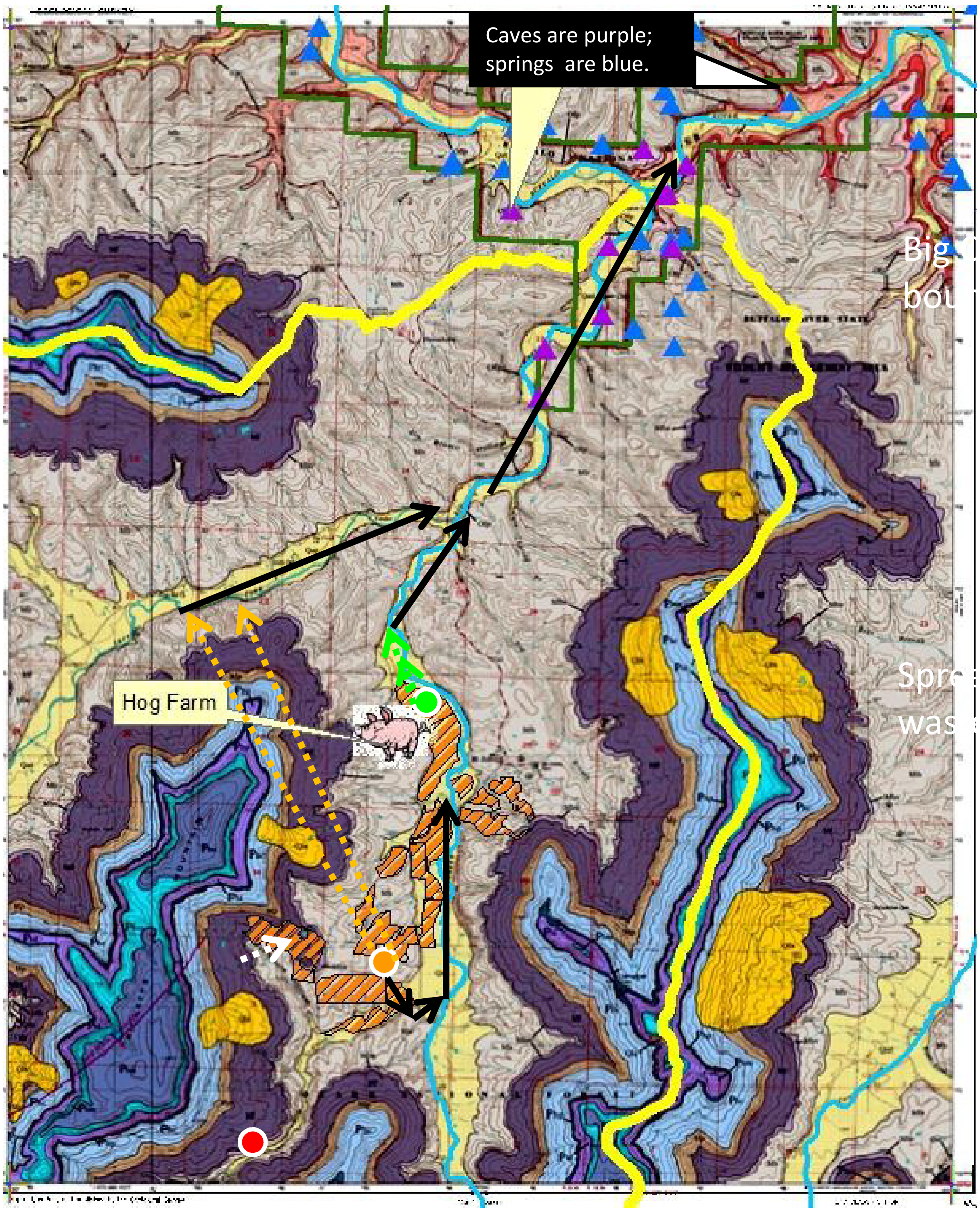

Figure 6.—Geologic map of a portion of the Big Creek drainage showing the results from the initial dye tracing, the area of direct impact of the swine CAFO, including spreading fields for the hog wastes. The karstified Boone Formation is shown in gray, dye injection points are shown by colored circles, groundwater flow is shown by dashed arrows, and surface flow is shown by solid black arrows. The continuous yellow line defines the boundary of the surface-water basin.

6. Conclusions from Dye Study

There is well-developed karst throughout the Mt. Judea valley. There are undoubtedly interconnections between the wells, springs, the groundwater, and the Buffalo with rapid flows and little if any attenuation of waste components. The risk to the Buffalo River (and to the wells in the area and to public health, e.g., the schools) is extremely high.

7. Another Case Study—the Pindall, Arkansas Landfill Issue of 1986-1987

Pindall, Arkansas is a small community on Highway 65 within the Buffalo River Watershed approximately 7 miles directly north of Woolum Ford on the Buffalo River. In August 1986 the Arkansas Department of Pollution Control and Ecology, the predecessor or ADEQ, granted a permit for a solid waste landfill approximately one mile from Pindall's water supply, a deep, 2,100 foot well with 500 feet of casing and a water level 275 feet below the land surface. The proposed landfill was also 4.5 miles from Mitch Hill Spring, a large spring flowing to the Buffalo River. The permit was issued over the objections of local citizens who formed a group called Citizens Against the Landfill, Inc. (CALF) to the fight the permit issuance. CALF along with the National Park Service hired Thomas Aley of the Underground Laboratory in Protem, MO to conduct a study of the geology of the area and the susceptibility of the town well and Mitch Hill Spring to contamination by the proposed landfill. Aley, through dye injection at six locations, documented the complex ground water flow in this karst area of the Buffalo River Watershed (Aley, 1987) (Aley, 1989) A recharge area for Mitch Hill Spring of 20.8 square miles was delineated. The area included the proposed landfill site and the town well.

Using the results of this study, CALF initiated legal action and eventually appealed to the Arkansas Pollution Control and Ecology Commission. They received a favorable ruling and the permit was revoked. Aley's contention was that "during the design and review process, the landfill proponents and the Arkansas regulatory agencies essentially ignored hydrologic assessment approaches appropriate to karst terranes. Had it not been for third party studies of the proposed landfill, and associated legal action, a landfill would have been located in the midst of an area which recharges water to a public water supply well and a major spring feeding the Buffalo National River."

8. Conclusions

Based on the geologic characteristics of the Buffalo River Watershed, particularly the predominant karstified limestone, the chances are essentially nil that a medium to large CAFO, constructed with present techniques, can be operated without extreme danger to the environment. The proposed amendments to Regulations 5 and 6 should be approved.

Note that this letter contains major contributions from John Van Brahana, Ph.D,
Professor Emeritus, Geosciences, University of Arkansas, Fayetteville, AR

Sincerely,

Robert Cross
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