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Thursday, 6April2016

Water-Draft-Permit-Comment@adeq.state.ar.us

Ms. Becky Keogh
Director
Arkansas Department of Environmental Quality
5301 Northshore Dr. North Little Rock, AR 72118-5317

Re: Permit 5264-W; AFIN 51-00164; C&H Hog Farms, Inc.

Dear Director Keogh:

Comments and concerns specific to listed permit conditions

NMP states "soil samples are to be taken once every five years or when the nutrient management plan is revised"[1]. Since addition of fields resulted in the revision of the nutrient management plan, recent soil samples should be available for existing fields as well. **Please update this in the Permit Conditions**[2], otherwise this is not an enforceable condition[3].

While spreadable acreage on Fields 15 and 17 seem to exclude the limestone outcroppings that were noted during a 2013 inspection[4], **shouldn't buffers be added to those areas?**

The NW corner of Field 15B should be excluded from spreadable acreage, as the September 2013 Inspection report noted that this area had visible limestone outcroppings[5].

Condition No. 26 requires that the interceptor trenches be sampled quarterly[6]; however, these data are being collected much more frequently than that by the BCRET team. **Please update this condition so that all data collected must be reported**, otherwise this obviously opens up an opportunity for data to be cherry picked to only include data with lowest concentrations. Also, it is stated that the monitoring and reporting of the interceptor trenches will provide a method to

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[1] See NMP on page 5 of Farm Overview, specific language in reference under "Soil and Swine Fertilizer Sampling" https://www.adeq.state.ar.us/downloads/WebDatabases/PermitsOnline/NPDES/PermitInformation/5264-W_Application%20Packet_20160406.pdf

[2] Part I on page 4 of Statement of Basis only mentions soil analysis will occur at least once every five years, but makes no mention of when NMP is updated.

[3] According to Specific Condition #4, see Page 1 of Part II of the permit.

[4] See page 13 of report. https://www.adeq.state.ar.us/downloads/WebDatabases/InspectionsOnline/073447-insp.pdf

[5] See page 15 of report. https://www.adeq.state.ar.us/downloads/WebDatabases/InspectionsOnline/073447-insp.pdf

[6] See page 4 of Part II for Specific Condition No. 26 of 5264-W.

assess the liner integrity[7], but at best this is an indirect method of assessing that. A detailed water balance study was suggested by the expert review team[8] and has been completely ignored[9]. From the very first inspection report from the facility it was noted that there were significant flaws with the integrity of the liner[10]; however, the permittee never addressed these concerns[11] and the Department still came to the conclusion that all issues had been resolved[12][13][14] without any indication that there had been anything done to address this[15] (Table 1). Just because the permittee has a daily inspection log in which they check a box indicating the ponds were checked, obviously does not ensure that self-inspecting is actually sufficient[16].

***Table 1**. Summary of violations noted regarding the integrity of holding ponds.*

Inspection Date	**ADEQ Inspection #**	**Violation**	**Corrective Action**
23July2013	073447	Erosion rills, desiccation cracks, gravel to cobble-sized substrate in liner	No specific actions were reported and no pictures were provided.[17]
23January2014	075752	Holding pond embankments were not stabilized and erosion rills still present. Large cobble still present in inspection photos of	No specific actions were reported, mention was made of future intent to install erosion control blankets[18].

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[7] See page 5 of the Statement of Basis of 5264-W.

[8] https://bigcreekresearch.org/project_reports/docs/Review%20Panel%20Report%20-%20May%2019%202014.pdf

[9] https://bigcreekresearch.org/project_reports/docs/Response%20to%20Expert%20Review.pdf

[10] See ADEQ Inspection Report #073447 dated 10September2013, https://www.adeq.state.ar.us/downloads/WebDatabases/InspectionsOnline/073447-insp.pdf

[11] See 20September2013 letter from Jason Henson (C&H Hog Farms, Inc) to Jason Bolenbaugh (ADEQ), *Re: Compliance Assistance Inspection (Newton Co) AFIN: 51-00164, Permit No.: ARG590001*, on page 16 of Inspection Report #073447 referenced above.

[12] See 3October2013 letter from Jason Bolenbaugh to Jason Henson, *RE: Response to Compliance Inspection, AFIN: 51-00164, Permit No.: ARG590001*, on page 20 of Inspection Report #073447 referenced above.

[13] See 5May2014 letter *RE: Adequate Response Letter, AFIN 51-00164, NPDES Permit Tracking Number: ARG590001*.

[14] It should be noted that p. 2 of 15-17April2014 EPA Inspection Report noted "turf reinforcement mats had recently been installed on the inside of the two waste holding ponds". https://www.adeq.state.ar.us/downloads/WebDatabases/InspectionsOnline/078360-insp.pdf

[15] *Id.* to footnote #14. Although an erosion control blanket was later added, as noted in Table 1, this has not been a long term or a remotely successful solution.

[16] See January 2014 CAFO Inspection Report on page 8 of document. Note that although the inspection log was completed every day, ADEQ still noted deficiencies with the pond liner. https://www.adeq.state.ar.us/downloads/WebDatabases/InspectionsOnline/075752-insp.pdf.

[17] See page 2 of response from permittee, 20 September 2013 in letter titled *Re: Compliance Assistance Inspection (Newton Co.) AFIN: 51-00164, Permit No.: ARG590001*. Permittee notes that necessary maintenance was performed on the "minor erosion rills and desiccation cracks on Pond 2", but makes no mention of any actions to correct issues with pond liner substrate. https://www.adeq.state.ar.us/downloads/WebDatabases/InspectionsOnline/073447-insp.pdf

[18] See page 1 of response from permittee, 6February 2014 in letter titled *Re: Compliance Inspection/Complaint Investigation AFIN: 51-00164, Permit No: ARG590001*. https://www.adeq.state.ar.us/downloads/WebDatabases/InspectionsOnline/075752-insp.pdf

		pond liner.	
15-17April2014	078360	None noted	N/A
5November2014	081071	None noted, but site pictures show vegetation still has not established on inner pond banks[19].	N/A
30December2015	088608	None noted, but site pictures show very little vegetation has established on inner pond banks[20].	N/A

Really, just in general, Condition No. 26 makes no sense. **Please describe the study design and anticipated inferential statistics that will be used to determine this statistical significance**. The interceptor trenches were installed after the installation of the ponds, so there are no "Before" data that can be used for comparison purposes. Likewise, there is not a "Control" site that can be used to make comparisons of the liner integrity. So, one would not anticipate there would be a statistically significant change in the monitoring results given that the study was not designed to find one in the first place. Other no-discharge permits that propose to monitor for groundwater contamination require the additional monitoring of upgradient wells to use for comparison purposes[21]. There is actually no other scenario in which statistical significance could be determined, so this should certainly be added to the permit requirements. Functionally, the waste produced at this CAFO is just as harmful as industrial waste[22] and should be treated as such.

BCRET Data Indicate Water Quality Degradation Related to C&H Hog Farm Operations

BCRET data indicate that C & H Hog farms is having a negative impact on surface waters. By evaluating nitrate concentrations in Left Fork Big Creek (BC9, Control) compared to Big Creek (BC7, Impact), we see they are significantly greater at BC7 (Student's t-test, df = 37.1, t = -2.11, P = 0.042; **Figure 1**). The same trend holds true with total nitrogen (**Figure 2**). Because the watershed sizes, land-use land-cover (**Table 2**), and proximity to one another, these sites serve as pretty decent control and impact sites. Despite the higher proportion of pasture land in LFBC, we still see higher nitrate concentrations in Big Creek. The significance of this should not be lost on the reviewer, as one would expect to see the highest concentrations in LFBC based on percent pasture alone.

Condition No. 2 prohibits discharge from this facility, and if the facility anticipates any discharge then the facility must be covered under a NPDES permit. Here ADEQ is relying on the argument that just because this particular CAFO is not actually *proposing* to discharge that a

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[19] See pages 4-5 of 25November2014 Inspection Report. https://www.adeq.state.ar.us/downloads/WebDatabases/InspectionsOnline/081071-insp.pdf

[20] See page 4 of 30December2015 Inspection Report https://www.adeq.state.ar.us/downloads/WebDatabases/InspectionsOnline/088608-insp.pdf

[21] See Future Fuel Chemical Company, Permit No. 5278-W.

[22] Download the document available on https://www.epa.gov/npdes/animal-feeding-operations-afos

NPDES permit is not necessary. However, data indicate that the permitted facility, either through the holding ponds or through the application fields, *has* already violated the condition of this permit by discharging to waters of the state (Figure 1).

Since the purpose of Governor Beebe requesting $340,510 of tax payer funds was for the University of Arkansas to form the Big Creek Research and Extension Team (BCRET) to develop a study for “the use and benefit of ADEQ and to inform its ultimate performance of its regulatory functions”[23], these data cannot be dismissed. If the Department cannot assume that the current study design and methods will allow the Department to make a permitting decision based on definitive evidence of contamination, then the Department is obligated to take a weight of evidence approach to determine the potential for irrevocable harm. And although the state has not adopted numeric nutrient criteria for Arkansas, the recommended total nitrogen aggregate ecoregion criteria for this area is 0.31mg/L[24], which is well below the 0.41 mg/L mean TN concentration found on Big Creek.

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[23] See page 2 of Memorandum of Agreement between the Board of Trustees of the University of Arkansas System for and on behalf of the University of Arkansas System-Division of Agriculture and the Arkansas Department of Environmental Quality, signed September 2013. (Attachment: UofA and ADEQ_BCRET MOA)

[24] See Aggregate Ecoregion XI for Rivers and Streams. https://www.epa.gov/sites/production/files/2014-08/documents/criteria-nutrient-ecoregions-sumtable.pdf . For more information for how these criteria were developed, see https://www.epa.gov/nutrient-policy-data/ecoregional-criteria.

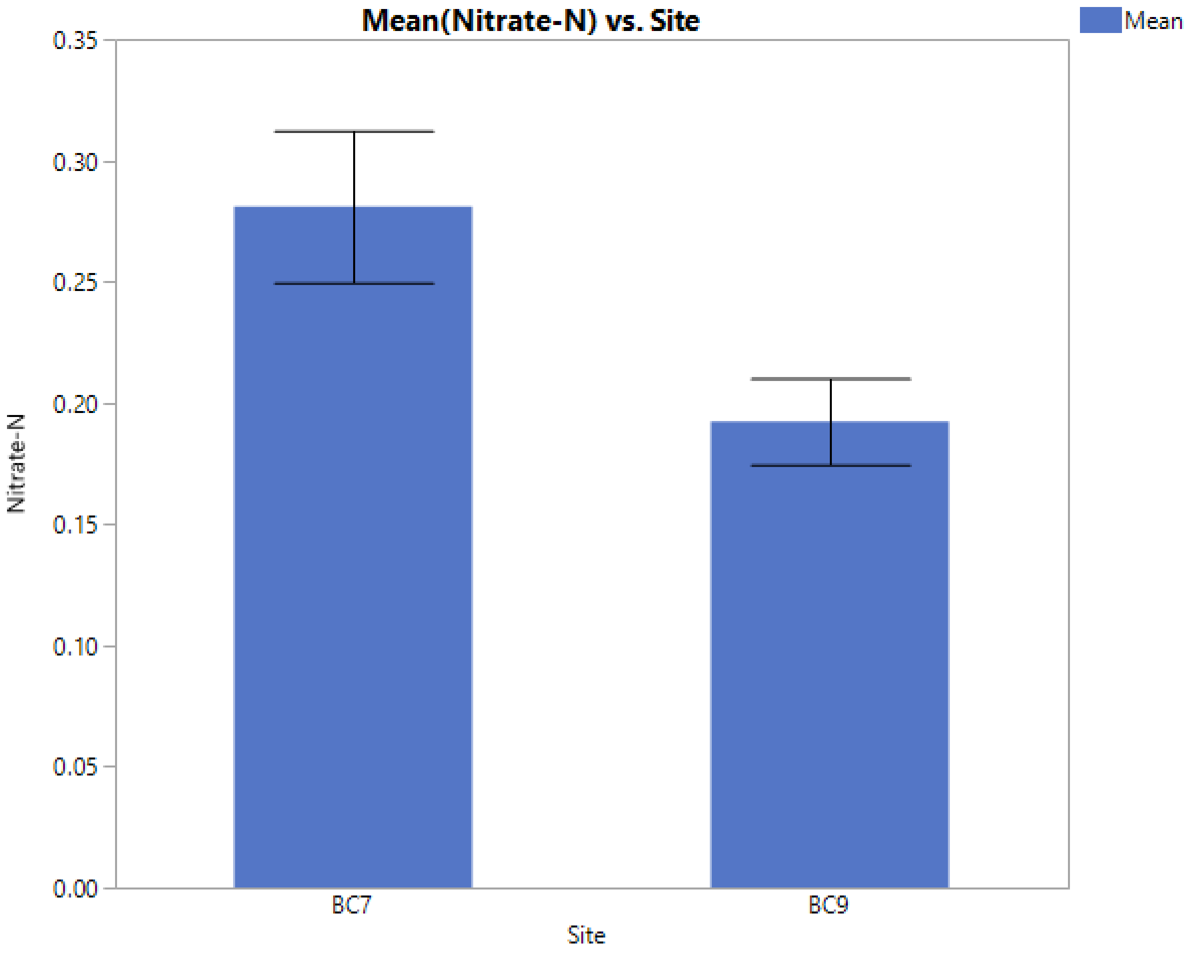

Figure 1. *Comparison of mean nitrate concentrations (mg/L) from BCRET sites BC7 (Big Creek downstream of hog farm) and BC9 (Left Fork Big Creek) with one standard error from the mean. Monthly mean nitrate concentrations were significantly greater at the Big Creek site downgradient of the large swine CAFO and waste application fields compared to the control site on Left Fork Big Creek (Student's t-test, df = 37.1, t = -2.11, P = 0.042)*[25].

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[25] Data obtained from Andrew Sharpley on 8March2017 via personal communication (see Attachment: BCRET_01-2017). Data were analyzed from 4May2015 to 5January2017, as these were the only dates data were available from Left Fork Big Creek. Because data were not normally distributed, values were Log_{10} transformed. Data plotted in graph are actual, non-transformed nitrate values. However, Zar claims that Student t-tests are robust enough to overcome most violations of assumptions – so really there is no need to transform data. Students t-test on non-transformed data are still significantly different, so that doesn't tell a different story (Student's t-test, df = 144.9, t = -3.84, P = 0.0002).

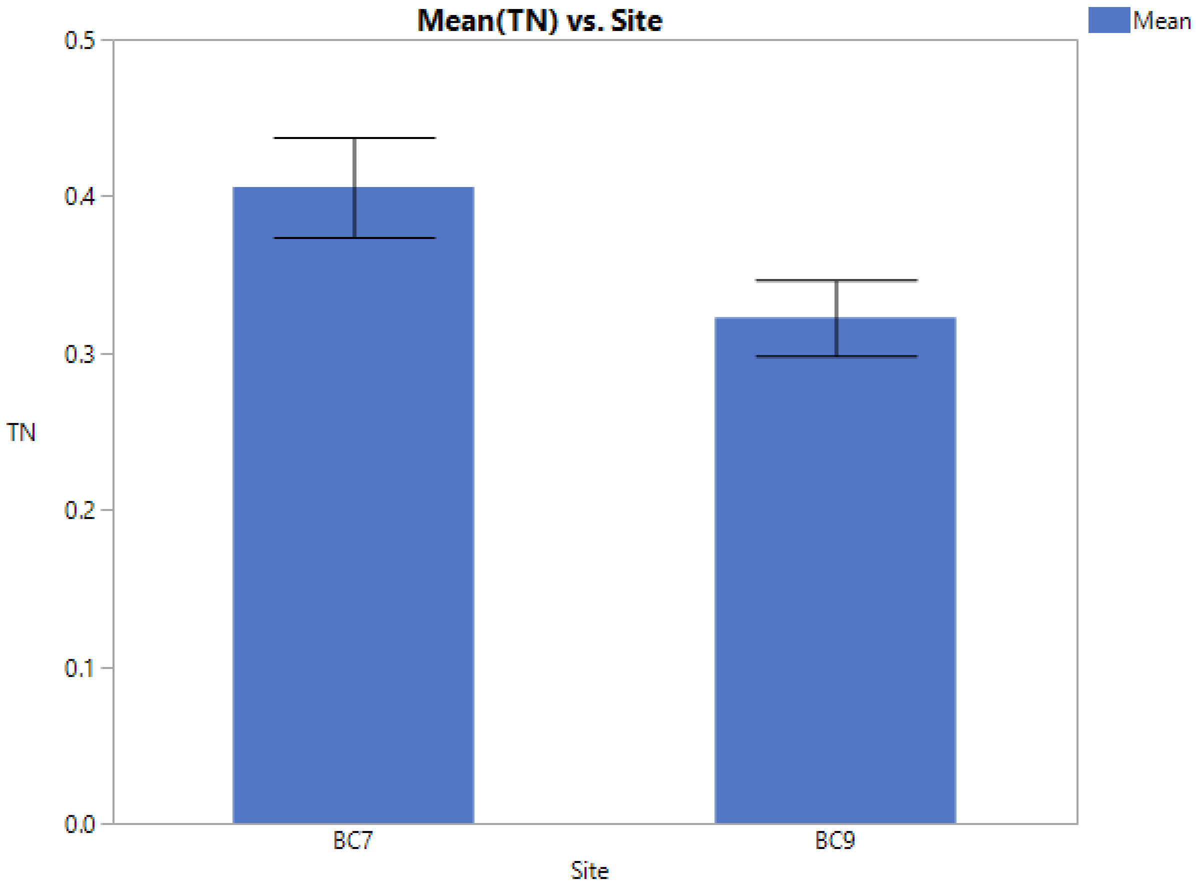

Figure 2. *Comparison of mean total nitrogen concentrations (mg/L) from BCRET sites BC7 (Big Creek downstream of hog farm) and BC9 (Left Fork Big Creek) with one standard error from the mean. Monthly mean total nitrogen concentrations were significantly greater at the Big Creek site downgradient of the large swine CAFO and waste application fields compared to the control site on Left Fork Big Creek (Student's t-test, df = 39.7, t = -2.07, P = 0.045)*[26].

Table 2*. Watershed area and land use land cover data*[27] *for BCRET sites at Big Creek (BC7) and Left Fork Big Creek (BC9).*

	BC7	**BC9**
Watershed Area (mi^2)	41.2	38.1
Urban (%)	3	3
Forest (%)	84	79
Pasture (%)	13	18

These data indicate that either a) current permitting requirements are not sufficient enough due to karst topography (more on this below) or b) the permittee is not following requirements set out in the permit and therefore is in violation and should not be issued a new permit. Because it is

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[26] *Id.*

[27] These data calculated from 2011 National Land Cover Database. https://www.mrlc.gov/nlcd2011.php

within ADEQ's right to deny a permit based on violations[28] and it should be their prerogative when considering how best to protect the Buffalo River.

Holding Ponds

Again, large cobble is still present in the existing clay liners of the holding ponds. Which is a violation of the existing permit as it stands[29]. Due to the poorly constructed clay liner and the apparent long term issues addressing erosion control on the inner sidewalls of the ponds, increased leakage is certain to be expected[30][31][32]. While it is the expectation that manure solids will clog subsurface pores beneath holding ponds, that's an assumption that is taken for granted and has proven to be false even under ideal construction circumstances[33].

Also, as I already explained how there would not actually be any way to detect a significant change in any kind of steady leak from the holding ponds. If the interceptor trenches are in fact properly placed, which it's karst, so I would agree that there should be a potential to catch *some* subsurface movement, but there is no reason to assume that this would be the case in the given setting, then they only have the potential to detect a catastrophic failure in the liner. But this is only a chance. Increased monitoring would have to be required if the Department expects to actually detect an impact, let alone a statistically significant one.

Sinkhole occurrence below the holding ponds should be expected. It's apparent that other states that understand the importance of taking karst into consideration in their permitting decisions acknowledge this. Missouri bans earthen liners in karst terranes with severe collapse potential[34]. Iowa also bans earthen liners in karst terrain for holding ponds other than for small CAFOs[35]. Minnesota has specific manure holding pond requirements for areas "susceptible to soil collapse or sinkhole formation" for karst areas where depth to bedrock is less than 50 feet, and does not allow earthen liners for CAFOs with more than 1000 animals if bedrock is less than 40 feet below liner[36][37]. That is because it is well understood and acknowledged that CAFOs can easily

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[28] Cite Arkansas code

[29] https://www.adeq.state.ar.us/downloads/WebDatabases/PermitsOnline/NPDES/PermitInformation/ARG590001_Additional%20Information%20Waste%20Management%20Plan_20120712.pdf

[30] Schulte, Dennis. 1998. Do Earthen Structures Leak? Manure Matters, Volume 4, Number 1. http://infohouse.p2ric.org/ref/16/15510.htm [accessed 20March2017]

[31] Benson, Craig, David Daniel, and Gordon Boutwell. 1999. Field Performance of Compacted Clay Liners. *Journal of Geotechnical and Geoenvironmental Engineering, 390-403.* https://chbenson.seas.virginia.edu/images/stories/pdfs/K/field%20performance.pdf

[32] Ham, J. M. Seepage Losses from Animal Waste Lagoons: *A Summary of a Four-Year Investigation in Kansas. Transactions of the American Society of Agricultural Engineers*, **45:** 983-992. http://www.agronomy.k-state.edu/documents/env-phys-group/ham2002--seepage-losses-from-animal-waste-lagoons.pdf

[33] See p 229-230 of Frank Spellman and Nancy Whiting. 2007. Environmental Management of Concentrated Animal Feeding Operations (CAFOs). Boca Raton, FL, CRC Press.

[34] Pfost, D.L., Fulhage, C.D., and Rastorfer, D., 2007, Anaerobic Lagoons for Storage/Treatment of Livestock Manure, Technical Report EQ 387, MU Extension, University of Missouri, Columbia, Mo., URL http://extension.missouri.edu/ explorepdf/envqual/eq0387.pdf, [accessed 18 March 2017].

[35] See p. 27 of Iowa Environmental Protection, Chapter 65, 65.9(5) https://www.legis.iowa.gov/docs/iac/chapter/11-23-2016.567.65.pdf [accessed 19March2017].

[36] Minnesota Pollution Control Agency. 2017. Locating Feedlots and Manure Storage Areas in Minnesota's Karst Region. https://www.pca.state.mn.us/sites/default/files/wq-f8-13.pdf [accessed 19March2017].

contaminate groundwater through runoff from land application of manure, leaching from manure that has been improperly spread on land, or through leaks from holding ponds[38][39]. Even if sinkhole formation doesn't occur, the holding ponds are undoubtedly currently leaking due to the insufficient integrity of the liner.

PVC liners are incapable of supporting liquid waste over a sinkhole and even plastic liners are susceptible to degradation due to environmental weathering[40]. The only way to provide a moderate safeguard for the very likely potential for contamination from the holding ponds would be to require that these are built to specification for hazardous waste lagoons (steel reinforced concrete) as required by USEPA Resource Conservation and Recovery Act. These requirements are similar to those that are required by Florida, New York, and Ohio for manure lagoons sited in karst terranes. This is because urine and manure can be rather acidic, which can result in the increased dissolution of underlying carbonate rocks. Even more unfortunate is this can lead to weakening of even concrete lined ponds[41]. Since it is standard practice that RCRA programs assume holding ponds and landfills assume leakage, regardless of double liners and leak detection and collection systems, it doesn't make any sense that this would not be the assumption in this case as well.

Abnormal rainfall events and water table declines are becoming more and more frequent in Arkansas. These issues are known to be the direct result of sinkhole development and are likely to exacerbate the increased potential that is likely to occur below these holding ponds given the karst terrain [42][43][44][45][46][47].
Because, again, this is literally our nation's first national river and if we don't require proactive and sustainable practices in this watershed then I don't really know where else they would be

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[37] Minnesota Pollution Control Agency. 2017. Liquid Manure Storage Areas: MPCA Guidelines for Design, Construction, and Operation of all Types of Liquid Manure Storage Areas. https://www.pca.state.mn.us/sites/default/files/wq-f8-04.pdf [accessed 19March2017].

[38] See p. 3 of Hribar, C., 2010, Understanding Concentrated Animal Feeding Operations and Their Impact on Communities, Technical Report, National Association of Local Boards of Health, Bowling Green, Ohio. https://www.cdc.gov/nceh/ehs/docs/understanding_cafos_nalboh.pdf [accessed 19March2017].

[39] Field, Malcom. 2011. DRAFT – CAFOs in Karst: How to Investigate Concentrated Animal Feeding Operations in Soluble Rock Terranes for Environmental Protection.

[40] http://www.ejnet.org/rachel/rhwn217.htm

[41] Ip, I., 2005, Sulphuric Acid Attack on Concrete Tanks: Waterloo Biofilter Systems Inc., The Science Corner, URL http://waterloo-biofilter.com/downloads/sulphuric-acid-attack-on-concrete-septic-tanks.pdf [accessed 19March2017]

[42] Zhao Haijun, Ma Fengshan, and Gao Jie, 2010, Regulatory and formation mechanism of large-scale abrupt large collapse in southern china in the first half of 2010: Natural Hazards, v. 60, no. 3, p. 1037–1054, doi:10.1007/s11069-011-9888-3.

[43] Youssef, A.M., Pradhan, B., Sabtan, A.A., and El-Harbi, H.M., 2012, Coupling of remote sensing data aided with field investigations for geological hazards assessment in jazan area, kingdom of saudi arabia: Environmental Earth Sciences, v. 65, no. 1, p. 119–130, doi:10.1007/s12665-011-1071-3.

[44] https://www.researchgate.net/profile/Jo_De_Waele/publication/264827203_A_review_on_natural_and_human-induced_geohazards_and_impacts_in_karst/links/5638f3f608ae4624b75ef7b9.pdf?origin=publication_list

[45] https://gq.pgi.gov.pl/article/download/7427/6077

[46] Hyatt, J.A., and Jacobs, P.M., 1996, Distribution and morphology of sinkholes triggered by flooding following tropical storm Alberto at Albany, Georgia, USA: Geomorphology, v. 17, no. 3–4, p. 305–316, doi:10.1016/0169-555X(96)00014-1.

[47] See Section 2.2 of https://www.pca.state.mn.us/sites/default/files/karst.pdf

more applicable. This is not an assault on landowner rights, and certainly not on farmers. This is just thinking about the big picture and long term consequences.

Insufficient Monitoring

First of all, for sufficient reason listed above, pH from holding ponds should be regularly monitored and reported. Preferably at different depth intervals to make sure there is an accurate depiction of the pH

If the Department believes that the 2015 Primary Contact season *E. coli* impairment on Big Creek, the 2015 dissolved oxygen impairment on Big Creek, and the significantly higher nitrate and nitrogen levels (**Figure 1** and **Figure 2**) are not sufficient enough to make a determination that **C & H Hog Farms is having a negative impact on water quality,** then it's obvious that using nutrients, *E. coli* and Fecal coliform as the only means for determining whether or not water quality impacts can definitively be attributed to this facility[48] is not sufficient enough for ADEQ to make a determination and they should require additional monitoring.

If the agency wanted to monitor parameters that they would not eventually end up disregarding or attributing to a number of other sources (e.g. feral hogs), they would also require monitoring of steroid hormones[49], antibiotics[50], or a number of the numerous carcinogenic pharmaceuticals that are commonly used at CAFO[51]s. As we all know, *E. coli* is a surrogate for measuring the potential for presence of other microbial pathogens. These pathogens that we should really be concerned about in swine manure are pathogens such as, *Salmonella* spp., *Campylobacter* spp., *Clostridium perfringens*, and *Cryptosporidium parvum*[52].

Pathogens can survive longer in groundwater than surface water because of the lower temperature and protection from the sun. Viruses can become attached to sediment particles and linger as a source of viral contamination to groundwater[53]. Unfortunately, long periods of survival in groundwater are somewhat irrelevant, as rapid transport of pathogens is extremely common in karst settings[54][55]. At the same time, long-term storage in karst terranes often occurs[56][57][58].

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[48] Big Creek Research and Extension Team data as a whole. Reports and water quality monitoring data can be found in quarterly reports at https://www.bigcreekresearch.org.

[49] Shan, Liu, Ying Guang-Guo, Zhou Li-Jun, Zhang Rui-Quan, Chen Zhi-Feng, and Lai Hua-Jie, 2012, Steroids in a typical swine farm and their release into the environment: Water Research, v. 46, p. 3754–3768, doi:10.1016/j.watres.2012.04. 006.

[50] Shore, L.S., and Pruden, A., 2009, Introduction, in Shore, L.S., and Pruden, A., eds., Hormones and Pharmaceuticals Generated by Concentrated Animal Feeding Operations: Emerging Topics in Ecotoxicology, Springer, p. 147.

[51] *Id.*

[52] Jenkins, M.B., 2009, Persistence and Transport of Pathogens from Animal Agriculture in Soil and Water, in Bowman, D.D., ed., Manure Pathogens: manure Management, Regulations, and Water Quality Protection: Alexandria, Va.,Water Environment Federation (WEF), p. 347–368. https://naldc.nal.usda.gov/download/34372/PDF [accessed 20March2017].
Jenkins,

[53] See p. 18-23 of USEPA, 2005, Detecting and Mitigating the Environmental Impact of Fecal Pathogens Originating from Confined Animal Feeding Operations: Review, Technical Report EPA/600/R-06/021, U.S. Environmental Protection Agency, Washington.

[54] See p. 34-35 of Worthingon, S. R. H., C. Smart, and W. Ruland, 2001 Karst Hydrogeological Investigations at Walkerton. http://www.worthingtongroundwater.com/Walkerton%20Exhibit%20416%20text.pdf [accessed 19March2017].

More issues attributable to karst

As part of a larger effort to map the threats to Arkansas' species of greatest conservation need, The Nature Conservancy of Arkansas modified the EPA DRASTIC index[59] to more accurately reflect the vulnerability of (relative attenuation capacity of geologic material between the land surface and saturated zone) groundwater in karst terrain, termed DRASTIK[60].

I spatially referenced overlays of land application maps provided in the permit application in order to create geographic shapefiles of the existing and proposed land application sites in ArcGIS 9.3 (**Figure 3**). Overlaying the land application sites on the DRASTIK map, the most comprehensive and groundwater vulnerability index specifically calibrated to the karst regions in Arkansas, it is apparent that these locations offer little soil attenuation and land application of waste poses a high risk to groundwater resources (**Figure 4** and **Figure 5**). Using these data to assess risk in sensitive karst terrains, such as the Big Creek watershed, provides a more comprehensive and accurate method of ascertaining potential for negative water quality impacts than simply relying on Web Soil Survey data to assess risk.

Rapid response of the groundwater level is an indicator that karst conditions facilitate rapid flow of precipitation into the ground[61]. This also indicates the importance of relying on dye trace studies to identify sampling locations of where nutrients transported through subsurface channels will eventually emerge, as was suggested by the BCRET expert review team[62] and also ignored[63]. This information also helps emphasize the importance of calculating realistic nutrient loss to surface and groundwater sources through land application and manure storage rather than relying on edge of field and nearby surface water monitoring alone[64].

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[55] **See Attachment: Brahana et al 2016_geochemical processes big creek**

[56] Even, H.I., Magaritz, M., and Gerson, R., 1986, Timing the transport of water through the upper vadose zone in a karstic system above a cave in Israel: Earth Surface Processes and Landforms, v. 11, no. 2, p. 181–191, doi:10.1002/esp. 3290110208.

[57] Chapman, J.B., Ingraham, N.L., and Hess, J.W., 1992, Isotopic investigation of infiltration and unsaturated zone flow processes at Carlsbad Cavern, New Mexico: Journal of Hydrology, v. 133, no. 3–4, p. 343–363, doi:10.1016/0022-1694(92) 90262-T.

[58] Kaufman, A., Bar-Matthews, M., Ayalon, A., and Carmi, I., 2003, The vadose flow above Soreq Cave, Israel: a tritium study of the cave waters: Journal of Hydrology, v. 273, no. 1–4, p. 155–163, doi:10.1016/S0022-1694(02)00394-3.

[59] https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryID=35474

[60] See Attachment: TNC DRASTIK

[61] Murdoch, J., C. Bitting, J. V. Brahana. 2016. Characterization of the karst hydrogeology of the Boone Formation in Big Creek Valley near Mt. Judea, Arkansas – documenting the close relation of groundwater and surface water. Environ Earth Sci 75:1160. **See Attachment: Murdoch et al 2016.**

[62] https://bigcreekresearch.org/project_reports/docs/Review%20Panel%20Report%20-%20May%2019%202014.pdf

[63] https://bigcreekresearch.org/project_reports/docs/Response%20to%20Expert%20Review.pdf

[64] **See Attachment: Sharpley et al 2003.**

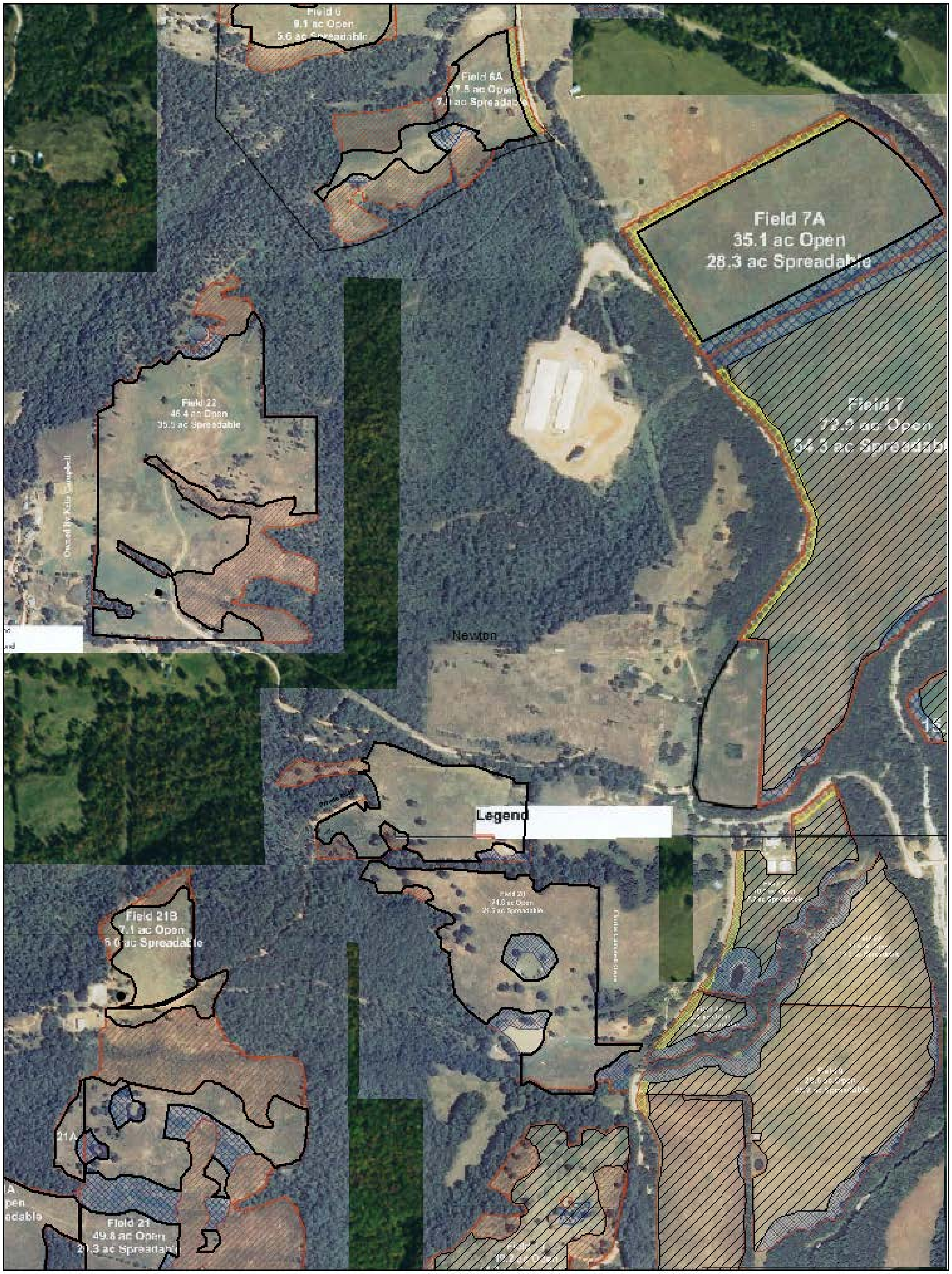

Figure 3. *Visual representation of how shapefiles were created of land application areas (excludes buffers) for C&H Hog Farm.*

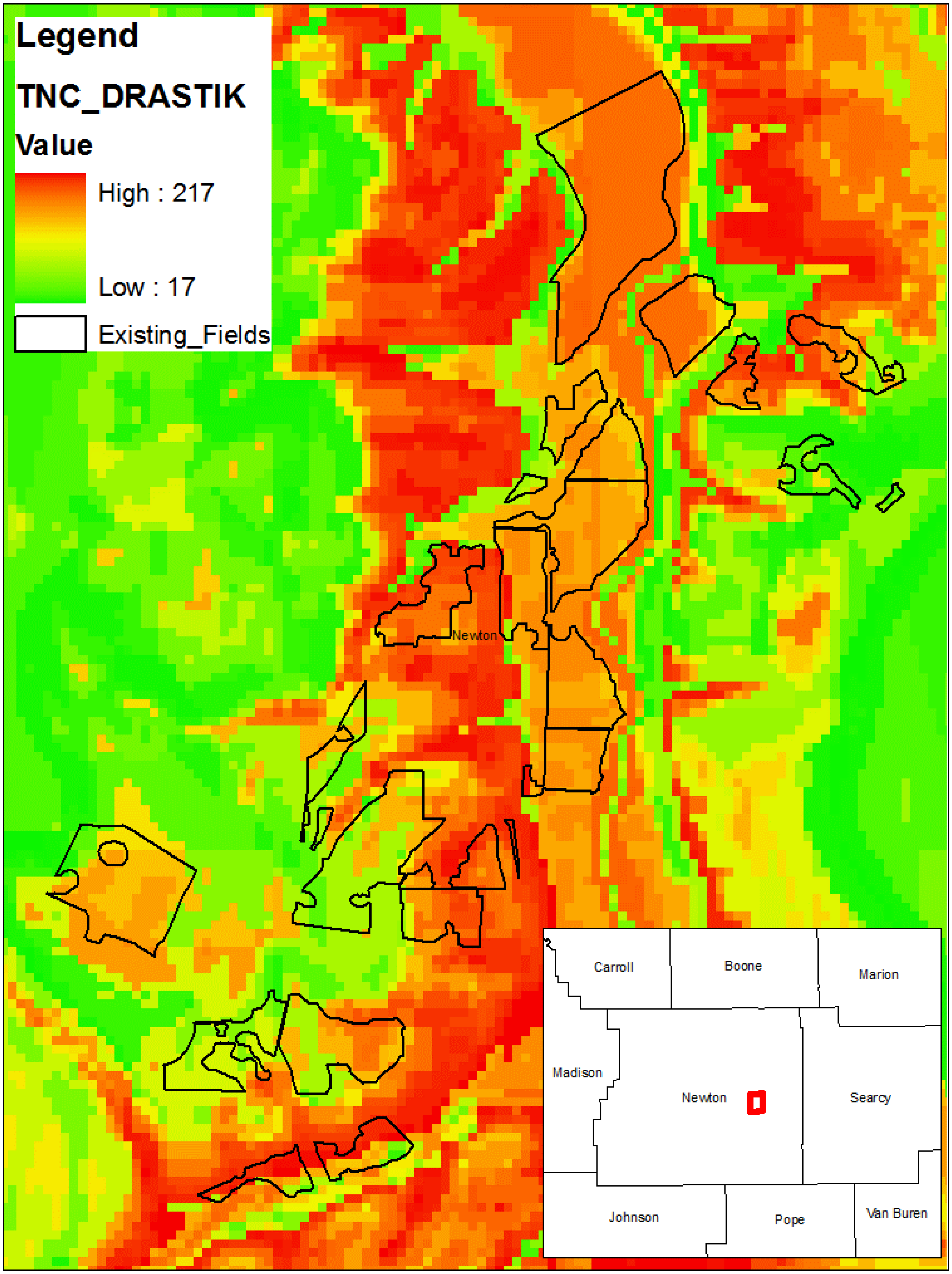

Figure 4. *Existing land application fields overlaying DRASTIK groundwater vulnerability map.*

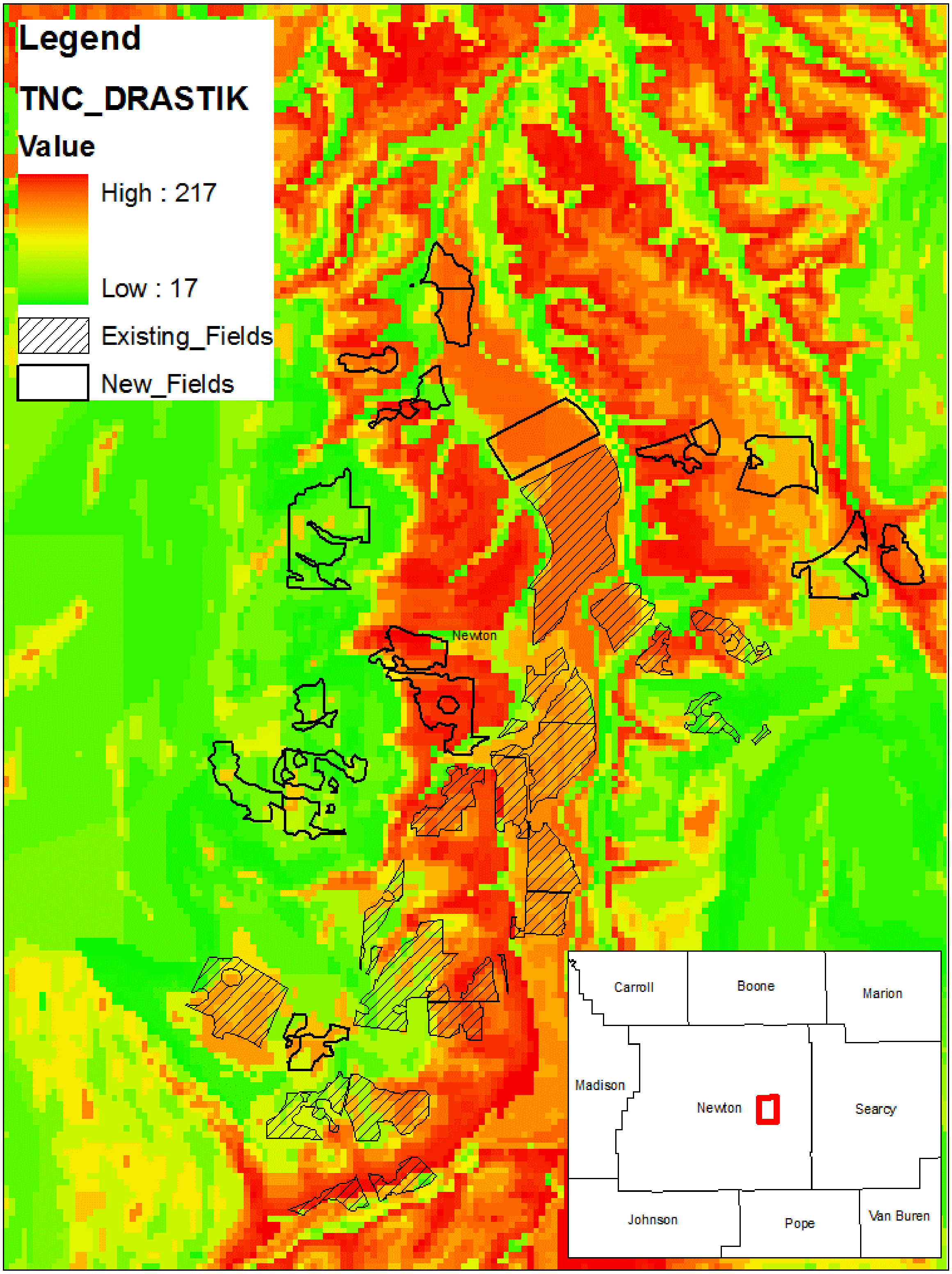

Figure 5. *New and existing land application fields overlaying DRASTIK groundwater vulnerability map.*

Miscellaneous comments regarding public health risks

Physical health risks such as toxic or inflammatory respiratory effects have been found to be significantly higher in close proximity to a large swine CAFO compared to rural residents living near minimal livestock production[65]. This should be of upmost consideration given the proximity to Mt. Judea School.

Pollutants expected to be found in swine waste poses a huge risk to human health considering X percentage of Newton county relies on groundwater as a drinking water source[66]. In addition, the thousands of people that recreate on the Buffalo National River each year are at a huge risk of falling suspect to ailments from pathogens transported through the subsurface or through surface runoff.

Suggestions for Basis of Permit Denial

This permit should not be issued on the basis that the permitted activity *does* endanger human health *and* the environment[67].

The director has the authority to deny a permit based on a history of noncompliance[68]. See above arguments for basis of noncompliance.

"A person with a history of noncompliance with the environmental laws or regulations of this state or any other jurisdiction is affiliated with the applicant to the extent of being capable of significantly influencing the practices or operations of the applicant that could have an impact upon the environment. "[69] The integrator, JBS, has been accused multiple times of violating rainforest deforestation laws[70][71].

In reference to placement of the holding ponds and land application fields within karst topography, Ark Code 8-4-217(a)(2) states "it shall be unlawful for any person to place or cause to be placed any sewage, industrial waste, or other wastes in a location where it is likely to cause pollution of any waters of this state".

The director shall not issue a permit under this chapter if the discharge or any term of the permit would violate the provisions of any federal law or rule or regulation promulgated thereunder, including the duration of such permit[72].

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[65] Thu, K., K. Donham, R. Ziegenhorn, S. Reynolds, P.S. Thorne, P. Subramanian, P. Whitten, and J. Stookesberry. 1997. A Control Study of the Physical and Mental Health of Residents Living Near a Large-scale Swine Operation. Journal of Agricultural Safety and Health, **3**: 13-26. http://www.sraproject.org/wp-content/uploads/2007/12/acontrolstudyofthephysicalandmentalhealth.pdf

[66] See Figure 7 on page 37 of https://pubs.usgs.gov/sir/2014/5149/pdf/sir2014-5149.pdf

[67] See page 1 of Part III of permit 5264-W which states that a determination of this may result in the termination of this permit.

[68] Ark. Code 8-1-106(b)(3)

[69] Ark Code 8-1-106(c)(3)

[70] Blankfeld, Keren. 2011. *JBS, World's largest beef producer, responds to lawsuit.* 20April2011. https://www.forbes.com/sites/kerenblankfeld/2011/04/20/jbs-worlds-largest-beef-producer-responds-to-lawsuit/#388a897641d3

[71] Boadle, Anthony. 2017. *Brazil's JBS accused of violating Amazon rainforest protection laws.* Reuters, 2April2017. http://www.reuters.com/article/us-brazil-environment-cattle-idUSKBN1722O1

[72] Ark Code 8-4-207(2)

Various Questions

Please provide an explanation for why ADEQ is not adhering to the definition of an ERW in this permitting decision.

Since ADEQ has no formal antidegradation implementation plan in place, **please describe the process the Department is using to insure protections of Tier III waters and determine when degrading high quality waters is necessary.**

Please describe how the ADEQ interprets the results of the 1994 CAFO study, the basis for determination that the 1992 CAFO moratorium is no longer in effect, and how a determination of a facility of this size meets the intent of the Basin-Wide Initiative of the Buffalo River Watershed and Moratorium[73].

Regardless of whether or not ADEQ acknowledged that data supported Big Creek was impaired for *E. coli* and dissolved oxygen during the 2016 305(b) integrated reporting cycle[74], these data and information should still be factored into the permitted decision when it comes to a facility likely to contribute to these impairments. This should especially be the case when it comes to sensitive waterbodies. Since the Department did not provide a justification as to why the 2016 Assessment Methodology and prior impairment decisions were not used as the basis for concluding there was not an impairment on Big Creek, then there is no reason to believe that EPA will not choose to list Big Creek as impaired when they approve the 2016 303(d) list. **Please provide an explanation as to why it should be believed EPA will conclude that Big Creek is impaired** and **an explanation of how a determination that Big Creek is impaired will impact this permitting decision**. [75][76]

Sustainability of the Buffalo River Watershed

As is pointed out in the 2011 Comprehensive Regulatory Review of CAFOs under the CWA,[77] we would be doing a great disservice to our first national river to do anything other than acknowledge the truth of the matter:

> *As is clear from its divisive history, the federal regulation of CAFO- produced pollutants under the Clean Water Act has been, and continues to be, complex. Yet, the basic principle behind their regulation remains the same: CAFOs are categorized as point sources under the Clean Water Act; as such, they must obtain a valid NPDES permit to discharge any pollutants into waters of the United States, except in accordance with the agricultural stormwater exemption. To interpret that principle any other way would not only contravene the plain*

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[73] See Attachment: 1992 CAFO Moratorium.

[74] 303(d) and 305(b) integrated report. https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/integrated-report.pdf

[75] https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/comments/teresa-turk.pdf

[76] https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/comments/carol-biting.pdf

[77] See page 325, Connor, Hannah. 2011. Comprehensive Regulatory Review: Concentrated Animal Feeding Operations under the Clean Water Act from 1972 to the Present. *Vermont Journal of Environmental Law.* **12**: 275-326. http://vjel.vermontlaw.edu/files/2013/06/Comprehensive-Regulatory-Review-Concentrated-Animal-Feeding-Operations-Under-the-Clean-Water-Act-from-1972-to-the-Present.pdf

> *language of the Act, but it would also jeopardize the Act's goal of "restor[ing] and maintain[ing] the chemical, physical, and biological integrity of the Nation's waters" by eliminating the discharge of pollutants from point sources into those waters.*

As the design plans allow for, and as the scientific community acknowledges, large CAFOs discharge waste. Simply refusing to acknowledge something doesn't mean it's not actually occurring. And I don't actually believe the Department has a defensible enough case to *prove* that reasonably expected discharge is not occurring. Estimates of holding pond leakage and loss of nutrients during runoff events could be calculated and would more accurately reflect current conditions. Estimating runoff through surface water monitoring is extremely complicated in karst topography without a comprehensive understanding of where and how water is transported from land surface to surface and groundwater sources. Assumptions of lamellar flow off of fields and into surface waters do not hold up in karst terrain. This is a huge problem when relying on surface water monitoring alone to inform the likelihood of pollution transport.

Although ADEQ ignores the "and its watershed" portion of the Extraordinary Resource Water definition due to difficulty in making management decisions in that regard, permitting of this large hog factory still undoubtedly ensures the degradation of Big Creek and the Buffalo River. By permitting a facility that is absolutely not sustainable in this watershed, ADEQ is thereby limiting the amount of sustainable farms that could potentially operate in the watershed. The necessity to continue adding land application fields will only persist in order to accommodate the waste generated from this one facility that only employs less than 10 individuals. Future options will either lead to transporting the waste out of the watershed entirely, which will result in burdensome costs to the permittee and pose a serious risk to the environment should a likely accident happen, OR will result in the conversion of more forest land to pasture. Permitting a facility that encourages the additional conversion of land to pasture should at least benefit more individuals than a measly few. In the event that ADEQ had an Antidegradation Implementation Plan in place and required an Analysis of Alternatives, I think it would be obvious that there are better options for both the permittee, the Buffalo National River, *and* Arkansas' tourism industry.

By permitting a facility that is estimated to generate 1,897,635 gallons of waste annually[78] with only 13,004,000 gallons that can be received by the currently proposed land application sites[79], the life expectancy of this facility to remain "sustainable" would be less than 7 years.

However, simply finding additional pasture land to spread waste on within this geographic area simply won't solve the issues of the Arkansas Phosphorous Index not being appropriate for the geologic area. By relying on a method that allows the application of nutrients in excess of agronomic needs, the excess nutrients will either build up in the soil or be transported to surface and groundwater through overland and subsurface flow. Obviously phosphorous buildup in the

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[78] See Condition No. 10 on page 3 of the Statement of Basis for Permit No. 5264-W.
[79] See Condition No. 11 on page 3 of the Statement of Basis for Permit No. 5264-W.

soil has its own set of issues, but when we are talking about protecting the Buffalo National River which will ultimately be the sink for excess nutrients that are not up taken by terrestrial crops, it really is necessary to evaluate the risk to sensitive receiving streams. And it has been well accepted that measuring surface water nutrient concentrations is not as environmentally protective as measuring nutrient loads when trying to manage an entire watershed or groundwater basin[80], hence the necessity for calculating loads when developing a Total Maximum Daily Load to manage point and nonpoint sources of pollution.

Also, relying on physicochemical measures of water quality alone to measure changes in stream ecosystems ignores nutrient cycles and disregards basic aquatic ecology principles of trophic interactions. Reactive nitrogen and phosphorous in the water column aren't the endpoints of concern when one is trying to protect water quality. Uptake of nutrients by plants such as algae (generally the most common form of submerged vegetation) and emergent vegetation such as water willow can have a significant impact on aesthetics and recreational quality of a waterbody, by stimulating plant growth. Aquatic life beneficial uses are impacted by the change in food web dynamics that result from increasing plant productivity (the result of increased nutrients), but they are also impacted by the oxygen depletion that results in response to increased photosynthesis and decomposition in the waterbody.

The whole premise of regulating large scale productions versus small scale productions, whether it be through construction stormwater permits administered based on size of area disturbed or through NPDES or no discharge permits for CAFOs based on the number of animals at a facility, this is to limit infringement on individual landowner rights while insuring large corporations and industries do not disproportionately impact shared resources. This concept is also the very basis for antidegradation implementation policies and the necessary consideration for weighing social and economic impacts against environmental impacts. While some might take the majority of the comments focusing on the importance of preserving the scenic beauty of the Buffalo National River as simply appeals to emotion, drawing such conclusions fails to connect the dots between the purpose of actively managing watersheds through regulatory avenues and tools water quality administrators have been given to protect our Outstanding Natural Resource waters. There is generally no textbook approach to managing natural environments. Adaptive management and best professional judgement are *always* going to be necessary when protecting our resources. The Arkansas Department of Environmental Quality, as well as every other management agency, realizes this. That is why it is built in to virtually every single piece of law, regulation, and policy administered by the Department there is always some clause that allows discretion by the Director. Now is the time to use that discretion. Sustainability has majorly differing definitions depending on the context. Think of dams. We all recognize that dams may be a sustainable source of energy, but dams prevent a sustainable fishery. I have no doubt that the state of the art facility currently in operation at C&H Hog Farms is sustainable in the context of recycling water, feed, and air, or whatever it may be – but it is not environmentally sustainable if your goal is to protect the Buffalo River. You have to weigh the risks in every decision. We cannot protect the recreational sustainability of our first national river, which was designated for it's recreation

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[80] http://cemonterey.ucanr.edu/files/171000.pdf

potential and scenic beauty, by permitting facilities that don't even provide enough social or economic benefit to outweigh the negative environmental effects. Not only due to the tourist dollars that are brought into the state by the beauty of the Buffalo River, but also the number of jobs that rely on the Buffalo River remaining a favored destination, it's imperative that we understand what we are managing this watershed for. We designate beneficial uses to our waterbodies in order to define our management goals and actions to achieve those goals. While I have no doubt denying this permit for a facility that is already in operation, but never should have been permitted in the first place, will not be without it's pushback; it must be acknowledged that we have already set our management goals for the Buffalo River watershed. We are to protect it for its "scenic beauty, aesthetics, scientific values, broad scope recreation potential and intangible social values". Please, use your regulatory discretion to uphold the values that have been set by the Buffalo River region, and state as a whole, and deny this permit.

Thank you for this opportunity to comment on this permit.

Jessie J Green

Jessie J. Green
White River WATERKEEPER®

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.

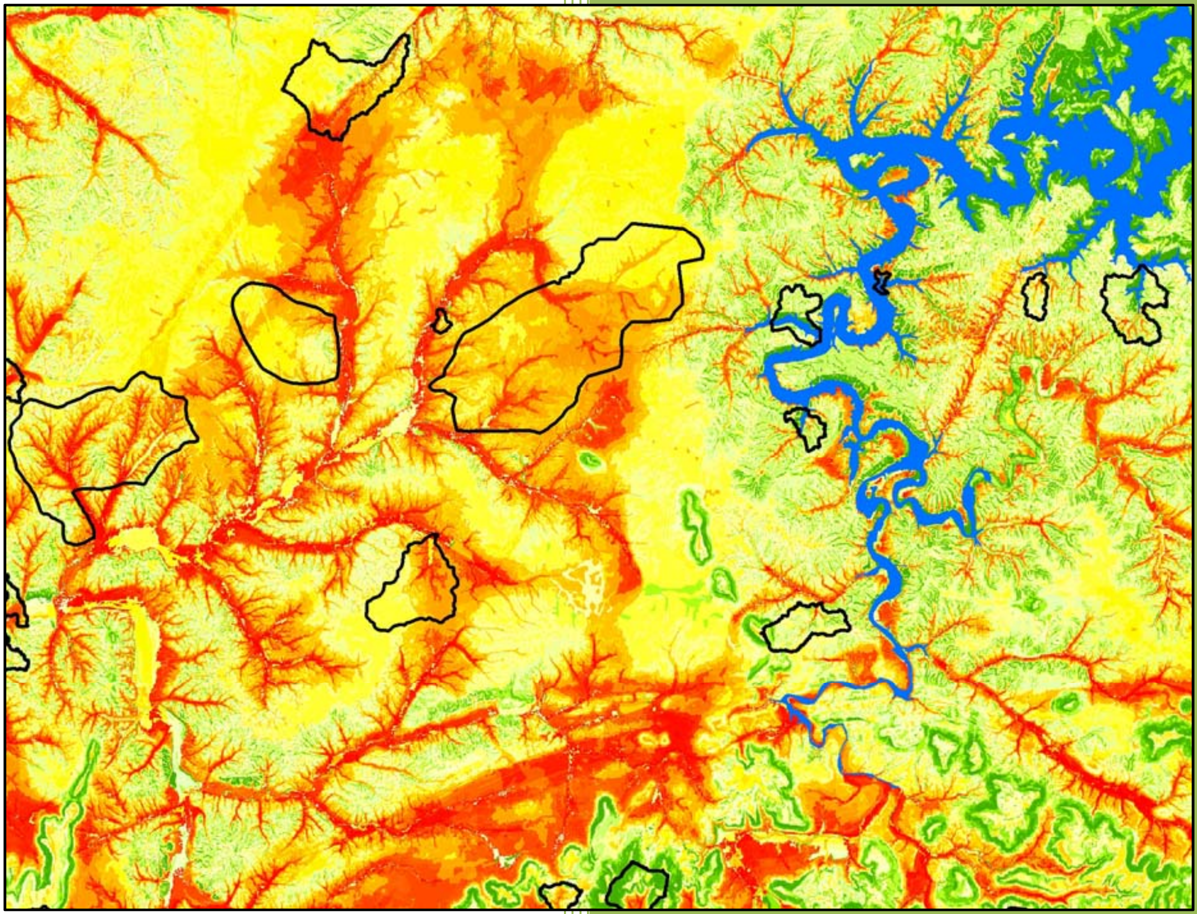
6. The Department does not consider this Administrative Notice a final agency action subject to appeal or other adjudicatory review. However, any person adversely affected by subsequent actions by the Department in pursuance of the policy announced herein (e,g., through denial of a permit or initiation 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

Mapping the Distribution, Habitat, and Threats for Arkansas' Species of Greatest Conservation Need



Final report for
Arkansas State Wildlife Grant
Agreement Number T20-9

Ethan Inlander, Cory Gallipeau,
and Michael Slay
The Nature Conservancy

3/31/2011

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MAPPING THE DISTRIBUTION, HABITAT, AND THREATS FOR ARKANSAS' SPECIES OF GREATEST CONSERVATION CONCERN

Final Report, submitted by

Ethan Inlander, Cory Gallipeau, and Michael Slay
Ozark Highlands Office, The Nature Conservancy
38 West Trenton Blvd., Suite 201, Fayetteville, Arkasas 72701

March 31, 2001

INTRODUCTION

Karst species are important components of species conservation planning efforts in the Arkansas State Wildlife Action Plan (AWAP). Karst is a terrain, generally underlain by limestone or dolomite, in which the topography is chiefly formed by the dissolving of rock, and which may be characterized by sinkholes, losing streams, closed depressions, subterranean drainage, and caves (USEPA 1999). Often, species living in karst habitats are uniquely adapted to rigorous environmental conditions that occur there. Because light is absent and food is limited, many species exhibit morphological, physiological, and behavioral characteristics that make them well suited for existence in subterranean habitats. These organisms are often among the rarest and most unique species inhabiting karst regions.

To effectively protect karst species and the groundwater resources they use, accurate maps of species locations and threats are needed. Species inventories are sparse and are often held in disparate databases and collections. Existing range maps yield vast gaps in expected distributions. Exhaustive inventory projects of the 3000 caves in Arkansas would be costly and time consuming. A predictive approach for mapping karst species may provide a more cost-effective way to plan for their conservation in the future.

The species-habitat affinity (or wildlife habitat relationship) approach for predicting species distributions is a widely accepted tool for terrestrial and aquatic species conservation planning. This approach relies on accurate habitat maps and species occurrence maps. Habitat affinities for each species of concern are identified through literature review and expert knowledge, as well as map analyses comparing habitat types to species occurrences. With species-habitat affinities identified, predicted species distribution maps can be generated. These maps are critical to conservation planning efforts, and they are used in programs such as GAP and CWCS.

Very little research has been developed to predict the distribution of karst species. Such an approach could yield great advances in our understanding of karst species and our abilities to conserve them over time. The purpose of this project was to generate the base-level maps, species biological data, and associate threats needed for a future attempt at predicting distributions for karst species in Arkansas.

Objectives

- To generate updated species range maps for each of the 36 Arkansas SGCN karst species occurring in the Ozark and Boston Mountains Ecorgions. These species maps will be derived from TNC's karst database, which integrates a variety of data sources beyond those of the Arkansas Natural Heritage database.
- To assess the current status of threats to each of these 36 species.
- To produce a conservation implementation priorities list based on the species distribution maps and threats.
- To create the first Ozark Karst Habitat Map, a critical step toward future predictive mapping efforts for karst species.
- To Identify species-habitat affinities by comparing the species ranges to the karst habitat map.

METHODS

Study Area

The study area for this project was limited to the portion of the state considered part of the Ozarks Ecoregion (Figure 1). This portion included sections of the Boston Mountains and the Ozark Plateau as designated by EPA Level 3 ecoregional mapping effort.

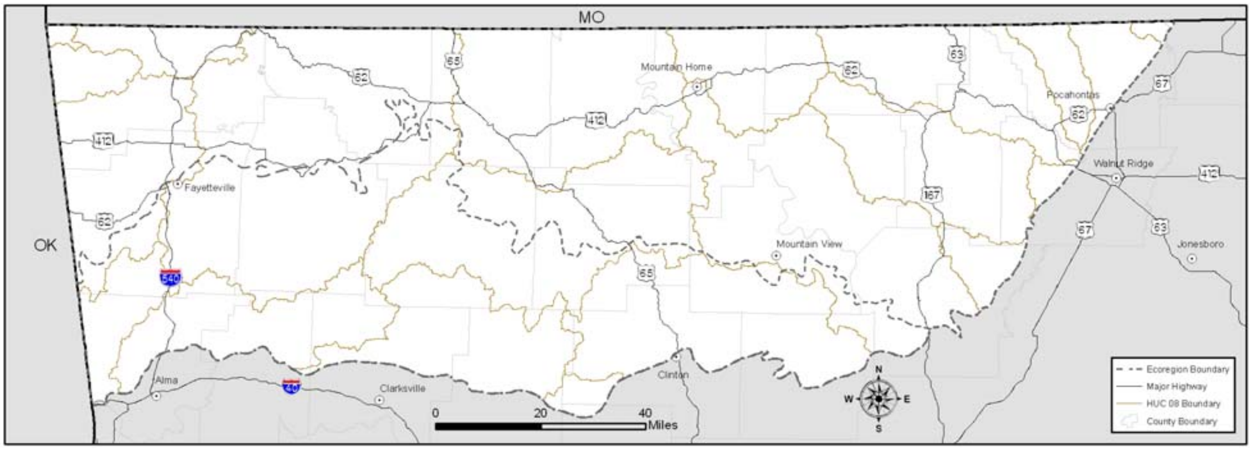

Figure 1. The study area for this project included all Arkansas lands within the Ozarks Ecoregion boundary and includes the Boston Mountains and the Ozarks Plateau.

Biological Information

Database Structure and Updates

TNC uses Microsoft Access database structure to characterize descriptions and locations of karst species. The TNC karst database includes occurrence information for 36 AWAP karst species (**Error! Reference source not found.**), as well as many other groundwater and karst-dependent species occurring throughout Arkansas and the entire Ozarks ecoregion. Species information is continually updated with the latest species and location information collected through inventory efforts by TNC and its partners.

Table 1. Karst species included in the Arkansas Wildlife Action Plan. Priority score is the priority ranking score assigned to each species during the formulation of the AWAP. Methodology for assigning priority scores can be found the AWAP.

Community Group	Class	Common Name	Scientific Name	Priority Score
Terrestrial	Invertebrate-Other	cave obligate pseudoscorpion	Apochthonius diabolus	65
	Invertebrate-Other	cave obligate pseudoscorpion	Apochthonius titanicus	65
	Invertebrate-Other	cave obligate harvestman	Crosbyella distincta	65
	Invertebrate-Other	cave obligate harvestman	Crosbyella roeweri	65
	Invertebrate-Other	pseudoscorpion	Hesperochernes occidentalis	23
	Invertebrate-Other	springtail	Pseudosinella dubia	50
	Invertebrate-Other	Shelled Cave Springtail	Pseudosinella testa	42
	Invertebrate-Other	springtail	Pygmarrhopalites clarus	25
	Insect	ground beetle	Rhadine ozarkensis	80
	Invertebrate-Other	cave obligate millipede	Trigenotyla parca	65
	Invertebrate-Other	cave obligate springtail	Typhlogastrura fousheensis	65
Bat	Mammal	Ozark Big-eared Bat	Corynorhinus townsendii ingens	80
	Mammal	Gray Bat	Myotis grisescens	23
	Mammal	Eastern Small-Footed Bat	Myotis leibii	34
	Mammal	Indiana Bat	Myotis sodalis	46
Aquatic	Invertebrate-Other	Hubricht's Long-tailed Amphipod	Allocrangonyx hubrichti	42
	Fish	Ozark Cavefish	Amblyopsis rosae	34
	Invertebrate-Other	Foushee Cavesnail	Amnicola cora	65
	Invertebrate-Other	amphipod	Bactrurus pseudomucronatus	42
	Invertebrate-Other	isopod	Caecidotea ancyla	30
	Invertebrate-Other	isopod	Caecidotea dimorpha	42
	Invertebrate-Other	bat cave isopod	Caecidotea macropropoda	57
	Invertebrate-Other	isopod	Caecidotea oculata	42
	Invertebrate-Other	isopod	Caecidotea salemensis	8
	Invertebrate-Other	cave obligate isopod	Caecidotea simulator	42
	Invertebrate-Other	isopod	Caecidotea steevesi	30
	Invertebrate-Other	isopod	Caecidotea stiladactyla	30
	Crayfish	crayfish	Cambarus aculabrum	80
	Crayfish	Bristly Cave Crayfish	Cambarus setosus	27
	Crayfish	Hell Creek Crayfish	Cambarus zophonastes	80
	Invertebrate-Other	cave obligate planarian	Dendrocoelopsis americana	42
	Amphibian	Grotto Salamander	Eurycea spelaea	19
	Invertebrate-Other	isopod	Lirceus bicuspidatus	27
	Invertebrate-Other	isopod	Lirceus bidentatus	80
	Invertebrate-Other	Ozark Cave Amphipod	Stygobromus ozarkensis	27
	Fish	Southern Cavefish	Typhlichthys subterraneus	27

For the purposes of this project, the 36 AWAP karst species were split into three biological community groups (**Error! Reference source not found.**). Those groups included the terrestrial, bat, and aquatic communities. Terrestrial species use in-cave terrestrial habitats. Bat species use caves and crevices for hibernation, raising their young and other life functions. Bats also forage beyond these karst features. Aquatic species primarily or solely use the aquatic habitats of caves, springs, and seeps. The grotto salamander (*Eurycea spelaea*) was placed in the aquatic community group though it uses both terrestrial and aquatic karst habitats

A master GIS layer was developed that represented all sites where the 36 AWAP karst species are known to occur based on the above database information. ESRI ArcGIS 9.3.1 software was used to create, update, and maintain the layer. The occurrence sites in this layer included cave entrances, springs, seeps, crevices, sinkholes etc. Sites were represented as points in the GIS, and the layer had a total of 297 sites. Most sites had a precise known location, which was represented at a Universal Transverse Mercator (UTM) easting (X-coordinate) and northing (Y-coordinate) in the North American Datum of 1983 (NAD1983). These coordinates were generally determined using GPS, or comparison to other known features in the GIS, such as streams, roads, or topographic features. Some sites in the database, especially historic references, were only described as occurring within a PLSS section (about 1 square mile). In those cases, the point representing the site was digitized at the centroid (geometric center) of the section. Thirty of the 297 sites were represented based on a section centroid, and three were based on a county centroid.

Species Range Maps

Individual Species

To provide updated information to the AWAP document, TNC produced species range maps for 33 of the 36 AWAP karst species. The range maps reflect the species range within Arkansas, but does not reflect the entire range of that species if it also occurs outside of Arkansas. Most species range maps were produced in late 2008, and reflect database information at that time.

For each terrestrial and aquatic species, occurrence sites were assigned to the 12-digit HUC sub-watersheds (HUC-12) that they occur within. For these species, the range map is a cartographic representation of the HUC-12. Two aquatic species, *Caecadotea salemensis* and *Lirceus bicuspidatus*, had no occurrence information in the database, so HUC-12 based range maps were not produced for these species. However, point-based maps are included for these two species, and these maps are based on point estimates derived from site descriptions available from the relevant literature. Although these maps are included to assist with visually interpreting the possible species ranges, information on these two species was not included in the resulting threat analyses.

For the AWAP bat species, specific site locations were buffered in the GIS with a five mile radius to generalize the species locations for the range maps. This yielded circular assessment areas to symbolize bat locations. *Myotis leibii* had no occurrence information in the database, so no range map was produced for this species. Additional maps were produced to show the total number of bat species in each five-mile area and the total bat AWAP priority score for these areas.

Summary Maps

Additional maps were produced to show the total number of terrestrial, aquatic and combined species in each HUC-12. Maps were also produced to show the total AWAP priority score for these community groups per HUC-12. Similar maps were produced for bats also.

Threat Assessment

GIS-based threat models were designed and implemented for each of the three biological community groups. These models were developed to assess and compare the relative level of threat from human land uses and activities at each species occurrence site, and also to determine the relative threat to each species across its range in Arkansas.

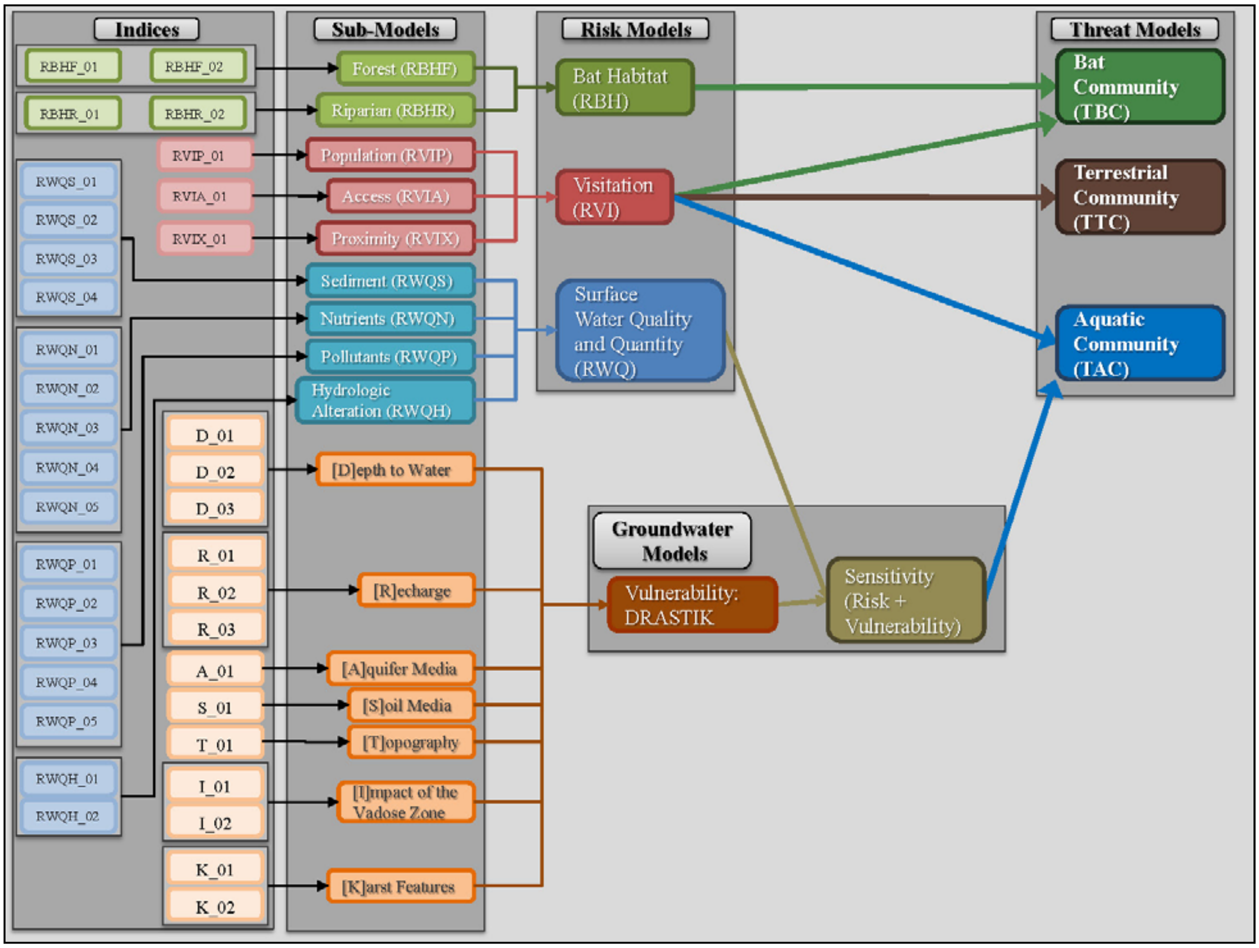

Figure 2. Generalized schematic of three community threat models.

The threat models varied in content and complexity with each biological community group. The threat model for the terrestrial group was the simplest of all the community threat models, only accounting for the risk of disturbance at the site by human visitation (Risk:

Visitation, or RVI). The threat model for the bat community accounted for the risk of visitation (RVI) , as well as the riparian and upland forest habitat characteristics near the site (Risk: Bat Habitat, or RBH). The threat model for the aquatic community was the most complex of the threat models. It accounted for site visitation (RVI), but also accounted for groundwater sensitivity. Groundwater sensitivity had two sub-models: The risk to water quality and quantity (RWQ), and the groundwater vulnerability, which describes the ability of the landscape and subsurface to filter and attenuate the factors assessed in RWQ. Figure 2 is a generalized schematic of the criteria for each threat model.

Terrestrial Community Group

The threat model for the terrestrial community group assumed that the primary threat to terrestrial karst species is from human visitation to the sites where the species occurs. Impacts from human visitation can include trampling, collection of animals, disturbance, destruction of habitat, vandalism, introduction of pollutants, and others. A GIS model was developed using available GIS data to measure the relative risk of visitation (RVI) across sites.

Sites and Assessment Areas

All site points with known occurrences of terrestrial species were selected as a subset from the master occurrences GIS layer and were designated as the terrestrial site layer. A total of 22 sites were included for this analysis. Of these sites, 8 points were generated based on PLSS centroids. For each site point, a GIS assessment area (AA) for calculating RVI indices was defined as a circular area with a 10-mile radius from the site. This visitation assessment area (VAA) was intended to describe the human activities and likelihood of visitation in proximity to the site.

Risk Model: Visitation (RVI)

As described earlier and shown in Figure 2, the terrestrial community threat model was based solely on the visitation risk model (RVI). The RVI model was developed with the assumption that the likelihood that a particular site will be visited is dependent on the proximate human population, the available access to the site, and the proximity of the site to a road. Therefore, RVI was comprised of three sub-models: population (RVIP), access (RVIA), and proximity (RVIX), as shown in Figure 3 below. Figure 3 also shows the indices that comprise each of these sub-models.

Visitation Sub-Model: Population (RVIP)

An index is the result of a specific GIS analysis. For example, the visitation sub-model for population (RVIP) is comprised of a single index called RVIP_01. RVIP_01 is based on a count of the total human population in the VAA for each site.

Data from the 2000 US Census were used to calculate RVIP_01. A "raw" index value was first calculated for each site which represented the human population count of the census blocks that occurred within the VAA. The raw values ranged from 585 people for a cave in rural Pope County to 135,654 people for a cave in urban Washington County that included the entire cities of Fayetteville and Springdale within the VAA. Raw index values are referred to in GIS layers and tables accompanying this document with a "_R" as a suffix. The raw index in this example is RVIP_01_R.

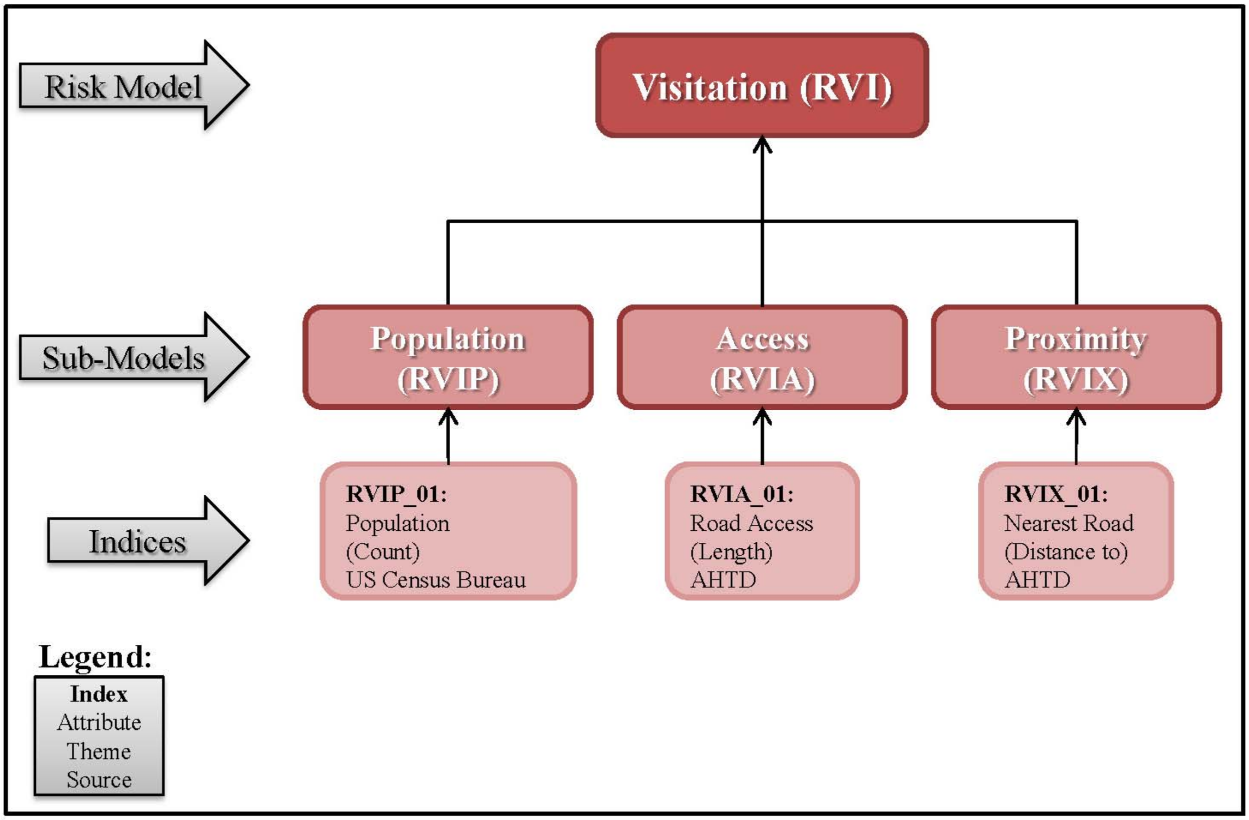

Figure 3. Visitation risk model schematic.

In the above example, and for all threat models, raw index values were re-scaled and normalized to have a maximum value of 1.0 and a minimum possible value of 0. Regardless of what attribute the index was measuring, the site with a final rescaled value of 1.0 indicated the best ecological condition for that index.

The process for rescaling an index included dividing the raw index value at each site by the highest raw value at any site. In the example above the result of this first rescaling calculation would give the Washington county site a 1.0 since it was the site with the highest raw value. The values for this index were inverted so the site with the lowest human population within the VAA would be assigned a 1.0. Final scaled index values are referred to in GIS layers and tables accompanying this document with a "_S" as a suffix. The scaled index in this example is RVIP_01_S. For more specific information about the modeling process and data sources for this and all other indices, see Appendix A.

Visitation Sub-Model: Access (RVIA)

The second sub-model comprising the Visitation risk model was developed to assess the likelihood of visitation based on the access (RVIA) that the proximate road network provides.

RVIA was comprised of a single index, RVIA_01, which summarized the amount of roads within the VAA. See Appendix A for more information about this index.

Visitation Sub-Model: Proximity (RVIX)

The third sub-model comprising the visitation risk model was developed to assess the likelihood of visitation based on the proximity (RVIX) of the site to a road. The logic of the index is that the closer a site is to a road, the more likely it would be disturbed. RVIX was comprised of a single index, RVIX_01, which indicated the distance of the site to the nearest road. The assessment area was the site itself. This index was not calculated for sites that were located based on centroids. See Appendix A for more information about this index.

Calculation of the Visitation Risk Model

Because the sub-models for the RVI risk model were each only comprised of a single index, the sub-model scores were the same as the index that they included. The raw RVI score was simply the summation of the RVIP, RVIA, and RVIX sub-models. The raw sum RVI_R was then rescaled from 0 to 1 to determine the final RVI_S score.

Calculation of the Terrestrial Community Threat Model

Because it is comprised solely of the RVI risk model, the terrestrial community threat model scores were calculated directly from the RVI_S score.

Bat Community Group

Bats use caves, crevices, and other karst sites as habitat. Visitation and disturbance by humans to these sites is a primary threat to multiple bat species. Bats also use forest and riparian lands near these sites to forage for food. As shown in Figure 2, the bat community threat model is based on both the visitation risk model (RVI) described above as well as the bat habitat risk model (RBH), which characterizes the condition of these foraging habitats.

Sites and Assessment Areas

All site points with known occurrences of bat species were selected as a subset from the master occurrences GIS layer and were saved separately as the bat site layer. A total of 152 sites were included for this analysis. For each site point, a GIS assessment area for calculating RVI indices was defined as a circular area with a 10-mile radius from the site (VAA), as described above for terrestrial sites. A bat foraging habitat assessment area (BAA) was also generated for assessing the indices of the RBH model. The BAA was defined as an area within a 5-mile radius to each point in the bat site layer.

Risk Model: Visitation (RVI)

The visitation risk model for bats was calculated using the same methodology as was used for terrestrial sites, described above. It was applied to the bat site layer.

Risk Model: Bat Habitat (RBH)

The bat habitat risk model (RBH) is shown in Figure 4. It was comprised of two sub-models: Forest (RBHF) and Riparian (RBHR).

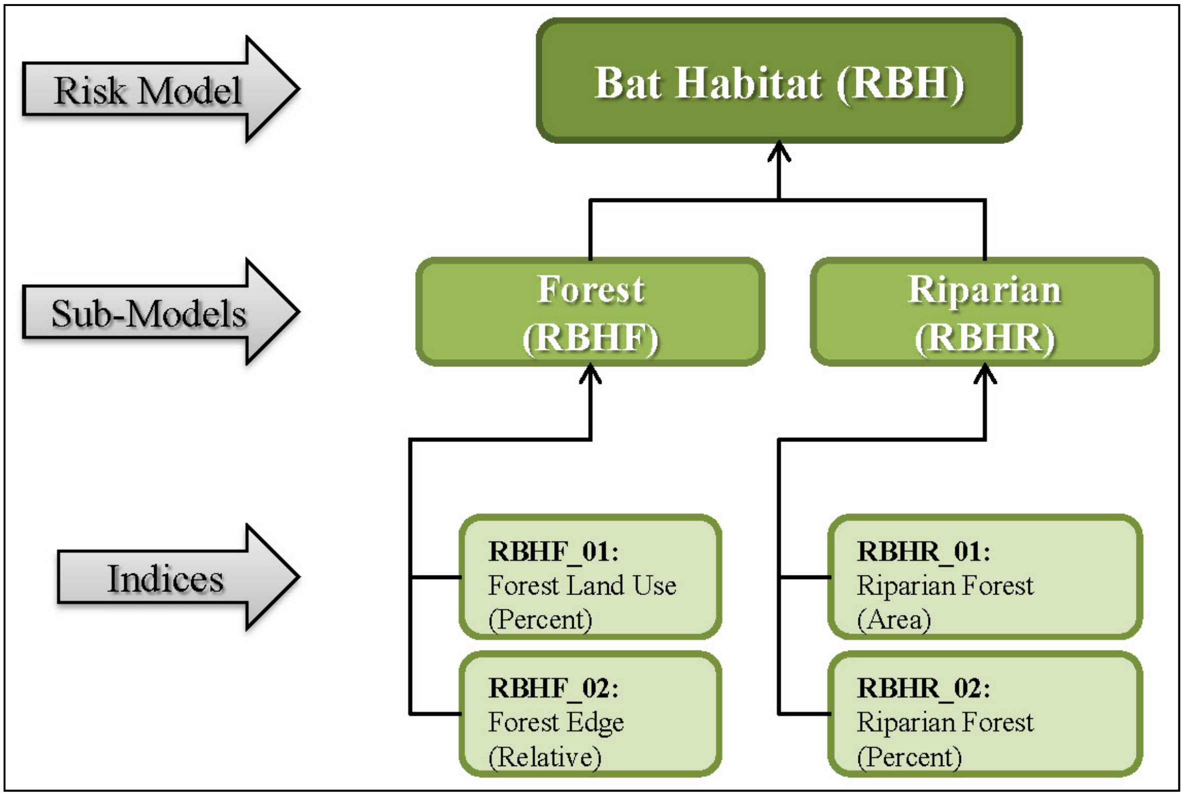

Figure 4. Bat habitat risk model schematic.

Bat Habitat Sub-Model: Forest (RBHF)

RBHF consisted of two indices. RBHF_01 described the percent of the BAA that was in forested land use. In the model, it is assumed that a greater amount of forest is preferable for bats. RBHF_02 described the relative amount of forest edge in the BAA. In the model, it is assumed that a greater amount of forest edge is preferable for bats. See Appendix A for more information about these indices.

After RBHF_01 and RBHF_02 were initially calculated, their raw scores were scaled from a value of 0 to 1. These two scaled indices were summed to generate the raw RBHF score (RBHF_R), which was then also rescaled from 0 to 1 in the sub-model score RBHF_S.

Bat Habitat Sub-Model: Riparian (RBHR)

Riparian forest is an important habitat for some bat species. RBHR accounted for the amount and condition of the riparian area within the BAA. The riparian area was defined as areas adjacent to water bodies, and was mapped in a raster GIS environment. Cells mapped as water in the CAST summer 2006 land use / land cover layer were first selected. This captured water features including lakes, ponds, and larger streams and rivers. Streams mapped in the USGS high resolution National Hydrologic Dataset (NHD) were also rasterized. All analysis was run with a 30m raster cell size. The water cells from the LULC and NHD datasets were then buffered by an additional 30m cell. The results of this analysis yielded the riparian area for this project. The stream riparian area was as wide as three 30m cells because the stream was represented with one cell, and had another cell on each side. Lake and pond shorelines were once cell.

The indices for RBHR were calculated solely based on data falling within the riparian area described above. RBHR_01 described the total area of forested land use within the riparian area. RBHR_02 described the percent of the riparian area that was forested as opposed to other land use classes. See Appendix A for more information about these indices.

After RBHR_01 and RBHR_02 were initially calculated, their raw scores were scaled from a value of 0 to 1. These two scaled indices were summed to generate the raw RBHR score (RBHR_R), which was then also rescaled from 0 to 1 in the sub-model score RBHR_S.

Calculation of the Bat Habitat Risk Model

The raw RHB score was simply the summation of the scaled RBHF and RBHR sub-model scores. The raw sum RBH_R was then rescaled from 0 to 1 to determine the final RBH_S score.

Calculation of the Bat Community Threat Model

The bat community threat model score was a summation of the RBH risk model and the RVI risk model, as shown in Figure 2. Again, the two scaled values for RHB and RVI were summed, then rescaled from 0 to 1 to form the bat community threat model.

Aquatic Community Group

The threat assessment for the aquatic community group was the most complex of all three taxa groups. Similar to terrestrial and bat species, visitation to aquatic sites by humans was assumed to be a significant risk component of threat to aquatic species. However, because aquatic species are immersed in aquatic habitats for a portion or all of their life cycle, the water quality and quantity in these habitats is also a significant risk component. A water quality and quantity risk model (RWQ) was developed to characterize potential impacts from sediment, nutrients, pollutants, and hydrologic alteration, each of which was described with separate sub-models. Each of the sub-models was comprised of a variety of unique indices (Figure 5), which address different measures of risk.

Risks to water quality and quantity are generated at the surface, but karst aquatic species primarily occur in subsurface habitats or spring runs that emerge from subsurface aquifers. Pollutants that enter surface waters are not delivered to subsurface aquifers uniformly.

Groundwater *vulnerability* describes the relative attenuation capacity of geologic materials between the land surface and saturated zone. Groundwater vulnerability mapping can be used as a guide in assessing which areas are more susceptible to groundwater contamination within a broader mapped area. Groundwater vulnerability mapping involves the simplification of complex geologic and hydrogeologic situations. For this effort, a groundwater vulnerability model was developed to characterize the attenuation of risks.

Groundwater *sensitivity* combines both the relative risk from surface human impact characteristics and the vulnerability that can attenuate the movement of risk factors through the subsurface to groundwater and subsurface habitats. For this effort, a groundwater sensitivity model was developed to determine how the risks are offset or augmented by vulnerability to ultimately impact the karst aquatic community.

Figure 2 shows all factors used to model threats to aquatic sites, including risk of visitation, risk to surface water quality and quantity, groundwater vulnerability, and groundwater sensitivity.

Sites and Assessment Areas

All site points with known occurrences of aquatic species were selected as a subset from the master occurrences GIS layer and were saved separately as the aquatic site layer. A total of 171 sites were included for this analysis. Twenty-one of the 171 sites were represented based on a section centroid, and three were based on a county centroid. Analysis was not completed for centroid based sites. For each site point, a GIS assessment area for calculating RVI indices was defined as a circular area with a 10-mile radius from the site (VAA), as described above for terrestrial sites.

For each site point, a recharge assessment area (RAA) had to be delineated that estimated groundwater recharge for calculating risk, vulnerability, and sensitivity measures. For some sites, especially those harboring federal threatened or endangered species, dye traced recharge areas had already been determined through previous studies. A dye traced recharge area can be thought of as a watershed of a cave or an underground watershed. A dye traced recharge area is the best information that exists to delineate a subsurface drainage area and involves field work performing dye injection tests into sinking streams and identifying where the dye outflow exists from surrounding caves and springs. A total of 10 sites had dye traced recharge areas delineated previously, which were used as RAAs.

For sites without dye traced recharge areas, a topographic estimate of recharge area (TERA) was determined by selecting one or multiple contiguous USGS NHD Plus catchments that were likely to capture surface flow upstream of the site. This was determined by TNC karst and GIS staff. While it is acknowledged that using surface watersheds (NHD Plus catchments) wasn't entirely reflective of the underground hydrological regime, it was determined to be the best available data to define RAAs for non-dye traced sites with aquatic species for this project.

Risk Model: Visitation

The visitation risk model for the aquatic community group was calculated using the same methodology as was used for terrestrial sites, described above. It was applied to the aquatic site layer.

Risk Model: Surface Water Quality and Quantity (RWQ)

The surface water quality and quantity risk model (RWQ) is shown in Figure 5, below. It was comprised of four sub-models: Sediment (RWQS), Nutrients (RWQN), Pollutants (RWQP) and Hydrologic Alteration (RWQH). Readily available GIS layers were queried to estimate risks within each RAA. Figure 5 also shows the indices that comprise the RWQ sub-models.

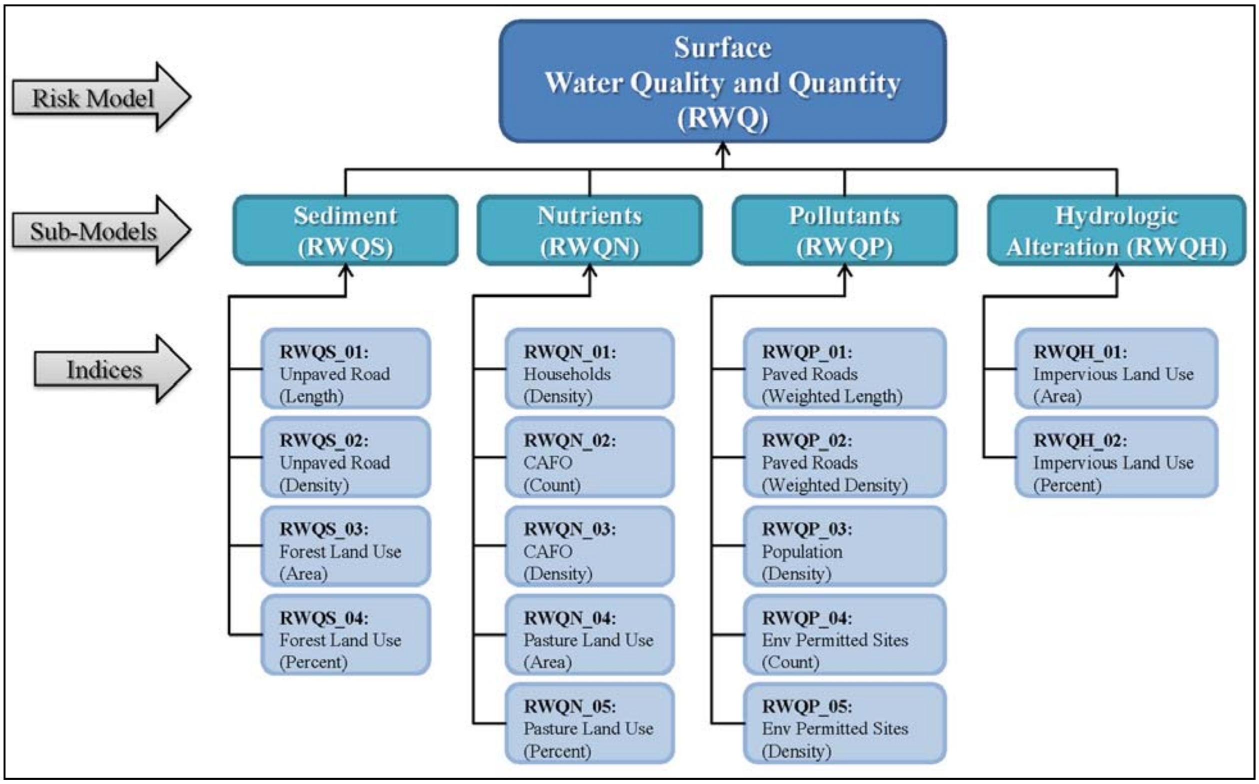

Figure 5. Surface water quality and quantity risk model schematic.

Surface Water Sub-Model: Sediment (RWQS)

Sediment is a primary impairment in Ozark streams. Unpaved roads and non-forest land uses are common sources of sediment. The sediment sub-model accounts for sediment sources from unpaved roads and non-forested land-use types. RWQS_01 accounts for the total length of unpaved roads within the RAA. RWQS_02 accounts for the density of roads within the RAA. With the variation in the size of RAAs, it was important to account for both the total length of roads, and road density. RWQS_03 accounts for the total area of forested land-use (and therefore non-forested land use). See Appendix A for more information about these indices.

After all RWQS indices were initially calculated, their raw scores were scaled from a value of 0 to 1. These scaled indices were summed to generate the raw RWQS score (RWQS_R), which was then also rescaled from 0 to 1 in the sub-model score RWQS_S.

Surface Water Sub-Model: Nutrients (RWQN)

The Nutrients sub-model accounts for nutrient sources from rural septic systems, confined animal feed operations, and pasture land use. RWQN_01 counts the density of rural households in the RAA based on US Census data. The index assumes that a household outside of city limits will us a decentralized septic system. RWQN_02 and RWQN_03 characterize the count and density of CAFOs in the RAA. Though much nutrient material that is produced at CAFOs is transported and spread elsewhere, the index assumes that some nutrients produced at CAFOs will get into groundwater. RWQN_04 and RWQN_05 quantify the total area and percent of the RAA in pasture land use. It is assumed that some pastures will have cattle present, which will be a source of nutrients. It is also assumed that pastures that do not have cattle are likely to be fertilized for grass production, also a nutrient source. See Appendix A for more information about these indices.

After all RWQN indices were initially calculated, their raw scores were scaled from a value of 0 to 1. These scaled indices were summed to generate the raw RWQN score (RWQN_R), which was then also rescaled from 0 to 1 in the sub-model score RWQN_S.

Surface Water Sub-Model: Pollutants (RWQP)

The Pollutants sub-model accounts for additional pollutant sources associated with paved roads and highways, residential density, and facilities that have permitted discharges. RWQP_01 and RWQP_02 measure total paved road length and density, respectively. Paved roads, including highways, are a potential source for pollution for a few reasons. First, the risk of a chemical or fuel tanker spill is higher on these transportation corridors. Second, regular discharge and leaking of fuel and oil from vehicles is expected to be greater on paved roads. Roads and highways were weighted to account for greater surface area and traffic volume on highways. The weighting scheme is shown in Appendix A. RWQP_03 measures human population density, which is expected to account for some non-point pollution sources. RWQP_04 and RWQP_05 count the number and density of pollution point sources permitted by ADEQ. See Appendix A for more information about these indices.

After all RWQP indices were initially calculated, their raw scores were scaled from a value of 0 to 1. These scaled indices were summed to generate the raw RWQP score (RWQP_R), which was then also rescaled from 0 to 1 in the sub-model score RWQP_S.

Surface Water Sub-Model: Hydrologic Alteration (RWQH)

The Hydrologic Alteration sub-model was intended to account for the impact of impervious surfaces on water quality, groundwater infiltration, and altered storm hydrograph. RWQH_01 and RWQH_02 account for total area and percent of the RAA with impervious surfaces. Impervious surfaces were mapped using urban and bare land uses, and paved roads. See Appendix A for more information about these indices.

After all RWQH indices were initially calculated, their raw scores were scaled from a value of 0 to 1. These scaled indices were summed to generate the raw RWQH score (RWQH_R), which was then also rescaled from 0 to 1 in the sub-model score RWQH_S.

Calculation of the Water Quality and Quantity (RWQ)

The raw RWQ score was simply the summation of the scaled RWQS, RWQN, RWQP and RWQH sub-model scores. The raw sum RWQ_R was then rescaled from 0 to 1 to determine the final RWQ_S score.

Groundwater Vulnerability Model: DRASTIK

Groundwater Vulnerability Model Selection

Groundwater vulnerability mapping can be used as a guide in assessing which areas are more susceptible to groundwater contamination within a broader mapped area. Groundwater vulnerability mapping involves the simplification of complex geologic and hydrogeologic situations and the attenuation capacity of the geologic materials between the land surface and saturated zone. Vulnerability maps are designed only as a guide and for relative comparisons and are not intended to replace specific site evaluations.

Several models exist for evaluating the vulnerability of groundwater, the models fall into one of two categories, “any aquifer” or “karst specific” models. The “any aquifer” models include DRASTIC, GOD, AVI, and SINTACS and have been mainly applied in porous aquifers. The “karst specific” models include EPIK, PI, and COP and were developed for the assessment of vulnerability in karst areas. Deciding which model to use depends on factors such as the type of aquifer, data availability, cost, and time. While EPIK, PI, and COP will all do a better job at mapping karst aquifers, the data needed to run these models includes spatial data on sinkholes, sinking streams, and other karst features.

In areas with low data availability, the DRASTIC method is a suitable model and methodology according to Foster and Hirata (1988). This method is relatively inexpensive and straightforward which makes it a popular approach in groundwater vulnerability mapping. According to Margane (2003), the model uses data that are commonly available or can be estimated to produce vulnerability maps that can be easily interpreted. A USGS publication also concurs by stating that “the index method is a popular approach to ground-water vulnerability assessments because it is relatively inexpensive, straightforward, and uses data that are commonly available or estimated, and produces an end product that is easily interpreted and incorporated into the decision-making process” (USGS 2002).

For this project, most karst spatial data were unavailable and prevented the utilization of one of these karst specific models. Therefore, DRASTIC was selected to assess groundwater vulnerability in the Ozarks in Arkansas with slight modifications from its original design to better represent the landscape setting.

DRASTIC Model Background

The DRASTIC model was developed by the U.S. Environmental Protection Agency (US EPA) and is the most widely used index-based method for mapping groundwater vulnerability in porous aquifers. DRASTIC is a composite mapping technique designed to produce scores for different geographic locations and is an acronym for the seven hydrogeological factors considered in the method:

- D Depth to Water Table
- R (Net) Recharge
- A Aquifer Media
- S Soil Media
- T Topography (Slope)
- I Impact of Vadose Zone Media
- C Conductivity (Hydraulic) of Aquifer

Within each parameter, a rating is given between 1 and 10, with 10 being the highest degree of pollution vulnerability and 1 being the lowest degree of pollution vulnerability. The USGS states “the point rating system for DRASTIC was determined by the best professional judgment of the original method developers.” (USGS 2002)

A weight is also given to each rating relative to each other in order of importance from 1 through 5, the most significant factors have weights of 5; the least significant a weight of 1. These weights are allocated based on a parameter’s contribution to the overall susceptibility of an area. Ratings for individual parameters were proposed in the DRASTIC EPA manual (Aller et al. 1987).

The DRASTIC Index (groundwater vulnerability) at any one location on the map is determined by the equation:

Vulnerability = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw
where r = rating and w = weight

In order to properly represent and overlay the multiple parameters within the DRASTIC methodology from a spatial context, a Geographic Information System (GIS) is generally used. The computed DRASTIC index identifies areas which are likely to be susceptible to groundwater contamination relative to one another. Similar hydrogeologic parameters produce similar vulnerability indices. The higher the DRASTIC index the greater the vulnerability to groundwater pollution. It must be remembered that the DRASTIC technique provides a relative evaluation tool and is not designed to provide absolute answers.

DRASTIC Model Modifications

Many modifications of the original DRASTIC model have been proposed by numerous authors in various locales throughout the world according to localized characteristics and data availability. Some of these modifications include adjusting the individual weights to emphasize or de-emphasize certain parameters, adding or removing parameters, or some combination of these procedures.

Piscopo (2001) used DRASTIC and GIS to produce a groundwater vulnerability map for the Castlereagh Catchment in Australia. In this research, the author excluded hydraulic conductivity (C) from the final DRASTIC calculation due to the lack of spatial data. Furthermore, the way the Recharge parameter (R) and Impact of vadose zone media (I) parameters were calculated was modified from how they were calculated by the US EPA. The author determined the recharge (R) parameter was more than simply a measure of rainfall; and additional environmental variables were summed together. The following equation was used to generate (R) taking into account three components:

Recharge value = Slope % + Rainfall + Soil permeability

The Impact on the vadose zone media (I) parameter was also determined by Piscopo (2001) to be more than only the geologic characteristics and was defined by the equation:

Impact of the Vadose Zone = Soil Permeability + Depth to Water Table

Lee (1996) modified DRASTIC in research in Korea because most of the aquifers there are developed in fractured rock causing groundwater to mainly move through the fault and fracture areas. Higher lineament density values may represent more potential to groundwater contamination. Therefore, by applying analysis of lineament density to the DRASTIC system, groundwater pollution susceptibility was assessed more accurately. Due to the importance of lineament density in this system, lineament density was assigned a weight of 5, the greatest value of DRASTIC system weights. The modified DRASTIC system index was calculated using the equation:

Modified DRASTIC index =
DRASTIC index + (Lineament density rating x weight = 5)

Davis et al (2001) proposed the KARSTIC method in research conducted in South Dakota, USA. This was a modification of the DRASTIC method that was designed specifically to apply to hydrogeologic properties in karst landscapes. The KARSTIC method uses nine parameters (summed into seven terms) including information on karst features such as sinkholes with surface recharge. To calculate the (K) parameter in this model, karst surface features were multiplied by fractures and other geologic structure because a greater degree of vulnerability can result from using a product.

Project Methodology

The DRASTIC model for this project was developed in a raster GIS environment in ArcGIS. The following modifications specific to the original DRASTIC model. Calculations of the (R) and (I) parameters were based on the methods and techniques described by Piscopo (2001). The Hydraulic Conductivity (C) parameter was excluded from the development of the DRASTIC index because detailed data were not available. A new parameter (K) was added to represent lineaments in the study area. We termed our model *DRASTIK* to keep the model identity similar to the traditional model while also incorporating lineaments and the important role they play with groundwater a karst landscape.

Parameter ranges were based on a combination of sources including Hallman (1997), Klug (2009), Aller et al (1987), as well as by the Jenks classification method in ArcGIS using 10 classes. See Appendix B for specific parameter ranges.

A comprehensive collection of key datasets was compiled including SSURGO soils, USGS bedrock geology, a USGS water well database, Oregon State PRISM average rainfall data, University of Arkansas AWRC Lineaments, and a USGS DEM. To bring consistency to the varying scales of the input datasets, a constant scale was determined by the DEM (30 meters) and each of the layers were converted to raster datasets in ArcGIS 9.3.

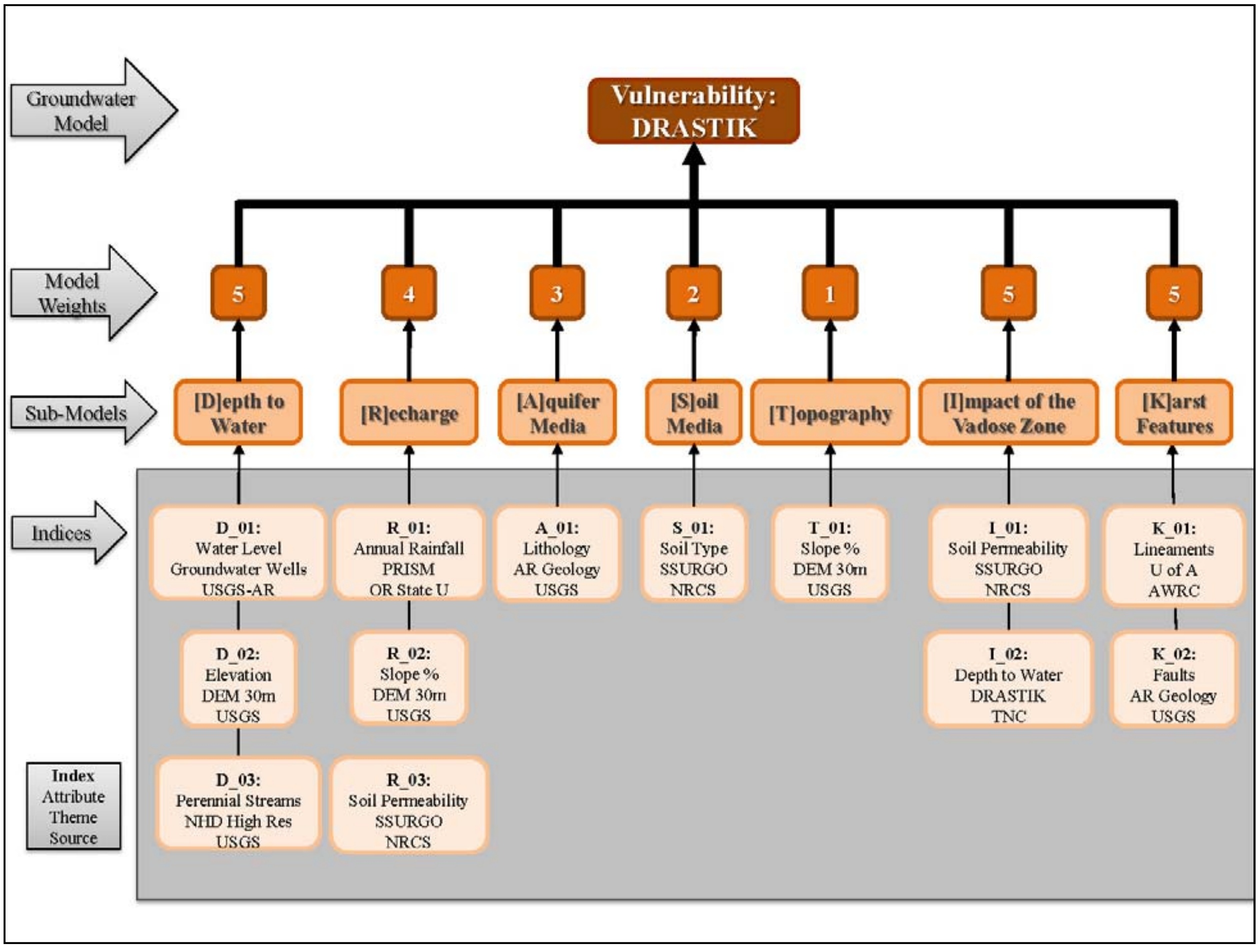

Figure 6. Schematic of DRASTIK groundwater vulnerability model.

Each cell in the model output dataset is represented by a vulnerability value, which corresponds to the cumulative rating of all input parameters and weights. Model outputs were then classed based on their levels of vulnerability. Below is a description of each model parameter and the applied weights that were used. Figure 6 below shows the indices, data sources, and weights of the DRASTIK model.

DRASTIK Sub-Model: Depth to Water (D)

Represents the depth from the ground surface to the water table, deeper water table levels imply lesser chance for contamination to occur. This is an important feature because it determines the depth of material through which a contaminant must travel before reaching the water table. In general, attenuation capacity increases as the depth to water increases. This is because deeper water levels result in a longer travel time of a contaminant. 5

DRASTIK Sub-Model: Recharge (R)

Represents the amount of water which penetrates the ground surface and reaches the water table, recharge water represents the vehicle for transporting pollutants. In general, the greater the recharge, the greater the potential for groundwater pollution. The components incorporated in the recharge feature for the Ozarks of Arkansas were slope, rainfall, and soil permeability. 4

DRASTIK Sub-Model: Aquafer Media (A)

Refers to the saturated zone material properties, which controls the pollutant attenuation processes. Aquifer medium governs the route and path length within the aquifer. The route which a contaminant will take can be strongly influenced by fracturing, porosity, or by an interconnected series of openings which may provide preferential pathways for groundwater flow. For the Ozarks of Arkansas, the aquifer media was defined by its geology type. 4

DRASTIK Sub-Model: Soil Media (S)

Represents the uppermost weathered portion of the unsaturated zone and controls the amount of recharge that can infiltrate downward into the water table. Soil media can be described in terms of its textural classification and ranked in order of pollution potential. For the Ozarks of Arkansas, a soil permeability class “ksat_r” was used from the SSURGO dataset. This map was suitable to be used for the soil media vulnerability feature map, as well as a component map for the development of the impact of Vadose Zone media map. 2

DRASTIK Sub-Model: Topography (T)

Refers to the slope of the land surface, it dictates whether the runoff will remain on the surface to allow contaminant percolation to the saturated zone. Slopes that provide a greater opportunity for contaminants to infiltrate will be associated with higher groundwater pollution potential. Topography influences soil development and therefore has an effect on contaminant attenuation. Slope in percentage was calculated using Digital Elevation Model (DEM) data for the Ozarks of Arkansas. Slope was then classified and ranked for use in the topography component map. 1

DRASTIK Sub-Model: Impact of the Vedose Zone (I)

Represents the unsaturated zone material above the water table. It controls the passage and attenuation of the contaminant to the saturated zone. The type of Vadose Zone media determines the attenuation characteristics of the material including the typical soil horizon and rock above the water table. The factors considered important in defining the impact of Vadose Zone in the Ozarks of Arkansas include soil permeability, and depth to water table. 5

DRASTIK Sub-Model: Karst Features (K)

Lineaments are geological structures such as fractures and joints. The lineament is closely related to groundwater flow and contaminants migration. Higher lineament density values may represent more potential to groundwater contamination. (REPLACED "C" PARAMETER)

Calculation of the Groundwater Vulnerability Model: DRASTIK

The weightings used for parameters (D) (R) (A) (S) (T) and (I) was based on those in the original DRASTIC weighting method proposed by Aller et al (1987). The weighting for the (K) parameter was based on published literature from Mendoza (2006), Lee (1996), and Davis (2001).

The raw DRASTIK scores at each aquatic site was rescaled from 0 to 1 to determine the scaled DRASTIK score for further analysis of threat.

Calculation of the Groundwater Sensitivity Model: RWQ + DRASTIK

Groundwater sensitivity is a function of both the surface risk factors, and the vulnerability, which characterizes the degree to which a system is susceptible to, or unable to cope with adverse risks. Assessment of groundwater vulnerability let to the creation of the DRASTIK layer. This layer is dependent on the physical hydrogeologic conditions found in a specific environment and is essentially independent of the land use. This data can be used by itself to help identify the potential areas in the Ozarks in Arkansas where groundwater is highly vulnerable to contamination and areas that are susceptible to degradation and need further site specific investigation.

For the purpose of determining groundwater sensitivity at aquatic sites, the scaled score RWQ_S and the scaled DRASTIK scores were summed. The raw sum for groundwater sensitivity was then rescaled from 0 to 1.

Calculation of the Aquatic Community Threat Model

The raw aquatic community threat score was simply the summation of the RVI and groundwater sensitivity. The raw sum of these two scores was then rescaled from 0 to 1 to determine the final aquatic community threat score.

RESULTS

Biological Information

Individual Species

Phylum Platyhelminthes
Order Tricladida
Family Dendrocoelidae

Dendrocoelopsis americana
(Hyman 1939) (Figure 7)

Locality information: Logan County (Kenk 1973), Newton County (this study), Polk County (Darlington and Chandler 1979), Washington County (Hyman 1939, Mohr 1950, Dearolf 1953, Kenk 1973, Darlington and Chandler 1979, this study).

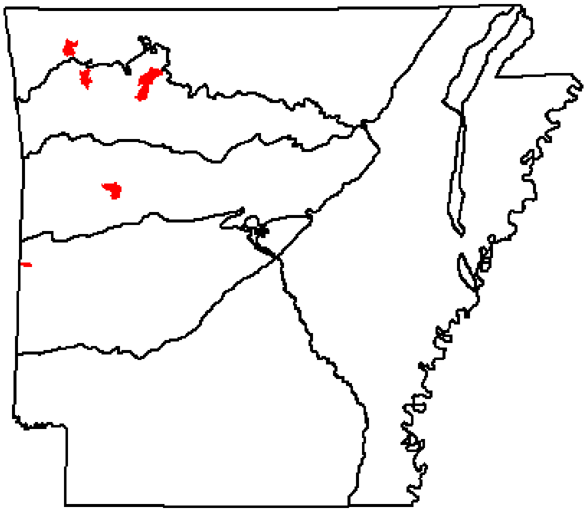

Figure 7. Distribution of *D. americana* in Arkansas. The red polygons are 12 HUCs that contain caves and/or springs where this species was documented.

Phylum Mollusca
Order Neotaenioglossa
Family Hydrobiidae

Amnicola cora
Hubricht 1979 (Figure 8)

Locality information: Independence County (Hubricht 1979, Graening 2003).

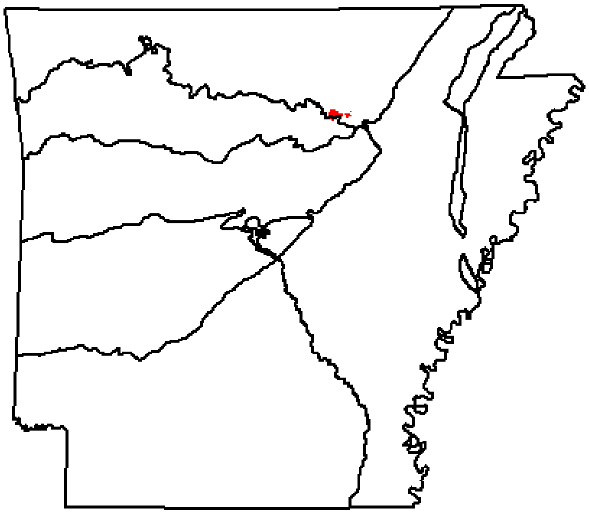

Figure 8. Distribution of *A. cora* in Arkansas. The red polygon is the 12 HUC that contains the cave where this species was documented.

Phylum Arthropoda
Class Malacostraca
Order Amphipoda
Family Allocrangonyctidae

Allocrangonyx hubrichti
Holsinger 1971 (Figure 9)

Locality information: White County (Robison and Holsinger 2000).

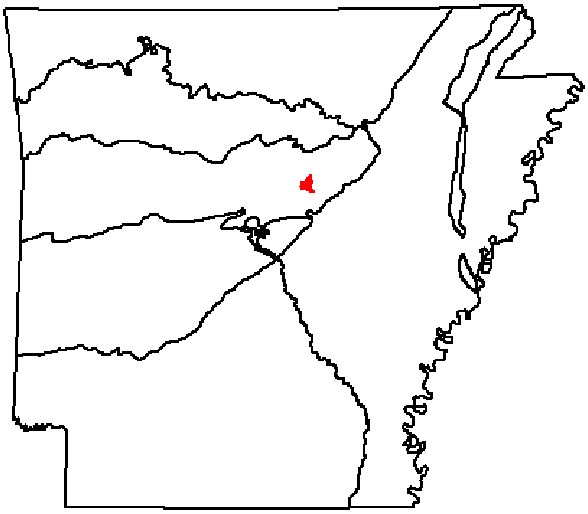

Figure 9. Distribution of *A. hubricthti* in Arkansas. The red polygon is the 12 HUC that contains the well where this species was documented.

Family Crangonyctidae

Bactrurus pseudomucronatus
Koenemann and Holsinger 2001 (Figure 10)

Locality information: Lawrence County (Konemann and Holsinger 2001), Randolph County (Konemann and Holsinger 2001).

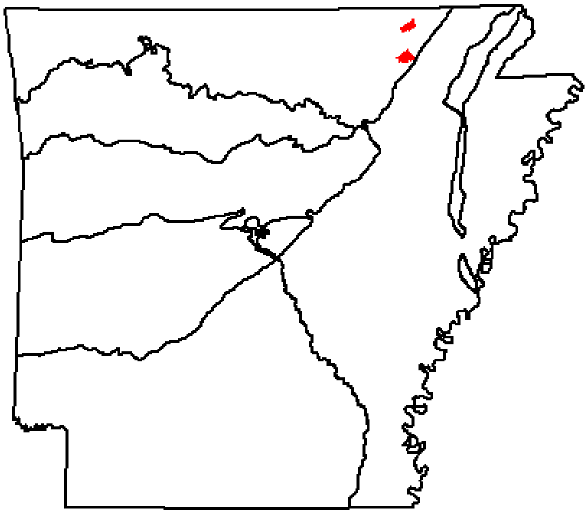

Figure 10. Distribution of *B. pseudomucronatus* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Stygobromus ozarkensis
(Holsinger 1967) (Figure 11)

Locality information: Benton County (Holsinger 1967, Holsinger 1972, Brown and Schram 1982, Graening et al. 2005), Carroll County (Schram 1982, Graening et al. 2005), Izard County (McDaniel et al. 1979, Graening et al. 2005), Madison County (Schram 1982, Schram 1983, Graening et al. 2005), Marion County (Graening et al. 2005), Newton County (Graening et al. 2005), Stone County (Graening et al. 2005), Washington County (Graening et al. 2005).

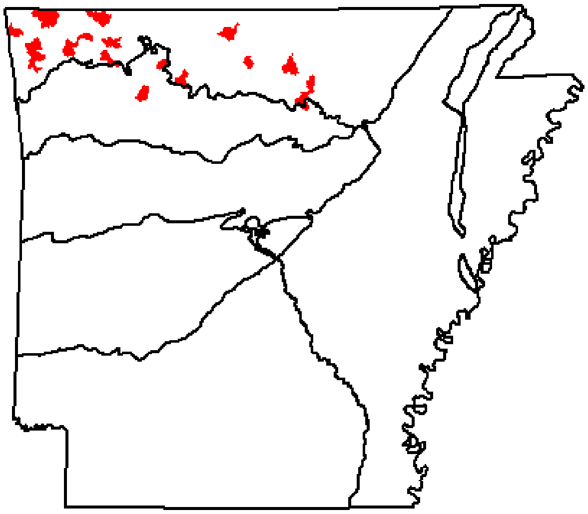

Figure 11. Distribution of *S. ozarkensis* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Order Isopoda
Family Asellidae

Caecidotea ancyla
(Fleming 1972b) (Figure 12)

Locality information: Benton County (Graening et al. 2007), Boone County (Fleming 1972b, Lewis et al. 2006), Independence County (Graening et al. 2007), Madison County (Schram 1982, Lewis et al. 2006, Graening et al. 2007), Newton County (Graening et al. 2007), Stone County (Graening et al. 2007), Washington County (Schram 1982).

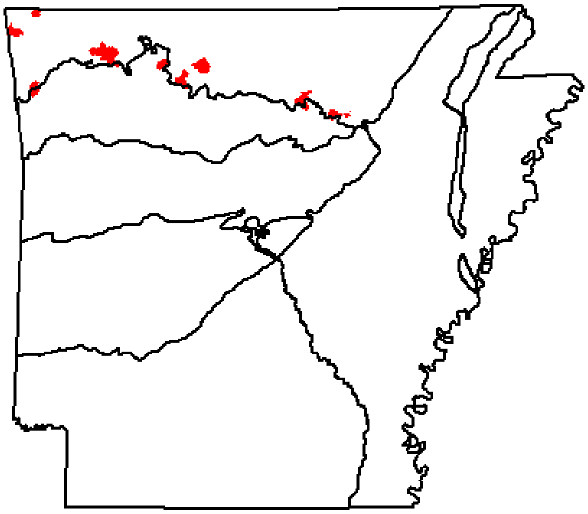

Figure 12. Distribution of *C. ancyla* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Caecidotea dimorpha
Mackin and Hubricht 1940 (Figure 13)

Locality information: Baxter County (Graening et al. 2007), Jackson County (Mackin and Hubricht 1940), Marion County (Graening et al. 2007), Searcy County (Fleming 1972a, Graening et al. 2007), Stone County (Graening et al. 2007).

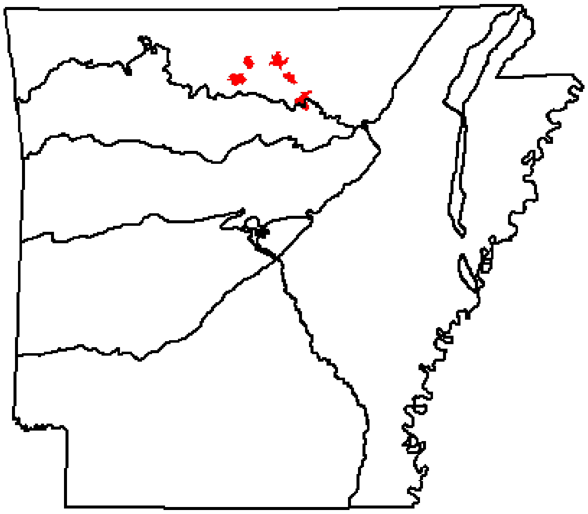

Figure 13. Distribution of *S. ozarkensis* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Caecidotea macropropoda
Chase and Blair 1937 (Figure 14)

Locality information: Carroll County (Lewis 1999), Crawford County (Graening et al. 2007), Washington County (Dearolf 1953, Lewis 1999, Lewis et al. 2006, Graening et al. 2007).

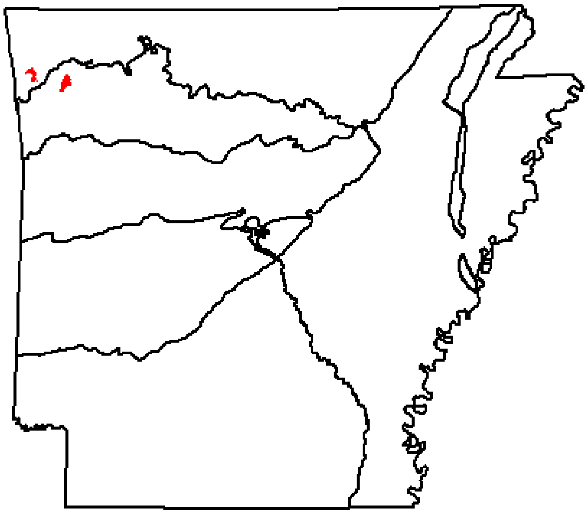

Figure 14. Distribution of *C. macropropoda* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Caecidotea salemensis
Lewis 1981 (Figure 15)

Locality information: Lawrence County (Lewis 1981).

Figure 15. Distribution of *C. salemensis* in Arkansas. The red circle is a geographic estimate of the literature based record where this species was documented.

Caecidotea simulator
Lewis 1999 (Figure 16)

Locality information: Washington County (Lewis 1999).

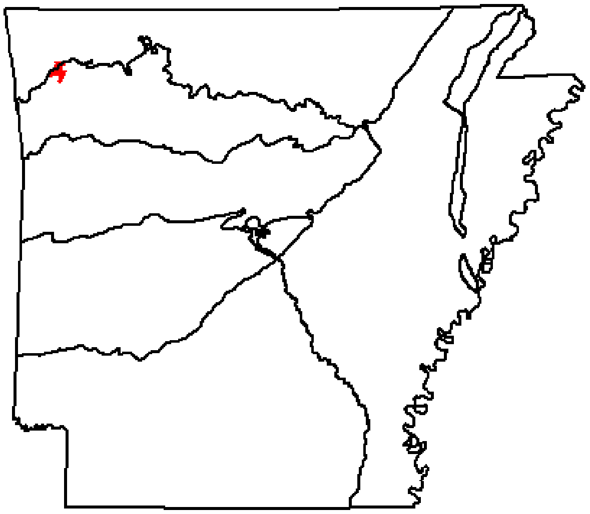

Figure 16. Distribution of *C. simulator* in Arkansas. The red polygon is the 12 HUC that contain the site where this species was documented.

Caecidotea steevesi
(Fleming 1972b) (Figure 17)

Locality information: Benton County (Graening et al. 2007), Carroll County (Graening et al. 2007), Madison County (Schram 1982, Schram 1983, Lewis et al. 2006).

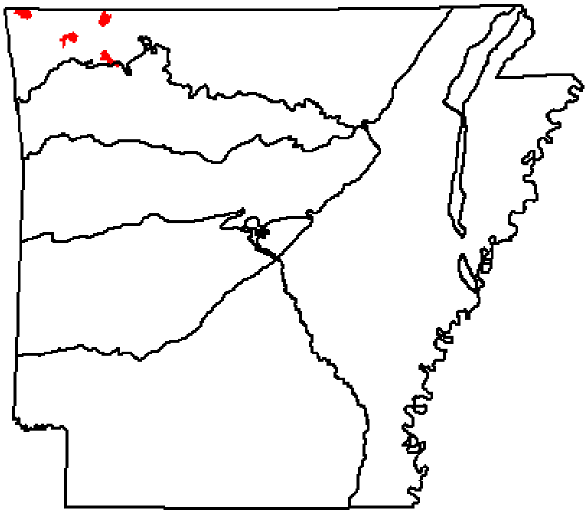

Figure 17. Distribution of *C. steevesi* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Caecidotea stiladactyla
Mackin and Hubricht 1940 (Figure 18)

Locality information: Baxter County (Graening et al. 2007), Benton County (Fleming 1972a, Schram 1982, Graening et al. 2007), Boone County (Mackin and Hubricht 1940), Carroll County (Schram 1982, Graening et al. 2007), Madison County (Schram 1982, Graening et al. 2007), Marion County (Graening et al. 2007), Newton County (Mackin and Hubricht 1940, Graening et al. 2007), Washington County (Graening et al. 2007).

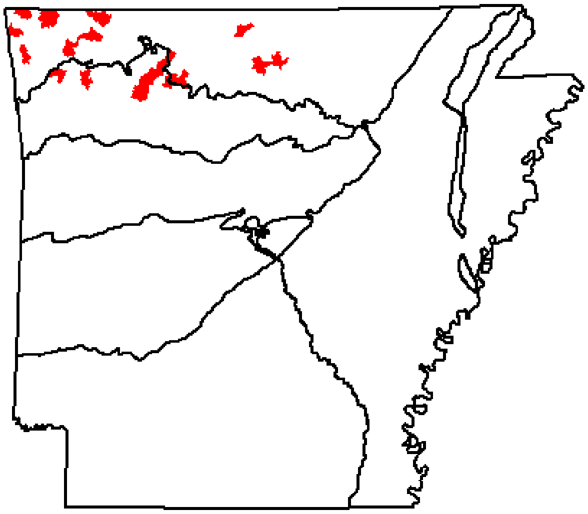

Figure 18. Distribution of *C. stiladactyla* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Lirceus bicuspidatus
Hubricht and Mackin 1949 (Figure 19)

Locality information: Conway County (Hubricht and Mackin 1949), Independence County (Graening et al. 2007), Jackson County (Hubricht and Mackin 1949), Johnson County (Hubricht and Mackin 1949), Logan County (Hubricht and Mackin 1949), Newton County (Hubricht and Mackin 1949), Pulaski County (Hubricht and Mackin 1949), Saline County (Hubricht and Mackin 1949), Searcy County (Hubricht and Mackin 1949), Yell County (Hubricht and Mackin 1949).

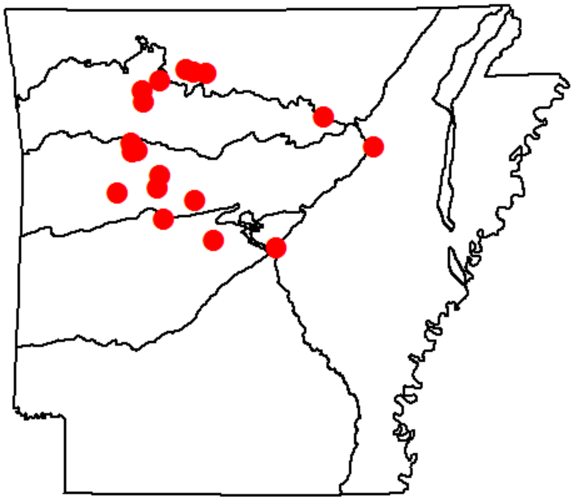

Figure 19. Distribution of *L. bicuspidatus* in Arkansas. The red circles are geographic estimates of literature based records where this species was documented.

Lirceus bidentatus
Hubricht and Mackin 1949 (Figure 20)

Locality information: Boone County (Hubricht and Mackin 1949).

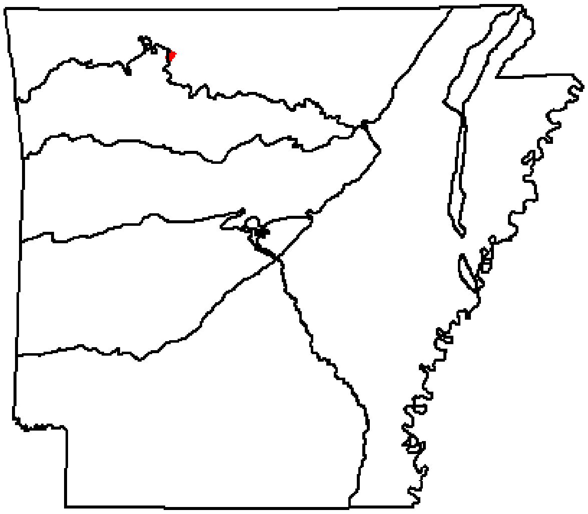

Figure 20. Distribution of *L. bidentatus* in Arkansas. The red polygon is the 12 HUC that contain the site where this species was documented.

Order Decapoda
Family Cambaridae

Cambarus aculabrum

Hobbs Jr and Brown 1987 (Figure 21)

Locality information: Benton County (Hobbs Jr and Brown 1987, Graening et al. 2006d), Washington County (Graening et al. 2006d).

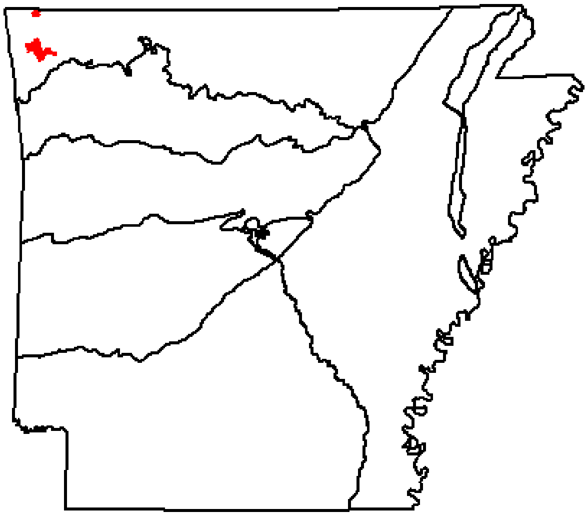

Figure 21. Distribution of *C. aculabrum* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Cambarus setosus

Faxxon 1889 (Figure 22)

Locality information: Benton County (Graening et al. 2006a), Independence County (Graening et al. 2006a).

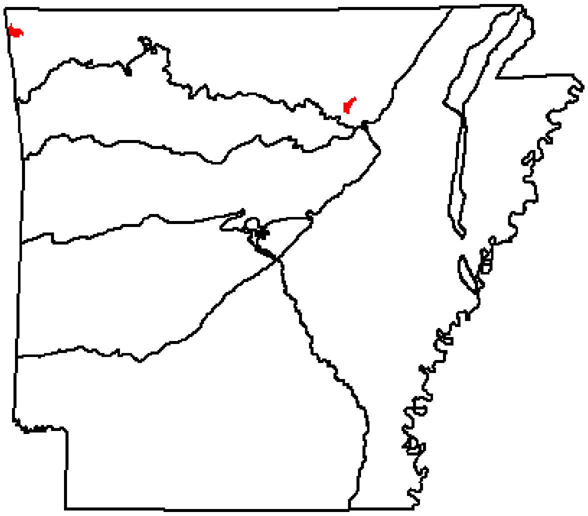

Figure 22. Distribution of *C. setosus* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Cambarus zophonastes
Hobbs Jr and Bedinger 1964 (Figure 23)

Locality information: Stone County (Hobbs Jr and Bedinger 1964, Graening et al. 2006b).

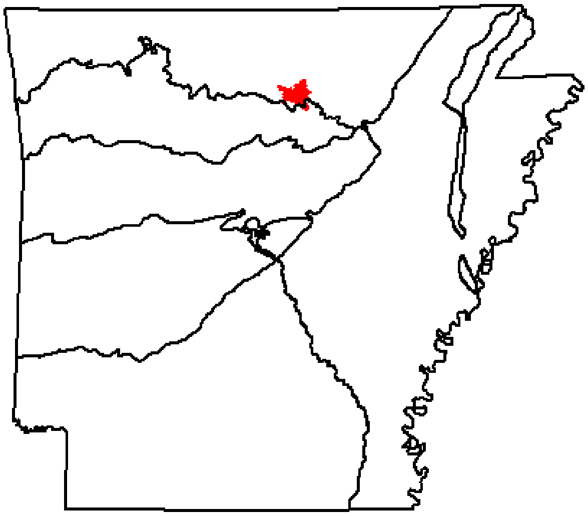

Figure 23. Distribution of *C. zophonastes* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Class Arachnida
Order Pseudoscorpionida
Family Chthoniidae

Apochthonius diabolus
Muchmore 1967 (Figure 24)

Locality information: Washington County (Muchmore 1967).

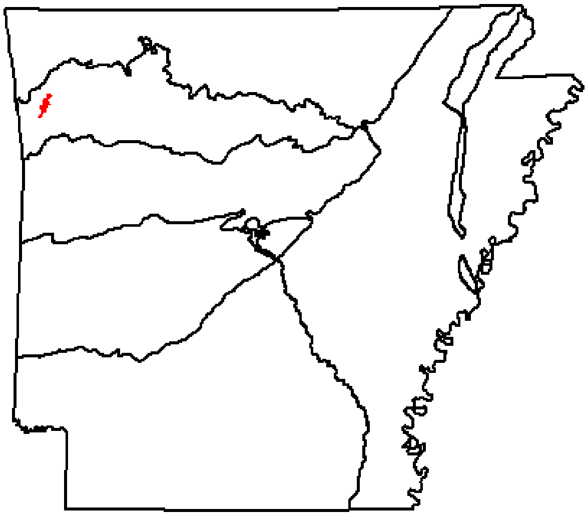

Figure 24. Distribution of *A. diabolus* in Arkansas. The red polygon is the 12 HUC that contain the site where this species was documented.

Apochthonius titanicus
Muchmore 1976 (Figure 25)

Locality information: Stone County (Muchmore 1976).

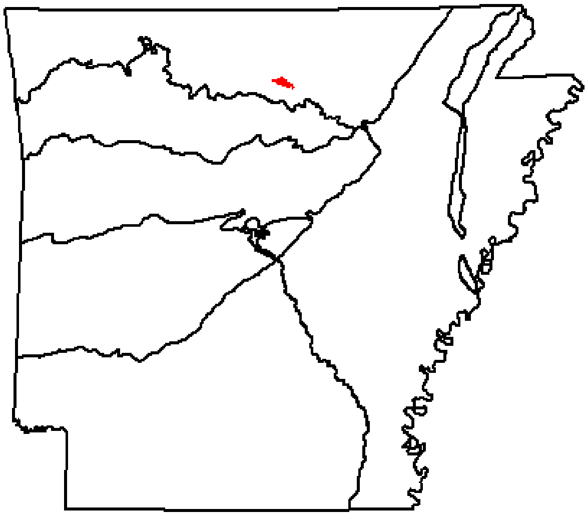

Figure 25. Distribution of *A. titanicus* in Arkansas. The red polygon is the 12 HUC that contain the site where this species was documented.

Family Chernitidae

Hesperochernes occidentalis
(Hoff and Bolsterli 1956) (Figure 26)

Locality information: Baxter County (Graening et al. unpublished), Benton County (Graening et al. unpublished), Boone County (Muchmore, pers. comm.), Independence County (Graening et al. unpublished), Lawrence County (Muchmore, pers. comm.), Marion County (Graening et al. 2006c, Muchmore, pers. comm.), Newton County (Graening et al. 2006c, Muchmore, pers. comm.), Randolph County (Muchmore, pers. comm.), Searcy County (Graening et al. 2006c, Muchmore, pers. comm.), and Washington County (Hoff and Bolsterli 1956, Muchmore, pers. comm.).

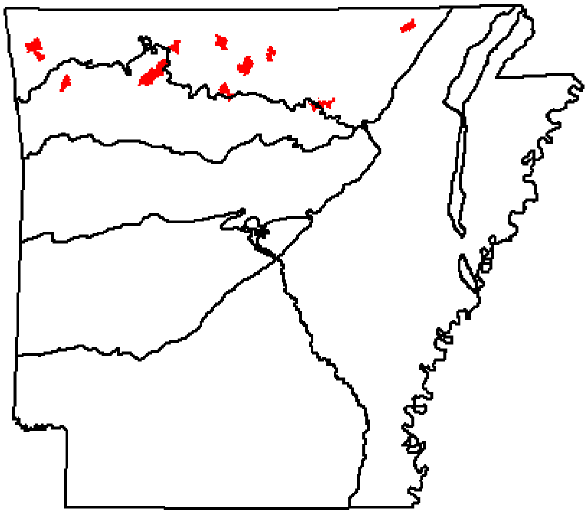

Figure 26. Distribution of *H. occidentalis* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Order Opiliones
Family Phalangodidae

Crosbyella distincta
Goodnight and Goodnight 1942 (Figure 27)

Locality information: Boone County (Goodnight and Goodnight 1942).

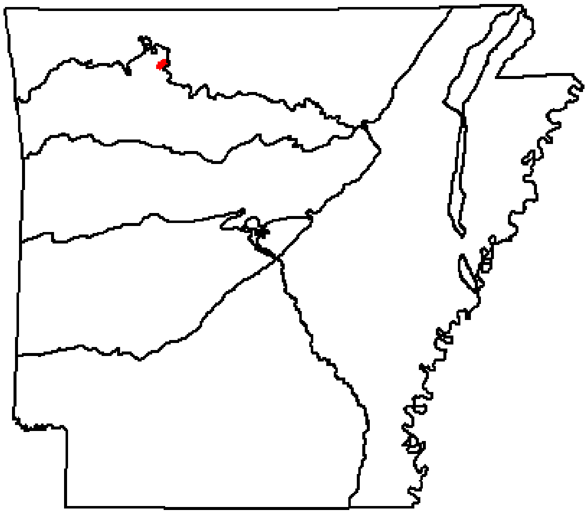

Figure 27. Distribution of *C. distincta* in Arkansas. The red polygon is the 12 HUC that contain the site where this species was documented.

Crosbyella roeweri
Goodnight and Goodnight 1942 (Figure 28)

Locality information: Benton County (Goodnight and Goodnight 1942).

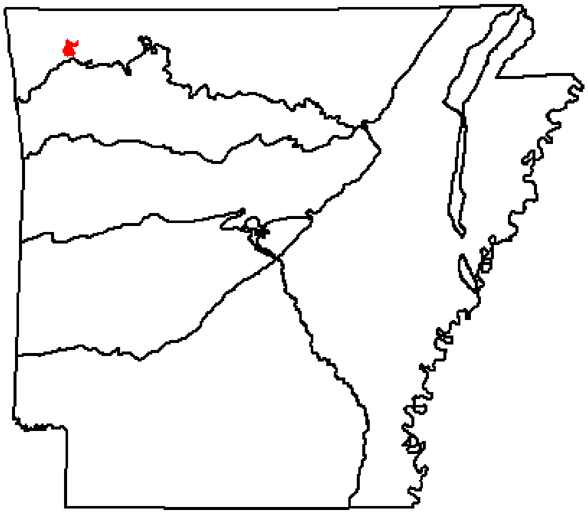

Figure 28. Distribution of *C. roeweri* in Arkansas. The red polygon is the 12 HUC that contain the site where this species was documented.

Class Diplopoda
Family Trichopetalidae

Trigenotyla parca
Causey 1951 (Figure 29)

Locality information: Benton County (Graening et al. unpublished), Newton County (Shear 2003, Graening et al. 2006c), Washington County (Shear 1972, Peck and Peck 1982, Shear 2003).

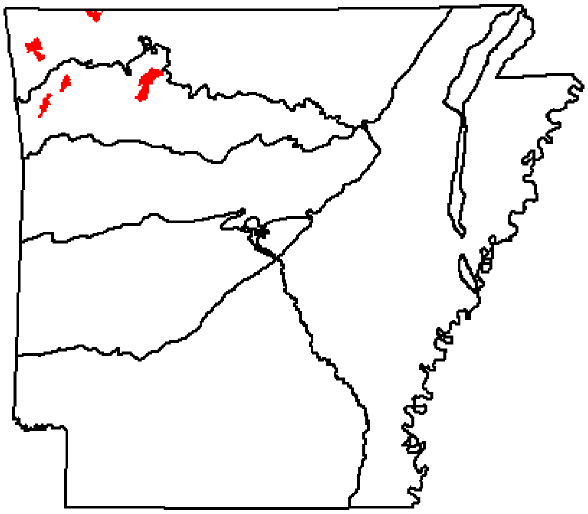

Figure 29. Distribution of *T. parca* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Class Hexapoda
Order Collembola
Family Arrhopalitidae

Pygmarrhopalites clarus
(Christiansen 1966) (Figure 30)

Locality information: Baxter County (Slay and Graening 2009), Benton County (Slay and Graening 2009), Carroll County (Slay and Graening 2009), Independence County (Slay and Graening 2009), Madison County (Slay and Graening 2009), Marion County (Slay and Graening 2009), Newton County (McDaniel and Smith 1976, Graening et al. 2006c), Pope County (Slay and Graening 2009), Searcy County (Slay and Graening 2009), Sharp County (Slay and Graening 2009), Stone County (Slay and Graening 2009), Washington County (Christiansen 1966, Slay and Graening 2009).

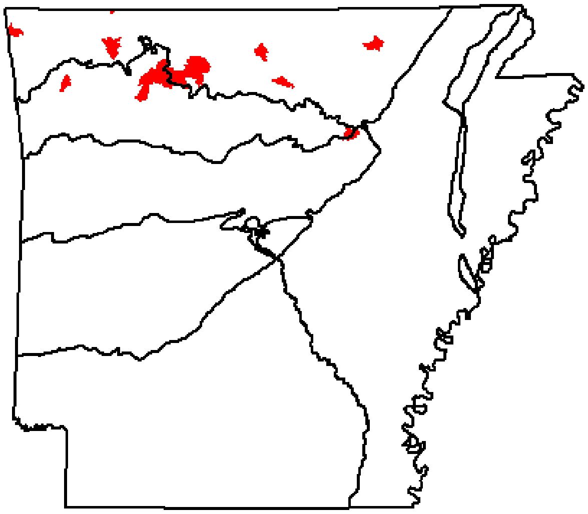

Figure 30. Distribution of *P. clarus* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Family Entomobryiidae

Pseudosinella dubia
Christiansen 1960 (Figure 31)

Locality information: Washington County (Christiansen 1960).

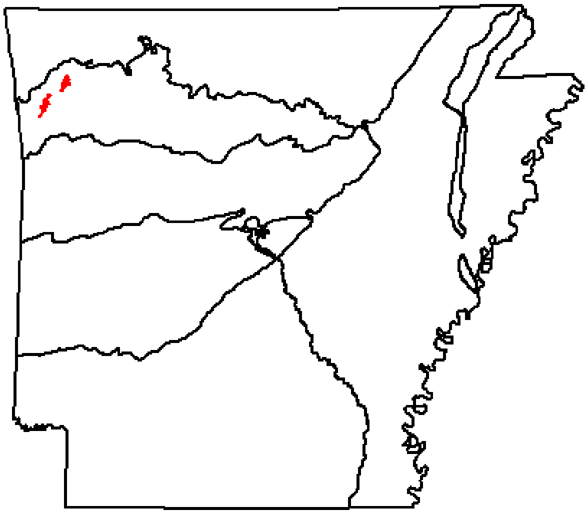

Figure 31. Distribution of *P. dubia* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Pseudosinella testa
Christiansen and Bellinger 1980 (Figure 32)

Locality information: Washington County (Slay and Graening 2009).

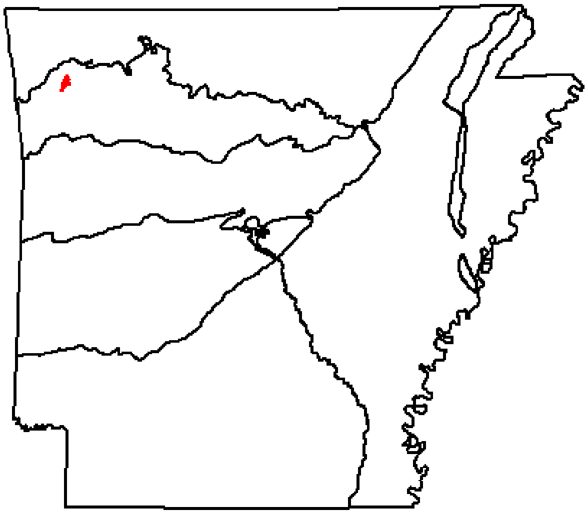

Figure 32. Distribution of *P. testa* in Arkansas. The red polygon is the 12 HUC that contains the sites where this species was documented.

Family Hypogastruridae

Typhlogastrura fousheensis
Christiansen and Wang 2006 (Figure 33)

Locality information: Independence County (Christiansen and Wang 2006).

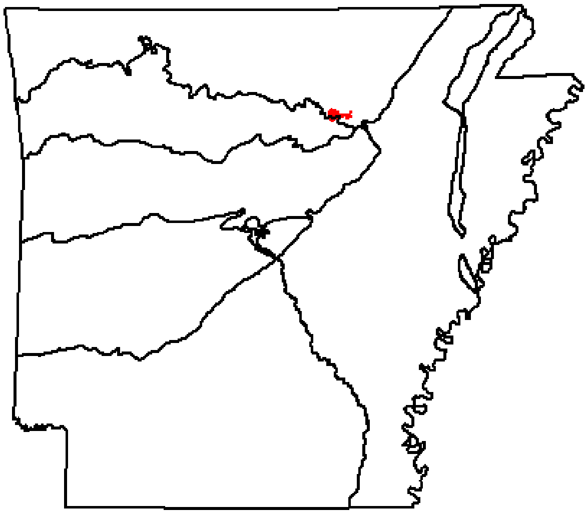

Figure 33. Distribution of *T. fousheensis* in Arkansas. The red polygon is the 12 HUC that contain the site where this species was documented.

Class Insecta
Order Coleoptera
Family Carabidae

Rhadine ozarkensis
Sanderson and Miller 1941 (Figure 34)

Locality information: Washington County (Sanderson and Miller 1941).

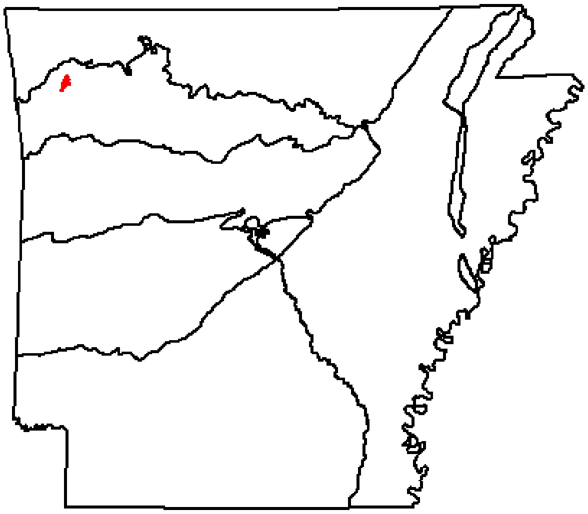

Figure 34. Distribution of *R. ozarkensis* in Arkansas. The red polygon is the 12 HUC that contain the site where this species was documented.

Phylum Chordata
Class Actinopterygii
Order Perciformes
Family Amblyopsidae

Amblyopsis rosae
(Eigenmann 1898) (Figure 35)

Locality information: Benton County (Poulson 1963, Willis and Brown 1985, Brown and Todd 1987, Graening et al. 2010).

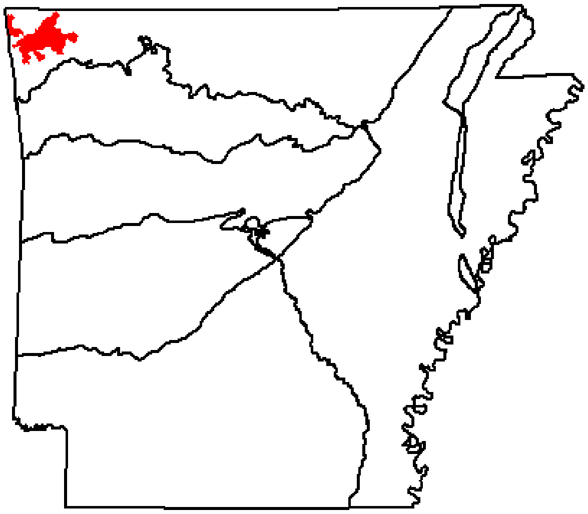

Figure 35. Distribution of *A. rosae* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Typhlichthys subterraneus
Girard 1859 (Figure 36)

Locality information: Fulton County (Paige et al. 1981), Randolph County (Woods and Inger 1957), Stone County (Graening et al. 2010, Dillman et al. 2011).

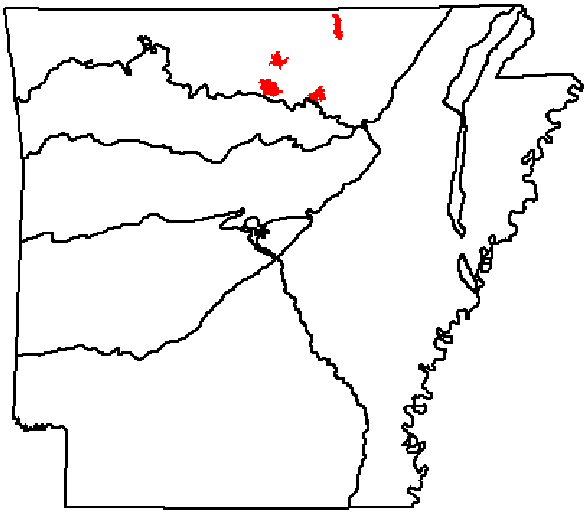

Figure 36. Distribution of *T. subterraneus* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Class Amphibia
Order Urodela
Family Plethodontidae

Eurycea spelaea
(Stejneger 1892) (Figure 37)

Locality information: Baxter County (Graening et al. unpublished), Benton County (Noble and Marshall 1929, Graening et al. unpublished), Boone County (Graening et al. unpublished), Carroll County (Brandon 1966, Graening et al. unpublished), Fulton County (Brandon 1966, Dunivan et al. 1982), Independence County (Brandon and Black 1970, Graening et al. unpublished), Izard County (Graening et al. unpublished), Johnson County (Graening et al. unpublished), Madison County (Schram 1983, Graening et al. unpublished), Marion County (Graening et al. 2006c, Graening et al. unpublished), Newton (Brandon and Black 1970, Graening et al. 2006c, Graening et al. unpublished), Searcy County (Graening et al. unpublished), Sharp County (Brandon 1966, Graening et al. unpublished), Stone County (Schuier et al. 1972, Dunivan et al. 1982, Graening et al. 2006b, Graening et al. unpublished), Washington County (Trauth et al. 2004).

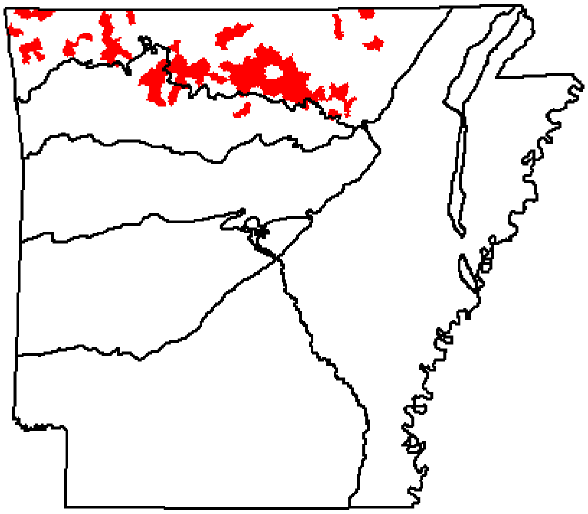

Figure 37. Distribution of *E. spelaea* in Arkansas. The red polygons are the 12 HUCs that contain the sites where this species was documented.

Summary Maps

Currently, in Arkansas, 93 sub-watersheds (categorized as HUC 12s) contain subterranean habitats with populations of the karst species listed in AWAP (Table 2). Of these sub-watersheds, 32 (34%) had at least one population of terrestrial karst species (**Error! Reference source not found.**) and while 87 (94%) had at least one population of aquatic karst species (Figure 39). For the 38 sub-watersheds with a single record of a karst species, 16 of these records were for the grotto salamander (*E. spelaea*). Sub-watersheds containing the most terrestrial karst species occurred mainly in the western part of the state. The sub-watershed with the highest number of terrestrial karst species was Koger Branch-Middle Fork White River located in Washington County. This watershed contained the only known population of the cave beetle, *Rhadine ozarkensis*, and the only Arkansas population of the cave springtail, *Pseudosinella testa*.

Sub-watersheds containing the most aquatic karst species were more evenly distributed across the state. The sub-watershed with the highest number of aquatic karst species (6) was Spavinaw-Eucha Lakes located in Benton County. Although the sub-watershed does not include any species that are single site endemics, it does include a population of Ozark cavefish (*A. rosae*), a species listed as threatened by the Endangered Species Act. The other aquatic species found within the sub-watershed include *C. anyla*, *C. stiladactyla*, *C. setosus*, *E. spelaea*, *Py. clarus*, and *S. ozarkensis*. The next highest ranking sub-watershed for aquatic richness was Prong Cove-Rocky Bayou in Stone County with had 5 aquatic species including the endangered Hell Creek cave crayfish (*C. zophonastes*).

Table 2. The 93 sub-watersheds that contain subterranean habitats for the aquatic and terrestrial karst species (not including bat species) listed in the Arkansas Wildlife Action Plan (AWAP) ranked by total number of species. Total number of species overall (Tt. Sp.), total aquatic species (Aq. Sp.), total terrestrial species (Tr. Sp.), and species names are listed for each HUC 12 sub-watershed.

HUC 10	HUC 12	Tt. Sp.	Aq. Sp.	Tr. Sp.	Species List
Middle Fork White River	Koger Branch-Middle Fork White River	7	1	6	*C. macropropoda, Ps. dubia, Ps. testa, H. occidentalis, Py. clarus, R. ozarkensis, T. parca*
Headwaters Buffalo River	Cove Creek-Buffalo River	7	4	3	*C. ancyla, C. stiladactyla, C. distincta, E. spelaea, H. occidentalis, Py. clarus, S. ozarkensis*
Spavinaw-Eucha Lakes	Upper Spavinaw Creek	7	6	1	*A. rosae, C. ancyla, C. stiladactyla, C. setosus, E. spelaea, Py. clarus, S. ozarkensis*
Headwaters Buffalo River	Whiteley Creek-Buffalo River	6	3	3	*C. stiladactyla, D. americana, E. spelaea, H. occidentalis, Py. clarus, T. parca*
Osage Creek-Illinois River	Osage Creek-Illinois River	6	4	2	*A. rosase, C. aculabrum, E. spelaea, H. occidentalis, S. ozarkensis, T. parca*

Headwaters Buffalo River	Smith Creek-Buffalo River	5	3	2	*C. stiladactyla, D. americana, E. spelaea, Py. clarus, T. parca*
Richland Creek-Buffalo River	Outlet Big Creek-Buffalo River	5	4	1	*C. ancyla, C. stiladactyla, E. spelaea, Py. clarus, S. ozarkensis*
Beaver Lake-White River	Beaver Lake	5	4	1	*C. stiladactyla, C. roeweri, D. americana, E. spelaea, S. ozarkensis*
Lafferty Creek-White River	Prong Cove-Rocky Bayou	5	5	0	*C. anclya, C. dimorpha, C. zophonastes, E. spelaea, S. ozarkensis*
Wolf Bayou-White River	Betsey Gill Creek-White River	4	3	1	*A. cora, C. ancyla, E. spelaea, T. fousheensis*
Outlet Buffalo River	Boat Creek-Buffalo River	4	3	1	*C. dimorpha, E. spelaea, H. occidentalis, S. ozarkensis*
Hicks Creek-White River	Sneeds Creek-White River	4	4	0	*C. dimorpha, C. stiladactyla, E. spelaea, T. subterraneus*
War Eagle Creek	Berry Branch-War Eagle Creek	4	4	0	*C. ancyla, C. steevesi, E. spelaea, S. ozarkensis*
Upper Table Rock Lake-White River	Leatherwood Creek	4	4	0	*C. steevesi, C. stiladactyla, E. spelaea, S. ozarkensis*
Little Sugar Creek	Browning Creek-Little Sugar Creek	4	4	0	*C. ancyla, C. aculabrum, E. spelaea, S. ozarkensis*
Robert S. Kerr Reservoir	Headwaters Lee Creek	3	0	3	*A. diabolus, Ps. dubia, Ps. testa, T. parca*
South Sylamore Creek-North Sylamore Creek	Outlet North Sylamore Creek	3	1	2	*A. titanicus, E. spelaea, Py. clarus*
Kings River-Table Rock Lake	Rockhouse Creek-Kings River	3	2	1	*E. spelaea, Py. clarus, S. ozarkensis*
Upper Table Rock Lake-White River	Cedar Creek-Table Rock Lake	3	2	1	*C. stiladactyla, S. ozarkensis, T. parca*
Upper Kings River	Pine Creek-Upper Kings River	3	2	1	*c. ancyla, E. spelaea, Py. clarus*
Clear Creek-Crooked Creek	Headwaters Clear Creek	3	2	1	*C. ancyla, E. spelaea, Py. clarus*
Little Sugar Creek	McKisic Creek-Little Sugar Creek	3	3	0	*A. rosae, C. stiladactyla, S. ozarkensis*
Lower Elk River-Lake O'	Butler Creek	3	3	0	*C. steevesi, C. stiladactyla, E. spelaea*

The Cherokees					
Little Sugar Creek	Tanyard Creek-Little Sugar Creek	3	3	0	*C. stiladactyla, E. spelaea, S. ozarkensis*
Beaver Lake-White River	West Fork Little Clifty Creek-Beaver Lake	3	3	0	*C. stiladactyla, E. spelaea, S. ozarkensis*
Upper Illinois River	Chambers Hollow-Illinois River	3	3	0	*A. rosae, C. stiladactyla, E. spelaea*
Headwaters Buffalo River	Hoskin Creek-Buffalo River	2	1	1	*E. spelaea, Py. clarus*
Little Buffalo River	Henson Creek	2	1	1	*E. spelaea, Py. clarus*
Lower Eleven Point River	Eassis Creek-Eleven Point River	2	1	1	*B. pseudomucronatus, H. occidentalis*
Outlet Spring River	Rock Creek-Spring River	2	1	1	*E. spelaea, Py. clarus*
Hicks Creek-White River	Perry Creek-White River	2	1	1	*E. spelaea, Py. clarus*
Outlet Buffalo River	Hickory Creek-Buffalo River	2	1	1	*E. spelaea, H. occidentalis*
Headwaters Crooked Creek	Dry Jordan Creek-Crooked Creek	2	1	1	*E. spelaea, H. occidentalis*
Little Buffalo River	Outlet Little Buffalo River	2	1	1	*C. stiladactyla, Py. clarus*
Hicks Creek-White River	Farris Creek-White River	2	1	1	*E. spelaea, H. occidentalis*
Richland Creek-Buffalo River	Cane Branch-Buffalo River	2	1	1	*E. spelaea, Py. clarus*
Outlet Crooked Creek	Georges Creek-Crooked Creek	2	1	1	*E. spelaea, H. occidentalis*
Lafferty Creek-White River	East Twin Creek-White River	2	2	0	*C. zophonastes, E. spelaea*
South Fork Spring River	Camp Creek-South Fork Spring River	2	2	0	*E. spelaea, T. subterraneus*
Poke Bayou	Lower Poke Bayou	2	2	0	*C. setosus, E. spelaea*
Bull Shoals Lake-White River	Outlet Bull Shoals Lake-White River	2	2	0	*C. stiladactyla, E. spelaea*

South Sylamore Creek-North Sylamore Creek	Headwaters Roasting Ear Creek	2	2	0	*E. spelaea, T. subterraneus*
Bear Creek-Buffalo River	Spring Creek-Buffalo River	2	2	0	*C. dimorpha, E. spelaea*
South Sylamore Creek-North Sylamore Creek	Outlet Roasting Ear Creek	2	2	0	*E. spelaea, T. subterraneus*
South Sylamore Creek-North Sylamore Creek	Outlet South Sylamore Creek	2	2	0	*C. zophonastes, E. spelaea*
Lafferty Creek-White River	Livingston Creek	2	2	0	*C. dimorpha, E. spelaea*
Outlet Buffalo River	Leatherwood Creek-Buffalo River	2	2	0	*C. stiladactyla, E. spelaea*
Bull Shoals Lake-White River	Jimmie Creek-Bull Shoals Lake	2	2	0	*E. spelaea, S. ozarkensis*
Black Fork	Big Creek	2	2	0	*C. oculata, D. americana*
Lafferty Creek-White River	Cagens Creek-White River	2	2	0	*E. spelaea, T. subterraneus*
Hicks Creek-White River	Sugarloaf Creek-White River	2	2	0	*E. spelaea, S. ozarkensis*
Headwaters Crooked Creek	West Fork Crooked Creek	2	2	0	*C. stiladactyla, L. bidentatus*
Beaver Lake-White River	Phillips Creek-Beaver Lake	2	2	0	*A. rosae, C. steevesi*
Richland Creek	Cherry Creek-Richland Creek	2	2	0	*C. stiladactyla, D. americana*
West Fork White River	Town Branch-West Fork White River	2	2	0	*C. simulator, C. stiladactyla*
Bear Creek-Buffalo River	Outlet Bear Creek	1	0	1	*H. occidentalis*
Wolf Bayou-White River	Mill Creek-White River	1	0	1	*H. occidentalis*
Upper Table Rock Lake-White River	Owl Creek-Table Rock Lake	1	0	1	*Py. clarus*
Clear Creek-Crooked Creek	Hog Creek	1	0	1	*Py. clarus*
Salado Creek-White River	Middle Salado Creek	1	0	1	*Py. clarus*
Headwaters Spring River	Trace Creek-Spring River	1	1	0	*E. spelaea*

Osage Creek-Illinois River	Little Osage Creek	1	1	0	*A. rosae*
Clear Creek-Illinois River	Mud Creek-Clear Creek	1	1	0	*C. simulator*
Bear Creek-Buffalo River	Dry Creek-Buffalo River	1	1	0	*E. spelaea*
Flint Creek	Headwaters Flint Creek	1	1	0	*A. rosae*
Headwaters Middle Fork Little Red River	Peyton Creek-Middle Fork Little Red River	1	1	0	*E. spelaea*
Osage Creek-Illinois River	Headwaters Osage Creek-Illinois River	1	1	0	*A. rosae*
Poke Bayou	Middle Poke Bayou	1	1	0	*E. spelaea*
Outlet Spring River	Brushy Creek-Spring River	1	1	0	*B. pseudomucronatus*
Lafferty Creek-White River	Lafferty Creek	1	1	0	*E. spelaea*
Little Buffalo River	Headwaters Little Buffalo River	1	1	0	*E. spelaea*
Upper Kings River	Lower Dry Fork	1	1	0	*E. spelaea*
Headwaters Crooked Creek	East Fork Crooked Creek-Crooked Creek	1	1	0	*E. spelaea*
Lafferty Creek-White River	Wideman Creek-White River	1	1	0	*E. spelaea*
Headwaters Buffalo River	Flatrock Creek	1	1	0	*E. spelaea*
Muddy Fork-Illinois River	Lower Muddy Fork-Illinois River	1	1	0	*C. macroproda*
Headwaters Illinois River	Lake Weddington-Illinois River	1	1	0	*S. ozarkensis*
Muddy Fork-Illinois River	Upper Muddy Fork-Illinois River	1	1	0	*C. ancyla*
Bear Creek-Buffalo River	Water Creek	1	1	0	*E. spelaea*
Osage Creek-Illinois River	Brush Creek-Osage Creek	1	1	0	*C. aculabrum*
Spavinaw-	Beaty Creek	1	1	0	*A. rosae*

Eucha Lakes					
Outlet Buffalo River	Bratton Creek-Big River	1	1	0	*E. spelaea*
Glade Creek-Bayou Des Arc	Lake Barnett	1	1	0	*A. hubrichti*
Richland Creek-Buffalo River	Left Fork Creek	1	1	0	*E. spelaea*
Kings River-Table Rock Lake	Keels Creek	1	1	0	*E. spelaea*
Headwaters Buffalo River	Beech Creek-Headwaters Buffalo River	1	1	0	*C. stiladactyla*
Beaver Lake-White River	Long Hollow-Beaver Lake	1	1	0	*C. stiladactyla*
War Eagle Creek	Clear Creek-War Eagle Creek	1	1	0	*C. ancyla*
Lafferty Creek-White River	Hidden Creek-White River	1	1	0	*S. ozarkensis*
Middle Table Rock Lake	Headwaters Indian Creek	1	1	0	*E. spelaea*
Outlet Buffalo River	Davis Creek-Big River	1	1	0	*E. spelaea*
Sixmile Creek	Upper Short Mountain Creek	1	1	0	*D. americana*
Osage Creek-Illinois River	Spring Creek-Osage Creek	1	1	0	*A. rosae*

Overall, three sub-watersheds had the highest richness (7 species) when terrestrial and aquatic species were combined. Two of these sub-watersheds were in northwest Arkansas, while the third was in Newton County (Figure 40). These 3 sub-watersheds collectively include at least one population of 13 of the AWAP karst species: *A. rosae*, *C. ancyla*, *C. macropropoda*, *C. stiladactyla*, *Cambarus setosus*, *Crosbyella distincta*, *E. spelaea*, *H. occidentalis*, *Ps. dubia*, *Ps. testa*, *Py. clarus*, *S. ozarkensis*, and *T. parca*. By adding the next 6 highest ranking sub-watersheds (i.e. the 9 sub-watersheds with total richness ≥ 5) at least one population of an additional 5 species are included. The additional species are: *C. dimorpha*, *Cambarus aculabrum*, *Cambarus zophonastes*, *Crosbyella roeweri*, and *D. americana*.

Regarding bat sites, only 4 sites had the highest number of bat species (Figure 41). For most sites, only one species of bat was documented. Because these sites are sensitive to disturbance, a list of sites prioritized by bat species richness is not provided here. However, the information is available from Arkansas Natural Heritage Commission or Arkansas Game and Fish Commission for valid research or conservation use. The gray bat was distributed across the state, while the Indiana bat and the Ozark Big-eared bat were clustered in more specific areas.

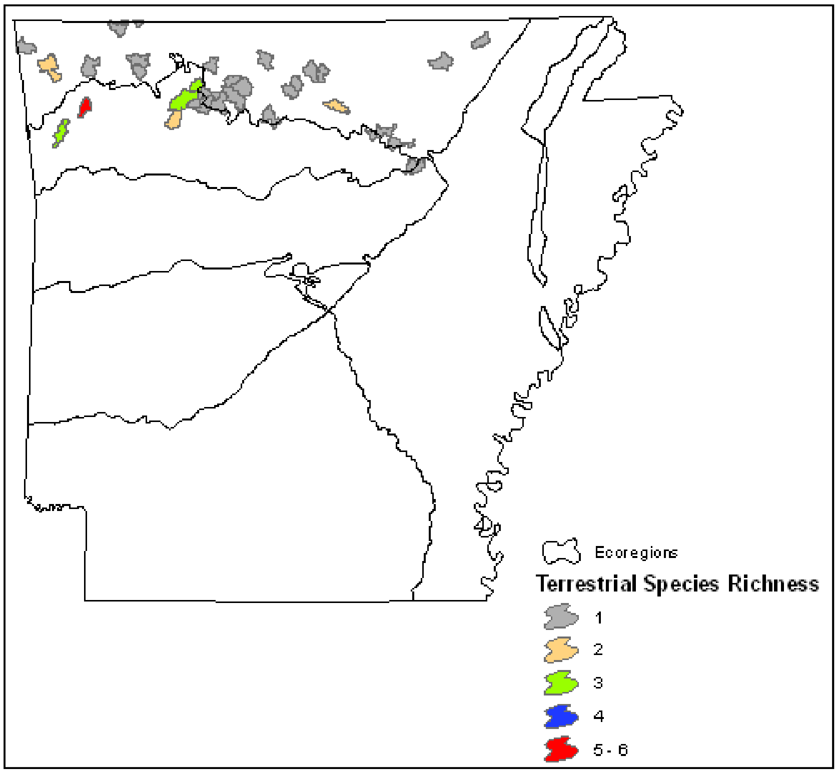

Figure 38. Total number of terrestrial species by HUC-12.

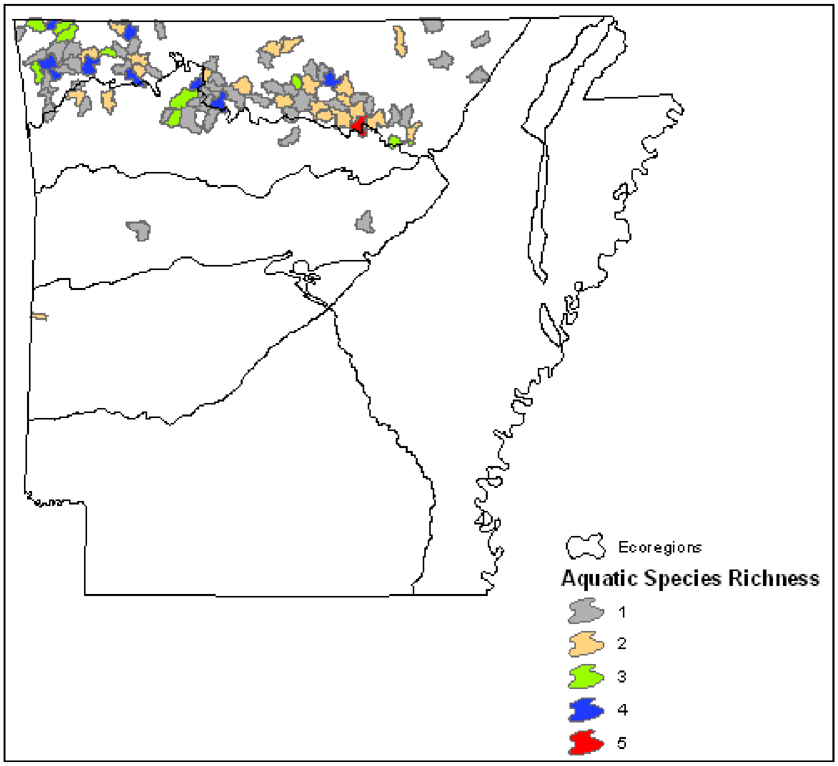

Figure 39. Total number of aquatic species by HUC-12.

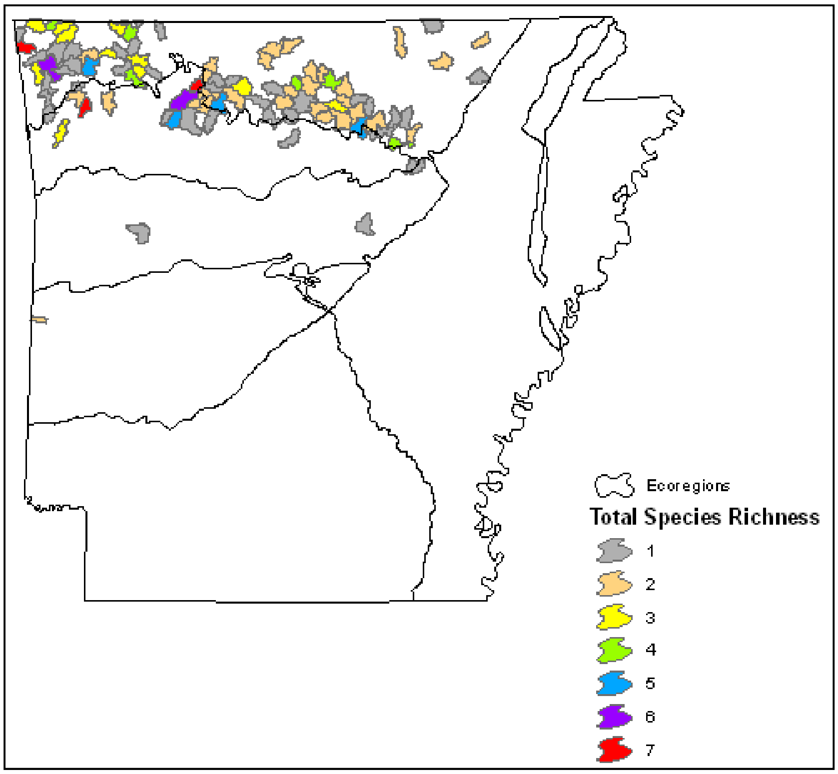

Figure 40. Total number of terrestrial and aquatic species by HUC-12.

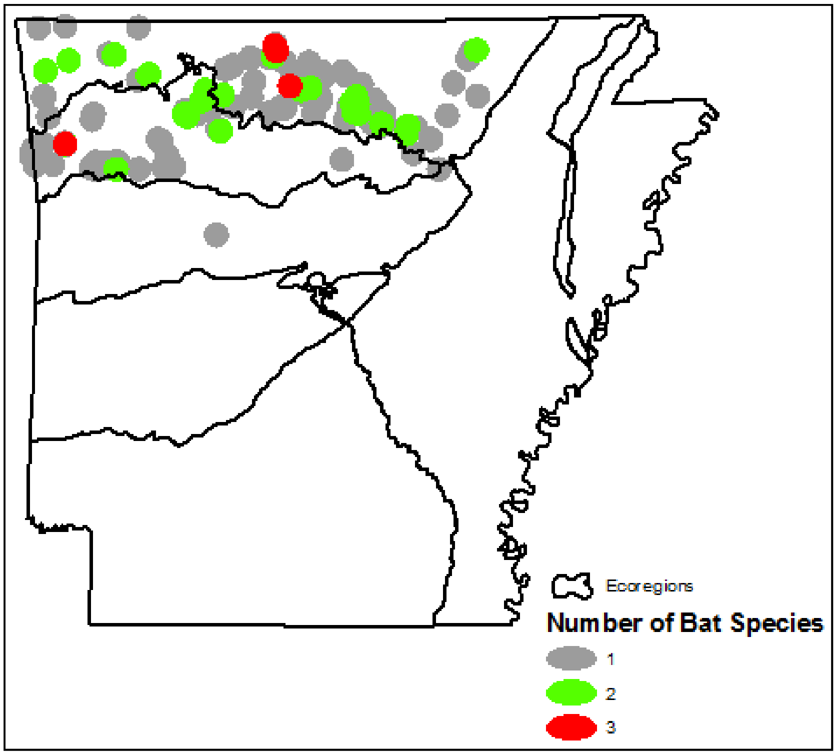

Figure 41. Total number of bat species by 5-mile radius ring from sites.

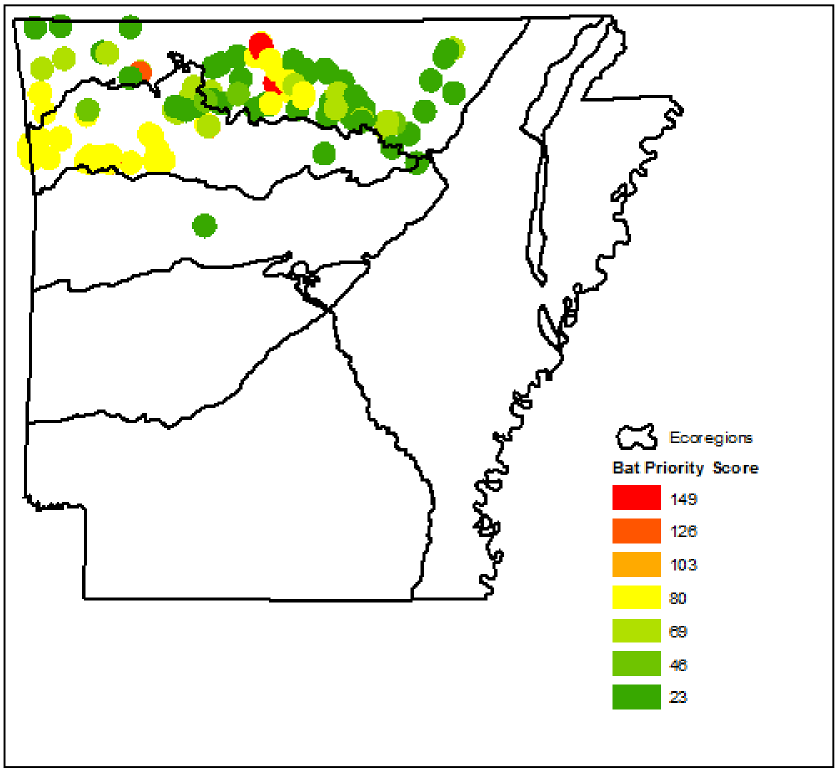

Figure 42. Sum of AWAP priority scores for bat species by 5-mile radius ring from sites.

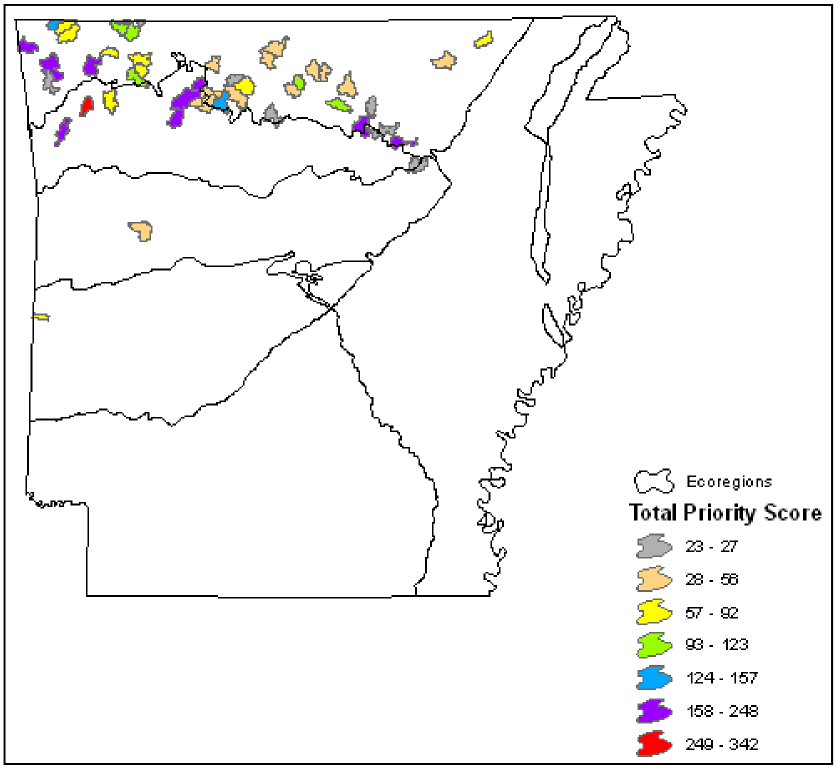

Figure 43. Sum of AWAP priority scores for terrestrial and aquatic species by HUC-12.

An alternative ranking was calculated using AWAP priority scores rather than richness. Using the AWAP priority score for each species, a cumulative score was calculated for each sub-watershed and each bat site based on the AWAP species present (Figure 42 and Figure 43). Generally, there is little difference between the highest ranking sub-watersheds and bats using richness or cumulative AWAP scores.

Threat Assessment

Terrestrial Community Group

Assessing threats associated with the terrestrial cave species was somewhat more complex given that these species could occur at sites that contained bat species, aquatic cave species, or both. For sites containing aquatic species or both aquatic species and bats, the assessment area was determined using the aquatic community method (recharge area or catchment). For sites containing bats (but no aquatic species), the assessment area was determined using the bat community method (5 mi radius). For example, the cave pseudoscorpion, *H. occidentalis*, occurs in Forest Trail Pit (no aquatic cave species or bats), Summit Cave (bats), Van Dyke Spring Cave (aquatic cave species but not bats), and Logan Cave (aquatic species and bats). Many of the terrestrial cave species co-occurred with aquatic cave species or bat species. Of the 297 sites assessed overall, less than 25 sites contained only terrestrial cave species (Figure 44). Additional sites that contained terrestrial cave species were assessed within the aquatic community (28 sites) or bat community framework (6 sites).

Table 3. Mean index values for threats associated with terrestrial cave species, ordered in decreasing values of RVI. RVIP is the derived threat score generated from proximate human population. RVIA is the derived threat score generated from available access to the site. RVIX is the derived threat score generated from the proximity of the site to a road. RVI is the overall threat from visitation generated by combining RVIP, RVIA, and RVIX.

Terrestrial Cave Species	No. sites	RVIP	RVIA	RVIX	RVI
Crosbyella roeweri	1		1.00	0.89	0.96
Rhadine ozarkensis	1	0.55	0.64	0.97	0.69
Pseudosinella testa	1	0.55	0.64	0.97	0.69
Pseudosinella dubia	2	0.33	0.55	0.87	0.54
Trigenotyla parca	6	0.17	0.47	0.84	0.44
Hesperochernes occidentalis	19	0.17	0.46	0.80	0.42
Pygmarrhopalites clarus	25	0.16	0.45	0.79	0.41
Typhlogastrura fousheensis	1	0.13	0.41	0.82	0.39
Apochthonius titanicus	1	0.05	0.38	0.89	0.38
Apochthonius diabolus	1	0.05	0.40	0.88	0.38
Crosbyella distincta	3	0.04	0.35	0.81	0.34

To characterize threats for each terrestrial cave species, Visitation Risk Model values (RVIP, RVIA, RVIX, and RVI) were extracted from each community threat model and averaged (Table 3). All terrestrial cave species experienced some level of threat from visitation. The species with the highest threat score was the cave harvestman, *C. roeweri*. Four species had overall scores greater than 0.5. The most frequently occurring species (*H. occidentalis* and *Py.*

clarus) had average threat values of 0.42 and 0.41, respectively. Separate threat values for each terrestrial cave species population at each site are included in Appendix C.

Bat Community Group

The overall threat assessment for bat sites included assessing threats generated by two risk models: visitation (RVI) and available foraging habitat (RBH). Relative to all bat sites, only two caves are highly threatened by visitation (Figure 45). However, numerous sites were scored as having a medium or higher threat associated with visitation. Bat sites with the highest threat scores associated with foraging habitat were not the same sites as those identified by using the visitation indices (Figure 46). In fact, only one site, Cave Springs Cave, ranked as highly threatened for each of these risk models separately. Combining these two risk models produced an overall threat index for bat sites that suggests some of these threats may interact to produce cumulative impacts (Figure 47). Bat sites categorized with the highest threat scores were fairly evenly distributed across the study area, although some broad scale clustering is noticeable (e.g. northwest Arkansas).

Table 4. Mean index scores for threats associated with bat species, ordered in decreasing values of overall threat (THREAT). Table is broken into 2 sections with "Species" and "No. Sites" repeating in each section. See Appendix A for definitions of threat variables.

Bat Species	No. Sites	RBHF 01	RBHF 02	RBHF	RBHR 01	RBHR 02	RBHR
Corynorhinus townsendii ingens	42	0.17	0.59	0.20	0.31	0.14	0.19
Myotis grisescens	70	0.24	0.46	0.16	0.27	0.20	0.20
Myotis leibii	3	0.17	0.62	0.21	0.21	0.13	0.13
Myotis sodalis	30	0.18	0.59	0.20	0.25	0.15	0.16

Bat Species	No. Sites	RBH	RVIP	RVIA	RVIX	RVI	THREAT
Corynorhinus townsendii ingens	42	0.13	0.06	0.40	0.70	0.32	0.18
Myotis grisescens	70	0.11	0.10	0.46	0.81	0.39	0.22
Myotis leibii	3	0.11	0.08	0.42	0.83	0.38	0.20
Myotis sodalis	30	0.12	0.09	0.43	0.83	0.39	0.21

For the purpose of generating threat scores for bat sites, a cave was considered "occupied" regardless of whether the species is currently known from the site. In some instances, bat species are no longer occupying sites (e.g. several historic gray bat and Indiana bat sites). However, all sites were included for analysis because even currently unoccupied sites have the potential to house bats should conditions change. Assessing and reducing threats associated with currently unoccupied sites may allow bats to re-colonize historic locations.

Average overall threat scores were low for all four species (Table 4). Some threats due to visitation and foraging habitat may be more important than others. Average values for proximity to roads (RVIX) ranged from 0.70 to 0.83, and average values for relative amount forest edge (RBHF 02) ranged from 0.46 to 0.62. Threat scores associated with proximate human population (RVIP) were low. Separate threat values for each bat species at each site are included in Appendix D.

Aquatic Community Group

The overall threat assessment for aquatic cave species sites included assessing threats generated from a visitation risk model (RVI) and a groundwater sensitivity model (SENS). The groundwater sensitivity model was generated from a water quality and quantity risk model (RWQ) and a groundwater vulnerability model (VULN). The groundwater vulnerability model was generated using a modification of the model DRASTIC. Each of these models are comprised of threat indices which, in addition to overall threat scores, are useful in describing threats for each of the aquatic cave species. Separate threat values for each aquatic cave species at each site are included in Appendix E.

All 18 aquatic cave species are experiencing some level of threat, and average overall threat values ranged from 0.19 to 0.63 (Table 5). Two species that occurred in the top 5 were the Ozark cavefish (*A. rosae*) and the Benton cave crayfish (*C. aculabrum*). Interestingly, the overall threat score for the Hell Creek cave crayfish (C. zophonastes) was in the bottom third of values. The Foushee cavsnail (*A. cora*) had the lowest overall threat score.

The highest visitation threats were at sites in northwestern Arkansas along the Interstate 540 corridor (Figure 48). Aquatic cave species within these sites include populations of *A. rosae*, *C. macropropoda*, *C. steevesi*, *C. stiladactyla*, *Cambarus aculabrum*, *D. americana*, *E. spelaea*, and *S. ozarkensis*. Many sites had lower threat scores relative to water quality and quantity threats (Figure 49), with the exception of Cave Springs Cave in Benton County which had a RWQ score of 0.70 (Appendix E). In addition to providing habitat for several aquatic cave species, Cave Springs Cave has the largest observable population of Ozark Cavefish (*A. rosae*) within its species range. The average RWQ score for the 10 sites containing *A. rosae* was 0.19 (Table 5), suggesting Cave Springs Cave is more threatened by water quality and quantity issues than the other Ozark cavefish sites assessed. Sediment (RWQS) may be an important threat for Ozark cavefish in general as the mean value for this index was higher than most of the other aquatic cave species assessed (Table 5). The most important component of threats from sediment for Ozark cavefish appear to come from RWQS 03 and RWQS 04 (both estimates of forested land) rather than other factors (Table 6 and Table 7).

Across northern Arkansas, karst areas with the highest vulnerabilities, as modeled by DRASTIK, occurred primarily in the western and eastern part of the state (Figure 50). As expected, vulnerabilities are also highest along the streams and rivers that drain the uplands. Sites with aquatic cave species that occurred in karst areas of high vulnerability, as modeled by DRASTIC, were typically characterized as highly vulnerable (Figure 51). Groundwater vulnerability is an estimate of how easy contaminants can enter groundwater systems. In some instances, locations (such as a sinking stream, cave, or spring) may be highly vulnerable but relatively well protected because the sites have few or no potential groundwater threats. Alternatively, sites may be highly vulnerable and have many threats. Intuitively, highly vulnerable sites with many threats should be more sensitive to groundwater degradation. This relationship was characterized using a Groundwater Sensitivity Index (SENS) which combined values generated from the groundwater vulnerability assessment with threat scores water quality and quantity threat indices (RWQ). Aquatic cave species sites with the highest groundwater sensitivities occurred mainly in northwest Arkansas (Figure 52). A similar pattern is observed overall when groundwater sensitivity is combined with threats due to visitation (Figure 53). Aquatic cave species that occur in sites found in northwest Arkansas and along the Interstate 540 corridor generally had higher overall threat scores relative to the rest of the state.

DISCUSSION

This project updated species range maps for 36 karst species listed in the Arkansas Wildlife Action Plan (AWAP). In addition, the project generated threat assessments for each of these species and for the 297 habitats were these species occur. Below, the results are briefly summarized relative to the objectives of the project.

Objective 1. To generate updated species range maps for each of the 36 Arkansas SGCN karst species occurring in the Ozark and Boston Mountains Ecorgions. These species maps will be derived from TNC's karst database, which integrates a variety of data sources beyond those of the Arkansas Natural Heritage database.

Range maps were produce for each of the 36 species. For terrestrial and aquatic cave species, maps were produced using sub-watersheds (HUC 12). For each species, a sub-watershed contained a minimum of 1 population. Other suitable habitats within identified sub-watersheds have a high probability of containing additional populations. For bat species, range maps were produced by buffering known locations with a 5 mile radius. Other suitable habitats within the buffers have a high probability of containing additional populations.

Objective 2. To assess the current status of threats to each of these 36 species.

Threat assessments were generated for each of the 36 species and each of the 297 sites were the species occurred. Tables and appendices provide details and summaries of the threat assessments.

Objective 3. To produce a conservation implementation priorities list based on the species distribution maps and threats.

The 36 species were characterized as part of an aquatic, terrestrial, or bat community, and threats were assessed accordingly. Therefore conservation implementation priorities can be set within each of these three groups, for a group of sites or species, or for a single site or species. Tables and appendices provide details and summaries of the threat assessments and are ranked according to highest overall threat.

Objective 4. To create the first Ozark Karst Habitat Map, a critical step toward future predictive mapping efforts for karst species.

The groundwater vulnerability map, generated by the model DRASTIK, provides a first attempt at developing an Arkansas Ozark Karst Habitat Map (Figure 50). The model was heavily weighted for karst landscapes including characteristics such as permeability of various carboniferous rock units, presence of faults, and density of photo lineaments. These characteristics are expressions of the solutional nature of karst and correlate well with known subterranean habitats such as caves and springs. It is likely that areas identified as highly vulnerable on Figure 50 are places where additional populations of these karst species may be found. However, conducting biological inventories of additional habitats in Arkansas will be necessary to validate this hypothesis.

Objective 5. To identify species-habitat affinities by comparing the species ranges to the karst habitat map.

Because our groundwater vulnerability map was only a preliminary attempt to develop an Arkansas Ozark Karst Habitat Map, exploring species-habitat affinities was not explored. However, a few observations can be made relative to the distribution of karst species included in this project. Figure 44, Figure 47, and Figure 53 not only identify overall threats associated with karst species. In addition, the distribution of points on these maps identifies places within the study area where focused biological inventory of caves, springs, and other subterranean habitats may yield new populations of karst species. For example, Figure 53 identifies two large areas where little biological inventory has been focused: 1.) north central Arkansas from Highway 65 west to Mountain Home north of Highway 412 and 2.) nearly all of northeast Arkansas. Several species such as the cave isopod, *C. salemensis*, and the Southern cavefish, *T. subterraneus*, are rare in Arkansas and occur near or within these large un-inventoried areas. The rarity of these species in the state may be due to lack of sampling rather than inherent geographical rarity.

Table 5. Mean index scores for threats associated with aquatic cave species, ordered in decreasing values of overall threat (THREAT). See Appendix A for definitions of threat variables.

Aquatic Cave Species	No. sites	RWQS	RWQN	RWQP	RWQH	RWQ	VULN	SENS	RVIP	RVIA	RVIX	RVI	THREAT
Typhlichthys subterraneus	2	0.61	0.51	0.50	0.50	0.52	0.78	0.52	0.54	0.83	0.97	0.75	0.63
Dendrocoelopsis americana	4	0.53	0.37	0.27	0.25	0.33	0.79	0.40	0.53	0.66	0.95	0.68	0.53
Amblyopsis rosae	10	0.40	0.21	0.12	0.13	0.19	0.78	0.29	0.55	0.76	0.95	0.72	0.49
Cambarus aculabrum	4	0.44	0.32	0.09	0.17	0.23	0.73	0.29	0.47	0.72	0.94	0.68	0.47
Caecidotea macropropoda	4	0.37	0.10	0.07	0.01	0.11	0.75	0.21	0.46	0.61	0.94	0.63	0.41
Caecidotea ancyla	16	0.41	0.24	0.14	0.17	0.22	0.72	0.26	0.24	0.54	0.92	0.52	0.38
Caecidotea salemensis	1	0.38	0.10	0.00	0.00	0.09	1.00	0.38	0.05	0.36	0.97	0.40	0.37
Caecidotea stiladactyla	34	0.36	0.19	0.15	0.15	0.19	0.68	0.22	0.31	0.58	0.88	0.54	0.37
Stygobromus ozarkensis	21	0.31	0.17	0.10	0.13	0.15	0.68	0.20	0.24	0.56	0.89	0.52	0.34
Bactrurus pseudomucronatus	2	0.35	0.09	0.00	0.00	0.08	0.92	0.32	0.07	0.39	0.87	0.39	0.33
Eurycea spelaea	112	0.34	0.19	0.16	0.16	0.19	0.70	0.23	0.22	0.51	0.82	0.46	0.33
Caecidotea steevesi	5	0.28	0.06	0.01	0.01	0.06	0.63	0.10	0.19	0.55	0.95	0.52	0.29
Cambarus setosus	3	0.20	0.03	0.00	0.00	0.03	0.77	0.17	0.16	0.50	0.64	0.37	0.25
Cambarus zophonastes	3	0.32	0.15	0.02	0.05	0.11	0.66	0.15	0.07	0.40	0.79	0.36	0.24
Lirceus bidentatus	1	0.21	0.07	0.00	0.00	0.04	0.53	0.02	0.17	0.46	0.94	0.47	0.23
Caecidotea dimorpha	7	0.25	0.04	0.00	0.00	0.05	0.69	0.13	0.04	0.38	0.85	0.36	0.23
Lirceus bicuspidatus	4	0.18	0.08	0.01	0.02	0.05	0.65	0.10	0.07	0.36	0.80	0.35	0.20
Amnicola cora	1	0.15	0.05	0.01	0.00	0.02	0.55	0.02	0.13	0.41	0.82	0.39	0.19

Table 6. Mean index scores for sediment (RWQS) and nutrient (RWQN) threats associated with aquatic cave species, ordered in decreasing values of overall threat (THREAT). See Appendix A for definitions of threat variables.

Aquatic Cave	No.	RWQS				RWQN						
Species	sites	01	02	03	04	01	02	03	04	05	RWQ	THREAT
Typhlichthys subterraneus	2	0.51	0.56	0.98	0.58	0.51	0.50	0.50	0.50	0.54	0.52	0.63
Dendrocoelopsis americana	4	0.30	0.52	0.96	0.58	0.42	0.30	0.25	0.28	0.59	0.33	0.53
Amblyopsis rosae	10	0.17	0.32	0.91	0.50	0.20	0.16	0.00	0.22	0.44	0.19	0.49
Cambarus aculabrum	4	0.53	0.38	0.65	0.47	0.37	0.48	0.00	0.28	0.45	0.23	0.47
Caecidotea macropropoda	4	0.03	0.24	0.97	0.57	0.05	0.00	0.00	0.03	0.43	0.11	0.41
Caecidotea ancyla	16	0.27	0.39	0.84	0.42	0.30	0.21	0.13	0.19	0.40	0.22	0.38
Caecidotea salemensis	1	0.04	0.46	0.98	0.36	0.03	0.00	0.00	0.02	0.43	0.09	0.37
Caecidotea stiladactyla	34	0.18	0.31	0.90	0.37	0.20	0.15	0.12	0.17	0.32	0.19	0.37
Stygobromus ozarkensis	21	0.24	0.28	0.77	0.31	0.22	0.17	0.05	0.18	0.24	0.15	0.34
Bactrurus pseudomucronatus	2	0.04	0.38	0.97	0.33	0.02	0.00	0.00	0.02	0.42	0.08	0.33
Eurycea spelaea	112	0.21	0.33	0.87	0.29	0.22	0.16	0.14	0.18	0.26	0.19	0.33
Caecidotea steevesi	5	0.06	0.30	0.90	0.23	0.12	0.03	0.00	0.03	0.14	0.06	0.29
Cambarus setosus	3	0.01	0.10	0.97	0.10	0.01	0.00	0.00	0.01	0.11	0.03	0.25
Cambarus zophonastes	3	0.21	0.32	0.79	0.32	0.36	0.03	0.01	0.08	0.25	0.11	0.24
Lirceus bidentatus	1	0.03	0.09	0.87	0.25	0.08	0.00	0.00	0.04	0.23	0.04	0.23
Caecidotea dimorpha	7	0.03	0.26	0.93	0.17	0.01	0.01	0.00	0.01	0.19	0.05	0.23
Lirceus bicuspidatus	4	0.09	0.15	0.79	0.12	0.27	0.01	0.00	0.04	0.10	0.05	0.20
Amnicola cora	1	0.03	0.08	0.82	0.07	0.15	0.00	0.00	0.02	0.09	0.02	0.19

Table 7. Mean index scores for pollutant (RWQP) and hydrologic alteration (RWQH) threats associated with aquatic cave species, ordered in decreasing values of overall threat (THREAT). See Appendix A for definitions of threat variables.

Aquatic Cave Species	No. sites	RWQP 01	RWQP 02	RWQP 03	RWQP 04	RWQP 05	RWQH 01	RWQH 02	RWQ	THREAT
Typhlichthys subterraneus	2	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.52	0.63
Dendrocoelopsis americana	4	0.25	0.25	0.26	0.26	0.30	0.26	0.25	0.33	0.53
Amblyopsis rosae	10	0.14	0.17	0.12	0.12	0.06	0.14	0.11	0.19	0.49
Cambarus aculabrum	4	0.03	0.09	0.12	0.09	0.11	0.17	0.17	0.23	0.47
Caecidotea macropropoda	4	0.00	0.00	0.07	0.03	0.25	0.02	0.00	0.11	0.41
Caecidotea ancyla	16	0.13	0.13	0.17	0.13	0.13	0.18	0.16	0.22	0.38
Caecidotea salemensis	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.37
Caecidotea stiladactyla	34	0.15	0.14	0.16	0.15	0.14	0.16	0.15	0.19	0.37
Stygobromus ozarkensis	21	0.10	0.09	0.13	0.11	0.08	0.14	0.12	0.15	0.34
Bactrurus pseudomucronatus	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.33
Eurycea spelaea	112	0.15	0.15	0.16	0.16	0.16	0.16	0.15	0.19	0.33
Caecidotea steevesi	5	0.00	0.00	0.01	0.01	0.02	0.02	0.00	0.06	0.29
Cambarus setosus	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.25
Cambarus zophonastes	3	0.01	0.01	0.07	0.02	0.02	0.08	0.03	0.11	0.24
Lirceus bidentatus	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.23
Caecidotea dimorpha	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.23
Lirceus bicuspidatus	4	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.05	0.20
Amnicola cora	1	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.02	0.19

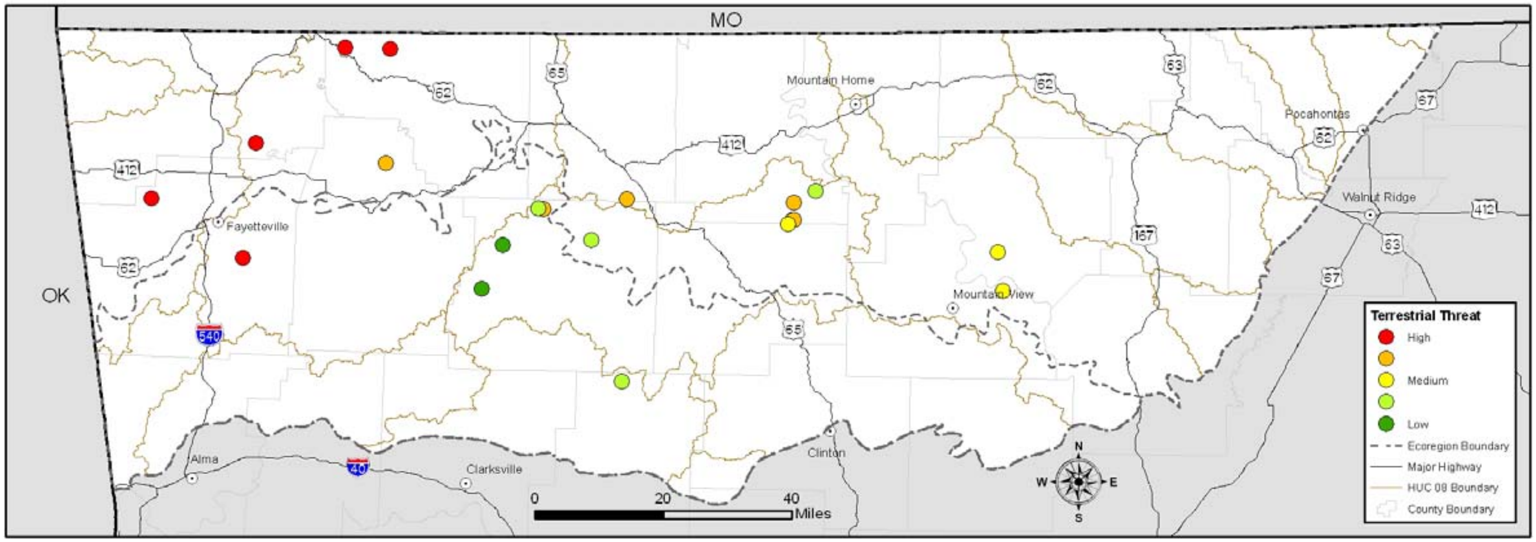

Figure 44. Threat score for sites occupied only by terrestrial cave species. Sites containing terrestrial cave species as well as bat species or aquatic cave species were included within bat community assessment or aquatic community assessments.

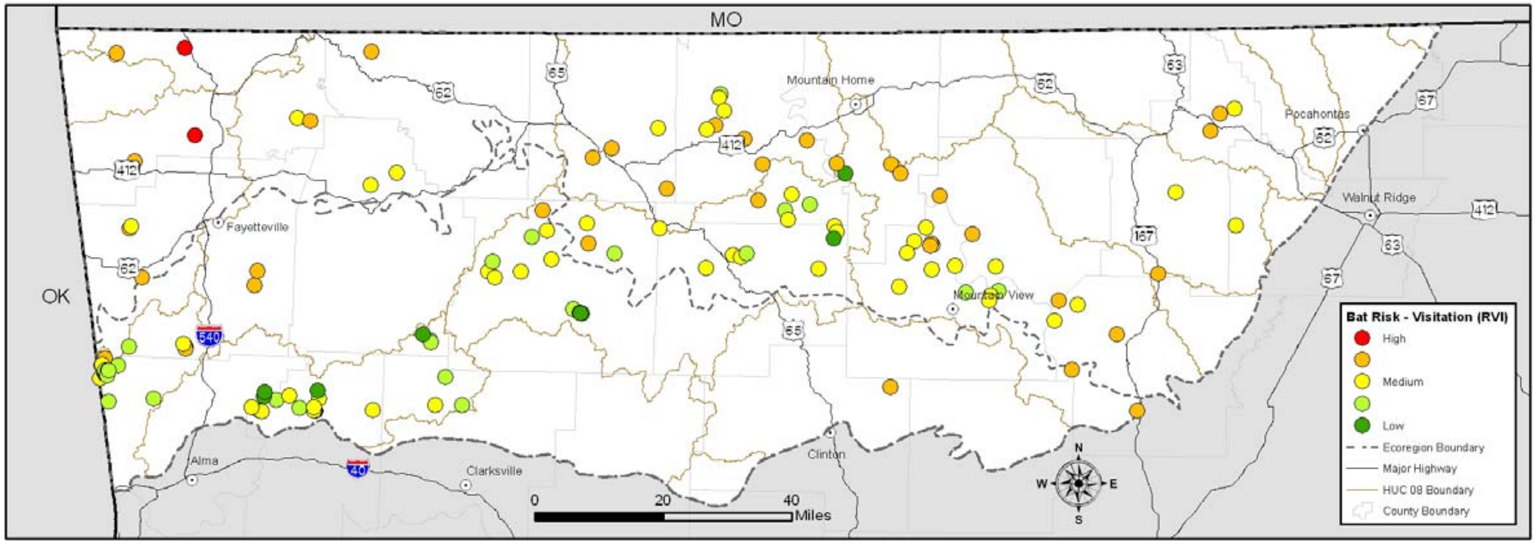

Figure 45. Threat scores generated from visitation indices (RVI) for sites occupied by bat species.

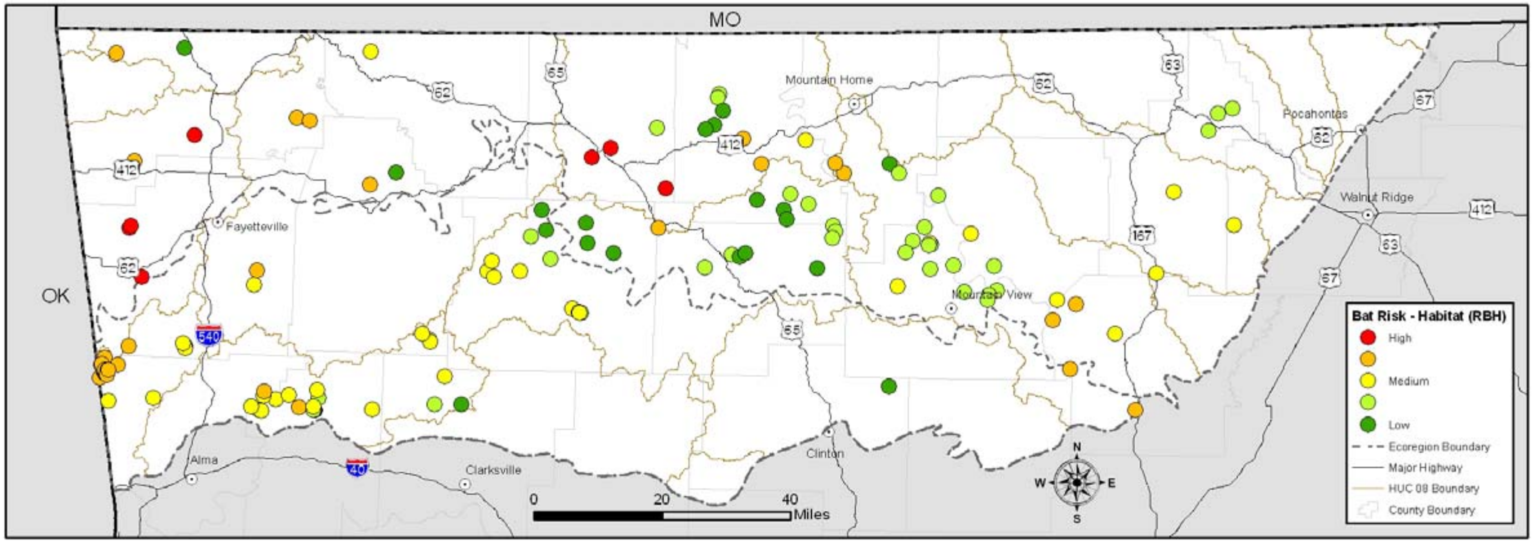

Figure 46. Threat scores generated from foraging habitat indices (RBH) for sites occupied by bat species.

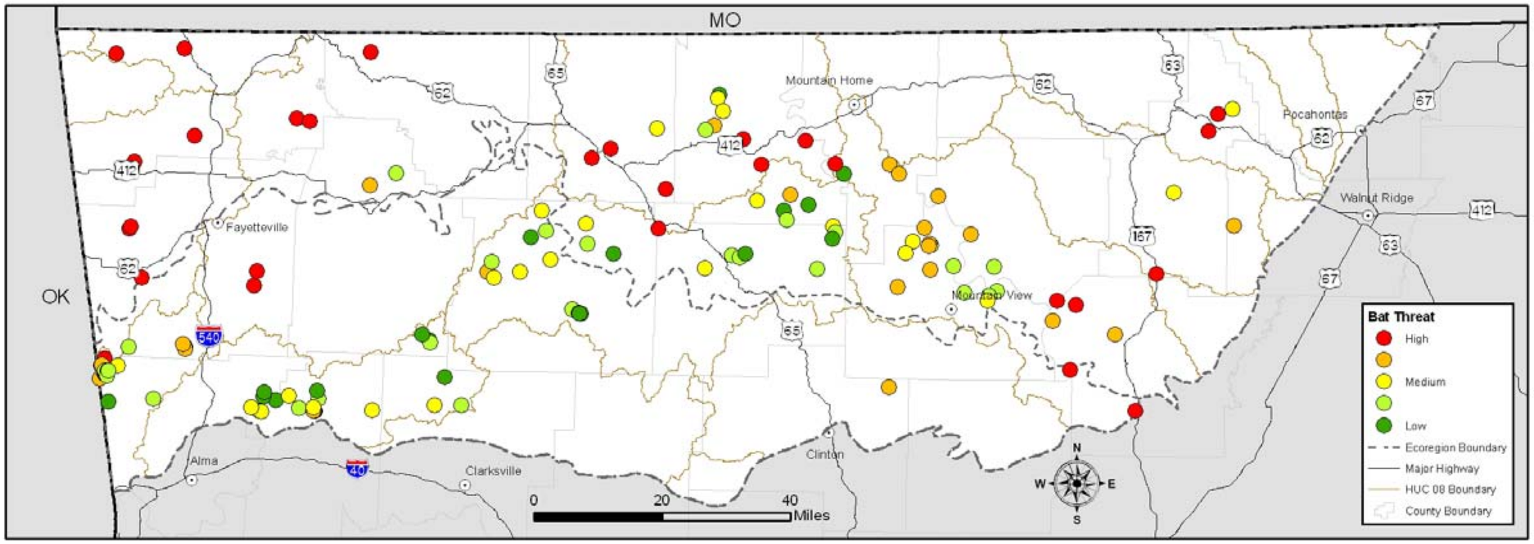

Figure 47. Overall threat scores for sites occupied by bat species. Scores were generated by combining values from visitation indices (RVI) and foraging habitat indices (RBH).

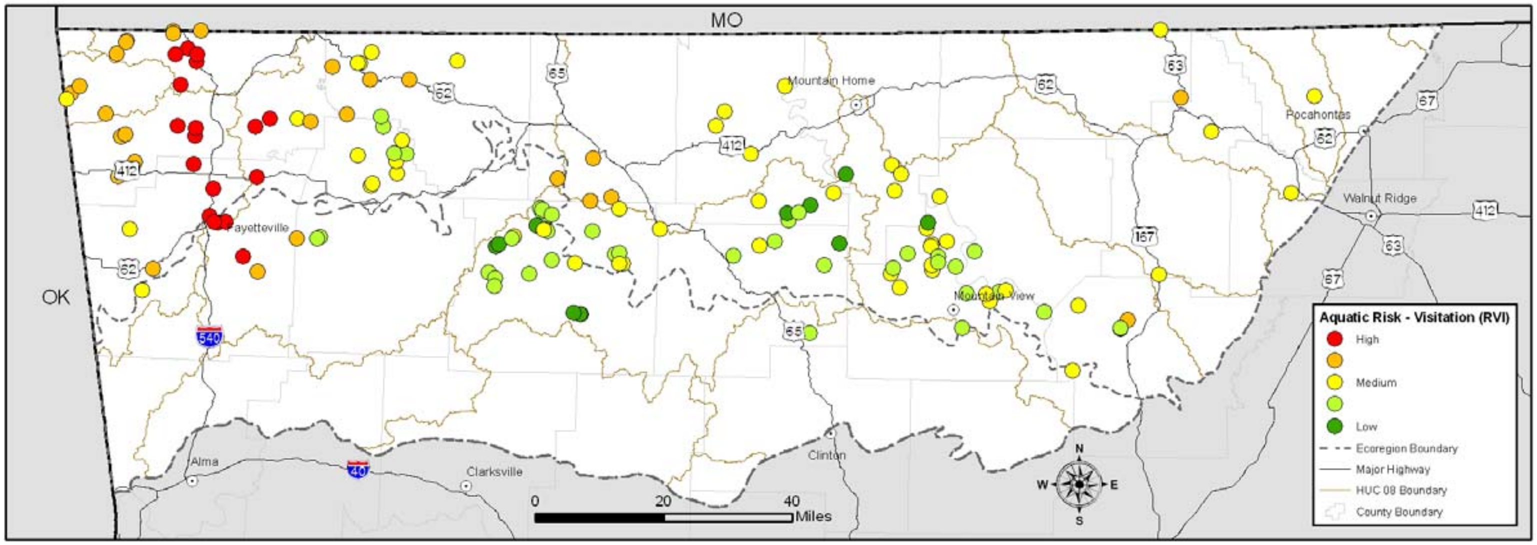

Figure 48. Threat scores generated from visitation indices (RVI) for sites occupied by aquatic cave species.

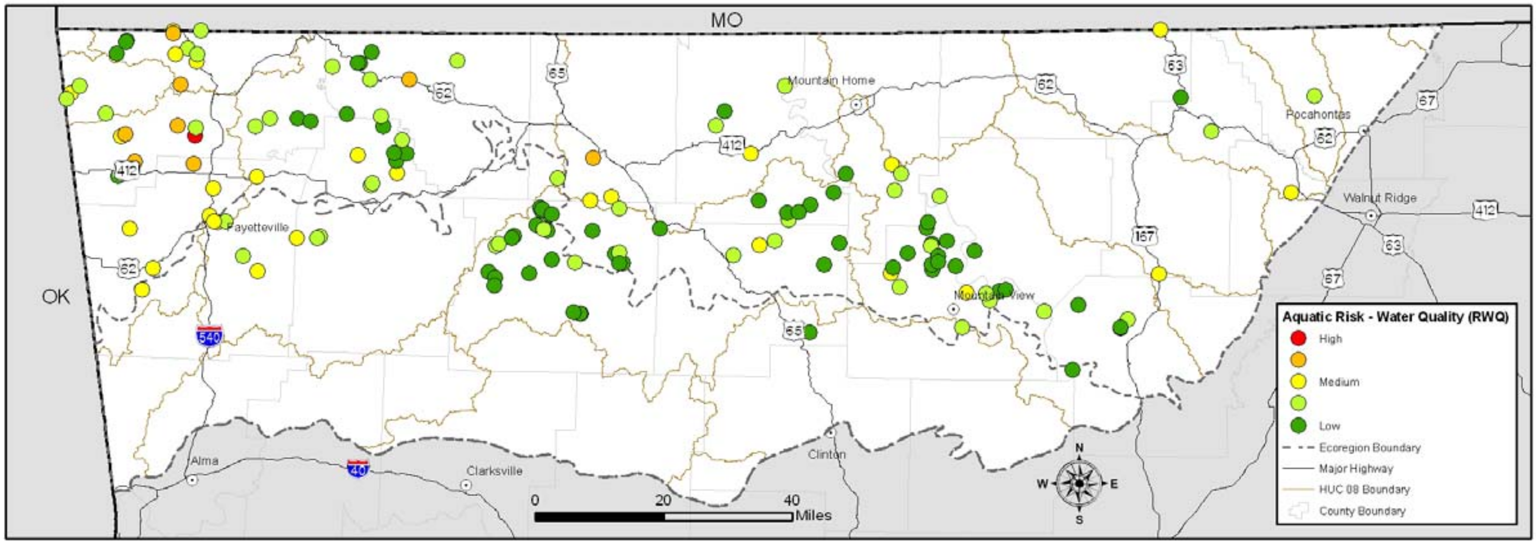

Figure 49. Threat scores generated from water quality and quantity indices (RWQ) for sites occupied by aquatic cave species.

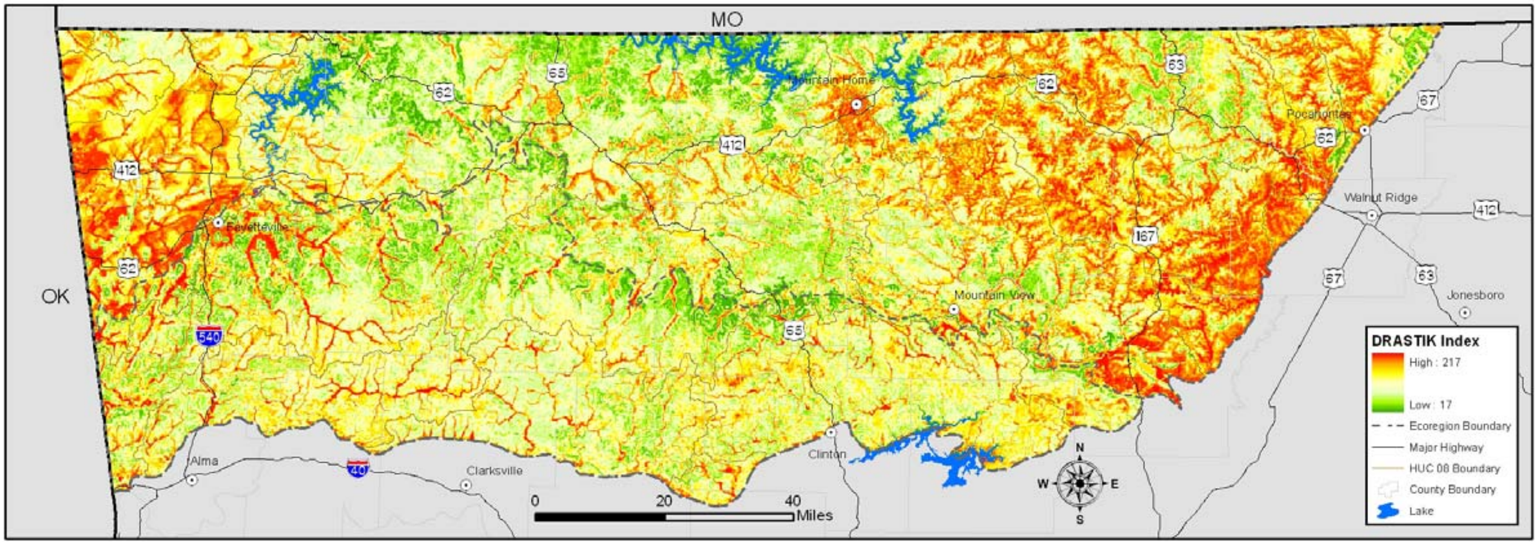

Figure 50. Groundwater vulnerability map, as modeled by DRASTIK, for northern Arkansas.

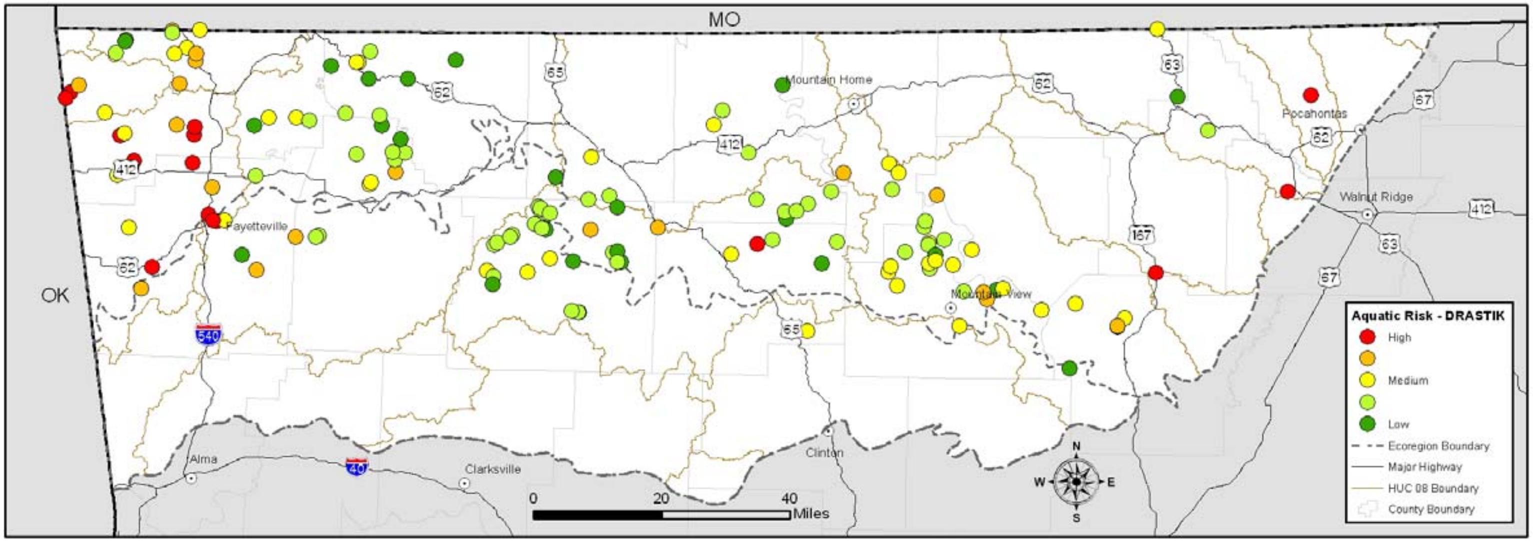

Figure 51. Groundwater vulnerability estimates were generated from the model DRASTIK for each site that contained aquatic cave species.

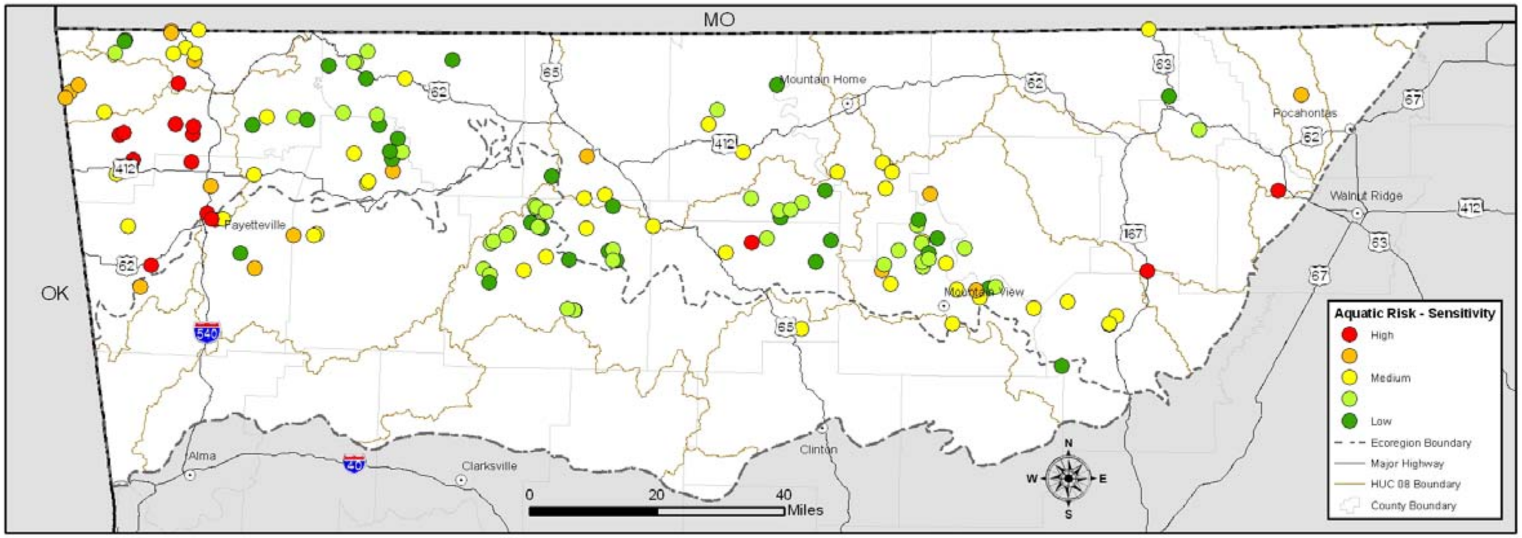

Figure 52. Groundwater sensitivity scores were generated by combining groundwater vulnerability (VULN) and RWQ values for each site that contained aquatic cave species.

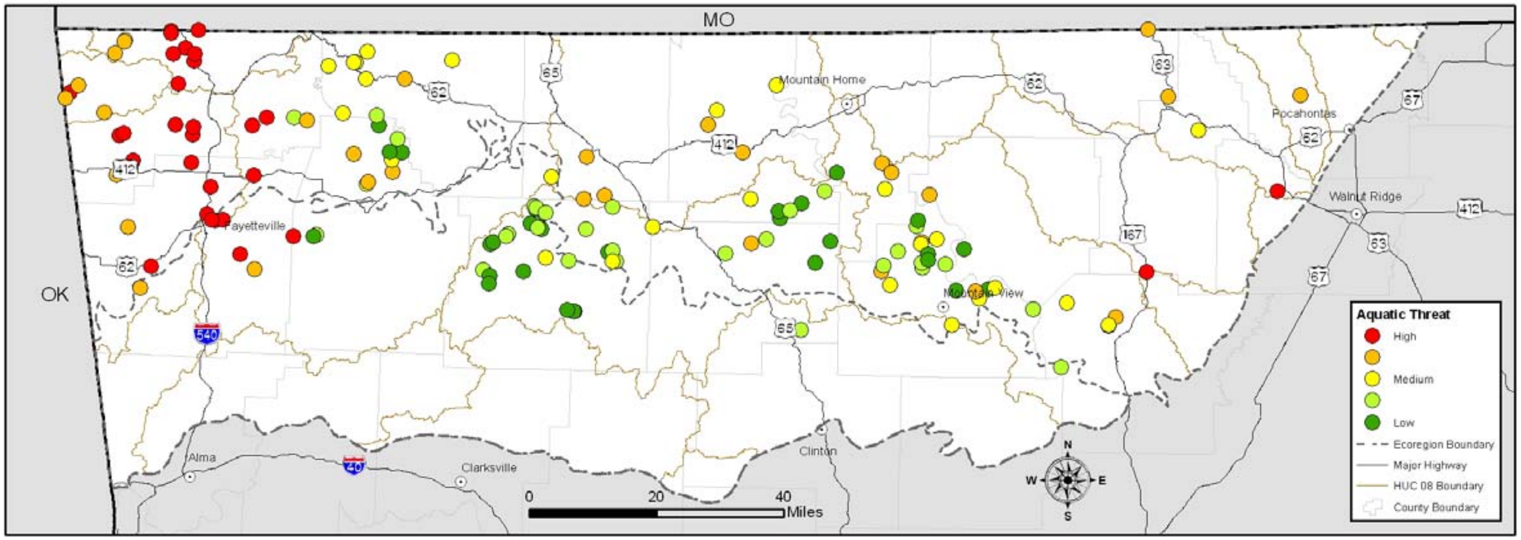

Figure 53. Overall threat scores for sites occupied by aquatic cave species. Scores were generated by combining groundwater sensitivity (SENS) and visitation (RVI) values.

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APPENDIX A. Descriptions of risk index variables and calculations.

MODEL: Risk: Visitation (RVI)

SUB-MODEL: Population (RVIP)

Index: RVIP_01
Name: Population (Count)
Assessment Area (AA): 10-mile radius from site.
Raw Score: The human population within the AA.
Highest Scaled Score: The site with the lowest human population within its AA (inverted).
Data Sources: US Census Bureau 2000 Census.
Notes: Used population count (chronic) for census block points occurring within the AA.

SUB-MODEL: Access (RVIA)

Index: RVIA_01
Name: Road Access
Assessment Area (AA): 10-mile radius from site.
Raw Score: The length of all roads in the AA
Highest Scaled Score: The site with the least amount of roads within its AA (inverted)
Data Sources: AHTD 2006 All Roads (AR), US Census TIGER 2010 Roads (OK), MoDOT 2006 Roads (MO).
Notes: Although all sites are within Arkansas, some areas within a 10-mile radius occurred within Oklahoma and Missouri. All road lines were rasterized to 30m cells for improved analysis efficiency. All road types were weighted equally.

SUB-MODEL: Proximity (RVIX)

Index: RVIX_01
Name: Road Proximity
Assessment Area (AA): Site.
Raw Score: The distance from the site to the nearest road in the AA
Highest Scaled Score: The site that is farthest from a road
Data Sources: AHTD 2006 All Roads
Notes: This index was not calculated for sites that were located based on centroids because proximity to the site location is inaccurate.

MODEL: Risk: Bat Habitat (RBH)

SUB-MODEL: Forest (RBHF)

Index: RBHF_01
Name: Forest Land Use (Percent)
Assessment Area (AA): 5-mile radius from site
Raw Score: The percent of the AA that has forest land use in the AA

Highest Scaled Score: The site with the highest percent of its AA in forest
Data Sources: CAST LULC Fall 2006 (AR), USEPA NLCD 2001 (MO, OK).
Notes:

Index: RBHF_02
Name: Forest Edge (Relative)
Assessment Area (AA): 5-mile radius from site
Raw Score: The number of forest edge cells in the AA
Highest Scaled Score: The site with the highest number of forest edge cells
Data Sources: CAST LULC Fall 2006 (AR), USEPA NLCD 2001 (MO, OK)
Notes: Forest edges were detected with a high-pass filter run on a binary forest land use raster. The raw value of the index is a count of edge cells.

SUB-MODEL: Riparian (RBHR)

Index: RBHR_01
Name: Riparian Forest (Area)
Assessment Area (AA): 5-mile radius from site
Raw Score: The total area of forest cells in the riparian zone in the AA
Highest Scaled Score: The site with the largest area of forest cells in the riparian zone
Data Sources: CAST LULC Fall 2006 (AR), USEPA NLCD 2001 (MO, OK), NHD High Resolution Flowlines
Notes: The riparian zone was defined by rasterizing the High Resolution NHD Flowline vector layer and cells within a 1 cell distance of a watercourse or water body were selected to define it. The raw value of the index is the calculated area of forest cells

Index: RBHR_02
Name: Riparian Forest (Percent)
Assessment Area (AA): 5-mile radius from site
Raw Score: The percent of the riparian zone in forest cells in the AA
Highest Scaled Score: The site with the largest area of forest cells in the riparian zone
Data Sources: CAST LULC Fall 2006 (AR), USEPA NLCD 2001 (MO, OK), NHD High Resolution Flowlines
Notes: The riparian zone was defined by rasterizing the High Resolution NHD Flowline vector layer and cells within a 1 cell distance of a watercourse or water body were selected to define it. The raw value of the index is the calculated area of forest cells within the AA.

MODEL: Risk: Water Quality (RWQ)

SUB-MODEL: Sediment (RWQS)

Index: RWQS_01
Name: Unpaved Road Length
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The total length of unpaved roads
Highest Scaled Score: The site with the shortest length of unpaved roads (inverted)

Data Sources: AHTD 2006 All Roads
Notes: Unpaved roads were summarized and their total length was calculated within the AA.

Index: RWQS_02
Name: Unpaved Road Density
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The density of unpaved roads
Highest Scaled Score: The site with the lowest density of unpaved roads (inverted)
Data Sources: AHTD 2006 All Roads
Notes: Unpaved roads were summarized and their total length was divided by the total area of the AA.

Index: RWQS_03
Name: Forest Land Use (Area)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The total area of forest cells
Highest Scaled Score: The site with the largest amount of forested area
Data Sources: AGIO / CAST LULC Fall 2006
Notes: The calculated area of forest cells within the AA.

Index: RWQS_04
Name: Forest Land Use (Percent)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The percent of the AA in forest cells
Highest Scaled Score: The site with the highest percent of forested area
Data Sources: AGIO / CAST LULC Fall 2006
Notes: The calculated area of forest cells within the AA divided by the total area of the AA.

SUB-MODEL: Nutrients (RWQN)

Index: RWQN_01
Name: Households (Density)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The density of households
Highest Scaled Score: The site with the lowest density of households (inverted)
Data Sources: US Census Bureau 2000 Census.
Notes: Used household count for census block points occurring within the AA. Only blocks outside of city limits were included as this was a surrogate measure of the number of septic systems. It was assumed that incorporated municipalities had managed wastewater facilities. Number of households per pixel was calculated by mathematical conversions and then the number of pixels was summed to get household density in each AA.

Index: RWQN_02
Name: CAFO (Chicken Houses Count)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The number of chicken houses

Highest Scaled Score: The site with the smallest number of chicken houses (inverted)
Data Sources: AHTD Chicken Houses
Notes: The total number of chicken houses within the AA.

Index: RWQN_03
Name: CAFO (Chicken Houses Density)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The density of chicken houses
Highest Scaled Score: The site with the lowest density of chicken houses (inverted)
Data Sources: AHTD Chicken Houses
Notes: The total number of chicken houses within the AA divided by the total area of the AA.

Index: RWQN_04
Name: Pasture Land Use (Area)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The total area of pasture cells
Highest Scaled Score: The site with the smallest amount of pasture area (inverted)
Data Sources: AGIO / CAST LULC Fall 2006
Notes: The calculated area of cool and warm season pasture cells within the AA.

Index: RWQN_05
Name: Pasture Land Use (Percent)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The percent of the AA in pasture cells
Highest Scaled Score: The site with the lowest percent of pasture area (inverted)
Data Sources: AGIO / CAST LULC Fall 2006
Notes: The calculated area of cool and warm season pasture cells within the AA divided by the total area of the AA.

SUB-MODEL: Pollutants (RWQP)

Index: RWQP_01
Name: Paved Roads (Weighted Length)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The total length of paved roads
Highest Scaled Score: The site with the shortest length of weighted paved roads (inverted)
Data Sources: AHTD 2006 All Roads
Notes: Paved roads were summarized and their total length was calculated within the AA. Some roads in the “Miscellaneous” class were included in this index including airport runways and service roads.
Weight: This index is a measure of spill potential along transportation corridors. Road types were weighted based on their traffic volume and road type with “Interstate” receiving the highest weight of 50 and “City” or “County” roads receiving the lowest weight of 1.

Index: RWQP_02
Name: Paved Roads (Weighted Density)

Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The density of weighted paved roads
Highest Scaled Score: The site with the shortest length of weighted paved roads (inverted)
Data Sources: AHTD 2006 All Roads
Notes: Weighted paved roads were summarized and their total length was calculated within the AA divided by the total area of the AA. Some roads in the "Miscellaneous" class were included in this index including airport runways and service roads.

Index: RWQP_03
Name: Population (Density)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The density of the human population within the AA.
Highest Scaled Score: The site with the lowest human population density within its AA (inverted)
Data Sources: US Census Bureau 2000 Census.
Notes: Used population count (chronic) for census block points occurring within the AA. Number of people per pixel was calculated by mathematical conversions and then the number of pixels was summed to get population density in each AA.

Index: RWQP_04
Name: Environmental Permitted Sites (Count)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The number of environmental permitted sites
Highest Scaled Score: The site with the smallest number of environmental permitted sites (inverted)
Data Sources: ADEQ Environmental Permitted Sites
Notes: The total number of environmental permitted sites within the AA.

Index: RWQP_05
Name: Environmental Permitted Sites (Density)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The density of environmental permitted sites
Highest Scaled Score: The site with the lowest density of environmental permitted sites (inverted)
Data Sources: ADEQ Environmental Permitted Sites
Notes: The total number of environmental permitted sites within the AA divided by the total area of the AA.

SUB-MODEL: Hydrologic Alteration (RWQH)

Index: RWQH_01
Name: Impervious Land Use (Area)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The area of impervious surfaces
Highest Scaled Score: The site with the smallest amount of impervious surfaces area (inverted)
Data Sources: AHTD 2006 All Roads, CAST LULC Fall 2006.

Notes: The calculated area of impervious cells within the AA. Impervious was defined as being either the “bare” or any of the “urban” classes from the Fall 2006 raster, merged with the paved roads from the AHTD roads layer used in the RWQP indices above.

Index: RWQH_02
Name: Impervious Land Use (Percent)
Assessment Area (AA): Dye-traced recharge area/NHD Plus Catchment area
Raw Score: The percent of the AA in impervious surfaces
Highest Scaled Score: The site with the smallest percent of impervious surfaces area (inverted)
Data Sources: AHTD 2006 All Roads, CAST LULC Fall 2006.
Notes: The calculated area of impervious cells within the AA divided by the total area of the AA. Impervious was defined as being either the “bare” or any of the “urban” classes from the Fall 2006 raster, merged with the paved roads from the AHTD roads layer used in the RWQP indices above.

APPENDIX B. DRASTIC Parameter ratings.

(D) Depth to Water Table	
Range (ft)	Rating
0	10
1 - 30	9
31 - 50	8
51 - 75	5
76 - 100	3
100+	1

(R) Recharge	
Range	Rating
0	0
1 -6	1
7 - 9	2
10 - 11	3
12 - 13	4
14 - 15	5
16 - 17	6
18 - 19	7
20 - 21	8
22 - 23	9
24 - 28	10

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PRISM (Rainfall in/yr)	
Range	Rating
42 - 45	1
46 - 47	2
48	3
49	4
50	5
51	6
52 - 53	7
54 - 56	8
57 - 59	9
60+	10

+

Ksat (Soil Permeability)	
Range	Rating
0.01 - 0.99	1
1 - 1.9	2
2 - 2.6	3
2.7 - 5.9	4
6 - 8.9	5
9 - 14	6
14.1 - 22.9	7
23 - 71.9	8
72 - 91.9	9
92+	10
0	10

+

(T) Topography (Percent Slope)	
Range	Rating
0 - 1	10
2 - 5	9
6 - 11	5
12 - 17	3
18 +	1

(A) Aquifer Media	
Range	Rating
Cretaceous rocks, Sand and clay	1
Chattanooga Shale (Lower Mississippian and Upper Devonian), Clifty Limestone (Middle Devonian), and Penters Chert (Lower Devonian), Moorefield Formation	4
Alluvium, Terrace deposits, Silt and sand, Wilcox Group	6
Atoka Formation, undivided, Bloyd Shale, and Prairie Grove Member of the Hale Formation, Pitkin Limestone, Fayetteville Shale (including the Wedington Sandstone member), and Batesville Sandstone (including the Hindsville Limestone Member)	7
Dune sand, Gravel	8
Boone Formation, Cason Shale and Fernvale Limestone (Upper Ordovician) and Kimmswick Limestone, Plattin Limestone, and Joachim Dolomite, Cotter and Jefferson City Dolomites, Lafferty, St. Clair and Brassfield Limestones, Powell Dolomite	10

(S) Soil Media

Range	Rating
Silty Clay	1
Silty Clay Loam	2
Silt Loam	4
Loam	5
Sandy Loam	6
Loamy Sand	7
Sand	8
Riverwash	9
Rock, Water	10

(T) Topography (Percent Slope)

Range	Rating
0 - 1	10
2 - 5	9
6 - 11	5
12 - 17	3
18 +	1

(I) Impact on Vadose Zone Media

Range	Rating
0	0
1 - 2	1
3 -4	2
5 - 6	3
7 - 8	4
9 - 10	5
11 - 12	6
13 - 14	7
15 -16	8
17 - 18	9
19 - 20	10

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Ksat (Soil Permeability)

Range	Rating
0.01 - 0.99	1
1 - 1.9	2
2 - 2.6	3
2.7 - 5.9	4
6 - 8.9	5
9 - 14	6
14.1 - 22.9	7
23 - 71.9	8
72 - 91.9	9
92+	10
0	10

+

(D) Depth to Water Table

Range (ft)	Rating (Dr)
0	10
1 - 30	9
31 - 50	8
51 - 75	5
76 - 100	3
100+	1

(K) Lineament Density	
Range (lineament/sq mi)	Rating
.01 - .26	1
.27 - .73	2
.74 - 1.16	3
1.17 - 1.60	4
1.61 - 2.04	5
2.05 - 2.50	6
2.51 - 3.03	7
3.04 - 3.67	8
3.68 - 4.66	9
4.67 - 7.40	10

APPENDIX C. Raw index values and scaled scores for components of the Visitation Risk Model for each terrestrial cave species population at each site. Scaled values are scaled from 0-1, with 1 being the score with the most ecological benefit. Threat scores discussed in the text are generated by subtracting scaled values from 1 (e.g. [1- (RVI Scaled)] equals overall threat from visitation). Descriptions of abbreviations used in this table can be found in Appendix A.

Species	Site	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	Assessment Area
Apochthonius diabolus										
	Devil's Den Cave	6,494	0.95	0.04	0.60	0.20	0.12	1.66	0.62	Bats
Apochthonius titanicus										
	Blanchard Springs Caverns	7,286	0.95	0.05	0.62	0.19	0.11	1.68	0.62	Aquatic
Crosbyella distincta										
	Fitton Cave	6,073	0.96	0.04	0.65	0.07	0.04	1.64	0.61	Aquatic
	Friday the 13th Cave	5,858	0.96	0.04	0.65	0.48	0.29	1.90	0.70	Aquatic
	Willis Cave	6,230	0.95	0.04	0.65	0.40	0.24	1.85	0.68	Aquatic
Crosbyella roeweri										
	Tom Danforth Cave	119,347		0.11	0.00	0.16	0.11	0.11	0.04	Terrestrial
Hesperochernes occidentalis										
	Cave Springs Cave	134,411	0.01	0.11	0.08	0.13	0.08	0.17	0.06	Aquatic
	Coon Cave	3,917	0.97	0.04	0.65	0.30	0.18	1.81	0.67	Aquatic
	Crane Cave	5,242	0.96	0.04	0.61	0.60	0.36	1.92	0.72	Bats
	Dodd Cave	6,278	0.95	0.04	0.62	0.15	0.09	1.66	0.62	Bats
	Earl's Cave	3,188	0.97	0.03	0.68	0.71	0.52	2.17	0.80	Terrestrial
	Fallout Cave	5,236	0.96	0.04	0.60	0.55	0.32	1.89	0.70	Bats
	Fincher Cave	75,017	0.45	0.08	0.36	0.05	0.03	0.83	0.31	Aquatic
	Fitton Spring Cave	6,924	0.95	0.04	0.64	0.30	0.18	1.77	0.65	Aquatic
	Forest Trail Pit	3,779	0.97	0.04	0.62	0.16	0.12	1.71	0.63	Terrestrial
	Granny Deen Cave	72,260	0.39	0.08	0.29	0.19	0.14	0.83	0.30	Terrestrial
	Len House Cave	3,188	0.97	0.03	0.68	0.71	0.52	2.17	0.80	Terrestrial
	Logan Cave	31,431	0.77	0.07	0.43	0.16	0.10	1.29	0.48	Aquatic

Species	Site	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	Assessment Area
	Major's Cave	26,637	0.80	0.06	0.49	0.03	0.02	1.32	0.48	Aquatic
	Mansell Cave	12,955	0.90	0.05	0.58	0.38	0.23	1.72	0.63	Aquatic
	Norfork Bat Cave	11,297	0.92	0.06	0.52	0.09	0.05	1.49	0.55	Aquatic
	Summer Cave	3,083	0.98	0.04	0.66	0.82	0.49	2.13	0.79	Aquatic
	Summit Cave	12,554	0.91	0.05	0.51	0.23	0.13	1.55	0.58	Bats
	Van Dyke Spring Cave	6,364	0.95	0.04	0.64	0.46	0.28	1.87	0.69	Aquatic
	Walnut Cave	6,326	0.95	0.04	0.61	0.02	0.01	1.56	0.58	Terrestrial
Pseudosinella dubia										
	Devil's Den Cave	6,494	0.95	0.04	0.60	0.20	0.12	1.66	0.62	Bats
	Granny Deen Cave	72,260	0.39	0.08	0.29	0.19	0.14	0.83	0.30	Terrestrial
Pseudosinella testa										
	Fincher Cave	75,017	0.45	0.08	0.36	0.05	0.03	0.83	0.31	Aquatic
Pygmarrhopalites clarus										
	Big Bear Cave	6,212	0.95	0.04	0.58	0.77	0.57	2.10	0.77	Terrestrial
	Big Hole Cave	19,234	0.84	0.05	0.50	0.29	0.21	1.55	0.57	Terrestrial
	Blanchard Springs Caverns	7,286	0.95	0.05	0.62	0.19	0.11	1.68	0.62	Aquatic
	Bonanza Cave	10,630	0.92	0.05	0.57	1.38	0.82	2.31	0.85	Aquatic
	Brewer Cave									Aquatic
	Cave Mountain Cave	2,347	0.98	0.03	0.74	0.05	0.03	1.76	0.65	Aquatic
	Cave Spring Cave	18,469	0.86	0.05	0.57	0.30	0.18	1.61	0.60	Bats
	Diamond Cave	4,922	0.96	0.04	0.68	0.19	0.11	1.76	0.65	Aquatic
	Earl's Cave	3,188	0.97	0.03	0.68	0.71	0.52	2.17	0.80	Terrestrial
	Eckel Cave	9,824	0.93	0.07	0.42	0.27	0.16	1.51	0.56	Aquatic
	Fitton Cave	6,073	0.96	0.04	0.65	0.07	0.04	1.64	0.61	Aquatic
	Granny Deen Cave	72,260	0.39	0.08	0.29	0.19	0.14	0.83	0.30	Terrestrial
	Huckleberry Point Cave	16,976	0.86	0.06	0.43	0.21	0.16	1.44	0.53	Terrestrial
	Hurricane River Cave	5,913	0.96	0.04	0.66	0.06	0.03	1.65	0.61	Aquatic

Species	Site	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	Assessment Area
	John Eddings Cave	5,692	0.96	0.04	0.64	0.69	0.41	2.01	0.74	Aquatic
	Len House Cave	3,188	0.97	0.03	0.68	0.71	0.52	2.17	0.80	Terrestrial
	Lewis Spring Cave									Aquatic
	Mr. Clean Cave	7,491	0.94	0.05	0.61	0.52	0.31	1.87	0.69	Aquatic
	Rootville Cave	17,093	0.87	0.06	0.49	0.01	0.01	1.37	0.51	Aquatic
	Sherfield Cave	2,556	0.98	0.03	0.75	0.13	0.08	1.81	0.67	Aquatic
	Sunk Bluff Cave	585	1.00	0.02	0.78	0.53	0.39	2.17	0.80	Terrestrial
	Walnut Cave	6,326	0.95	0.04	0.61	0.02	0.01	1.56	0.58	Terrestrial
	Whippoorwill Cave	6,932	0.95	0.05	0.59	0.00	0.00	1.54	0.57	Aquatic
	Womack Spring Cave	7,686	0.94	0.05	0.54	0.05	0.04	1.52	0.56	Terrestrial
	Wounded Knee Cave	5,072	0.96	0.05	0.59	0.55	0.33	1.88	0.69	Aquatic
Rhadine ozarkensis										
	Fincher Cave	75,017	0.45	0.08	0.36	0.05	0.03	0.83	0.31	Aquatic
Trigenotyla parca										
	Blue Spring	13,731	0.88	0.06	0.44	0.11	0.08	1.41	0.52	Terrestrial
	Cave Mountain Cave	2,347	0.98	0.03	0.74	0.05	0.03	1.76	0.65	Aquatic
	Devil's Den Cave	6,494	0.95	0.04	0.60	0.20	0.12	1.66	0.62	Bats
	Granny Deen Cave	72,260	0.39	0.08	0.29	0.19	0.14	0.83	0.30	Terrestrial
	Len House Cave	3,188	0.97	0.03	0.68	0.71	0.52	2.17	0.80	Terrestrial
	Logan Cave	31,431	0.77	0.07	0.43	0.16	0.10	1.29	0.48	Aquatic
Typhlogastrura fousheensis										
	Foushee Cave	17,478	0.87	0.05	0.59	0.31	0.18	1.64	0.61	Aquatic

APPENDIX D. Raw index values and scaled scores for components of the Visitation Risk Model, Bat Habitat Risk Model, and overall Bat Community Threat Model for each bat species population at each site. Scaled values are scaled from 0-1, with 1 being the score with the most ecological benefit. Threat scores discussed in the text are generated by subtracting scaled values from 1 (e.g. [1-(RVI Scaled)] equals overall threat from visitation). Descriptions of abbreviations used in these tables can be found in Appendix A.

Table Appendix D-1. Index values and scaled scores for RBHF_01 Raw through RBHR_01 Scaled.

Species	Site	RBHF_01 Raw	RBHF_01 Scaled	RBHF_02 Raw	RBHF_02 Scaled	RBHF Raw	RBHF Scaled	RBHR_01 Raw	RBHR_01 Scaled
Corynorhinus townsendii ingens									
	AACS # CW2307	0.88	0.90	16174	0.31	1.21	0.79	18793	0.60
	AACS # CW2318	0.81	0.83	20724	0.40	1.23	0.80	17791	0.57
	AACS # CW2337	0.88	0.90	15992	0.31	1.21	0.78	18704	0.60
	AACS # CW2339	0.88	0.90	15765	0.30	1.20	0.78	18077	0.58
	AACS # CW2365	0.88	0.90	15919	0.31	1.21	0.78	18649	0.60
	AACS # CW2367	0.88	0.90	16355	0.32	1.22	0.79	18792	0.60
	AACS # CW2385	0.83	0.86	20063	0.39	1.24	0.81	18287	0.58
	AACS # CW23BT1	0.88	0.90	15757	0.30	1.21	0.78	18896	0.60
	AACS # CW29BT2	0.95	0.98	7084	0.14	1.11	0.72	22859	0.73
	AACS # CW29BT3	0.95	0.97	7528	0.15	1.12	0.72	20836	0.67
	AACS # FR17BT1a	0.89	0.92	12108	0.23	1.15	0.75	24792	0.79
	AACS # FR17BT1b	0.89	0.92	12656	0.24	1.16	0.75	23420	0.75
	AACS # FR17BT1g	0.89	0.91	12182	0.23	1.15	0.75	24895	0.79
	AACS # FR17BT1h	0.89	0.91	12119	0.23	1.15	0.74	24800	0.79
	AACS # FR19BT1a	0.92	0.95	9787	0.19	1.14	0.74	24876	0.79
	AACS # FR28BT2a,b	0.97	1.00	3461	0.07	1.07	0.69	23534	0.75
	Bassett Cave	0.77	0.79	28591	0.55	1.35	0.87	20071	0.64
	Bat Cave	0.90	0.93	13522	0.26	1.19	0.77	28421	0.91
	Big-eared Bat Crevice	0.90	0.92	14327	0.28	1.20	0.78	20804	0.66
	Blue Heaven Cave	0.72	0.74	36278	0.70	1.44	0.93	23232	0.74
	Bradley Shelter	0.41	0.42	34617	0.67	1.08	0.70	14909	0.48

Species	Site	RBHF_01 Raw	RBHF_01 Scaled	RBHF_02 Raw	RBHF_02 Scaled	RBHF Raw	RBHF Scaled	RBHR_01 Raw	RBHR_01 Scaled
	Brown Cave	0.70	0.72	39302	0.76	1.47	0.96	22652	0.72
	Charley One Ridge Cave	0.78	0.80	29218	0.56	1.37	0.89	22824	0.73
	Coon Cave	0.93	0.96	12345	0.24	1.19	0.77	28775	0.92
	CW11BT1	0.87	0.89	16917	0.33	1.22	0.79	21993	0.70
	Delap Cave	0.44	0.45	37702	0.73	1.18	0.76	11405	0.36
	Devil's Den Cave	0.90	0.92	13748	0.26	1.19	0.77	22278	0.71
	Devil's Icebox Cave	0.90	0.92	14371	0.28	1.20	0.78	22411	0.72
	Elm Cave	0.77	0.79	25996	0.50	1.29	0.84	29159	0.93
	FR17BT2	0.93	0.95	7829	0.15	1.11	0.72	22556	0.72
	Garrett Hollow Cave	0.85	0.87	17231	0.33	1.21	0.78	18772	0.60
	Goard Cave	0.62	0.63	40374	0.78	1.41	0.92	18813	0.60
	Hewlitt / Ezel Cave(s)	0.42	0.43	33222	0.64	1.07	0.69	15706	0.50
	Imp's Leap Crevice	0.90	0.93	13459	0.26	1.19	0.77	22404	0.72
	Marble Falls Cave	0.78	0.80	29276	0.56	1.37	0.89	21962	0.70
	Mitchell Cave	0.65	0.67	39491	0.76	1.43	0.93	26859	0.86
	Morning Star Mine # 15	0.86	0.88	17037	0.33	1.21	0.78	27369	0.87
	Reed Cave	0.80	0.82	28858	0.56	1.37	0.89	25034	0.80
	Summit Cave	0.67	0.69	36805	0.71	1.40	0.91	19140	0.61
	Switchback Cave	0.71	0.73	35960	0.69	1.42	0.92	25510	0.81
	WA5201	0.44	0.45	37702	0.73	1.18	0.76	11405	0.36
	Yellow Rock Crevice	0.89	0.91	15510	0.30	1.21	0.78	22197	0.71
Myotis grisescens									
	AACS # FR17BT1c	0.89	0.92	12058	0.23	1.15	0.75	25642	0.82
	AACS # FR17BT1h	0.89	0.91	12119	0.23	1.15	0.74	24800	0.79
	Back o' Beyond Cave	0.68	0.70	37756	0.73	1.42	0.92	23532	0.75
	Bald Scrappy Cave	0.89	0.92	16850	0.32	1.24	0.80	24016	0.77
	Bennett Cave	0.79	0.81	27419	0.53	1.33	0.86	19538	0.62

Species	Site	RBHF_01 Raw	RBHF_01 Scaled	RBHF_02 Raw	RBHF_02 Scaled	RBHF Raw	RBHF Scaled	RBHR_01 Raw	RBHR_01 Scaled
	Bergren Cave	0.71	0.73	33827	0.65	1.38	0.90	20699	0.66
	Big Creek Cave	0.74	0.76	35437	0.68	1.44	0.93	24434	0.78
	Blagg Cave	0.74	0.75	29535	0.57	1.32	0.86	23219	0.74
	Blanchard Springs Caverns	0.90	0.92	16612	0.32	1.24	0.80	24033	0.77
	Blue Heaven Cave	0.72	0.74	36278	0.70	1.44	0.93	23232	0.74
	Bonanza Cave	0.83	0.85	19781	0.38	1.23	0.80	20760	0.66
	Bone Cave	0.59	0.60	38647	0.74	1.35	0.87	25200	0.80
	Brewer Cave	0.29	0.30	49773	0.96	1.26	0.82	10179	0.32
	Cave Mountain Cave	0.89	0.91	13793	0.27	1.17	0.76	23276	0.74
	Cave River Cave	0.85	0.88	21281	0.41	1.29	0.83	23461	0.75
	Cave Spring Cave	0.68	0.69	32377	0.62	1.32	0.85	20784	0.66
	Cave Springs Cave	0.21	0.22	45446	0.88	1.09	0.71	9495	0.30
	Corkscrew Cave	0.87	0.90	17655	0.34	1.24	0.80	27179	0.87
	Crane Cave	0.69	0.71	35971	0.69	1.41	0.91	24935	0.80
	Crystal Cave	0.63	0.65	46390	0.89	1.54	1.00	24295	0.78
	Crystal River Cave	0.60	0.62	44615	0.86	1.48	0.96	18374	0.59
	Denny Cave	0.65	0.67	39491	0.76	1.43	0.93	26859	0.86
	Devil's Den Cave	0.90	0.92	13748	0.26	1.19	0.77	22278	0.71
	Diamond Cave	0.85	0.87	22233	0.43	1.30	0.84	24589	0.78
	Dodd Cave	0.66	0.68	30733	0.59	1.27	0.82	21053	0.67
	Eckel Cave	0.84	0.86	21918	0.42	1.28	0.83	24277	0.77
	Elm Cave	0.77	0.79	25996	0.50	1.29	0.84	29159	0.93
	Fallout Cave	0.69	0.71	37511	0.72	1.43	0.93	24908	0.80
	Fitton Cave	0.83	0.85	22077	0.43	1.28	0.83	25547	0.82
	Flea Cave	0.82	0.84	23795	0.46	1.29	0.84	26994	0.86
	Foushee Cave	0.67	0.69	30683	0.59	1.28	0.83	19641	0.63

Species	Site	RBHF_01 Raw	RBHF_01 Scaled	RBHF_02 Raw	RBHF_02 Scaled	RBHF Raw	RBHF Scaled	RBHR_01 Raw	RBHR_01 Scaled
	Gunner Cave	0.95	0.98	7015	0.14	1.11	0.72	28085	0.90
	Gustafson Cave	0.91	0.93	11898	0.23	1.16	0.75	27257	0.87
	Hankin's Cave	0.73	0.74	28192	0.54	1.29	0.84	23464	0.75
	Hell Creek Cave	0.76	0.78	26602	0.51	1.29	0.84	25272	0.81
	Hidden Spring Cave	0.96	0.99	6197	0.12	1.10	0.72	26426	0.84
	Huffman Cave	0.58	0.59	41353	0.80	1.39	0.90	20079	0.64
	Hurricane River Cave	0.61	0.62	36056	0.69	1.32	0.85	18913	0.60
	Indian Creek Cave	0.88	0.90	17212	0.33	1.23	0.80	23964	0.76
	Joe Bright Cave	0.83	0.85	23524	0.45	1.30	0.84	23393	0.75
	John Eddings Cave	0.78	0.80	26830	0.52	1.32	0.86	29507	0.94
	Jones Cave	0.62	0.63	41544	0.80	1.43	0.93	21362	0.68
	Land's End Cave	0.39	0.40	48184	0.93	1.33	0.86	15748	0.50
	Little Bear Cave	0.84	0.86	24523	0.47	1.33	0.86	31330	1.00
	Logan Cave	0.54	0.55	44738	0.86	1.41	0.92	19687	0.63
	Major's Cave	0.26	0.27	49025	0.94	1.21	0.79	8935	0.29
	Marble Falls Cave	0.78	0.80	29276	0.56	1.37	0.89	21962	0.70
	Miner's Cave	0.78	0.80	29411	0.57	1.37	0.89	19331	0.62
	Morris Cave	0.82	0.85	25555	0.49	1.34	0.87	23558	0.75
	Nesbitt Spring Cave	0.81	0.83	25150	0.48	1.31	0.85	24742	0.79
	Norfork Bat Cave	0.74	0.76	34328	0.66	1.42	0.92	22848	0.73
	Old Joe Cave	0.79	0.81	29553	0.57	1.38	0.89	23009	0.73
	Optimus Cave	0.89	0.91	15756	0.30	1.21	0.79	23301	0.74
	Ozark Acres Cave	0.81	0.83	26165	0.50	1.33	0.86	24071	0.77
	Ozark Mystery Cave	0.89	0.91	17196	0.33	1.24	0.80	24904	0.79
	Pentrance Cave	0.90	0.92	15090	0.29	1.21	0.79	24474	0.78
	Peter Cave	0.67	0.68	37863	0.73	1.41	0.92	23422	0.75
	Pigeon Roost Cave	0.65	0.67	24294	0.47	1.14	0.74	20567	0.66

Species	Site	RBHF_01 Raw	RBHF_01 Scaled	RBHF_02 Raw	RBHF_02 Scaled	RBHF Raw	RBHF Scaled	RBHR_01 Raw	RBHR_01 Scaled
	Rory Cave	0.72	0.74	28347	0.55	1.28	0.83	23598	0.75
	Sherfield Cave	0.90	0.93	13679	0.26	1.19	0.77	24062	0.77
	Shirley Bat Cave	0.82	0.84	22887	0.44	1.28	0.83	27698	0.88
	Silver Valley Mines	0.28	0.29	51907	1.00	1.29	0.84	10830	0.35
	Spanish Piano Cave	0.89	0.92	15351	0.30	1.21	0.79	23084	0.74
	Still Cave	0.76	0.78	25295	0.49	1.26	0.82	19421	0.62
	Summer Cave	0.94	0.96	9680	0.19	1.15	0.74	26830	0.86
	Villines Spring Cave	0.86	0.88	17461	0.34	1.22	0.79	23056	0.74
	War Eagle Cave	0.51	0.52	48854	0.94	1.46	0.95	19498	0.62
	War Eagle Cavern	0.68	0.69	27624	0.53	1.23	0.80	22261	0.71
	Wet Cave	0.59	0.61	45047	0.87	1.48	0.96	21236	0.68
	Wolf Creek Cave	0.90	0.93	14788	0.28	1.21	0.79	22734	0.73
Myotis leibii									
	Amphitheater Cave	0.96	0.98	6822	0.13	1.11	0.72	26212	0.84
	Bone Cave	0.59	0.60	38647	0.74	1.35	0.87	25200	0.80
	Cave Mountain Cave	0.89	0.91	13793	0.27	1.17	0.76	23276	0.74
Myotis sodalis									
	AACS # FR17BT1g	0.89	0.91	12182	0.23	1.15	0.75	24895	0.79
	AACS # FR17BT1h	0.89	0.91	12119	0.23	1.15	0.74	24800	0.79
	Amphitheater Cave	0.96	0.98	6822	0.13	1.11	0.72	26212	0.84
	Barkshed Saltpeter Cave	0.96	0.98	5475	0.11	1.09	0.71	27120	0.87
	Bat Cave	0.90	0.93	13522	0.26	1.19	0.77	28421	0.91
	Big-eared Bat Crevice	0.90	0.92	14327	0.28	1.20	0.78	20804	0.66
	Biology Cave	0.95	0.98	6544	0.13	1.10	0.72	24901	0.79
	Blanchard Springs Caverns	0.90	0.92	16612	0.32	1.24	0.80	24033	0.77
	Cave Mountain Cave	0.89	0.91	13793	0.27	1.17	0.76	23276	0.74

Species	Site	RBHF_01 Raw	RBHF_01 Scaled	RBHF_02 Raw	RBHF_02 Scaled	RBHF Raw	RBHF Scaled	RBHR_01 Raw	RBHR_01 Scaled
	Cave Springs Cave	0.21	0.22	45446	0.88	1.09	0.71	9495	0.30
	Corkscrew Cave	0.87	0.90	17655	0.34	1.24	0.80	27179	0.87
	Cushman Cave	0.63	0.64	35150	0.68	1.32	0.86	20541	0.66
	Denny Cave	0.65	0.67	39491	0.76	1.43	0.93	26859	0.86
	Devil's Den Cave	0.90	0.92	13748	0.26	1.19	0.77	22278	0.71
	Dodd Cave	0.66	0.68	30733	0.59	1.27	0.82	21053	0.67
	Elm Cave	0.77	0.79	25996	0.50	1.29	0.84	29159	0.93
	Fitton Cave	0.83	0.85	22077	0.43	1.28	0.83	25547	0.82
	Flea Cave	0.82	0.84	23795	0.46	1.29	0.84	26994	0.86
	Gustafson Cave	0.91	0.93	11898	0.23	1.16	0.75	27257	0.87
	Hankin's Cave	0.73	0.74	28192	0.54	1.29	0.84	23464	0.75
	Hidden Spring Cave	0.96	0.99	6197	0.12	1.10	0.72	26426	0.84
	Hurricane River Cave	0.61	0.62	36056	0.69	1.32	0.85	18913	0.60
	Indian Creek Cave	0.88	0.90	17212	0.33	1.23	0.80	23964	0.76
	Logan Cave	0.54	0.55	44738	0.86	1.41	0.92	19687	0.63
	Marble Falls Cave	0.78	0.80	29276	0.56	1.37	0.89	21962	0.70
	Morris Cave	0.82	0.85	25555	0.49	1.34	0.87	23558	0.75
	Nichol's Cave	0.70	0.72	32866	0.63	1.35	0.88	18285	0.58
	Sherfield Cave	0.90	0.93	13679	0.26	1.19	0.77	24062	0.77
	War Eagle Cavern	0.68	0.69	27624	0.53	1.23	0.80	22261	0.71
	Wolf Creek Cave	0.90	0.93	14788	0.28	1.21	0.79	22734	0.73

Table Appendix D-2. Index values and scaled scores for RBHR_02 Raw through RVIA Scaled.

Species	Site	RBHR_02 Raw	RBHR_02 Scaled	RBHR Raw	RBHR Scaled	RBH Raw	RBH Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
Corynorhinus townsendii ingens											
	AACS # CW2307	0.90	0.91	1.51	0.79	1.57	0.85	5938	0.96	0.04	0.65
	AACS # CW2318	0.83	0.84	1.41	0.74	1.53	0.83	6932	0.95	0.04	0.62
	AACS # CW2337	0.90	0.91	1.51	0.79	1.57	0.85	5889	0.96	0.04	0.65
	AACS # CW2339	0.90	0.91	1.49	0.78	1.56	0.84	5796	0.96	0.04	0.65
	AACS # CW2365	0.91	0.92	1.52	0.79	1.57	0.85	5768	0.96	0.04	0.65
	AACS # CW2367	0.91	0.92	1.52	0.80	1.58	0.86	5779	0.96	0.04	0.65
	AACS # CW2385	0.86	0.87	1.45	0.76	1.56	0.85	7165	0.95	0.04	0.63
	AACS # CW23BT1	0.91	0.92	1.52	0.79	1.57	0.85	5635	0.96	0.04	0.66
	AACS # CW29BT2	0.97	0.98	1.71	0.90	1.61	0.87	5151	0.96	0.04	0.65
	AACS # CW29BT3	0.97	0.98	1.64	0.86	1.58	0.86	5033	0.96	0.04	0.66
	AACS # FR17BT1a	0.94	0.95	1.74	0.91	1.65	0.90	3965	0.97	0.04	0.64
	AACS # FR17BT1b	0.94	0.95	1.69	0.89	1.63	0.89	3966	0.97	0.04	0.65
	AACS # FR17BT1g	0.94	0.95	1.74	0.91	1.65	0.90	4088	0.97	0.04	0.64
	AACS # FR17BT1h	0.94	0.95	1.74	0.91	1.65	0.89	3966	0.97	0.04	0.64
	AACS # FR19BT1a	0.95	0.96	1.75	0.92	1.65	0.89	8344	0.94	0.04	0.61
	AACS # FR28BT2a,b	0.99	1.00	1.75	0.92	1.60	0.87	3215	0.98	0.03	0.69
	Bassett Cave	0.79	0.80	1.44	0.75	1.62	0.88	16535	0.88	0.05	0.51
	Bat Cave	0.92	0.93	1.84	0.96	1.73	0.94	4212	0.97	0.04	0.61
	Big-eared Bat Crevice	0.94	0.95	1.61	0.84	1.62	0.88	6351	0.95	0.04	0.60
	Blue Heaven Cave	0.79	0.80	1.54	0.81	1.74	0.94	7821	0.94	0.05	0.56
	Bradley Shelter	0.52	0.53	1.00	0.52	1.22	0.66	24474	0.82	0.06	0.47
	Brown Cave	0.78	0.78	1.51	0.79	1.74	0.94	7782	0.94	0.05	0.57
	Charley One Ridge Cave	0.85	0.86	1.59	0.83	1.71	0.93	7518	0.94	0.05	0.56
	Coon Cave	0.95	0.96	1.88	0.98	1.75	0.95	3917	0.97	0.04	0.62
	CW11BT1	0.87	0.88	1.58	0.83	1.62	0.88	9218	0.93	0.04	0.61

Species	Site	RBHR_02 Raw	RBHR_02 Scaled	RBHR Raw	RBHR Scaled	RBH Raw	RBH Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Delap Cave	0.50	0.51	0.87	0.46	1.22	0.66	18877	0.86	0.05	0.52
	Devil's Den Cave	0.94	0.95	1.66	0.87	1.63	0.89	6494	0.95	0.04	0.60
	Devil's Icebox Cave	0.94	0.95	1.66	0.87	1.64	0.89	6583	0.95	0.04	0.60
	Elm Cave	0.85	0.86	1.79	0.94	1.77	0.96	6371	0.95	0.04	0.59
	FR17BT2	0.96	0.97	1.69	0.89	1.60	0.87	3240	0.98	0.04	0.67
	Garrett Hollow Cave	0.88	0.89	1.48	0.78	1.56	0.84	5348	0.96	0.04	0.64
	Goard Cave	0.65	0.66	1.26	0.66	1.57	0.85	11682	0.91	0.05	0.51
	Hewlitt / Ezel Cave(s)	0.54	0.54	1.05	0.55	1.24	0.67	24997	0.81	0.06	0.47
	Imp's Leap Crevice	0.94	0.95	1.66	0.87	1.63	0.89	6223	0.95	0.04	0.60
	Marble Falls Cave	0.85	0.86	1.56	0.82	1.70	0.92	7883	0.94	0.05	0.56
	Mitchell Cave	0.75	0.75	1.61	0.84	1.77	0.96	7480	0.94	0.05	0.56
	Morning Star Mine # 15	0.88	0.89	1.77	0.92	1.70	0.92	7063	0.95	0.05	0.59
	Reed Cave	0.87	0.87	1.67	0.88	1.76	0.95	10276	0.92	0.05	0.54
	Summit Cave	0.68	0.69	1.30	0.68	1.59	0.86	12554	0.91	0.05	0.51
	Switchback Cave	0.80	0.81	1.62	0.85	1.77	0.96	5456	0.96	0.04	0.60
	WA5201	0.50	0.51	0.87	0.46	1.22	0.66	18877	0.86	0.05	0.52
	Yellow Rock Crevice	0.93	0.94	1.65	0.86	1.64	0.89	6713	0.95	0.04	0.59
Myotis grisescens											
	AACS # FR17BT1c	0.94	0.95	1.77	0.93	1.67	0.90	3986	0.97	0.04	0.64
	AACS # FR17BT1h	0.94	0.95	1.74	0.91	1.65	0.89	3966	0.97	0.04	0.64
	Back o' Beyond Cave	0.77	0.78	1.53	0.80	1.72	0.93	4848	0.96	0.04	0.62
	Bald Scrappy Cave	0.91	0.92	1.69	0.88	1.68	0.91	6921	0.95	0.05	0.57
	Bennett Cave	0.84	0.85	1.47	0.77	1.63	0.88	12694	0.91	0.06	0.44
	Bergren Cave	0.80	0.81	1.47	0.77	1.66	0.90	5013	0.96	0.05	0.53
	Big Creek Cave	0.81	0.81	1.59	0.83	1.77	0.96	4970	0.96	0.04	0.63
	Blagg Cave	0.76	0.77	1.51	0.79	1.64	0.89	5413	0.96	0.05	0.57
	Blanchard Springs	0.91	0.92	1.68	0.88	1.68	0.91	7286	0.95	0.05	0.58

Species	Site	RBHR_02 Raw	RBHR_02 Scaled	RBHR Raw	RBHR Scaled	RBH Raw	RBH Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Caverns										
	Blue Heaven Cave	0.79	0.80	1.54	0.81	1.74	0.94	7821	0.94	0.05	0.56
	Bonanza Cave	0.86	0.87	1.53	0.80	1.60	0.86	10630	0.92	0.05	0.53
	Bone Cave	0.69	0.70	1.50	0.78	1.65	0.90	24786	0.82	0.06	0.47
	Brewer Cave	0.36	0.36	0.68	0.36	1.17	0.64	8378	0.94	0.05	0.58
	Cave Mountain Cave	0.91	0.92	1.67	0.87	1.63	0.88	2347	0.98	0.03	0.72
	Cave River Cave	0.85	0.86	1.61	0.84	1.67	0.91	6744	0.95	0.05	0.58
	Cave Spring Cave	0.73	0.73	1.40	0.73	1.58	0.86	18469	0.86	0.05	0.57
	Cave Springs Cave	0.31	0.32	0.62	0.32	1.03	0.56	134411	0.00	0.11	0.00
	Corkscrew Cave	0.90	0.91	1.78	0.93	1.73	0.94	5539	0.96	0.04	0.62
	Crane Cave	0.79	0.79	1.59	0.83	1.74	0.94	5242	0.96	0.04	0.61
	Crystal Cave	0.70	0.71	1.48	0.78	1.77	0.96	60465	0.55	0.10	0.10
	Crystal River Cave	0.64	0.65	1.24	0.65	1.60	0.87	8190	0.94	0.05	0.53
	Denny Cave	0.75	0.75	1.61	0.84	1.77	0.96	7480	0.94	0.05	0.56
	Devil's Den Cave	0.94	0.95	1.66	0.87	1.63	0.89	6494	0.95	0.04	0.60
	Diamond Cave	0.86	0.87	1.66	0.87	1.71	0.92	4922	0.96	0.04	0.65
	Dodd Cave	0.76	0.76	1.44	0.75	1.57	0.85	6278	0.95	0.04	0.62
	Eckel Cave	0.84	0.84	1.62	0.85	1.67	0.91	9824	0.93	0.07	0.37
	Elm Cave	0.85	0.86	1.79	0.94	1.77	0.96	6371	0.95	0.04	0.59
	Fallout Cave	0.78	0.79	1.59	0.83	1.76	0.95	5236	0.96	0.04	0.60
	Fitton Cave	0.92	0.93	1.74	0.91	1.74	0.94	6073	0.95	0.04	0.62
	Flea Cave	0.85	0.86	1.72	0.90	1.73	0.94	8161	0.94	0.05	0.58
	Foushee Cave	0.78	0.78	1.41	0.74	1.56	0.85	17478	0.87	0.05	0.55
	Gunner Cave	0.97	0.97	1.87	0.98	1.69	0.92	3462	0.97	0.04	0.62
	Gustafson Cave	0.93	0.94	1.81	0.95	1.70	0.92	4229	0.97	0.05	0.56
	Hankin's Cave	0.75	0.76	1.51	0.79	1.62	0.88	5611	0.96	0.04	0.60
	Hell Creek Cave	0.82	0.83	1.63	0.85	1.69	0.92	7658	0.94	0.05	0.58

Species	Site	RBHR_02 Raw	RBHR_02 Scaled	RBHR Raw	RBHR Scaled	RBH Raw	RBH Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Hidden Spring Cave	0.98	0.99	1.83	0.96	1.67	0.90	4566	0.97	0.05	0.57
	Huffman Cave	0.70	0.71	1.35	0.71	1.60	0.87	27133	0.80	0.07	0.38
	Hurricane River Cave	0.64	0.64	1.25	0.65	1.50	0.82	5913	0.96	0.04	0.63
	Indian Creek Cave	0.91	0.92	1.68	0.88	1.68	0.91	4845	0.96	0.04	0.64
	Joe Bright Cave	0.85	0.86	1.61	0.84	1.68	0.91	6863	0.95	0.05	0.59
	John Eddings Cave	0.86	0.86	1.81	0.94	1.80	0.97	5692	0.96	0.04	0.61
	Jones Cave	0.66	0.67	1.35	0.71	1.63	0.89	4537	0.97	0.04	0.62
	Land's End Cave	0.54	0.55	1.05	0.55	1.41	0.76	0	0.00	0.00	0.00
	Little Bear Cave	0.88	0.89	1.89	0.99	1.84	1.00	6463	0.95	0.04	0.60
	Logan Cave	0.59	0.60	1.23	0.64	1.55	0.84	31431	0.77	0.07	0.37
	Major's Cave	0.30	0.31	0.59	0.31	1.10	0.59	26637	0.80	0.06	0.45
	Marble Falls Cave	0.85	0.86	1.56	0.82	1.70	0.92	7883	0.94	0.05	0.56
	Miner's Cave	0.84	0.84	1.46	0.76	1.65	0.89	12711	0.91	0.06	0.45
	Morris Cave	0.79	0.80	1.55	0.81	1.68	0.91	5379	0.96	0.05	0.50
	Nesbitt Spring Cave	0.84	0.85	1.64	0.86	1.70	0.92	7626	0.94	0.04	0.59
	Norfork Bat Cave	0.82	0.83	1.56	0.81	1.73	0.94	11297	0.92	0.06	0.48
	Old Joe Cave	0.84	0.85	1.58	0.83	1.72	0.93	8412	0.94	0.06	0.49
	Optimus Cave	0.89	0.90	1.64	0.86	1.64	0.89	6164	0.95	0.05	0.56
	Ozark Acres Cave	0.80	0.80	1.57	0.82	1.68	0.91	9002	0.93	0.06	0.43
	Ozark Mystery Cave	0.90	0.91	1.70	0.89	1.69	0.92	7858	0.94	0.05	0.56
	Pentrance Cave	0.91	0.92	1.70	0.89	1.67	0.91	3469	0.97	0.03	0.71
	Peter Cave	0.76	0.77	1.52	0.80	1.71	0.93	3205	0.98	0.04	0.68
	Pigeon Roost Cave	0.80	0.81	1.46	0.77	1.50	0.81	25901	0.81	0.08	0.30
	Rory Cave	0.78	0.79	1.55	0.81	1.64	0.89	6795	0.95	0.04	0.60
	Sherfield Cave	0.92	0.92	1.69	0.89	1.65	0.90	2556	0.98	0.03	0.73
	Shirley Bat Cave	0.90	0.91	1.79	0.94	1.76	0.96	7610	0.94	0.05	0.52
	Silver Valley Mines	0.36	0.36	0.71	0.37	1.20	0.65	25912	0.81	0.06	0.44

Species	Site	RBHR_02 Raw	RBHR_02 Scaled	RBHR Raw	RBHR Scaled	RBH Raw	RBH Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Spanish Piano Cave	0.89	0.90	1.64	0.86	1.64	0.89	3838	0.97	0.03	0.70
	Still Cave	0.81	0.82	1.44	0.75	1.57	0.85	16979	0.87	0.06	0.49
	Summer Cave	0.93	0.94	1.80	0.94	1.68	0.91	3083	0.98	0.04	0.63
	Villines Spring Cave	0.90	0.91	1.64	0.86	1.65	0.89	2774	0.98	0.03	0.71
	War Eagle Cave	0.62	0.63	1.25	0.65	1.60	0.87	7899	0.94	0.05	0.57
	War Eagle Cavern	0.78	0.79	1.50	0.78	1.58	0.85	16349	0.88	0.07	0.36
	Wet Cave	0.70	0.70	1.38	0.72	1.68	0.91	13816	0.90	0.05	0.53
	Wolf Creek Cave	0.92	0.93	1.66	0.87	1.65	0.89	3458	0.97	0.03	0.71
Myotis leibii											
	Amphitheater Cave	0.97	0.98	1.82	0.95	1.67	0.90	5267	0.96	0.05	0.57
	Bone Cave	0.69	0.70	1.50	0.78	1.65	0.90	24786	0.82	0.06	0.47
	Cave Mountain Cave	0.91	0.92	1.67	0.87	1.63	0.88	2347	0.98	0.03	0.72
Myotis sodalis											
	AACS # FR17BT1g	0.94	0.95	1.74	0.91	1.65	0.90	4088	0.97	0.04	0.64
	AACS # FR17BT1h	0.94	0.95	1.74	0.91	1.65	0.89	3966	0.97	0.04	0.64
	Amphitheater Cave	0.97	0.98	1.82	0.95	1.67	0.90	5267	0.96	0.05	0.57
	Barkshed Saltpeter Cave	0.98	0.99	1.86	0.97	1.67	0.91	3945	0.97	0.05	0.58
	Bat Cave	0.92	0.93	1.84	0.96	1.73	0.94	4212	0.97	0.04	0.61
	Big-eared Bat Crevice	0.94	0.95	1.61	0.84	1.62	0.88	6351	0.95	0.04	0.60
	Biology Cave	0.97	0.98	1.77	0.93	1.64	0.89	5075	0.96	0.05	0.57
	Blanchard Springs Caverns	0.91	0.92	1.68	0.88	1.68	0.91	7286	0.95	0.05	0.58
	Cave Mountain Cave	0.91	0.92	1.67	0.87	1.63	0.88	2347	0.98	0.03	0.72
	Cave Springs Cave	0.31	0.32	0.62	0.32	1.03	0.56	134411	0.00	0.11	0.00
	Corkscrew Cave	0.90	0.91	1.78	0.93	1.73	0.94	5539	0.96	0.04	0.62
	Cushman Cave	0.63	0.64	1.29	0.68	1.53	0.83	9247	0.93	0.05	0.57
	Denny Cave	0.75	0.75	1.61	0.84	1.77	0.96	7480	0.94	0.05	0.56

Species	Site	RBHR_02 Raw	RBHR_02 Scaled	RBHR Raw	RBHR Scaled	RBH Raw	RBH Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Devil's Den Cave	0.94	0.95	1.66	0.87	1.63	0.89	6494	0.95	0.04	0.60
	Dodd Cave	0.76	0.76	1.44	0.75	1.57	0.85	6278	0.95	0.04	0.62
	Elm Cave	0.85	0.86	1.79	0.94	1.77	0.96	6371	0.95	0.04	0.59
	Fitton Cave	0.92	0.93	1.74	0.91	1.74	0.94	6073	0.95	0.04	0.62
	Flea Cave	0.85	0.86	1.72	0.90	1.73	0.94	8161	0.94	0.05	0.58
	Gustafson Cave	0.93	0.94	1.81	0.95	1.70	0.92	4229	0.97	0.05	0.56
	Hankin's Cave	0.75	0.76	1.51	0.79	1.62	0.88	5611	0.96	0.04	0.60
	Hidden Spring Cave	0.98	0.99	1.83	0.96	1.67	0.90	4566	0.97	0.05	0.57
	Hurricane River Cave	0.64	0.64	1.25	0.65	1.50	0.82	5913	0.96	0.04	0.63
	Indian Creek Cave	0.91	0.92	1.68	0.88	1.68	0.91	4845	0.96	0.04	0.64
	Logan Cave	0.59	0.60	1.23	0.64	1.55	0.84	31431	0.77	0.07	0.37
	Marble Falls Cave	0.85	0.86	1.56	0.82	1.70	0.92	7883	0.94	0.05	0.56
	Morris Cave	0.79	0.80	1.55	0.81	1.68	0.91	5379	0.96	0.05	0.50
	Nichol's Cave	0.72	0.73	1.31	0.69	1.56	0.85	28440	0.79	0.06	0.47
	Sherfield Cave	0.92	0.92	1.69	0.89	1.65	0.90	2556	0.98	0.03	0.73
	War Eagle Cavern	0.78	0.79	1.50	0.78	1.58	0.85	16349	0.88	0.07	0.36
	Wolf Creek Cave	0.92	0.93	1.66	0.87	1.65	0.89	3458	0.97	0.03	0.71

Table Appendix D-3. Index values and scaled scores for RVIX Raw through THREAT Scaled.

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
Corynorhinus townsendii ingens							
	AACS # CW2307	0.95	0.57	2.17	0.81	1.66	0.88
	AACS # CW2318	0.07	0.04	1.60	0.60	1.43	0.75
	AACS # CW2337	1.16	0.69	2.30	0.86	1.71	0.90
	AACS # CW2339	1.09	0.65	2.26	0.84	1.68	0.89
	AACS # CW2365	1.22	0.72	2.33	0.87	1.72	0.91
	AACS # CW2367	1.26	0.75	2.35	0.88	1.73	0.92
	AACS # CW2385	0.25	0.15	1.72	0.64	1.49	0.79
	AACS # CW23BT1	0.94	0.56	2.18	0.81	1.66	0.88
	AACS # CW29BT2	1.24	0.73	2.34	0.87	1.75	0.92
	AACS # CW29BT3	1.38	0.82	2.44	0.91	1.76	0.93
	AACS # FR17BT1a	0.33	0.20	1.81	0.67	1.57	0.83
	AACS # FR17BT1b	0.12	0.07	1.69	0.63	1.51	0.80
	AACS # FR17BT1g	0.36	0.22	1.83	0.68	1.58	0.83
	AACS # FR17BT1h	0.32	0.19	1.80	0.67	1.57	0.83
	AACS # FR19BT1a	0.40	0.24	1.79	0.66	1.56	0.82
	AACS # FR28BT2a,b	0.32	0.19	1.85	0.69	1.56	0.82
	Bassett Cave	0.25	0.15	1.54	0.57	1.45	0.77
	Bat Cave	0.64	0.38	1.96	0.73	1.66	0.88
	Big-eared Bat Crevice	0.21	0.12	1.67	0.62	1.50	0.79
	Blue Heaven Cave	0.10	0.06	1.55	0.58	1.52	0.80
	Bradley Shelter	0.46	0.27	1.56	0.58	1.24	0.66
	Brown Cave	0.36	0.21	1.72	0.64	1.59	0.84
	Charley One Ridge Cave	0.79	0.47	1.97	0.73	1.66	0.88
	Coon Cave	0.30	0.18	1.77	0.66	1.61	0.85
	CW11BT1	0.95	0.56	2.11	0.78	1.66	0.88

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Delap Cave	0.28	0.17	1.55	0.58	1.24	0.65
	Devil's Den Cave	0.20	0.12	1.66	0.62	1.50	0.79
	Devil's Icebox Cave	0.16	0.10	1.64	0.61	1.50	0.79
	Elm Cave	0.08	0.05	1.59	0.59	1.55	0.82
	FR17BT2	0.83	0.49	2.14	0.79	1.66	0.88
	Garrett Hollow Cave	0.78	0.46	2.06	0.77	1.61	0.85
	Goard Cave	0.12	0.07	1.49	0.56	1.41	0.74
	Hewlitt / Ezel Cave(s)	0.69	0.41	1.69	0.63	1.30	0.69
	Imp's Leap Crevice	0.04	0.02	1.57	0.58	1.47	0.78
	Marble Falls Cave	0.33	0.20	1.70	0.63	1.55	0.82
	Mitchell Cave	0.32	0.19	1.69	0.63	1.59	0.84
	Morning Star Mine # 15	0.14	0.09	1.62	0.60	1.53	0.81
	Reed Cave	0.26	0.15	1.62	0.60	1.56	0.82
	Summit Cave	0.23	0.13	1.55	0.58	1.44	0.76
	Switchback Cave	0.63	0.37	1.93	0.72	1.68	0.88
	WA5201	0.28	0.17	1.55	0.58	1.24	0.65
	Yellow Rock Crevice	0.32	0.19	1.73	0.64	1.54	0.81
Myotis grisescens							
	AACS # FR17BT1c	0.14	0.09	1.70	0.63	1.54	0.81
	AACS # FR17BT1h	0.32	0.19	1.80	0.67	1.57	0.83
	Back o' Beyond Cave	0.44	0.26	1.84	0.69	1.62	0.85
	Bald Scrappy Cave	0.63	0.37	1.89	0.70	1.62	0.85
	Bennett Cave	0.23	0.14	1.49	0.55	1.44	0.76
	Bergren Cave	0.04	0.02	1.52	0.57	1.47	0.77
	Big Creek Cave	0.12	0.07	1.67	0.62	1.58	0.83
	Blagg Cave	0.47	0.28	1.81	0.67	1.56	0.83
	Blanchard Springs	0.19	0.11	1.64	0.61	1.52	0.80

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Caverns						
	Blue Heaven Cave	0.10	0.06	1.55	0.58	1.52	0.80
	Bonanza Cave	1.38	0.82	2.26	0.84	1.71	0.90
	Bone Cave	0.44	0.26	1.55	0.58	1.47	0.78
	Brewer Cave	0.16	0.09	1.61	0.60	1.23	0.65
	Cave Mountain Cave	0.05	0.03	1.73	0.64	1.53	0.81
	Cave River Cave	0.79	0.47	2.00	0.74	1.65	0.87
	Cave Spring Cave	0.30	0.18	1.61	0.60	1.46	0.77
	Cave Springs Cave	0.13	0.08	0.08	0.03	0.59	0.31
	Corkscrew Cave	0.41	0.24	1.82	0.68	1.61	0.85
	Crane Cave	0.60	0.36	1.92	0.72	1.66	0.88
	Crystal Cave	0.04	0.02	0.67	0.25	1.21	0.64
	Crystal River Cave	0.07	0.04	1.51	0.56	1.43	0.75
	Denny Cave	0.32	0.19	1.69	0.63	1.59	0.84
	Devil's Den Cave	0.20	0.12	1.66	0.62	1.50	0.79
	Diamond Cave	0.19	0.11	1.73	0.64	1.57	0.83
	Dodd Cave	0.15	0.09	1.66	0.62	1.47	0.78
	Eckel Cave	0.27	0.16	1.46	0.54	1.45	0.77
	Elm Cave	0.08	0.05	1.59	0.59	1.55	0.82
	Fallout Cave	0.55	0.32	1.89	0.70	1.66	0.87
	Fitton Cave	0.07	0.04	1.61	0.60	1.54	0.81
	Flea Cave	0.18	0.11	1.63	0.60	1.54	0.82
	Foushee Cave	0.31	0.18	1.60	0.60	1.44	0.76
	Gunner Cave	0.24	0.15	1.74	0.65	1.56	0.83
	Gustafson Cave	0.23	0.14	1.66	0.62	1.54	0.81
	Hankin's Cave	0.00	0.00	1.56	0.58	1.46	0.77
	Hell Creek Cave	0.77	0.46	1.98	0.74	1.65	0.87

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Hidden Spring Cave	0.07	0.04	1.58	0.59	1.49	0.79
	Huffman Cave	0.04	0.02	1.20	0.45	1.32	0.70
	Hurricane River Cave	0.06	0.03	1.62	0.60	1.42	0.75
	Indian Creek Cave	0.93	0.55	2.16	0.80	1.71	0.91
	Joe Bright Cave	0.43	0.25	1.79	0.67	1.58	0.83
	John Eddings Cave	0.69	0.41	1.97	0.73	1.71	0.90
	Jones Cave	0.14	0.08	1.67	0.62	1.51	0.80
	Land's End Cave	0.00	0.00	0.00	0.00	0.00	0.00
	Little Bear Cave	0.06	0.04	1.59	0.59	1.59	0.84
	Logan Cave	0.16	0.10	1.24	0.46	1.30	0.69
	Major's Cave	0.03	0.02	1.27	0.47	1.07	0.56
	Marble Falls Cave	0.33	0.20	1.70	0.63	1.55	0.82
	Miner's Cave	0.25	0.15	1.50	0.56	1.45	0.77
	Morris Cave	0.54	0.32	1.78	0.66	1.57	0.83
	Nesbitt Spring Cave	0.27	0.16	1.70	0.63	1.55	0.82
	Norfork Bat Cave	0.09	0.05	1.45	0.54	1.48	0.78
	Old Joe Cave	0.23	0.14	1.56	0.58	1.51	0.80
	Optimus Cave	0.07	0.04	1.55	0.58	1.47	0.77
	Ozark Acres Cave	0.16	0.10	1.46	0.54	1.46	0.77
	Ozark Mystery Cave	0.51	0.31	1.81	0.67	1.59	0.84
	Pentrance Cave	1.55	0.92	2.60	0.97	1.88	0.99
	Peter Cave	0.11	0.06	1.72	0.64	1.56	0.83
	Pigeon Roost Cave	0.92	0.55	1.65	0.62	1.43	0.75
	Rory Cave	0.18	0.11	1.66	0.62	1.51	0.80
	Sherfield Cave	0.13	0.08	1.79	0.66	1.56	0.82
	Shirley Bat Cave	0.11	0.06	1.53	0.57	1.52	0.80
	Silver Valley Mines	0.21	0.12	1.37	0.51	1.16	0.61

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Spanish Piano Cave	0.16	0.10	1.76	0.66	1.54	0.82
	Still Cave	0.17	0.10	1.47	0.55	1.40	0.74
	Summer Cave	0.82	0.49	2.10	0.78	1.69	0.89
	Villines Spring Cave	0.41	0.24	1.93	0.72	1.61	0.85
	War Eagle Cave	0.19	0.11	1.62	0.60	1.47	0.78
	War Eagle Cavern	0.04	0.02	1.26	0.47	1.32	0.70
	Wet Cave	0.45	0.27	1.70	0.63	1.54	0.81
	Wolf Creek Cave	1.67	0.99	2.68	1.00	1.89	1.00
Myotis leibii							
	Amphitheater Cave	0.37	0.22	1.75	0.65	1.55	0.82
	Bone Cave	0.44	0.26	1.55	0.58	1.47	0.78
	Cave Mountain Cave	0.05	0.03	1.73	0.64	1.53	0.81
Myotis sodalis							
	AACS # FR17BT1g	0.36	0.22	1.83	0.68	1.58	0.83
	AACS # FR17BT1h	0.32	0.19	1.80	0.67	1.57	0.83
	Amphitheater Cave	0.37	0.22	1.75	0.65	1.55	0.82
	Barkshed Saltpeter Cave	0.30	0.18	1.73	0.64	1.55	0.82
	Bat Cave	0.64	0.38	1.96	0.73	1.66	0.88
	Big-eared Bat Crevice	0.21	0.12	1.67	0.62	1.50	0.79
	Biology Cave	0.03	0.02	1.55	0.58	1.46	0.77
	Blanchard Springs Caverns	0.19	0.11	1.64	0.61	1.52	0.80
	Cave Mountain Cave	0.05	0.03	1.73	0.64	1.53	0.81
	Cave Springs Cave	0.13	0.08	0.08	0.03	0.59	0.31
	Corkscrew Cave	0.41	0.24	1.82	0.68	1.61	0.85
	Cushman Cave	0.26	0.16	1.66	0.62	1.45	0.76
	Denny Cave	0.32	0.19	1.69	0.63	1.59	0.84

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Devil's Den Cave	0.20	0.12	1.66	0.62	1.50	0.79
	Dodd Cave	0.15	0.09	1.66	0.62	1.47	0.78
	Elm Cave	0.08	0.05	1.59	0.59	1.55	0.82
	Fitton Cave	0.07	0.04	1.61	0.60	1.54	0.81
	Flea Cave	0.18	0.11	1.63	0.60	1.54	0.82
	Gustafson Cave	0.23	0.14	1.66	0.62	1.54	0.81
	Hankin's Cave	0.00	0.00	1.56	0.58	1.46	0.77
	Hidden Spring Cave	0.07	0.04	1.58	0.59	1.49	0.79
	Hurricane River Cave	0.06	0.03	1.62	0.60	1.42	0.75
	Indian Creek Cave	0.93	0.55	2.16	0.80	1.71	0.91
	Logan Cave	0.16	0.10	1.24	0.46	1.30	0.69
	Marble Falls Cave	0.33	0.20	1.70	0.63	1.55	0.82
	Morris Cave	0.54	0.32	1.78	0.66	1.57	0.83
	Nichol's Cave	0.24	0.14	1.40	0.52	1.36	0.72
	Sherfield Cave	0.13	0.08	1.79	0.66	1.56	0.82
	War Eagle Cavern	0.04	0.02	1.26	0.47	1.32	0.70
	Wolf Creek Cave	1.67	0.99	2.68	1.00	1.89	1.00

APPENDIX E. Raw index values and scaled scores for components of the Visitation Risk Model, Water Quality and Quantity Risk Model, Groundwater Vulnerability Model, Groundwater Sensitivity Model, and overall Aquatic Community Threat Model for each aquatic cave species population at each site. Scaled values are scaled from 0-1, with 1 being the score with the most ecological benefit. Threat scores discussed in the text are generated by subtracting scaled values from 1 (e.g. [1- (RVI Scaled)] equals overall threat from visitation). Descriptions of abbreviations used in these tables can be found in Appendix A.

Table Appendix E-1. Index values and scaled scores for RWQS 01 Raw through RWQS 03 Scaled.

Species	Site	RWQS_01 Raw	RWQS_01 Scaled	RWQS_02 Raw	RWQS_02 Scaled	RWQS_03 Raw	RWQS_03 Scaled
Amblyopsis rosae							
	AGFC Nursery Pond on Beaver Lake	0.96	0.99	2.83	0.35	249360.75	0.01
	Cave Springs Cave	29.48	0.60	0.60	0.86	3932102.25	0.11
	Civil War Cave	17.01	0.77	1.43	0.67	2781144.00	0.08
	Hewlitt's Spring Hole	16.72	0.77	1.24	0.71	2888361.00	0.08
	James-Ditto Cave	3.48	0.95	2.37	0.46	705033.00	0.02
	Logan Cave	48.70	0.33	1.60	0.63	16335972.00	0.46
	Monte Ne Sinkhole	1.12	0.98	0.35	0.92	2261304.00	0.06
	Mule Hole Sink	0.57	0.99	1.33	0.70	215246.25	0.01
	Rootville Cave	1.77	0.98	0.87	0.80	1483980.75	0.04
	Tom Allen's Cave	2.96	0.96	1.33	0.69	1542462.75	0.04
Amnicola cora							
	Foushee Cave	2.44	0.97	0.36	0.92	6294125.25	0.18
Bactrurus pseudomucronatus							
	Deep cistern 5.5 mi. S of Imboden	2.73	0.96	2.02	0.54	860172.75	0.02
	Mansell Cave	2.52	0.97	1.32	0.70	1345898.25	0.04
Caecidotea ancyla							
	Bear Hollow Cave	21.55	0.70	2.40	0.45	3313167.75	0.09
	Brewer Cave						
	Denny Cave	9.42	0.87	1.07	0.75	4200144.75	0.12
	Fitton Spring Cave	23.48	0.68	0.70	0.84	28463676.75	0.80

Species	Site	RWQS_01 Raw	RWQS_01 Scaled	RWQS_02 Raw	RWQS_02 Scaled	RWQS_03 Raw	RWQS_03 Scaled
	Foushee Cave	2.44	0.97	0.36	0.92	6294125.25	0.18
	Greasy Valley Cave	3.85	0.95	1.91	0.56	960079.50	0.03
	Ivy Springs Cave	5.19	0.93	2.65	0.39	689600.25	0.02
	Major's Cave	3.99	0.95	0.52	0.88	1480731.75	0.04
	Marshall Caves	1.83	0.97	2.27	0.48	435366.00	0.01
	Nesbitt Spring Cave	3.00	0.96	1.11	0.75	2098854.00	0.06
	Old Pendergrass Cave	72.83	0.00	1.47	0.66	29493609.75	0.83
	Pretty Clean Cave	3.44	0.95	1.52	0.65	2209320.00	0.06
	Rootville Cave	1.77	0.98	0.87	0.80	1483980.75	0.04
	Spavinaw Creek Cave						
	War Eagle Cave	7.18	0.90	0.83	0.81	6021209.25	0.17
	Withrow Springs Cave	7.18	0.90	0.83	0.81	6021209.25	0.17
Caecidotea dimorpha							
	Elm Cave	1.16	0.98	1.05	0.76	1014500.25	0.03
	Martin Hollow Cave	0.10	1.00	0.04	0.99	1722782.25	0.05
	Mr. Griffin's Cave # 1	2.06	0.97	0.37	0.92	5627268.00	0.16
	Nesbitt Spring Cave	3.00	0.96	1.11	0.75	2098854.00	0.06
	Riley's Springbox	4.99	0.93	2.35	0.46	1846244.25	0.05
	Stovepipe Cave	1.49	0.98	1.91	0.56	437802.75	0.01
	Summer Cave	4.58	0.94	0.97	0.78	4607894.25	0.13
Caecidotea macropropoda							
	Fincher Cave	3.96	0.95	1.68	0.61	2085858.00	0.06
	Spring at Bradley Shelter	0.85	0.99	0.50	0.88	694473.75	0.02
	Stormdrain Spring at University of Arkansas	0.00	1.00	0.00	1.00	89347.50	0.00
	Watson Cave	4.31	0.94	1.94	0.55	852050.25	0.02
Caecidotea salemensis							

Species	Site	RWQS_01 Raw	RWQS_01 Scaled	RWQS_02 Raw	RWQS_02 Scaled	RWQS_03 Raw	RWQS_03 Scaled
	Deep cistern 5.5 mi. S of Imboden	2.73	0.96	2.02	0.54	860172.75	0.02
Caecidotea steevesi							
	AGFC Nursery Pond on Beaver Lake	0.96	0.99	2.83	0.35	249360.75	0.01
	Cave on Pond Above Black Bass Lake	4.41	0.94	1.17	0.73	3318853.50	0.09
	Old Spanish Treasure Cave	2.60	0.96	0.86	0.80	2578893.75	0.07
	War Eagle Cave	7.18	0.90	0.83	0.81	6021209.25	0.17
	Withrow Springs Cave	7.18	0.90	0.83	0.81	6021209.25	0.17
Caecidotea stiladactyla							
	Arkansas Archaeological Survey Site #3BE352	1.97	0.97	1.56	0.64	676604.25	0.02
	Bently Cave	0.00	1.00	0.00	1.00	185193.00	0.01
	Big Mouth Cave						
	Brock Spring	8.09	0.89	1.87	0.57	1767456.00	0.05
	Bull Shoals Caverns	2.31	0.97	0.81	0.81	2068800.75	0.06
	Cal Cave	4.63	0.94	1.15	0.74	2528534.25	0.07
	Cave Mountain Cave	2.80	0.96	0.91	0.79	2551277.25	0.07
	Cave on North Boundary Trail	0.00	1.00	0.00	1.00	1388135.25	0.04
	Cave Springs Cave	29.48	0.60	0.60	0.86	3932102.25	0.11
	Cold Cave	0.52	0.99	1.33	0.69	167323.50	0.00
	Covington's Cave						
	Dickerson Cave	5.39	0.93	0.96	0.78	3481303.50	0.10
	Eden Falls Cave	2.37	0.97	0.47	0.89	3915045.00	0.11
	Fish Pond Cave	0.50	0.99	0.73	0.83	487350.00	0.01
	Fitton Cave	23.48	0.68	0.70	0.84	28463676.75	0.80
	Granny Parker's Cave						
	John Eddings Cave	0.31	1.00	0.25	0.94	1036431.00	0.03
	Laningham's Cave	4.63	0.94	1.15	0.74	2528534.25	0.07

Species	Site	RWQS_01 Raw	RWQS_01 Scaled	RWQS_02 Raw	RWQS_02 Scaled	RWQS_03 Raw	RWQS_03 Scaled
	Middle Creek Spring Cave						
	Novack Spring Cave	2.37	0.97	0.47	0.89	3915045.00	0.11
	Old Joe Cave	8.42	0.88	1.48	0.66	3934539.00	0.11
	Sherfield Cave	14.52	0.80	0.66	0.85	19961856.00	0.56
	Simpson's Cave	10.31	0.86	1.04	0.76	5013207.00	0.14
	Spring at Hogscald	6.94	0.90	1.11	0.74	5598839.25	0.16
	Spring at Sequoyah Woods	2.56	0.96	0.58	0.87	1987575.75	0.06
	Spring on Butler Creek Road	10.51	0.86	1.06	0.76	9325442.25	0.26
	Spring on North Boundary Trail	0.00	1.00	0.00	1.00	1388135.25	0.04
	Stillhouse Hollow Cave	0.83	0.99	1.55	0.64	346830.75	0.01
	Tanyard Creek Nature Trail Cave	3.06	0.96	2.99	0.31	697722.75	0.02
	Unnamed seep 4 mi. S of Boxley	1.46	0.98	0.71	0.84	1902289.50	0.05
	Unnamed seep 9 mi. SW of Harrison	2.37	0.97	0.39	0.91	4504738.50	0.13
	Unnamed spring 3.5 mi. S of Jasper	3.97	0.95	1.71	0.61	2130531.75	0.06
	War Eagle Cavern	6.95	0.90	1.19	0.73	5548479.75	0.16
	White River Below Beaver Dam	2.80	0.96	1.12	0.74	1964832.75	0.06
Cambarus aculabrum							
	Bear Hollow Cave	21.55	0.70	2.40	0.45	3313167.75	0.09
	Brush Creek	10.22	0.86	1.12	0.74	540146.25	0.02
	Logan Cave	48.70	0.33	1.60	0.63	16335972.00	0.46
	Old Pendergrass Cave	72.83	0.00	1.47	0.66	29493609.75	0.83
Cambarus setosus							
	Blowing Cave	0.00	1.00	0.00	1.00	585632.25	0.02
	Poke Cave	0.00	1.00	0.00	1.00	585632.25	0.02
	Tom Allen's Cave	2.96	0.96	1.33	0.69	1542462.75	0.04
Cambarus zophonastes							
	Hell Creek Cave	17.62	0.76	0.89	0.79	15036372.00	0.42

Species	Site	RWQS_01 Raw	RWQS_01 Scaled	RWQS_02 Raw	RWQS_02 Scaled	RWQS_03 Raw	RWQS_03 Scaled
	Nesbitt Spring Cave	3.00	0.96	1.11	0.75	2098854.00	0.06
	site in Yellville	24.35	0.67	2.17	0.50	5485936.50	0.16
Dendrocoelopsis americana							
	Brock Spring	8.09	0.89	1.87	0.57	1767456.00	0.05
	Granny Parker's Cave						
	Steel Creek Campground Cave	3.23	0.96	0.84	0.81	3507295.50	0.10
	Watson Cave	4.31	0.94	1.94	0.55	852050.25	0.02
Eurycea spelaea							
	Alexander Cave	36.21	0.50	1.25	0.71	15735719.25	0.44
	Allen Cave						
	Back o' Beyond Cave	1.30	0.98	0.49	0.89	1634247.00	0.05
	Bald Scrappy Cave	3.20	0.96	1.40	0.68	2106976.50	0.06
	Bear Hollow Cave	21.55	0.70	2.40	0.45	3313167.75	0.09
	Bear Pit	0.00	1.00	0.00	1.00	1613128.50	0.05
	Bell Cave						
	Bently Cave	0.00	1.00	0.00	1.00	185193.00	0.01
	Big Mouth Cave						
	Big Spring Cave						
	Biology Cave	1.45	0.98	1.58	0.64	925152.75	0.03
	Blanchard Springs Caverns	20.68	0.72	0.53	0.88	35379985.50	1.00
	Blowing Cave	0.00	1.00	0.00	1.00	585632.25	0.02
	Blowing Spring Cave	0.00	1.00	0.00	1.00	3064619.25	0.09
	Blowing Springs Cave	1.31	0.98	0.54	0.88	1719533.25	0.05
	Blowing Springs Cave	2.95	0.96	1.24	0.71	1888481.25	0.05
	Blue Heaven Cave	4.91	0.93	0.85	0.80	3882555.00	0.11
	Bonanza Cave	0.98	0.99	0.29	0.93	2932222.50	0.08
	Bonanza Mine	4.35	0.94	1.21	0.72	3582022.50	0.10

Species	Site	RWQS_01 Raw	RWQS_01 Scaled	RWQS_02 Raw	RWQS_02 Scaled	RWQS_03 Raw	RWQS_03 Scaled
	Breakdown Cave	2.05	0.97	0.50	0.89	3996270.00	0.11
	Brewer Cave						
	Bull Shoals Caverns	2.31	0.97	0.81	0.81	2068800.75	0.06
	Cave River Cave	4.23	0.94	1.10	0.75	3617761.50	0.10
	Cave Springs Cave	29.48	0.60	0.60	0.86	3932102.25	0.11
	Chambers Hollow Cave	3.85	0.95	1.17	0.73	3135285.00	0.09
	Chilly Bowl Cave	7.24	0.90	2.26	0.48	2962275.75	0.08
	Chinn Springs Cave	11.19	0.85	0.65	0.85	14145333.75	0.40
	Congo Crawl						
	Coon Cave	0.43	0.99	0.43	0.90	955206.00	0.03
	Copperhead Cave	5.78	0.92	1.86	0.57	2551277.25	0.07
	Corkscrew Cave	3.92	0.95	0.91	0.79	4085617.50	0.12
	Cosmic Caverns	4.87	0.93	0.85	0.80	3870371.25	0.11
	Crystal Dome Cave	10.99	0.85	1.99	0.54	3324539.25	0.09
	Cushman Cave	2.82	0.96	1.22	0.72	2051743.50	0.06
	Cyner Cave	6.14	0.92	0.46	0.89	10584429.75	0.30
	Davis Creek Cave						
	Dear Buster Cave	2.06	0.97	0.23	0.95	7778918.25	0.22
	Diamond Cave	3.28	0.95	0.63	0.86	4718360.25	0.13
	Dickerson Cave	5.39	0.93	0.96	0.78	3481303.50	0.10
	Eckel Cave	1.27	0.98	1.05	0.76	1004753.25	0.03
	Elm Cave	1.16	0.98	1.05	0.76	1014500.25	0.03
	Ennis Cave	11.67	0.84	1.74	0.60	5988719.25	0.17
	Fancher Cave						
	Fish Pond Cave	0.50	0.99	0.73	0.83	487350.00	0.01
	Fitton Cave	23.48	0.68	0.70	0.84	28463676.75	0.80
	Fitton Spring Cave	23.48	0.68	0.70	0.84	28463676.75	0.80

Species	Site	RWQS_01 Raw	RWQS_01 Scaled	RWQS_02 Raw	RWQS_02 Scaled	RWQS_03 Raw	RWQS_03 Scaled
	Foushee Cave	2.44	0.97	0.36	0.92	6294125.25	0.18
	Friday the 13th Cave	23.48	0.68	0.70	0.84	28463676.75	0.80
	Green River Cave	5.14	0.93	1.95	0.55	1651304.25	0.05
	Gunner Cave	8.60	0.88	0.90	0.79	8399477.25	0.24
	Gustafson Cave	4.29	0.94	2.03	0.53	2114286.75	0.06
	Hammer Springs Cave	0.96	0.99	0.17	0.96	5563100.25	0.16
	Hell Creek Cave	17.62	0.76	0.89	0.79	15036372.00	0.42
	Herald Hollow Cave	1.73	0.98	1.02	0.76	1678108.50	0.05
	Hickory Creek Cave						
	Hidden Spring Cave	3.27	0.96	4.35	0.00	753768.00	0.02
	Hog Head Cave	0.73	0.99	0.13	0.97	4583526.75	0.13
	Huchingson's Waterfall Cave						
	Hunter's Cave	0.73	0.99	0.19	0.96	3731476.50	0.11
	Hurricane River Cave	3.10	0.96	0.72	0.83	4031196.75	0.11
	Icebox Cave						
	Indian Rockhouse Cave	7.29	0.90	0.80	0.82	8146055.25	0.23
	In-D-Pendants Cave	6.45	0.91	1.85	0.57	3058933.50	0.09
	Janus Pit	0.63	0.99	0.39	0.91	1602569.25	0.05
	Jelico Hollow Cave	6.05	0.92	1.38	0.68	4332541.50	0.12
	John Eddings Cave	0.31	1.00	0.25	0.94	1036431.00	0.03
	Lewis Spring Cave						
	Little Den Cave	23.48	0.68	0.70	0.84	28463676.75	0.80
	Logan Cave	48.70	0.33	1.60	0.63	16335972.00	0.46
	Major's Cave	3.99	0.95	0.52	0.88	1480731.75	0.04
	Mammoth Spring	1.35	0.98	0.88	0.80	134021.25	0.00
	Martin Hollow Cave	0.10	1.00	0.04	0.99	1722782.25	0.05
	Miner's Cave	1.38	0.98	0.38	0.91	3024006.75	0.09

Species	Site	RWQS_01 Raw	RWQS_01 Scaled	RWQS_02 Raw	RWQS_02 Scaled	RWQS_03 Raw	RWQS_03 Scaled
	Mr. Clean Cave	3.34	0.95	0.93	0.79	3228693.75	0.09
	Mr. Griffin's Cave # 1	2.06	0.97	0.37	0.92	5627268.00	0.16
	Needles Cave	4.12	0.94	2.11	0.52	1072982.25	0.03
	Nesbitt Spring Cave	3.00	0.96	1.11	0.75	2098854.00	0.06
	Norfork Bat Cave	5.16	0.93	1.92	0.56	1477482.75	0.04
	Old Joe Cave	8.42	0.88	1.48	0.66	3934539.00	0.11
	Omega Cave						
	Panther Mountain Cave						
	Pigeon Roost Cave	0.05	1.00	0.04	0.99	1426311.00	0.04
	Potato Cave						
	Pregnant Nun Cave	10.51	0.86	1.06	0.76	9325442.25	0.26
	Pretty Clean Cave	3.44	0.95	1.52	0.65	2209320.00	0.06
	Reed Cave	1.65	0.98	1.26	0.71	1214313.75	0.03
	Richardson Cave	0.90	0.99	0.56	0.87	1357269.75	0.04
	Riley's Springbox	4.99	0.93	2.35	0.46	1846244.25	0.05
	Rootville Cave	1.77	0.98	0.87	0.80	1483980.75	0.04
	Rory Cave	0.70	0.99	0.45	0.90	1085166.00	0.03
	Salamander Cave	4.18	0.94	2.42	0.44	1715472.00	0.05
	Saltpeter Cave	0.17	1.00	0.12	0.97	1410066.00	0.04
	Slick Rock Hollow Cave						
	Springhouse at Steel Creek Ranger Cabin	1.76	0.98	0.71	0.84	2306790.00	0.07
	Steel Creek Campground Cave	3.23	0.96	0.84	0.81	3507295.50	0.10
	Stillhouse Hollow Cave	0.83	0.99	1.55	0.64	346830.75	0.01
	Stovepipe Cave	1.49	0.98	1.91	0.56	437802.75	0.01
	Summer Cave	4.58	0.94	0.97	0.78	4607894.25	0.13
	Tom Allen's Cave	2.96	0.96	1.33	0.69	1542462.75	0.04
	Tom Barnes Cave	0.88	0.99	0.87	0.80	856923.75	0.02

Species	Site	RWQS_01 Raw	RWQS_01 Scaled	RWQS_02 Raw	RWQS_02 Scaled	RWQS_03 Raw	RWQS_03 Scaled
	Toney Bend Mine # 2	3.33	0.95	0.43	0.90	6999158.25	0.20
	Tweet's Cave	1.63	0.98	0.42	0.90	3486177.00	0.10
	Unnamed cave	0.24	1.00	0.86	0.80	219307.50	0.01
	Unnamed caves at Devil's Knob Natural Area	0.00	1.00	0.00	1.00	921903.75	0.03
	Van Dyke Spring Cave	23.48	0.68	0.70	0.84	28463676.75	0.80
	Von Wadding's Memorial Cave	2.05	0.97	0.50	0.89	3996270.00	0.11
	War Eagle Cave	7.18	0.90	0.83	0.81	6021209.25	0.17
	War Eagle Cavern	6.95	0.90	1.19	0.73	5548479.75	0.16
	Whippoorwill Cave	6.05	0.92	1.38	0.68	4332541.50	0.12
	Willis Cave	23.48	0.68	0.70	0.84	28463676.75	0.80
	Wolf Creek Cave	2.71	0.96	0.51	0.88	5168346.75	0.15
	Wounded Knee Cave	1.03	0.99	0.36	0.92	2698294.50	0.08
Lirceus bicuspidatus							
	Diamond Cave	3.28	0.95	0.63	0.86	4718360.25	0.13
	Foushee Cave	2.44	0.97	0.36	0.92	6294125.25	0.18
	Hell Creek Cave	17.62	0.76	0.89	0.79	15036372.00	0.42
	Hurricane River Cave	3.10	0.96	0.72	0.83	4031196.75	0.11
Lirceus bidentatus							
	Unnamed seep 9 mi. SW of Harrison	2.37	0.97	0.39	0.91	4504738.50	0.13
Stygobromus ozarkensis							
	Bear Hollow Cave	21.55	0.70	2.40	0.45	3313167.75	0.09
	Blowing Springs Cave	1.31	0.98	0.54	0.88	1719533.25	0.05
	Cave on Pond Above Black Bass Lake	4.41	0.94	1.17	0.73	3318853.50	0.09
	Cave Springs Cave	29.48	0.60	0.60	0.86	3932102.25	0.11
	Civil War Cave	17.01	0.77	1.43	0.67	2781144.00	0.08
	Dickerson Cave	5.39	0.93	0.96	0.78	3481303.50	0.10

Species	Site	RWQS_01 Raw	RWQS_01 Scaled	RWQS_02 Raw	RWQS_02 Scaled	RWQS_03 Raw	RWQS_03 Scaled
	Fitton Cave	23.48	0.68	0.70	0.84	28463676.75	0.80
	Fitton Spring Cave	23.48	0.68	0.70	0.84	28463676.75	0.80
	Hunter's Cave	0.73	0.99	0.19	0.96	3731476.50	0.11
	John Eddings Cave	0.31	1.00	0.25	0.94	1036431.00	0.03
	Logan Cave	48.70	0.33	1.60	0.63	16335972.00	0.46
	Needles Cave	4.12	0.94	2.11	0.52	1072982.25	0.03
	Old Pendergrass Cave	72.83	0.00	1.47	0.66	29493609.75	0.83
	Pretty Clean Cave	3.44	0.95	1.52	0.65	2209320.00	0.06
	Reed Cave	1.65	0.98	1.26	0.71	1214313.75	0.03
	Sherfield Cave	14.52	0.80	0.66	0.85	19961856.00	0.56
	Spavinaw Creek Cave						
	War Eagle Cave	7.18	0.90	0.83	0.81	6021209.25	0.17
	War Eagle Cavern	6.95	0.90	1.19	0.73	5548479.75	0.16
	White River Below Beaver Dam	2.80	0.96	1.12	0.74	1964832.75	0.06
	Withrow Springs Cave	7.18	0.90	0.83	0.81	6021209.25	0.17
Typhlichthys subterraneus							
	Richardson Cave	0.90	0.99	0.56	0.87	1357269.75	0.04
-	Unnamed well in Randolph County	-	-	-	-	-	-

Table Appendix E-2. Index values and scaled scores for RWQS 04 Raw through RWQN 01 Scaled.

Species	Site	RWQS_04 Raw	RWQS_04 Scaled	RWQS Raw	RWQS Scaled	RWQN_01 Raw	RWQN_01 Scaled
Amblyopsis rosae							
	AGFC Nursery Pond on Beaver Lake	0.73	0.73	2.08	0.59	0.81	1.00
	Cave Springs Cave	0.08	0.08	1.65	0.47	74.04	0.62
	Civil War Cave	0.23	0.23	1.75	0.50	35.58	0.82

Species	Site	RWQS_04 Raw	RWQS_04 Scaled	RWQS Raw	RWQS Scaled	RWQN_01 Raw	RWQN_01 Scaled
	Hewlitt's Spring Hole	0.21	0.21	1.78	0.51	1.45	0.99
	James-Ditto Cave	0.48	0.48	1.91	0.55	6.56	0.97
	Logan Cave	0.54	0.54	1.96	0.56	155.61	0.20
	Monte Ne Sinkhole	0.70	0.70	2.67	0.76	95.76	0.51
	Mule Hole Sink	0.51	0.51	2.21	0.63	0.00	1.00
	Rootville Cave	0.74	0.74	2.55	0.73	7.19	0.96
	Tom Allen's Cave	0.72	0.72	2.42	0.69	4.62	0.98
Amnicola cora							
	Foushee Cave	0.93	0.93	2.99	0.85	29.35	0.85
Bactrurus pseudomucronatus							
	Deep cistern 5.5 mi. S of Imboden	0.64	0.64	2.16	0.62	5.66	0.97
	Mansell Cave	0.70	0.70	2.40	0.69	2.66	0.99
Caecidotea ancyla							
	Bear Hollow Cave	0.88	0.88	2.13	0.61	0.00	1.00
	Brewer Cave						
	Denny Cave	0.48	0.48	2.22	0.63	37.03	0.81
	Fitton Spring Cave	0.85	0.85	3.17	0.90	62.96	0.68
	Foushee Cave	0.93	0.93	2.99	0.85	29.35	0.85
	Greasy Valley Cave	0.48	0.48	2.01	0.58	8.31	0.96
	Ivy Springs Cave	0.35	0.35	1.69	0.48	5.78	0.97
	Major's Cave	0.19	0.19	2.06	0.59	194.92	0.00
	Marshall Caves	0.57	0.57	2.03	0.58	0.89	1.00
	Nesbitt Spring Cave	0.77	0.77	2.54	0.73	3.11	0.98
	Old Pendergrass Cave	0.63	0.63	2.13	0.61	105.17	0.46
	Pretty Clean Cave	0.97	0.97	2.64	0.75	0.14	1.00
	Rootville Cave	0.74	0.74	2.55	0.73	7.19	0.96
	Spavinaw Creek Cave						

Species	Site	RWQS_04 Raw	RWQS_04 Scaled	RWQS Raw	RWQS Scaled	RWQN_01 Raw	RWQN_01 Scaled
	War Eagle Cave	0.70	0.70	2.58	0.74	40.82	0.79
	Withrow Springs Cave	0.70	0.70	2.58	0.74	40.82	0.79
Caecidotea dimorpha							
	Elm Cave	0.93	0.93	2.70	0.77	2.70	0.99
	Martin Hollow Cave	0.73	0.73	2.77	0.79	5.18	0.97
	Mr. Griffin's Cave # 1	1.00	1.00	3.05	0.87	0.01	1.00
	Nesbitt Spring Cave	0.77	0.77	2.54	0.73	3.11	0.98
	Riley's Springbox	0.88	0.88	2.32	0.66	4.76	0.98
	Stovepipe Cave	0.56	0.56	2.11	0.60	1.07	0.99
	Summer Cave	0.97	0.97	2.82	0.80	0.04	1.00
Caecidotea macropropoda							
	Fincher Cave	0.89	0.89	2.50	0.72	10.35	0.95
	Spring at Bradley Shelter	0.41	0.41	2.30	0.66	4.62	0.98
	Stormdrain Spring at University of Arkansas	0.05	0.05	2.05	0.59	0.00	1.00
	Watson Cave	0.38	0.38	1.90	0.54	23.14	0.88
Caecidotea salemensis							
	Deep cistern 5.5 mi. S of Imboden	0.64	0.64	2.16	0.62	5.66	0.97
Caecidotea steevesi							
	AGFC Nursery Pond on Beaver Lake	0.73	0.73	2.08	0.59	0.81	1.00
	Cave on Pond Above Black Bass Lake	0.88	0.88	2.64	0.75	16.24	0.92
	Old Spanish Treasure Cave	0.85	0.85	2.69	0.77	15.60	0.92
	War Eagle Cave	0.70	0.70	2.58	0.74	40.82	0.79
	Withrow Springs Cave	0.70	0.70	2.58	0.74	40.82	0.79
Caecidotea stiladactyla							
	Arkansas Archaeological Survey Site #3BE352	0.54	0.54	2.18	0.62	10.63	0.95
	Bently Cave	0.59	0.59	2.60	0.74	0.00	1.00

Species	Site	RWQS_04 Raw	RWQS_04 Scaled	RWQS Raw	RWQS Scaled	RWQN_01 Raw	RWQN_01 Scaled
	Big Mouth Cave						
	Brock Spring	0.41	0.41	1.92	0.55	106.37	0.45
	Bull Shoals Caverns	0.72	0.72	2.56	0.73	0.00	1.00
	Cal Cave	0.63	0.63	2.37	0.68	15.33	0.92
	Cave Mountain Cave	0.83	0.83	2.66	0.76	1.68	0.99
	Cave on North Boundary Trail	0.89	0.89	2.93	0.84	1.22	0.99
	Cave Springs Cave	0.08	0.08	1.65	0.47	74.04	0.62
	Cold Cave	0.43	0.43	2.12	0.61	15.72	0.92
	Covington's Cave						
	Dickerson Cave	0.62	0.62	2.42	0.69	16.48	0.92
	Eden Falls Cave	0.77	0.77	2.74	0.78	7.96	0.96
	Fish Pond Cave	0.71	0.71	2.55	0.73	4.25	0.98
	Fitton Cave	0.85	0.85	3.17	0.90	62.96	0.68
	Granny Parker's Cave						
	John Eddings Cave	0.84	0.84	2.81	0.80	3.85	0.98
	Laningham's Cave	0.63	0.63	2.37	0.68	15.33	0.92
	Middle Creek Spring Cave						
	Novack Spring Cave	0.77	0.77	2.74	0.78	7.96	0.96
	Old Joe Cave	0.69	0.69	2.35	0.67	27.53	0.86
	Sherfield Cave	0.91	0.91	3.12	0.89	22.29	0.89
	Simpson's Cave	0.51	0.51	2.27	0.65	41.53	0.79
	Spring at Hogscald	0.89	0.89	2.70	0.77	16.70	0.91
	Spring at Sequoyah Woods	0.45	0.45	2.34	0.67	0.00	1.00
	Spring on Butler Creek Road	0.94	0.94	2.82	0.80	4.72	0.98
	Spring on North Boundary Trail	0.89	0.89	2.93	0.84	1.22	0.99
	Stillhouse Hollow Cave	0.64	0.64	2.29	0.65	1.62	0.99
	Tanyard Creek Nature Trail Cave	0.68	0.68	1.97	0.56	3.51	0.98

Species	Site	RWQS_04 Raw	RWQS_04 Scaled	RWQS Raw	RWQS Scaled	RWQN_01 Raw	RWQN_01 Scaled
	Unnamed seep 4 mi. S of Boxley	0.93	0.93	2.80	0.80	0.97	1.00
	Unnamed seep 9 mi. SW of Harrison	0.75	0.75	2.76	0.79	15.04	0.92
	Unnamed spring 3.5 mi. S of Jasper	0.92	0.92	2.53	0.72	6.06	0.97
	War Eagle Cavern	0.95	0.95	2.74	0.78	23.87	0.88
	White River Below Beaver Dam	0.79	0.79	2.55	0.73	7.79	0.96
Cambarus aculabrum							
	Bear Hollow Cave	0.88	0.88	2.13	0.61	0.00	1.00
	Brush Creek	0.06	0.06	1.68	0.48	28.48	0.85
	Logan Cave	0.54	0.54	1.96	0.56	155.61	0.20
	Old Pendergrass Cave	0.63	0.63	2.13	0.61	105.17	0.46
Cambarus setosus							
	Blowing Cave	0.99	0.99	3.01	0.86	0.08	1.00
	Poke Cave	0.99	0.99	3.01	0.86	0.08	1.00
	Tom Allen's Cave	0.72	0.72	2.42	0.69	4.62	0.98
Cambarus zophonastes							
	Hell Creek Cave	0.76	0.76	2.74	0.78	164.73	0.15
	Nesbitt Spring Cave	0.77	0.77	2.54	0.73	3.11	0.98
	site in Yellville	0.49	0.49	1.81	0.52	41.11	0.79
Dendrocoelopsis americana							
	Brock Spring	0.41	0.41	1.92	0.55	106.37	0.45
	Granny Parker's Cave						
	Steel Creek Campground Cave	0.91	0.91	2.77	0.79	3.60	0.98
	Watson Cave	0.38	0.38	1.90	0.54	23.14	0.88
Eurycea spelaea							
	Alexander Cave	0.55	0.55	2.20	0.63	83.34	0.57
	Allen Cave						
	Back o' Beyond Cave	0.62	0.62	2.54	0.72	3.79	0.98

Species	Site	RWQS_04 Raw	RWQS_04 Scaled	RWQS Raw	RWQS Scaled	RWQN_01 Raw	RWQN_01 Scaled
	Bald Scrappy Cave	0.93	0.93	2.62	0.75	1.39	0.99
	Bear Hollow Cave	0.88	0.88	2.13	0.61	0.00	1.00
	Bear Pit	0.81	0.81	2.86	0.82	1.10	0.99
	Bell Cave						
	Bently Cave	0.59	0.59	2.60	0.74	0.00	1.00
	Big Mouth Cave						
	Big Spring Cave						
	Biology Cave	1.00	1.00	2.64	0.75	0.00	1.00
	Blanchard Springs Caverns	0.91	0.91	3.50	1.00	30.01	0.85
	Blowing Cave	0.99	0.99	3.01	0.86	0.08	1.00
	Blowing Spring Cave	1.00	1.00	3.09	0.88	1.02	0.99
	Blowing Springs Cave	0.70	0.70	2.61	0.75	20.64	0.89
	Blowing Springs Cave	0.80	0.80	2.52	0.72	2.77	0.99
	Blue Heaven Cave	0.67	0.67	2.52	0.72	15.95	0.92
	Bonanza Cave	0.85	0.85	2.86	0.82	2.88	0.99
	Bonanza Mine	1.00	1.00	2.76	0.79	1.40	0.99
	Breakdown Cave	0.96	0.96	2.93	0.84	0.00	1.00
	Brewer Cave						
	Bull Shoals Caverns	0.72	0.72	2.56	0.73	0.00	1.00
	Cave River Cave	0.94	0.94	2.73	0.78	3.67	0.98
	Cave Springs Cave	0.08	0.08	1.65	0.47	74.04	0.62
	Chambers Hollow Cave	0.95	0.95	2.72	0.78	4.83	0.98
	Chilly Bowl Cave	0.92	0.92	2.39	0.68	7.29	0.96
	Chinn Springs Cave	0.83	0.83	2.92	0.83	63.28	0.68
	Congo Crawl						
	Coon Cave	0.94	0.94	2.86	0.82	1.75	0.99
	Copperhead Cave	0.82	0.82	2.39	0.68	5.61	0.97

Species	Site	RWQS_04 Raw	RWQS_04 Scaled	RWQS Raw	RWQS Scaled	RWQN_01 Raw	RWQN_01 Scaled
	Corkscrew Cave	0.94	0.94	2.79	0.80	13.46	0.93
	Cosmic Caverns	0.68	0.68	2.52	0.72	24.51	0.87
	Crystal Dome Cave	0.60	0.60	2.09	0.60	71.51	0.63
	Cushman Cave	0.89	0.89	2.63	0.75	1.00	0.99
	Cyner Cave	0.79	0.79	2.90	0.83	13.43	0.93
	Davis Creek Cave						
	Dear Buster Cave	0.89	0.89	3.02	0.86	6.49	0.97
	Diamond Cave	0.90	0.90	2.85	0.81	10.34	0.95
	Dickerson Cave	0.62	0.62	2.42	0.69	16.48	0.92
	Eckel Cave	0.83	0.83	2.60	0.74	2.32	0.99
	Elm Cave	0.93	0.93	2.70	0.77	2.70	0.99
	Ennis Cave	0.89	0.89	2.50	0.71	9.56	0.95
	Fancher Cave						
	Fish Pond Cave	0.71	0.71	2.55	0.73	4.25	0.98
	Fitton Cave	0.85	0.85	3.17	0.90	62.96	0.68
	Fitton Spring Cave	0.85	0.85	3.17	0.90	62.96	0.68
	Foushee Cave	0.93	0.93	2.99	0.85	29.35	0.85
	Friday the 13th Cave	0.85	0.85	3.17	0.90	62.96	0.68
	Green River Cave	0.62	0.62	2.15	0.61	16.61	0.91
	Gunner Cave	0.87	0.87	2.79	0.80	6.67	0.97
	Gustafson Cave	1.00	1.00	2.53	0.72	0.21	1.00
	Hammer Springs Cave	0.97	0.97	3.08	0.88	4.55	0.98
	Hell Creek Cave	0.76	0.76	2.74	0.78	164.73	0.15
	Herald Hollow Cave	1.00	1.00	2.79	0.80	0.00	1.00
	Hickory Creek Cave						
	Hidden Spring Cave	1.00	1.00	1.98	0.56	0.00	1.00
	Hog Head Cave	0.83	0.83	2.92	0.83	5.21	0.97

Species	Site	RWQS_04 Raw	RWQS_04 Scaled	RWQS Raw	RWQS Scaled	RWQN_01 Raw	RWQN_01 Scaled
	Huchingson's Waterfall Cave						
	Hunter's Cave	0.99	0.99	3.04	0.87	0.31	1.00
	Hurricane River Cave	0.94	0.94	2.85	0.81	4.56	0.98
	Icebox Cave						
	Indian Rockhouse Cave	0.89	0.89	2.84	0.81	16.37	0.92
	In-D-Pendants Cave	0.88	0.88	2.45	0.70	0.78	1.00
	Janus Pit	0.98	0.98	2.93	0.84	1.73	0.99
	Jelico Hollow Cave	0.99	0.99	2.71	0.77	1.81	0.99
	John Eddings Cave	0.84	0.84	2.81	0.80	3.85	0.98
	Lewis Spring Cave						
	Little Den Cave	0.85	0.85	3.17	0.90	62.96	0.68
	Logan Cave	0.54	0.54	1.96	0.56	155.61	0.20
	Major's Cave	0.19	0.19	2.06	0.59	194.92	0.00
	Mammoth Spring	0.15	0.15	1.93	0.55	0.25	1.00
	Martin Hollow Cave	0.73	0.73	2.77	0.79	5.18	0.97
	Miner's Cave	0.82	0.82	2.80	0.80	14.97	0.92
	Mr. Clean Cave	0.91	0.91	2.74	0.78	2.77	0.99
	Mr. Griffin's Cave # 1	1.00	1.00	3.05	0.87	0.01	1.00
	Needles Cave	0.55	0.55	2.04	0.58	4.28	0.98
	Nesbitt Spring Cave	0.77	0.77	2.54	0.73	3.11	0.98
	Norfork Bat Cave	0.55	0.55	2.08	0.59	13.47	0.93
	Old Joe Cave	0.69	0.69	2.35	0.67	27.53	0.86
	Omega Cave						
	Panther Mountain Cave						
	Pigeon Roost Cave	0.99	0.99	3.02	0.86	0.70	1.00
	Potato Cave						
	Pregnant Nun Cave	0.94	0.94	2.82	0.80	4.72	0.98

Species	Site	RWQS_04 Raw	RWQS_04 Scaled	RWQS Raw	RWQS Scaled	RWQN_01 Raw	RWQN_01 Scaled
	Pretty Clean Cave	0.97	0.97	2.64	0.75	0.14	1.00
	Reed Cave	0.93	0.93	2.65	0.76	5.16	0.97
	Richardson Cave	0.85	0.85	2.74	0.78	5.28	0.97
	Riley's Springbox	0.88	0.88	2.32	0.66	4.76	0.98
	Rootville Cave	0.74	0.74	2.55	0.73	7.19	0.96
	Rory Cave	0.69	0.69	2.61	0.75	1.54	0.99
	Salamander Cave	1.00	1.00	2.43	0.69	0.46	1.00
	Saltpeter Cave	1.00	1.00	3.01	0.86	1.57	0.99
	Slick Rock Hollow Cave						
	Springhouse at Steel Creek Ranger Cabin	0.93	0.93	2.81	0.80	4.70	0.98
	Steel Creek Campground Cave	0.91	0.91	2.77	0.79	3.60	0.98
	Stillhouse Hollow Cave	0.64	0.64	2.29	0.65	1.62	0.99
	Stovepipe Cave	0.56	0.56	2.11	0.60	1.07	0.99
	Summer Cave	0.97	0.97	2.82	0.80	0.04	1.00
	Tom Allen's Cave	0.72	0.72	2.42	0.69	4.62	0.98
	Tom Barnes Cave	0.86	0.86	2.68	0.76	0.75	1.00
	Toney Bend Mine # 2	0.91	0.91	2.96	0.85	3.29	0.98
	Tweet's Cave	0.90	0.90	2.88	0.82	6.70	0.97
	Unnamed cave	0.79	0.79	2.59	0.74	0.48	1.00
	Unnamed caves at Devil's Knob Natural Area	0.99	0.99	3.02	0.86	0.32	1.00
	Van Dyke Spring Cave	0.85	0.85	3.17	0.90	62.96	0.68
	Von Wadding's Memorial Cave	0.96	0.96	2.93	0.84	0.00	1.00
	War Eagle Cave	0.70	0.70	2.58	0.74	40.82	0.79
	War Eagle Cavern	0.95	0.95	2.74	0.78	23.87	0.88
	Whippoorwill Cave	0.99	0.99	2.71	0.77	1.81	0.99
	Willis Cave	0.85	0.85	3.17	0.90	62.96	0.68

Species	Site	RWQS_04 Raw	RWQS_04 Scaled	RWQS Raw	RWQS Scaled	RWQN_01 Raw	RWQN_01 Scaled
	Wolf Creek Cave	0.97	0.97	2.96	0.85	1.85	0.99
	Wounded Knee Cave	0.95	0.95	2.93	0.84	0.78	1.00
Lirceus bicuspidatus							
	Diamond Cave	0.90	0.90	2.85	0.81	10.34	0.95
	Foushee Cave	0.93	0.93	2.99	0.85	29.35	0.85
	Hell Creek Cave	0.76	0.76	2.74	0.78	164.73	0.15
	Hurricane River Cave	0.94	0.94	2.85	0.81	4.56	0.98
Lirceus bidentatus							
	Unnamed seep 9 mi. SW of Harrison	0.75	0.75	2.76	0.79	15.04	0.92
Stygobromus ozarkensis							
	Bear Hollow Cave	0.88	0.88	2.13	0.61	0.00	1.00
	Blowing Springs Cave	0.70	0.70	2.61	0.75	20.64	0.89
	Cave on Pond Above Black Bass Lake	0.88	0.88	2.64	0.75	16.24	0.92
	Cave Springs Cave	0.08	0.08	1.65	0.47	74.04	0.62
	Civil War Cave	0.23	0.23	1.75	0.50	35.58	0.82
	Dickerson Cave	0.62	0.62	2.42	0.69	16.48	0.92
	Fitton Cave	0.85	0.85	3.17	0.90	62.96	0.68
	Fitton Spring Cave	0.85	0.85	3.17	0.90	62.96	0.68
	Hunter's Cave	0.99	0.99	3.04	0.87	0.31	1.00
	John Eddings Cave	0.84	0.84	2.81	0.80	3.85	0.98
	Logan Cave	0.54	0.54	1.96	0.56	155.61	0.20
	Needles Cave	0.55	0.55	2.04	0.58	4.28	0.98
	Old Pendergrass Cave	0.63	0.63	2.13	0.61	105.17	0.46
	Pretty Clean Cave	0.97	0.97	2.64	0.75	0.14	1.00
	Reed Cave	0.93	0.93	2.65	0.76	5.16	0.97
	Sherfield Cave	0.91	0.91	3.12	0.89	22.29	0.89
	Spavinaw Creek Cave						

Species	Site	RWQS_04 Raw	RWQS_04 Scaled	RWQS Raw	RWQS Scaled	RWQN_01 Raw	RWQN_01 Scaled
	War Eagle Cave	0.70	0.70	2.58	0.74	40.82	0.79
	War Eagle Cavern	0.95	0.95	2.74	0.78	23.87	0.88
	White River Below Beaver Dam	0.79	0.79	2.55	0.73	7.79	0.96
	Withrow Springs Cave	0.70	0.70	2.58	0.74	40.82	0.79
Typhlichthys subterraneus							
	Richardson Cave	0.85	0.85	2.74	0.78	5.28	0.97
-	Unnamed well in Randolph County	-	-	-	-	-	-

Table Appendix E-3. Index values and scaled scores for RWQN 02 Raw through RWQN 04 Scaled.

Species	Site	RWQN_02 Raw	RWQN_02 Scaled	RWQN_03 Raw	RWQN_03 Scaled	RWQN_04 Raw	RWQN_04 Scaled
Amblyopsis rosae							
	AGFC Nursery Pond on Beaver Lake	0	1.00	0.00	1.00	8934.75	1.00
	Cave Springs Cave	26	0.60	0.00	1.00	22110257.25	0.00
	Civil War Cave	11	0.83	0.00	1.00	4983153.75	0.77
	Hewlitt's Spring Hole	2	0.97	0.00	1.00	8144430.75	0.63
	James-Ditto Cave	0	1.00	0.00	1.00	583195.50	0.97
	Logan Cave	65	0.00	0.01	1.00	12589875.00	0.43
	Monte Ne Sinkhole	0	1.00	0.00	1.00	242050.50	0.99
	Mule Hole Sink	0	1.00	0.00	1.00	116964.00	0.99
	Rootville Cave	2	0.97	0.00	1.00	365512.50	0.98
	Tom Allen's Cave	0	1.00	0.00	1.00	470292.75	0.98
Amnicola cora							
	Foushee Cave	0	1.00	0.00	1.00	433741.50	0.98
Bactrurus pseudomucronatus							
	Deep cistern 5.5 mi. S of Imboden	0	1.00	0.00	1.00	406125.00	0.98

Species	Site	RWQN_02 Raw	RWQN_02 Scaled	RWQN_03 Raw	RWQN_03 Scaled	RWQN_04 Raw	RWQN_04 Scaled
	Mansell Cave	0	1.00	0.00	1.00	536897.25	0.98
Caecidotea ancyla							
	Bear Hollow Cave	0	1.00	0.00	1.00	5685.75	1.00
	Brewer Cave						
	Denny Cave	10	0.85	0.00	1.00	3581210.25	0.84
	Fitton Spring Cave	0	1.00	0.00	1.00	3556842.75	0.84
	Foushee Cave	0	1.00	0.00	1.00	433741.50	0.98
	Greasy Valley Cave	13	0.80	0.03	0.99	936524.25	0.96
	Ivy Springs Cave	4	0.94	0.01	1.00	951144.75	0.96
	Major's Cave	0	1.00	0.00	1.00	2630877.75	0.88
	Marshall Caves	0	1.00	0.00	1.00	155139.75	0.99
	Nesbitt Spring Cave	3	0.95	0.00	1.00	571824.00	0.97
	Old Pendergrass Cave	43	0.34	0.00	1.00	6243765.75	0.72
	Pretty Clean Cave	0	1.00	0.00	1.00	30865.50	1.00
	Rootville Cave	2	0.97	0.00	1.00	365512.50	0.98
	Spavinaw Creek Cave						
	War Eagle Cave	5	0.92	0.00	1.00	1796697.00	0.92
	Withrow Springs Cave	5	0.92	0.00	1.00	1796697.00	0.92
Caecidotea dimorpha							
	Elm Cave	0	1.00	0.00	1.00	8122.50	1.00
	Martin Hollow Cave	0	1.00	0.00	1.00	624620.25	0.97
	Mr. Griffin's Cave # 1	0	1.00	0.00	1.00	0.00	1.00
	Nesbitt Spring Cave	3	0.95	0.00	1.00	571824.00	0.97
	Riley's Springbox	0	1.00	0.00	1.00	123462.00	0.99
	Stovepipe Cave	0	1.00	0.00	1.00	287536.50	0.99
	Summer Cave	0	1.00	0.00	1.00	43861.50	1.00
Caecidotea macropropoda							

Species	Site	RWQN_02 Raw	RWQN_02 Scaled	RWQN_03 Raw	RWQN_03 Scaled	RWQN_04 Raw	RWQN_04 Scaled
	Fincher Cave	0	1.00	0.00	1.00	154327.50	0.99
	Spring at Bradley Shelter	0	1.00	0.00	1.00	939773.25	0.96
	Stormdrain Spring at University of Arkansas	0	1.00	0.00	1.00	30053.25	1.00
	Watson Cave	0	1.00	0.00	1.00	1219999.50	0.94
Caecidotea salemensis							
	Deep cistern 5.5 mi. S of Imboden	0	1.00	0.00	1.00	406125.00	0.98
Caecidotea steevesi							
	AGFC Nursery Pond on Beaver Lake	0	1.00	0.00	1.00	8934.75	1.00
	Cave on Pond Above Black Bass Lake	0	1.00	0.00	1.00	38988.00	1.00
	Old Spanish Treasure Cave	0	1.00	0.00	1.00	114527.25	0.99
	War Eagle Cave	5	0.92	0.00	1.00	1796697.00	0.92
	Withrow Springs Cave	5	0.92	0.00	1.00	1796697.00	0.92
Caecidotea stiladactyla							
	Arkansas Archaeological Survey Site #3BE352	0	1.00	0.00	1.00	420745.50	0.98
	Bently Cave	0	1.00	0.00	1.00	22743.00	1.00
	Big Mouth Cave						
	Brock Spring	13	0.80	0.01	1.00	1575765.00	0.93
	Bull Shoals Caverns	0	1.00	0.00	1.00	110466.00	1.00
	Cal Cave	3	0.95	0.00	1.00	1185072.75	0.95
	Cave Mountain Cave	0	1.00	0.00	1.00	275352.75	0.99
	Cave on North Boundary Trail	0	1.00	0.00	1.00	13808.25	1.00
	Cave Springs Cave	26	0.60	0.00	1.00	22110257.25	0.00
	Cold Cave	0	1.00	0.00	1.00	107217.00	1.00
	Covington's Cave						
	Dickerson Cave	13	0.80	0.01	1.00	1841370.75	0.92
	Eden Falls Cave	0	1.00	0.00	1.00	949520.25	0.96

Species	Site	RWQN_02 Raw	RWQN_02 Scaled	RWQN_03 Raw	RWQN_03 Scaled	RWQN_04 Raw	RWQN_04 Scaled
	Fish Pond Cave	0	1.00	0.00	1.00	169760.25	0.99
	Fitton Cave	0	1.00	0.00	1.00	3556842.75	0.84
	Granny Parker's Cave						
	John Eddings Cave	0	1.00	0.00	1.00	95845.50	1.00
	Laningham's Cave	3	0.95	0.00	1.00	1185072.75	0.95
	Middle Creek Spring Cave						
	Novack Spring Cave	0	1.00	0.00	1.00	949520.25	0.96
	Old Joe Cave	0	1.00	0.00	1.00	353328.75	0.98
	Sherfield Cave	0	1.00	0.00	1.00	1051863.75	0.95
	Simpson's Cave	7	0.89	0.00	1.00	3952408.50	0.82
	Spring at Hogscald	0	1.00	0.00	1.00	363888.00	0.98
	Spring at Sequoyah Woods	0	1.00	0.00	1.00	304593.75	0.99
	Spring on Butler Creek Road	3	0.95	0.00	1.00	376071.75	0.98
	Spring on North Boundary Trail	0	1.00	0.00	1.00	13808.25	1.00
	Stillhouse Hollow Cave	0	1.00	0.00	1.00	77163.75	1.00
	Tanyard Creek Nature Trail Cave	0	1.00	0.00	1.00	230679.00	0.99
	Unnamed seep 4 mi. S of Boxley	0	1.00	0.00	1.00	122649.75	0.99
	Unnamed seep 9 mi. SW of Harrison	0	1.00	0.00	1.00	969014.25	0.96
	Unnamed spring 3.5 mi. S of Jasper	0	1.00	0.00	1.00	38175.75	1.00
	War Eagle Cavern	0	1.00	0.00	1.00	29241.00	1.00
	White River Below Beaver Dam	0	1.00	0.00	1.00	149454.00	0.99
Cambarus aculabrum							
	Bear Hollow Cave	0	1.00	0.00	1.00	5685.75	1.00
	Brush Creek	17	0.74	0.01	1.00	6331488.75	0.71
	Logan Cave	65	0.00	0.01	1.00	12589875.00	0.43
	Old Pendergrass Cave	43	0.34	0.00	1.00	6243765.75	0.72
Cambarus setosus							

Species	Site	RWQN_02 Raw	RWQN_02 Scaled	RWQN_03 Raw	RWQN_03 Scaled	RWQN_04 Raw	RWQN_04 Scaled
	Blowing Cave	0	1.00	0.00	1.00	3249.00	1.00
	Poke Cave	0	1.00	0.00	1.00	3249.00	1.00
	Tom Allen's Cave	0	1.00	0.00	1.00	470292.75	0.98
Cambarus zophonastes							
	Hell Creek Cave	2	0.97	0.00	1.00	2838813.75	0.87
	Nesbitt Spring Cave	3	0.95	0.00	1.00	571824.00	0.97
	site in Yellville	1	0.98	0.09	0.96	1763394.75	0.92
Dendrocoelopsis americana							
	Brock Spring	13	0.80	0.01	1.00	1575765.00	0.93
	Granny Parker's Cave						
	Steel Creek Campground Cave	0	1.00	0.00	1.00	139707.00	0.99
	Watson Cave	0	1.00	0.00	1.00	1219999.50	0.94
Eurycea spelaea							
	Alexander Cave	14	0.78	0.00	1.00	9510635.25	0.57
	Allen Cave						
	Back o' Beyond Cave	0	1.00	0.00	1.00	622995.75	0.97
	Bald Scrappy Cave	0	1.00	0.00	1.00	129960.00	0.99
	Bear Hollow Cave	0	1.00	0.00	1.00	5685.75	1.00
	Bear Pit	0	1.00	0.00	1.00	264793.50	0.99
	Bell Cave						
	Bently Cave	0	1.00	0.00	1.00	22743.00	1.00
	Big Mouth Cave						
	Big Spring Cave						
	Biology Cave	0	1.00	0.00	1.00	0.00	1.00
	Blanchard Springs Caverns	0	1.00	0.00	1.00	1293914.25	0.94
	Blowing Cave	0	1.00	0.00	1.00	3249.00	1.00
	Blowing Spring Cave	0	1.00	0.00	1.00	0.00	1.00

Species	Site	RWQN_02 Raw	RWQN_02 Scaled	RWQN_03 Raw	RWQN_03 Scaled	RWQN_04 Raw	RWQN_04 Scaled
	Blowing Springs Cave	0	1.00	0.00	1.00	34926.75	1.00
	Blowing Springs Cave	0	1.00	0.00	1.00	383382.00	0.98
	Blue Heaven Cave	0	1.00	0.00	1.00	1128215.25	0.95
	Bonanza Cave	0	1.00	0.00	1.00	317589.75	0.99
	Bonanza Mine	0	1.00	0.00	1.00	0.00	1.00
	Breakdown Cave	0	1.00	0.00	1.00	9747.00	1.00
	Brewer Cave						
	Bull Shoals Caverns	0	1.00	0.00	1.00	110466.00	1.00
	Cave River Cave	0	1.00	0.00	1.00	205499.25	0.99
	Cave Springs Cave	26	0.60	0.00	1.00	22110257.25	0.00
	Chambers Hollow Cave	0	1.00	0.00	1.00	140519.25	0.99
	Chilly Bowl Cave	0	1.00	0.00	1.00	90972.00	1.00
	Chinn Springs Cave	0	1.00	0.00	1.00	2239373.25	0.90
	Congo Crawl						
	Coon Cave	0	1.00	0.00	1.00	8934.75	1.00
	Copperhead Cave	0	1.00	0.00	1.00	345206.25	0.98
	Corkscrew Cave	0	1.00	0.00	1.00	146205.00	0.99
	Cosmic Caverns	1	0.98	0.00	1.00	1119280.50	0.95
	Crystal Dome Cave	0	1.00	0.00	1.00	1265485.50	0.94
	Cushman Cave	0	1.00	0.00	1.00	79600.50	1.00
	Cyner Cave	0	1.00	0.00	1.00	1909599.75	0.91
	Davis Creek Cave						
	Dear Buster Cave	3	0.95	0.00	1.00	527150.25	0.98
	Diamond Cave	0	1.00	0.00	1.00	291597.75	0.99
	Dickerson Cave	13	0.80	0.01	1.00	1841370.75	0.92
	Eckel Cave	0	1.00	0.00	1.00	178695.00	0.99
	Elm Cave	0	1.00	0.00	1.00	8122.50	1.00

Species	Site	RWQN_02 Raw	RWQN_02 Scaled	RWQN_03 Raw	RWQN_03 Scaled	RWQN_04 Raw	RWQN_04 Scaled
	Ennis Cave	0	1.00	0.00	1.00	637616.25	0.97
	Fancher Cave						
	Fish Pond Cave	0	1.00	0.00	1.00	169760.25	0.99
	Fitton Cave	0	1.00	0.00	1.00	3556842.75	0.84
	Fitton Spring Cave	0	1.00	0.00	1.00	3556842.75	0.84
	Foushee Cave	0	1.00	0.00	1.00	433741.50	0.98
	Friday the 13th Cave	0	1.00	0.00	1.00	3556842.75	0.84
	Green River Cave	2	0.97	0.00	1.00	592942.50	0.97
	Gunner Cave	5	0.92	0.00	1.00	909720.00	0.96
	Gustafson Cave	0	1.00	0.00	1.00	812.25	1.00
	Hammer Springs Cave	0	1.00	0.00	1.00	60106.50	1.00
	Hell Creek Cave	2	0.97	0.00	1.00	2838813.75	0.87
	Herald Hollow Cave	0	1.00	0.00	1.00	2436.75	1.00
	Hickory Creek Cave						
	Hidden Spring Cave	0	1.00	0.00	1.00	0.00	1.00
	Hog Head Cave	0	1.00	0.00	1.00	500346.00	0.98
	Huchingson's Waterfall Cave						
	Hunter's Cave	0	1.00	0.00	1.00	30053.25	1.00
	Hurricane River Cave	0	1.00	0.00	1.00	77163.75	1.00
	Icebox Cave						
	Indian Rockhouse Cave	0	1.00	0.00	1.00	325712.25	0.99
	In-D-Pendants Cave	0	1.00	0.00	1.00	216870.75	0.99
	Janus Pit	0	1.00	0.00	1.00	25179.75	1.00
	Jelico Hollow Cave	0	1.00	0.00	1.00	8934.75	1.00
	John Eddings Cave	0	1.00	0.00	1.00	95845.50	1.00
	Lewis Spring Cave						
	Little Den Cave	0	1.00	0.00	1.00	3556842.75	0.84

Species	Site	RWQN_02 Raw	RWQN_02 Scaled	RWQN_03 Raw	RWQN_03 Scaled	RWQN_04 Raw	RWQN_04 Scaled
	Logan Cave	65	0.00	0.01	1.00	12589875.00	0.43
	Major's Cave	0	1.00	0.00	1.00	2630877.75	0.88
	Mammoth Spring	0	1.00	0.00	1.00	84474.00	1.00
	Martin Hollow Cave	0	1.00	0.00	1.00	624620.25	0.97
	Miner's Cave	0	1.00	0.00	1.00	168948.00	0.99
	Mr. Clean Cave	0	1.00	0.00	1.00	237989.25	0.99
	Mr. Griffin's Cave # 1	0	1.00	0.00	1.00	0.00	1.00
	Needles Cave	0	1.00	0.00	1.00	160013.25	0.99
	Nesbitt Spring Cave	3	0.95	0.00	1.00	571824.00	0.97
	Norfork Bat Cave	0	1.00	0.00	1.00	315965.25	0.99
	Old Joe Cave	0	1.00	0.00	1.00	353328.75	0.98
	Omega Cave						
	Panther Mountain Cave						
	Pigeon Roost Cave	0	1.00	0.00	1.00	0.00	1.00
	Potato Cave						
	Pregnant Nun Cave	3	0.95	0.00	1.00	376071.75	0.98
	Pretty Clean Cave	0	1.00	0.00	1.00	30865.50	1.00
	Reed Cave	0	1.00	0.00	1.00	43049.25	1.00
	Richardson Cave	0	1.00	0.00	1.00	84474.00	1.00
	Riley's Springbox	0	1.00	0.00	1.00	123462.00	0.99
	Rootville Cave	2	0.97	0.00	1.00	365512.50	0.98
	Rory Cave	0	1.00	0.00	1.00	293222.25	0.99
	Salamander Cave	0	1.00	0.00	1.00	2436.75	1.00
	Saltpeter Cave	0	1.00	0.00	1.00	0.00	1.00
	Slick Rock Hollow Cave						
	Springhouse at Steel Creek Ranger Cabin	0	1.00	0.00	1.00	71478.00	1.00
	Steel Creek Campground Cave	0	1.00	0.00	1.00	139707.00	0.99

Species	Site	RWQN_02 Raw	RWQN_02 Scaled	RWQN_03 Raw	RWQN_03 Scaled	RWQN_04 Raw	RWQN_04 Scaled
	Stillhouse Hollow Cave	0	1.00	0.00	1.00	77163.75	1.00
	Stovepipe Cave	0	1.00	0.00	1.00	287536.50	0.99
	Summer Cave	0	1.00	0.00	1.00	43861.50	1.00
	Tom Allen's Cave	0	1.00	0.00	1.00	470292.75	0.98
	Tom Barnes Cave	0	1.00	0.00	1.00	62543.25	1.00
	Toney Bend Mine # 2	0	1.00	0.00	1.00	342769.50	0.98
	Tweet's Cave	0	1.00	0.00	1.00	298908.00	0.99
	Unnamed cave	0	1.00	0.00	1.00	51984.00	1.00
	Unnamed caves at Devil's Knob Natural Area	0	1.00	0.00	1.00	7310.25	1.00
	Van Dyke Spring Cave	0	1.00	0.00	1.00	3556842.75	0.84
	Von Wadding's Memorial Cave	0	1.00	0.00	1.00	9747.00	1.00
	War Eagle Cave	5	0.92	0.00	1.00	1796697.00	0.92
	War Eagle Cavern	0	1.00	0.00	1.00	29241.00	1.00
	Whippoorwill Cave	0	1.00	0.00	1.00	8934.75	1.00
	Willis Cave	0	1.00	0.00	1.00	3556842.75	0.84
	Wolf Creek Cave	0	1.00	0.00	1.00	101531.25	1.00
	Wounded Knee Cave	0	1.00	0.00	1.00	65792.25	1.00
Lirceus bicuspidatus							
	Diamond Cave	0	1.00	0.00	1.00	291597.75	0.99
	Foushee Cave	0	1.00	0.00	1.00	433741.50	0.98
	Hell Creek Cave	2	0.97	0.00	1.00	2838813.75	0.87
	Hurricane River Cave	0	1.00	0.00	1.00	77163.75	1.00
Lirceus bidentatus							
	Unnamed seep 9 mi. SW of Harrison	0	1.00	0.00	1.00	969014.25	0.96
Stygobromus ozarkensis							
	Bear Hollow Cave	0	1.00	0.00	1.00	5685.75	1.00

Species	Site	RWQN_02 Raw	RWQN_02 Scaled	RWQN_03 Raw	RWQN_03 Scaled	RWQN_04 Raw	RWQN_04 Scaled
	Blowing Springs Cave	0	1.00	0.00	1.00	34926.75	1.00
	Cave on Pond Above Black Bass Lake	0	1.00	0.00	1.00	38988.00	1.00
	Cave Springs Cave	26	0.60	0.00	1.00	22110257.25	0.00
	Civil War Cave	11	0.83	0.00	1.00	4983153.75	0.77
	Dickerson Cave	13	0.80	0.01	1.00	1841370.75	0.92
	Fitton Cave	0	1.00	0.00	1.00	3556842.75	0.84
	Fitton Spring Cave	0	1.00	0.00	1.00	3556842.75	0.84
	Hunter's Cave	0	1.00	0.00	1.00	30053.25	1.00
	John Eddings Cave	0	1.00	0.00	1.00	95845.50	1.00
	Logan Cave	65	0.00	0.01	1.00	12589875.00	0.43
	Needles Cave	0	1.00	0.00	1.00	160013.25	0.99
	Old Pendergrass Cave	43	0.34	0.00	1.00	6243765.75	0.72
	Pretty Clean Cave	0	1.00	0.00	1.00	30865.50	1.00
	Reed Cave	0	1.00	0.00	1.00	43049.25	1.00
	Sherfield Cave	0	1.00	0.00	1.00	1051863.75	0.95
	Spavinaw Creek Cave						
	War Eagle Cave	5	0.92	0.00	1.00	1796697.00	0.92
	War Eagle Cavern	0	1.00	0.00	1.00	29241.00	1.00
	White River Below Beaver Dam	0	1.00	0.00	1.00	149454.00	0.99
	Withrow Springs Cave	5	0.92	0.00	1.00	1796697.00	0.92
Typhlichthys subterraneus							
	Richardson Cave	0	1.00	0.00	1.00	84474.00	1.00
-	Unnamed well in Randolph County	-	-	-	-	-	-

Table Appendix E-4. Index values and scaled scores for RWQN 05 Raw through RWQP 01 Scaled.

Species	Site	RWQN_05 Raw	RWQN_05 Scaled	RWQN Raw	RWQN Scaled	RWQP_01 Raw	RWQP_01 Scaled
Amblyopsis rosae							
	AGFC Nursery Pond on Beaver Lake	0.03	0.96	4.96	0.99	0.00	1.00
	Cave Springs Cave	0.45	0.35	2.57	0.51	18364394.54	0.00
	Civil War Cave	0.42	0.39	3.81	0.76	106.94	1.00
	Hewlitt's Spring Hole	0.60	0.13	3.72	0.74	6957051.50	0.62
	James-Ditto Cave	0.40	0.42	4.36	0.87	12.82	1.00
	Logan Cave	0.41	0.40	2.03	0.41	63625.53	1.00
	Monte Ne Sinkhole	0.07	0.89	4.39	0.88	14.04	1.00
	Mule Hole Sink	0.28	0.60	4.59	0.92	4.20	1.00
	Rootville Cave	0.18	0.74	4.65	0.93	17.38	1.00
	Tom Allen's Cave	0.22	0.68	4.64	0.93	13.33	1.00
Amnicola cora							
	Foushee Cave	0.06	0.91	4.74	0.95	112382.79	0.99
Bactrurus pseudomucronatus							
	Deep cistern 5.5 mi. S of Imboden	0.30	0.57	4.52	0.90	0.00	1.00
	Mansell Cave	0.28	0.60	4.56	0.91	0.00	1.00
Caecidotea ancyla							
	Bear Hollow Cave	0.00	1.00	5.00	1.00	389524.21	0.98
	Brewer Cave						
	Denny Cave	0.41	0.41	3.90	0.78	30.77	1.00
	Fitton Spring Cave	0.11	0.85	4.36	0.87	61.70	1.00
	Foushee Cave	0.06	0.91	4.74	0.95	112382.79	0.99
	Greasy Valley Cave	0.47	0.33	4.03	0.81	0.00	1.00
	Ivy Springs Cave	0.49	0.30	4.16	0.83	0.00	1.00
	Major's Cave	0.34	0.51	3.39	0.68	82.37	1.00
	Marshall Caves	0.20	0.71	4.70	0.94	2.92	1.00

Species	Site	RWQN_05 Raw	RWQN_05 Scaled	RWQN Raw	RWQN Scaled	RWQP_01 Raw	RWQP_01 Scaled
	Nesbitt Spring Cave	0.21	0.70	4.61	0.92	0.00	1.00
	Old Pendergrass Cave	0.13	0.81	3.32	0.66	970705.95	0.95
	Pretty Clean Cave	0.01	0.98	4.98	1.00	0.00	1.00
	Rootville Cave	0.18	0.74	4.65	0.93	17.38	1.00
	Spavinaw Creek Cave						
	War Eagle Cave	0.21	0.70	4.33	0.87	106.21	1.00
	Withrow Springs Cave	0.21	0.70	4.33	0.87	106.21	1.00
Caecidotea dimorpha							
	Elm Cave	0.01	0.99	4.98	1.00	10.05	1.00
	Martin Hollow Cave	0.26	0.62	4.56	0.91	0.00	1.00
	Mr. Griffin's Cave # 1	0.00	1.00	5.00	1.00	0.00	1.00
	Nesbitt Spring Cave	0.21	0.70	4.61	0.92	0.00	1.00
	Riley's Springbox	0.06	0.92	4.89	0.98	0.00	1.00
	Stovepipe Cave	0.37	0.47	4.45	0.89	0.00	1.00
	Summer Cave	0.01	0.99	4.98	1.00	0.00	1.00
Caecidotea macropropoda							
	Fincher Cave	0.07	0.91	4.85	0.97	0.47	1.00
	Spring at Bradley Shelter	0.56	0.20	4.13	0.83	0.00	1.00
	Stormdrain Spring at University of Arkansas	0.02	0.98	4.98	1.00	44.97	1.00
	Watson Cave	0.55	0.21	4.04	0.81	0.00	1.00
Caecidotea salemensis							
	Deep cistern 5.5 mi. S of Imboden	0.30	0.57	4.52	0.90	0.00	1.00
Caecidotea steevesi							
	AGFC Nursery Pond on Beaver Lake	0.03	0.96	4.96	0.99	0.00	1.00
	Cave on Pond Above Black Bass Lake	0.01	0.99	4.90	0.98	20.80	1.00
	Old Spanish Treasure Cave	0.04	0.95	4.86	0.97	30.82	1.00

Species	Site	RWQN_05 Raw	RWQN_05 Scaled	RWQN Raw	RWQN Scaled	RWQP_01 Raw	RWQP_01 Scaled
	War Eagle Cave	0.21	0.70	4.33	0.87	106.21	1.00
	Withrow Springs Cave	0.21	0.70	4.33	0.87	106.21	1.00
Caecidotea stiladactyla							
	Arkansas Archaeological Survey Site #3BE352	0.34	0.51	4.44	0.89	15.95	1.00
	Bently Cave	0.07	0.90	4.89	0.98	3.01	1.00
	Big Mouth Cave						
	Brock Spring	0.36	0.48	3.65	0.73	43.16	1.00
	Bull Shoals Caverns	0.04	0.94	4.94	0.99	29.24	1.00
	Cal Cave	0.29	0.57	4.39	0.88	0.00	1.00
	Cave Mountain Cave	0.09	0.87	4.85	0.97	20.33	1.00
	Cave on North Boundary Trail	0.01	0.99	4.98	1.00	4.43	1.00
	Cave Springs Cave	0.45	0.35	2.57	0.51	18364394.54	0.00
	Cold Cave	0.28	0.60	4.51	0.90	6.89	1.00
	Covington's Cave						
	Dickerson Cave	0.33	0.53	4.16	0.83	21.73	1.00
	Eden Falls Cave	0.19	0.73	4.65	0.93	4.55	1.00
	Fish Pond Cave	0.25	0.64	4.61	0.92	0.00	1.00
	Fitton Cave	0.11	0.85	4.36	0.87	61.70	1.00
	Granny Parker's Cave						
	John Eddings Cave	0.08	0.89	4.86	0.97	0.89	1.00
	Laningham's Cave	0.29	0.57	4.39	0.88	0.00	1.00
	Middle Creek Spring Cave						
	Novack Spring Cave	0.19	0.73	4.65	0.93	4.55	1.00
	Old Joe Cave	0.06	0.91	4.75	0.95	33.37	1.00
	Sherfield Cave	0.05	0.93	4.77	0.95	82.32	1.00
	Simpson's Cave	0.40	0.42	3.92	0.78	19.85	1.00

Species	Site	RWQN_05 Raw	RWQN_05 Scaled	RWQN Raw	RWQN Scaled	RWQP_01 Raw	RWQP_01 Scaled
	Spring at Hogscald	0.06	0.92	4.81	0.96	4.79	1.00
	Spring at Sequoyah Woods	0.07	0.90	4.89	0.98	47.93	1.00
	Spring on Butler Creek Road	0.04	0.95	4.86	0.97	0.65	1.00
	Spring on North Boundary Trail	0.01	0.99	4.98	1.00	4.43	1.00
	Stillhouse Hollow Cave	0.14	0.79	4.78	0.96	9.42	1.00
	Tanyard Creek Nature Trail Cave	0.22	0.68	4.65	0.93	6.17	1.00
	Unnamed seep 4 mi. S of Boxley	0.06	0.91	4.90	0.98	0.00	1.00
	Unnamed seep 9 mi. SW of Harrison	0.16	0.77	4.65	0.93	17.86	1.00
	Unnamed spring 3.5 mi. S of Jasper	0.02	0.98	4.94	0.99	22.36	1.00
	War Eagle Cavern	0.01	0.99	4.87	0.97	26.70	1.00
	White River Below Beaver Dam	0.06	0.91	4.87	0.97	27.02	1.00
Cambarus aculabrum							
	Bear Hollow Cave	0.00	1.00	5.00	1.00	389524.21	0.98
	Brush Creek	0.69	0.00	3.30	0.66	1142938.94	0.94
	Logan Cave	0.41	0.40	2.03	0.41	63625.53	1.00
	Old Pendergrass Cave	0.13	0.81	3.32	0.66	970705.95	0.95
Cambarus setosus							
	Blowing Cave	0.01	0.99	4.99	1.00	0.00	1.00
	Poke Cave	0.01	0.99	4.99	1.00	0.00	1.00
	Tom Allen's Cave	0.22	0.68	4.64	0.93	13.33	1.00
Cambarus zophonastes							
	Hell Creek Cave	0.14	0.79	3.79	0.76	377902.44	0.98
	Nesbitt Spring Cave	0.21	0.70	4.61	0.92	0.00	1.00
	site in Yellville	0.16	0.77	4.43	0.89	151.16	1.00
Dendrocoelopsis americana							
	Brock Spring	0.36	0.48	3.65	0.73	43.16	1.00
	Granny Parker's Cave						

Species	Site	RWQN_05 Raw	RWQN_05 Scaled	RWQN Raw	RWQN Scaled	RWQP_01 Raw	RWQP_01 Scaled
	Steel Creek Campground Cave	0.04	0.95	4.92	0.98	22.07	1.00
	Watson Cave	0.55	0.21	4.04	0.81	0.00	1.00
Eurycea spelaea							
	Alexander Cave	0.33	0.52	3.45	0.69	651201.76	0.96
	Allen Cave						
	Back o' Beyond Cave	0.24	0.66	4.61	0.92	0.00	1.00
	Bald Scrappy Cave	0.06	0.92	4.90	0.98	9.03	1.00
	Bear Hollow Cave	0.00	1.00	5.00	1.00	389524.21	0.98
	Bear Pit	0.13	0.81	4.79	0.96	0.00	1.00
	Bell Cave						
	Bently Cave	0.07	0.90	4.89	0.98	3.01	1.00
	Big Mouth Cave						
	Big Spring Cave						
	Biology Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Blanchard Springs Caverns	0.03	0.95	4.74	0.95	1474952.81	0.92
	Blowing Cave	0.01	0.99	4.99	1.00	0.00	1.00
	Blowing Spring Cave	0.00	1.00	4.99	1.00	0.00	1.00
	Blowing Springs Cave	0.01	0.98	4.87	0.97	18.11	1.00
	Blowing Springs Cave	0.16	0.77	4.73	0.95	0.00	1.00
	Blue Heaven Cave	0.19	0.72	4.59	0.92	16.61	1.00
	Bonanza Cave	0.09	0.87	4.84	0.97	0.00	1.00
	Bonanza Mine	0.00	1.00	4.99	1.00	0.00	1.00
	Breakdown Cave	0.00	1.00	5.00	1.00	4.59	1.00
	Brewer Cave						
	Bull Shoals Caverns	0.04	0.94	4.94	0.99	29.24	1.00
	Cave River Cave	0.05	0.92	4.89	0.98	0.00	1.00
	Cave Springs Cave	0.45	0.35	2.57	0.51	18364394.54	0.00

Species	Site	RWQN_05 Raw	RWQN_05 Scaled	RWQN Raw	RWQN Scaled	RWQP_01 Raw	RWQP_01 Scaled
	Chambers Hollow Cave	0.04	0.94	4.91	0.98	0.00	1.00
	Chilly Bowl Cave	0.03	0.96	4.92	0.98	0.00	1.00
	Chinn Springs Cave	0.13	0.81	4.38	0.88	11.06	1.00
	Congo Crawl						
	Coon Cave	0.01	0.99	4.98	1.00	7.71	1.00
	Copperhead Cave	0.11	0.84	4.79	0.96	6.32	1.00
	Corkscrew Cave	0.03	0.95	4.88	0.98	0.00	1.00
	Cosmic Caverns	0.20	0.72	4.52	0.90	21.62	1.00
	Crystal Dome Cave	0.23	0.67	4.24	0.85	40.57	1.00
	Cushman Cave	0.03	0.95	4.94	0.99	1.06	1.00
	Cyner Cave	0.14	0.79	4.64	0.93	27.61	1.00
	Davis Creek Cave						
	Dear Buster Cave	0.06	0.91	4.81	0.96	13.25	1.00
	Diamond Cave	0.06	0.92	4.85	0.97	8.14	1.00
	Dickerson Cave	0.33	0.53	4.16	0.83	21.73	1.00
	Eckel Cave	0.15	0.79	4.77	0.95	0.00	1.00
	Elm Cave	0.01	0.99	4.98	1.00	10.05	1.00
	Ennis Cave	0.09	0.86	4.78	0.96	0.09	1.00
	Fancher Cave						
	Fish Pond Cave	0.25	0.64	4.61	0.92	0.00	1.00
	Fitton Cave	0.11	0.85	4.36	0.87	61.70	1.00
	Fitton Spring Cave	0.11	0.85	4.36	0.87	61.70	1.00
	Foushee Cave	0.06	0.91	4.74	0.95	112382.79	0.99
	Friday the 13th Cave	0.11	0.85	4.36	0.87	61.70	1.00
	Green River Cave	0.22	0.68	4.53	0.91	0.00	1.00
	Gunner Cave	0.09	0.86	4.71	0.94	33.76	1.00
	Gustafson Cave	0.00	1.00	5.00	1.00	0.00	1.00

Species	Site	RWQN_05 Raw	RWQN_05 Scaled	RWQN Raw	RWQN Scaled	RWQP_01 Raw	RWQP_01 Scaled
	Hammer Springs Cave	0.01	0.98	4.96	0.99	17.66	1.00
	Hell Creek Cave	0.14	0.79	3.79	0.76	377902.44	0.98
	Herald Hollow Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Hickory Creek Cave						
	Hidden Spring Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Hog Head Cave	0.09	0.87	4.82	0.96	18.71	1.00
	Huchingson's Waterfall Cave						
	Hunter's Cave	0.01	0.99	4.99	1.00	0.00	1.00
	Hurricane River Cave	0.02	0.97	4.95	0.99	0.90	1.00
	Icebox Cave						
	Indian Rockhouse Cave	0.04	0.95	4.85	0.97	38.48	1.00
	In-D-Pendants Cave	0.06	0.91	4.90	0.98	0.00	1.00
	Janus Pit	0.02	0.98	4.97	0.99	0.00	1.00
	Jelico Hollow Cave	0.00	1.00	4.99	1.00	0.00	1.00
	John Eddings Cave	0.08	0.89	4.86	0.97	0.89	1.00
	Lewis Spring Cave						
	Little Den Cave	0.11	0.85	4.36	0.87	61.70	1.00
	Logan Cave	0.41	0.40	2.03	0.41	63625.53	1.00
	Major's Cave	0.34	0.51	3.39	0.68	82.37	1.00
	Mammoth Spring	0.09	0.86	4.86	0.97	28.16	1.00
	Martin Hollow Cave	0.26	0.62	4.56	0.91	0.00	1.00
	Miner's Cave	0.05	0.93	4.85	0.97	28.65	1.00
	Mr. Clean Cave	0.07	0.90	4.88	0.98	0.00	1.00
	Mr. Griffin's Cave # 1	0.00	1.00	5.00	1.00	0.00	1.00
	Needles Cave	0.08	0.88	4.85	0.97	12.75	1.00
	Nesbitt Spring Cave	0.21	0.70	4.61	0.92	0.00	1.00
	Norfork Bat Cave	0.12	0.83	4.75	0.95	14.16	1.00

Species	Site	RWQN_05 Raw	RWQN_05 Scaled	RWQN Raw	RWQN Scaled	RWQP_01 Raw	RWQP_01 Scaled
	Old Joe Cave	0.06	0.91	4.75	0.95	33.37	1.00
	Omega Cave						
	Panther Mountain Cave						
	Pigeon Roost Cave	0.00	1.00	5.00	1.00	7.68	1.00
	Potato Cave						
	Pregnant Nun Cave	0.04	0.95	4.86	0.97	0.65	1.00
	Pretty Clean Cave	0.01	0.98	4.98	1.00	0.00	1.00
	Reed Cave	0.03	0.95	4.92	0.98	0.00	1.00
	Richardson Cave	0.05	0.92	4.89	0.98	29.43	1.00
	Riley's Springbox	0.06	0.92	4.89	0.98	0.00	1.00
	Rootville Cave	0.18	0.74	4.65	0.93	17.38	1.00
	Rory Cave	0.19	0.73	4.71	0.94	0.00	1.00
	Salamander Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Saltpeter Cave	0.00	1.00	4.99	1.00	0.00	1.00
	Slick Rock Hollow Cave						
	Springhouse at Steel Creek Ranger Cabin	0.03	0.96	4.93	0.99	12.57	1.00
	Steel Creek Campground Cave	0.04	0.95	4.92	0.98	22.07	1.00
	Stillhouse Hollow Cave	0.14	0.79	4.78	0.96	9.42	1.00
	Stovepipe Cave	0.37	0.47	4.45	0.89	0.00	1.00
	Summer Cave	0.01	0.99	4.98	1.00	0.00	1.00
	Tom Allen's Cave	0.22	0.68	4.64	0.93	13.33	1.00
	Tom Barnes Cave	0.06	0.91	4.90	0.98	2.03	1.00
	Toney Bend Mine # 2	0.04	0.94	4.90	0.98	0.00	1.00
	Tweet's Cave	0.08	0.89	4.84	0.97	0.00	1.00
	Unnamed cave	0.19	0.73	4.72	0.94	0.00	1.00
	Unnamed caves at Devil's Knob Natural Area	0.01	0.99	4.99	1.00	0.00	1.00

Species	Site	RWQN_05 Raw	RWQN_05 Scaled	RWQN Raw	RWQN Scaled	RWQP_01 Raw	RWQP_01 Scaled
	Van Dyke Spring Cave	0.11	0.85	4.36	0.87	61.70	1.00
	Von Wadding's Memorial Cave	0.00	1.00	5.00	1.00	4.59	1.00
	War Eagle Cave	0.21	0.70	4.33	0.87	106.21	1.00
	War Eagle Cavern	0.01	0.99	4.87	0.97	26.70	1.00
	Whippoorwill Cave	0.00	1.00	4.99	1.00	0.00	1.00
	Willis Cave	0.11	0.85	4.36	0.87	61.70	1.00
	Wolf Creek Cave	0.02	0.97	4.96	0.99	0.00	1.00
	Wounded Knee Cave	0.02	0.97	4.96	0.99	0.00	1.00
Lirceus bicuspidatus							
	Diamond Cave	0.06	0.92	4.85	0.97	8.14	1.00
	Foushee Cave	0.06	0.91	4.74	0.95	112382.79	0.99
	Hell Creek Cave	0.14	0.79	3.79	0.76	377902.44	0.98
	Hurricane River Cave	0.02	0.97	4.95	0.99	0.90	1.00
Lirceus bidentatus							
	Unnamed seep 9 mi. SW of Harrison	0.16	0.77	4.65	0.93	17.86	1.00
Stygobromus ozarkensis							
	Bear Hollow Cave	0.00	1.00	5.00	1.00	389524.21	0.98
	Blowing Springs Cave	0.01	0.98	4.87	0.97	18.11	1.00
	Cave on Pond Above Black Bass Lake	0.01	0.99	4.90	0.98	20.80	1.00
	Cave Springs Cave	0.45	0.35	2.57	0.51	18364394.54	0.00
	Civil War Cave	0.42	0.39	3.81	0.76	106.94	1.00
	Dickerson Cave	0.33	0.53	4.16	0.83	21.73	1.00
	Fitton Cave	0.11	0.85	4.36	0.87	61.70	1.00
	Fitton Spring Cave	0.11	0.85	4.36	0.87	61.70	1.00
	Hunter's Cave	0.01	0.99	4.99	1.00	0.00	1.00
	John Eddings Cave	0.08	0.89	4.86	0.97	0.89	1.00
	Logan Cave	0.41	0.40	2.03	0.41	63625.53	1.00

Species	Site	RWQN_05 Raw	RWQN_05 Scaled	RWQN Raw	RWQN Scaled	RWQP_01 Raw	RWQP_01 Scaled
	Needles Cave	0.08	0.88	4.85	0.97	12.75	1.00
	Old Pendergrass Cave	0.13	0.81	3.32	0.66	970705.95	0.95
	Pretty Clean Cave	0.01	0.98	4.98	1.00	0.00	1.00
	Reed Cave	0.03	0.95	4.92	0.98	0.00	1.00
	Sherfield Cave	0.05	0.93	4.77	0.95	82.32	1.00
	Spavinaw Creek Cave						
	War Eagle Cave	0.21	0.70	4.33	0.87	106.21	1.00
	War Eagle Cavern	0.01	0.99	4.87	0.97	26.70	1.00
	White River Below Beaver Dam	0.06	0.91	4.87	0.97	27.02	1.00
	Withrow Springs Cave	0.21	0.70	4.33	0.87	106.21	1.00
Typhlichthys subterraneus							
	Richardson Cave	0.05	0.92	4.89	0.98	29.43	1.00
-	Unnamed well in Randolph County	-	-	-	-	-	-

Table Appendix E-5. Index values and scaled scores for RWQP 02 Raw through RWQP 04 Scaled.

Species	Site	RWQP_02 Raw	RWQP_02 Scaled	RWQP_03 Raw	RWQP_03 Scaled	RWQP_04 Raw	RWQP_04 Scaled
Amblyopsis rosae							
	AGFC Nursery Pond on Beaver Lake	0.00	1.00	1.35	1.00	0	1.00
	Cave Springs Cave	372568.23	0.28	10473.00	0.00	38	0.00
	Civil War Cave	9.02	1.00	1445.95	0.86	2	0.95
	Hewlitt's Spring Hole	516601.11	0.00	78.70	0.99	3	0.92
	James-Ditto Cave	8.73	1.00	46.63	1.00	0	1.00
	Logan Cave	2094.24	1.00	442.17	0.96	4	0.89
	Monte Ne Sinkhole	4.34	1.00	242.55	0.98	0	1.00

Species	Site	RWQP_02 Raw	RWQP_02 Scaled	RWQP_03 Raw	RWQP_03 Scaled	RWQP_04 Raw	RWQP_04 Scaled
	Mule Hole Sink	9.78	1.00	16.46	1.00	0	1.00
	Rootville Cave	8.58	1.00	21.22	1.00	0	1.00
	Tom Allen's Cave	5.99	1.00	7.94	1.00	0	1.00
Amnicola cora							
	Foushee Cave	16558.45	0.97	71.73	0.99	0	1.00
Bactrurus pseudomucronatus							
	Deep cistern 5.5 mi. S of Imboden	0.00	1.00	16.03	1.00	0	1.00
	Mansell Cave	0.00	1.00	5.13	1.00	0	1.00
Caecidotea ancyla							
	Bear Hollow Cave	43306.29	0.92	364.56	0.97	0	1.00
	Brewer Cave						
	Denny Cave	3.51	1.00	97.76	0.99	2	0.95
	Fitton Spring Cave	1.83	1.00	152.03	0.99	0	1.00
	Foushee Cave	16558.45	0.97	71.73	0.99	0	1.00
	Greasy Valley Cave	0.00	1.00	26.37	1.00	0	1.00
	Ivy Springs Cave	0.00	1.00	16.75	1.00	0	1.00
	Major's Cave	10.71	1.00	2589.85	0.75	0	1.00
	Marshall Caves	3.63	1.00	25.86	1.00	0	1.00
	Nesbitt Spring Cave	0.00	1.00	8.87	1.00	0	1.00
	Old Pendergrass Cave	19538.85	0.96	3639.24	0.65	2	0.95
	Pretty Clean Cave	0.00	1.00	0.41	1.00	0	1.00
	Rootville Cave	8.58	1.00	21.22	1.00	0	1.00
	Spavinaw Creek Cave						
	War Eagle Cave	12.30	1.00	107.23	0.99	0	1.00
	Withrow Springs Cave	12.30	1.00	107.23	0.99	0	1.00
Caecidotea dimorpha							
	Elm Cave	9.15	1.00	9.00	1.00	0	1.00

Species	Site	RWQP_02 Raw	RWQP_02 Scaled	RWQP_03 Raw	RWQP_03 Scaled	RWQP_04 Raw	RWQP_04 Scaled
	Martin Hollow Cave	0.00	1.00	13.43	1.00	0	1.00
	Mr. Griffin's Cave # 1	0.00	1.00	0.02	1.00	0	1.00
	Nesbitt Spring Cave	0.00	1.00	8.87	1.00	0	1.00
	Riley's Springbox	0.00	1.00	10.43	1.00	0	1.00
	Stovepipe Cave	0.00	1.00	2.45	1.00	0	1.00
	Summer Cave	0.00	1.00	0.08	1.00	0	1.00
Caecidotea macropropoda							
	Fincher Cave	0.20	1.00	28.24	1.00	0	1.00
	Spring at Bradley Shelter	0.00	1.00	11.97	1.00	0	1.00
	Stormdrain Spring at University of Arkansas	23.96	1.00	2629.53	0.75	4	0.89
	Watson Cave	0.00	1.00	62.64	0.99	0	1.00
Caecidotea salemensis							
	Deep cistern 5.5 mi. S of Imboden	0.00	1.00	16.03	1.00	0	1.00
Caecidotea steevesi							
	AGFC Nursery Pond on Beaver Lake	0.00	1.00	1.35	1.00	0	1.00
	Cave on Pond Above Black Bass Lake	5.52	1.00	115.09	0.99	1	0.97
	Old Spanish Treasure Cave	10.13	1.00	327.23	0.97	0	1.00
	War Eagle Cave	12.30	1.00	107.23	0.99	0	1.00
	Withrow Springs Cave	12.30	1.00	107.23	0.99	0	1.00
Caecidotea stiladactyla							
	Arkansas Archaeological Survey Site #3BE352	12.66	1.00	28.74	1.00	0	1.00
	Bently Cave	9.59	1.00	155.87	0.99	0	1.00
	Big Mouth Cave						
	Brock Spring	9.96	1.00	278.66	0.97	2	0.95
	Bull Shoals Caverns	10.31	1.00	382.92	0.96	0	1.00
	Cal Cave	0.00	1.00	41.12	1.00	0	1.00

Species	Site	RWQP_02 Raw	RWQP_02 Scaled	RWQP_03 Raw	RWQP_03 Scaled	RWQP_04 Raw	RWQP_04 Scaled
	Cave Mountain Cave	6.63	1.00	4.42	1.00	0	1.00
	Cave on North Boundary Trail	2.85	1.00	5.43	1.00	0	1.00
	Cave Springs Cave	372568.23	0.28	10473.00	0.00	38	0.00
	Cold Cave	17.77	1.00	35.47	1.00	0	1.00
	Covington's Cave						
	Dickerson Cave	3.86	1.00	39.37	1.00	0	1.00
	Eden Falls Cave	0.89	1.00	17.30	1.00	0	1.00
	Fish Pond Cave	0.00	1.00	11.25	1.00	0	1.00
	Fitton Cave	1.83	1.00	152.03	0.99	0	1.00
	Granny Parker's Cave						
	John Eddings Cave	0.72	1.00	9.97	1.00	0	1.00
	Laningham's Cave	0.00	1.00	41.12	1.00	0	1.00
	Middle Creek Spring Cave						
	Novack Spring Cave	0.89	1.00	17.30	1.00	0	1.00
	Old Joe Cave	5.88	1.00	121.43	0.99	1	0.97
	Sherfield Cave	3.75	1.00	56.50	0.99	0	1.00
	Simpson's Cave	2.01	1.00	123.39	0.99	0	1.00
	Spring at Hogscald	0.77	1.00	38.73	1.00	0	1.00
	Spring at Sequoyah Woods	10.79	1.00	1579.62	0.85	0	1.00
	Spring on Butler Creek Road	0.07	1.00	15.71	1.00	0	1.00
	Spring on North Boundary Trail	2.85	1.00	5.43	1.00	0	1.00
	Stillhouse Hollow Cave	17.53	1.00	4.19	1.00	0	1.00
	Tanyard Creek Nature Trail Cave	6.03	1.00	8.78	1.00	0	1.00
	Unnamed seep 4 mi. S of Boxley	0.00	1.00	3.25	1.00	0	1.00
	Unnamed seep 9 mi. SW of Harrison	2.98	1.00	42.81	1.00	0	1.00
	Unnamed spring 3.5 mi. S of Jasper	9.64	1.00	15.41	1.00	0	1.00
	War Eagle Cavern	4.56	1.00	61.12	0.99	0	1.00

Species	Site	RWQP_02 Raw	RWQP_02 Scaled	RWQP_03 Raw	RWQP_03 Scaled	RWQP_04 Raw	RWQP_04 Scaled
	White River Below Beaver Dam	10.87	1.00	19.06	1.00	0	1.00
Cambarus aculabrum							
	Bear Hollow Cave	43306.29	0.92	364.56	0.97	0	1.00
	Brush Creek	124811.67	0.76	478.39	0.95	7	0.82
	Logan Cave	2094.24	1.00	442.17	0.96	4	0.89
	Old Pendergrass Cave	19538.85	0.96	3639.24	0.65	2	0.95
Cambarus setosus							
	Blowing Cave	0.00	1.00	0.24	1.00	0	1.00
	Poke Cave	0.00	1.00	0.24	1.00	0	1.00
	Tom Allen's Cave	5.99	1.00	7.94	1.00	0	1.00
Cambarus zophonastes							
	Hell Creek Cave	19138.08	0.96	475.42	0.95	2	0.95
	Nesbitt Spring Cave	0.00	1.00	8.87	1.00	0	1.00
	site in Yellville	13.49	1.00	1705.19	0.84	0	1.00
Dendrocoelopsis americana							
	Brock Spring	9.96	1.00	278.66	0.97	2	0.95
	Granny Parker's Cave						
	Steel Creek Campground Cave	5.72	1.00	11.67	1.00	0	1.00
	Watson Cave	0.00	1.00	62.64	0.99	0	1.00
Eurycea spelaea							
	Alexander Cave	22564.72	0.96	207.01	0.98	1	0.97
	Allen Cave						
	Back o' Beyond Cave	0.00	1.00	6.87	1.00	0	1.00
	Bald Scrappy Cave	3.95	1.00	3.18	1.00	0	1.00
	Bear Hollow Cave	43306.29	0.92	364.56	0.97	0	1.00
	Bear Pit	0.00	1.00	2.20	1.00	0	1.00
	Bell Cave						

Species	Site	RWQP_02 Raw	RWQP_02 Scaled	RWQP_03 Raw	RWQP_03 Scaled	RWQP_04 Raw	RWQP_04 Scaled
	Bently Cave	9.59	1.00	155.87	0.99	0	1.00
	Big Mouth Cave						
	Big Spring Cave						
	Biology Cave	0.00	1.00	0.00	1.00	0	1.00
	Blanchard Springs Caverns	37772.42	0.93	190.27	0.98	2	0.95
	Blowing Cave	0.00	1.00	0.24	1.00	0	1.00
	Blowing Spring Cave	0.00	1.00	2.71	1.00	0	1.00
	Blowing Springs Cave	7.41	1.00	408.79	0.96	0	1.00
	Blowing Springs Cave	0.00	1.00	6.35	1.00	0	1.00
	Blue Heaven Cave	2.87	1.00	36.36	1.00	0	1.00
	Bonanza Cave	0.00	1.00	6.79	1.00	0	1.00
	Bonanza Mine	0.00	1.00	3.10	1.00	0	1.00
	Breakdown Cave	1.11	1.00	0.00	1.00	0	1.00
	Brewer Cave						
	Bull Shoals Caverns	10.31	1.00	382.92	0.96	0	1.00
	Cave River Cave	0.00	1.00	8.71	1.00	0	1.00
	Cave Springs Cave	372568.23	0.28	10473.00	0.00	38	0.00
	Chambers Hollow Cave	0.00	1.00	14.06	1.00	0	1.00
	Chilly Bowl Cave	0.00	1.00	21.19	1.00	0	1.00
	Chinn Springs Cave	0.65	1.00	150.25	0.99	0	1.00
	Congo Crawl						
	Coon Cave	7.58	1.00	4.39	1.00	2	0.95
	Copperhead Cave	2.03	1.00	14.20	1.00	0	1.00
	Corkscrew Cave	0.00	1.00	33.53	1.00	0	1.00
	Cosmic Caverns	3.79	1.00	63.57	0.99	0	1.00
	Crystal Dome Cave	7.35	1.00	165.58	0.98	0	1.00
	Cushman Cave	0.46	1.00	25.35	1.00	0	1.00

Species	Site	RWQP_02 Raw	RWQP_02 Scaled	RWQP_03 Raw	RWQP_03 Scaled	RWQP_04 Raw	RWQP_04 Scaled
	Cyner Cave	2.06	1.00	30.57	1.00	0	1.00
	Davis Creek Cave						
	Dear Buster Cave	1.51	1.00	16.32	1.00	1	0.97
	Diamond Cave	1.56	1.00	26.62	1.00	0	1.00
	Dickerson Cave	3.86	1.00	39.37	1.00	0	1.00
	Eckel Cave	0.00	1.00	4.52	1.00	0	1.00
	Elm Cave	9.15	1.00	9.00	1.00	0	1.00
	Ennis Cave	0.01	1.00	23.02	1.00	0	1.00
	Fancher Cave						
	Fish Pond Cave	0.00	1.00	11.25	1.00	0	1.00
	Fitton Cave	1.83	1.00	152.03	0.99	0	1.00
	Fitton Spring Cave	1.83	1.00	152.03	0.99	0	1.00
	Foushee Cave	16558.45	0.97	71.73	0.99	0	1.00
	Friday the 13th Cave	1.83	1.00	152.03	0.99	0	1.00
	Green River Cave	0.00	1.00	42.16	1.00	0	1.00
	Gunner Cave	3.52	1.00	12.91	1.00	0	1.00
	Gustafson Cave	0.00	1.00	0.45	1.00	0	1.00
	Hammer Springs Cave	3.08	1.00	11.42	1.00	0	1.00
	Hell Creek Cave	19138.08	0.96	475.42	0.95	2	0.95
	Herald Hollow Cave	0.00	1.00	0.00	1.00	0	1.00
	Hickory Creek Cave						
	Hidden Spring Cave	0.00	1.00	0.00	1.00	0	1.00
	Hog Head Cave	3.39	1.00	13.10	1.00	0	1.00
	Huchingson's Waterfall Cave						
	Hunter's Cave	0.00	1.00	0.63	1.00	0	1.00
	Hurricane River Cave	0.21	1.00	13.26	1.00	0	1.00
	Icebox Cave						

Species	Site	RWQP_02 Raw	RWQP_02 Scaled	RWQP_03 Raw	RWQP_03 Scaled	RWQP_04 Raw	RWQP_04 Scaled
	Indian Rockhouse Cave	4.23	1.00	41.52	1.00	0	1.00
	In-D-Pendants Cave	0.00	1.00	1.50	1.00	0	1.00
	Janus Pit	0.00	1.00	3.99	1.00	0	1.00
	Jelico Hollow Cave	0.00	1.00	5.00	1.00	0	1.00
	John Eddings Cave	0.72	1.00	9.97	1.00	0	1.00
	Lewis Spring Cave						
	Little Den Cave	1.83	1.00	152.03	0.99	0	1.00
	Logan Cave	2094.24	1.00	442.17	0.96	4	0.89
	Major's Cave	10.71	1.00	2589.85	0.75	0	1.00
	Mammoth Spring	18.26	1.00	537.79	0.95	0	1.00
	Martin Hollow Cave	0.00	1.00	13.43	1.00	0	1.00
	Miner's Cave	7.82	1.00	125.07	0.99	1	0.97
	Mr. Clean Cave	0.00	1.00	7.93	1.00	0	1.00
	Mr. Griffin's Cave # 1	0.00	1.00	0.02	1.00	0	1.00
	Needles Cave	6.51	1.00	146.15	0.99	0	1.00
	Nesbitt Spring Cave	0.00	1.00	8.87	1.00	0	1.00
	Norfork Bat Cave	5.26	1.00	208.03	0.98	1	0.97
	Old Joe Cave	5.88	1.00	121.43	0.99	1	0.97
	Omega Cave						
	Panther Mountain Cave						
	Pigeon Roost Cave	5.29	1.00	1.43	1.00	0	1.00
	Potato Cave						
	Pregnant Nun Cave	0.07	1.00	15.71	1.00	0	1.00
	Pretty Clean Cave	0.00	1.00	0.41	1.00	0	1.00
	Reed Cave	0.00	1.00	14.40	1.00	0	1.00
	Richardson Cave	18.26	1.00	10.93	1.00	0	1.00
	Riley's Springbox	0.00	1.00	10.43	1.00	0	1.00

Species	Site	RWQP_02 Raw	RWQP_02 Scaled	RWQP_03 Raw	RWQP_03 Scaled	RWQP_04 Raw	RWQP_04 Scaled
	Rootville Cave	8.58	1.00	21.22	1.00	0	1.00
	Rory Cave	0.00	1.00	5.01	1.00	0	1.00
	Salamander Cave	0.00	1.00	0.83	1.00	0	1.00
	Saltpeter Cave	0.00	1.00	3.37	1.00	0	1.00
	Slick Rock Hollow Cave						
	Springhouse at Steel Creek Ranger Cabin	5.11	1.00	12.38	1.00	0	1.00
	Steel Creek Campground Cave	5.72	1.00	11.67	1.00	0	1.00
	Stillhouse Hollow Cave	17.53	1.00	4.19	1.00	0	1.00
	Stovepipe Cave	0.00	1.00	2.45	1.00	0	1.00
	Summer Cave	0.00	1.00	0.08	1.00	0	1.00
	Tom Allen's Cave	5.99	1.00	7.94	1.00	0	1.00
	Tom Barnes Cave	2.00	1.00	1.60	1.00	0	1.00
	Toney Bend Mine # 2	0.00	1.00	8.25	1.00	0	1.00
	Tweet's Cave	0.00	1.00	14.66	1.00	0	1.00
	Unnamed cave	0.00	1.00	1.37	1.00	0	1.00
	Unnamed caves at Devil's Knob Natural Area	0.00	1.00	0.63	1.00	0	1.00
	Van Dyke Spring Cave	1.83	1.00	152.03	0.99	0	1.00
	Von Wadding's Memorial Cave	1.11	1.00	0.00	1.00	0	1.00
	War Eagle Cave	12.30	1.00	107.23	0.99	0	1.00
	War Eagle Cavern	4.56	1.00	61.12	0.99	0	1.00
	Whippoorwill Cave	0.00	1.00	5.00	1.00	0	1.00
	Willis Cave	1.83	1.00	152.03	0.99	0	1.00
	Wolf Creek Cave	0.00	1.00	5.83	1.00	0	1.00
	Wounded Knee Cave	0.00	1.00	2.13	1.00	0	1.00
Lirceus bicuspidatus							
	Diamond Cave	1.56	1.00	26.62	1.00	0	1.00

Species	Site	RWQP_02 Raw	RWQP_02 Scaled	RWQP_03 Raw	RWQP_03 Scaled	RWQP_04 Raw	RWQP_04 Scaled
	Foushee Cave	16558.45	0.97	71.73	0.99	0	1.00
	Hell Creek Cave	19138.08	0.96	475.42	0.95	2	0.95
	Hurricane River Cave	0.21	1.00	13.26	1.00	0	1.00
Lirceus bidentatus							
	Unnamed seep 9 mi. SW of Harrison	2.98	1.00	42.81	1.00	0	1.00
Stygobromus ozarkensis							
	Bear Hollow Cave	43306.29	0.92	364.56	0.97	0	1.00
	Blowing Springs Cave	7.41	1.00	408.79	0.96	0	1.00
	Cave on Pond Above Black Bass Lake	5.52	1.00	115.09	0.99	1	0.97
	Cave Springs Cave	372568.23	0.28	10473.00	0.00	38	0.00
	Civil War Cave	9.02	1.00	1445.95	0.86	2	0.95
	Dickerson Cave	3.86	1.00	39.37	1.00	0	1.00
	Fitton Cave	1.83	1.00	152.03	0.99	0	1.00
	Fitton Spring Cave	1.83	1.00	152.03	0.99	0	1.00
	Hunter's Cave	0.00	1.00	0.63	1.00	0	1.00
	John Eddings Cave	0.72	1.00	9.97	1.00	0	1.00
	Logan Cave	2094.24	1.00	442.17	0.96	4	0.89
	Needles Cave	6.51	1.00	146.15	0.99	0	1.00
	Old Pendergrass Cave	19538.85	0.96	3639.24	0.65	2	0.95
	Pretty Clean Cave	0.00	1.00	0.41	1.00	0	1.00
	Reed Cave	0.00	1.00	14.40	1.00	0	1.00
	Sherfield Cave	3.75	1.00	56.50	0.99	0	1.00
	Spavinaw Creek Cave						
	War Eagle Cave	12.30	1.00	107.23	0.99	0	1.00
	War Eagle Cavern	4.56	1.00	61.12	0.99	0	1.00
	White River Below Beaver Dam	10.87	1.00	19.06	1.00	0	1.00
	Withrow Springs Cave	12.30	1.00	107.23	0.99	0	1.00

Species	Site	RWQP_02 Raw	RWQP_02 Scaled	RWQP_03 Raw	RWQP_03 Scaled	RWQP_04 Raw	RWQP_04 Scaled
Typhlichthys subterraneus							
	Richardson Cave	18.26	1.00	10.93	1.00	0	1.00
-	Unnamed well in Randolph County	-	-	-	-	-	-

Table Appendix E-6. Index values and scaled scores for RWQP 05 Raw through RWQH 01 Scaled.

Species	Site	RWQP_05 Raw	RWQP_05 Scaled	RWQP Raw	RWQP Scaled	RWQH_01 Raw	RWQH_01 Scaled
Amblyopsis rosae							
	AGFC Nursery Pond on Beaver Lake	0.00	1.00	5.00	1.00	9747.00	1.00
	Cave Springs Cave	0.77	0.64	0.92	0.18	20140551.00	0.00
	Civil War Cave	0.17	0.92	4.73	0.95	3623447.25	0.82
	Hewlitt's Spring Hole	0.22	0.90	3.43	0.69	2352276.00	0.88
	James-Ditto Cave	0.00	1.00	5.00	1.00	123462.00	0.99
	Logan Cave	0.13	0.94	4.78	0.96	444300.75	0.98
	Monte Ne Sinkhole	0.00	1.00	4.98	1.00	470292.75	0.98
	Mule Hole Sink	0.00	1.00	5.00	1.00	73914.75	1.00
	Rootville Cave	0.00	1.00	5.00	1.00	116964.00	0.99
	Tom Allen's Cave	0.00	1.00	5.00	1.00	67416.75	1.00
Amnicola cora							
	Foushee Cave	0.00	1.00	4.95	0.99	19494.00	1.00
Bactrurus pseudomucronatus							
	Deep cistern 5.5 mi. S of Imboden	0.00	1.00	5.00	1.00	14620.50	1.00
	Mansell Cave	0.00	1.00	5.00	1.00	812.25	1.00
Caecidotea ancyla							
	Bear Hollow Cave	0.00	1.00	4.86	0.97	484101.00	0.98
	Brewer Cave						

Species	Site	RWQP_05 Raw	RWQP_05 Scaled	RWQP Raw	RWQP Scaled	RWQH_01 Raw	RWQH_01 Scaled
	Denny Cave	0.23	0.89	4.83	0.97	280226.25	0.99
	Fitton Spring Cave	0.00	1.00	4.99	1.00	293222.25	0.99
	Foushee Cave	0.00	1.00	4.95	0.99	19494.00	1.00
	Greasy Valley Cave	0.00	1.00	5.00	1.00	55233.00	1.00
	Ivy Springs Cave	0.00	1.00	5.00	1.00	36551.25	1.00
	Major's Cave	0.00	1.00	4.75	0.95	2786829.75	0.86
	Marshall Caves	0.00	1.00	5.00	1.00	134833.50	0.99
	Nesbitt Spring Cave	0.00	1.00	5.00	1.00	17057.25	1.00
	Old Pendergrass Cave	0.04	0.98	4.49	0.90	10871966.25	0.46
	Pretty Clean Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Rootville Cave	0.00	1.00	5.00	1.00	116964.00	0.99
	Spavinaw Creek Cave						
	War Eagle Cave	0.00	1.00	4.99	1.00	508468.50	0.97
	Withrow Springs Cave	0.00	1.00	4.99	1.00	508468.50	0.97
Caecidotea dimorpha							
	Elm Cave	0.00	1.00	5.00	1.00	52796.25	1.00
	Martin Hollow Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Mr. Griffin's Cave # 1	0.00	1.00	5.00	1.00	0.00	1.00
	Nesbitt Spring Cave	0.00	1.00	5.00	1.00	17057.25	1.00
	Riley's Springbox	0.00	1.00	5.00	1.00	12996.00	1.00
	Stovepipe Cave	0.00	1.00	5.00	1.00	9747.00	1.00
	Summer Cave	0.00	1.00	5.00	1.00	27616.50	1.00
Caecidotea macropropoda							
	Fincher Cave	0.00	1.00	5.00	1.00	22743.00	1.00
	Spring at Bradley Shelter	0.00	1.00	5.00	1.00	8934.75	1.00
	Stormdrain Spring at University of Arkansas	2.13	0.00	3.64	0.73	1743088.50	0.91

Species	Site	RWQP_05 Raw	RWQP_05 Scaled	RWQP Raw	RWQP Scaled	RWQH_01 Raw	RWQH_01 Scaled
	Watson Cave	0.00	1.00	4.99	1.00	62543.25	1.00
Caecidotea salemensis							
	Deep cistern 5.5 mi. S of Imboden	0.00	1.00	5.00	1.00	14620.50	1.00
Caecidotea steevesi							
	AGFC Nursery Pond on Beaver Lake	0.00	1.00	5.00	1.00	9747.00	1.00
	Cave on Pond Above Black Bass Lake	0.27	0.88	4.84	0.97	380133.00	0.98
	Old Spanish Treasure Cave	0.00	1.00	4.97	0.99	321651.00	0.98
	War Eagle Cave	0.00	1.00	4.99	1.00	508468.50	0.97
	Withrow Springs Cave	0.00	1.00	4.99	1.00	508468.50	0.97
Caecidotea stiladactyla							
	Arkansas Archaeological Survey Site #3BE352	0.00	1.00	5.00	1.00	130772.25	0.99
	Bently Cave	0.00	1.00	4.99	1.00	120213.00	0.99
	Big Mouth Cave						
	Brock Spring	0.46	0.78	4.70	0.94	579946.50	0.97
	Bull Shoals Caverns	0.00	1.00	4.96	0.99	597003.75	0.97
	Cal Cave	0.00	1.00	5.00	1.00	27616.50	1.00
	Cave Mountain Cave	0.00	1.00	5.00	1.00	92596.50	1.00
	Cave on North Boundary Trail	0.00	1.00	5.00	1.00	156764.25	0.99
	Cave Springs Cave	0.77	0.64	0.92	0.18	20140551.00	0.00
	Cold Cave	0.00	1.00	5.00	1.00	113715.00	0.99
	Covington's Cave						
	Dickerson Cave	0.00	1.00	5.00	1.00	160825.50	0.99
	Eden Falls Cave	0.00	1.00	5.00	1.00	28428.75	1.00
	Fish Pond Cave	0.00	1.00	5.00	1.00	1624.50	1.00
	Fitton Cave	0.00	1.00	4.99	1.00	293222.25	0.99
	Granny Parker's Cave						

Species	Site	RWQP_05 Raw	RWQP_05 Scaled	RWQP Raw	RWQP Scaled	RWQH_01 Raw	RWQH_01 Scaled
	John Eddings Cave	0.00	1.00	5.00	1.00	43861.50	1.00
	Laningham's Cave	0.00	1.00	5.00	1.00	27616.50	1.00
	Middle Creek Spring Cave						
	Novack Spring Cave	0.00	1.00	5.00	1.00	28428.75	1.00
	Old Joe Cave	0.18	0.92	4.88	0.98	1129027.50	0.94
	Sherfield Cave	0.00	1.00	4.99	1.00	330585.75	0.98
	Simpson's Cave	0.00	1.00	4.99	1.00	90972.00	1.00
	Spring at Hogscald	0.00	1.00	5.00	1.00	166511.25	0.99
	Spring at Sequoyah Woods	0.00	1.00	4.85	0.97	1947775.50	0.90
	Spring on Butler Creek Road	0.00	1.00	5.00	1.00	126711.00	0.99
	Spring on North Boundary Trail	0.00	1.00	5.00	1.00	156764.25	0.99
	Stillhouse Hollow Cave	0.00	1.00	5.00	1.00	60106.50	1.00
	Tanyard Creek Nature Trail Cave	0.00	1.00	5.00	1.00	80412.75	1.00
	Unnamed seep 4 mi. S of Boxley	0.00	1.00	5.00	1.00	0.00	1.00
	Unnamed seep 9 mi. SW of Harrison	0.00	1.00	5.00	1.00	86098.50	1.00
	Unnamed spring 3.5 mi. S of Jasper	0.00	1.00	5.00	1.00	84474.00	1.00
	War Eagle Cavern	0.00	1.00	4.99	1.00	198189.00	0.99
	White River Below Beaver Dam	0.00	1.00	5.00	1.00	313528.50	0.98
Cambarus aculabrum							
	Bear Hollow Cave	0.00	1.00	4.86	0.97	484101.00	0.98
	Brush Creek	0.76	0.64	4.11	0.82	2131344.00	0.89
	Logan Cave	0.13	0.94	4.78	0.96	444300.75	0.98
	Old Pendergrass Cave	0.04	0.98	4.49	0.90	10871966.25	0.46
Cambarus setosus							
	Blowing Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Poke Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Tom Allen's Cave	0.00	1.00	5.00	1.00	67416.75	1.00

Species	Site	RWQP_05 Raw	RWQP_05 Scaled	RWQP Raw	RWQP Scaled	RWQH_01 Raw	RWQH_01 Scaled
Cambarus zophonastes							
	Hell Creek Cave	0.10	0.95	4.80	0.96	1645618.50	0.92
	Nesbitt Spring Cave	0.00	1.00	5.00	1.00	17057.25	1.00
	site in Yellville	0.00	1.00	4.84	0.97	2925724.50	0.85
Dendrocoelopsis americana							
	Brock Spring	0.46	0.78	4.70	0.94	579946.50	0.97
	Granny Parker's Cave						
	Steel Creek Campground Cave	0.00	1.00	5.00	1.00	103155.75	0.99
	Watson Cave	0.00	1.00	4.99	1.00	62543.25	1.00
Eurycea spelaea							
	Alexander Cave	0.03	0.98	4.86	0.97	547456.50	0.97
	Allen Cave						
	Back o' Beyond Cave	0.00	1.00	5.00	1.00	69853.50	1.00
	Bald Scrappy Cave	0.00	1.00	5.00	1.00	43049.25	1.00
	Bear Hollow Cave	0.00	1.00	4.86	0.97	484101.00	0.98
	Bear Pit	0.00	1.00	5.00	1.00	0.00	1.00
	Bell Cave						
	Bently Cave	0.00	1.00	4.99	1.00	120213.00	0.99
	Big Mouth Cave						
	Big Spring Cave						
	Biology Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Blanchard Springs Caverns	0.05	0.98	4.75	0.95	1799946.00	0.91
	Blowing Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Blowing Spring Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Blowing Springs Cave	0.00	1.00	4.96	0.99	752143.50	0.96
	Blowing Springs Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Blue Heaven Cave	0.00	1.00	5.00	1.00	117776.25	0.99

Species	Site	RWQP_05 Raw	RWQP_05 Scaled	RWQP Raw	RWQP Scaled	RWQH_01 Raw	RWQH_01 Scaled
	Bonanza Cave	0.00	1.00	5.00	1.00	8934.75	1.00
	Bonanza Mine	0.00	1.00	5.00	1.00	0.00	1.00
	Breakdown Cave	0.00	1.00	5.00	1.00	151890.75	0.99
	Brewer Cave						
	Bull Shoals Caverns	0.00	1.00	4.96	0.99	597003.75	0.97
	Cave River Cave	0.00	1.00	5.00	1.00	8934.75	1.00
	Cave Springs Cave	0.77	0.64	0.92	0.18	20140551.00	0.00
	Chambers Hollow Cave	0.00	1.00	5.00	1.00	4061.25	1.00
	Chilly Bowl Cave	0.00	1.00	5.00	1.00	4873.50	1.00
	Chinn Springs Cave	0.00	1.00	4.99	1.00	480039.75	0.98
	Congo Crawl						
	Coon Cave	1.96	0.08	4.03	0.81	62543.25	1.00
	Copperhead Cave	0.00	1.00	5.00	1.00	37363.50	1.00
	Corkscrew Cave	0.00	1.00	5.00	1.00	1624.50	1.00
	Cosmic Caverns	0.00	1.00	4.99	1.00	129960.00	0.99
	Crystal Dome Cave	0.00	1.00	4.98	1.00	296471.25	0.99
	Cushman Cave	0.00	1.00	5.00	1.00	178695.00	0.99
	Cyner Cave	0.00	1.00	5.00	1.00	166511.25	0.99
	Davis Creek Cave						
	Dear Buster Cave	0.11	0.95	4.92	0.98	61731.00	1.00
	Diamond Cave	0.00	1.00	5.00	1.00	105592.50	0.99
	Dickerson Cave	0.00	1.00	5.00	1.00	160825.50	0.99
	Eckel Cave	0.00	1.00	5.00	1.00	812.25	1.00
	Elm Cave	0.00	1.00	5.00	1.00	52796.25	1.00
	Ennis Cave	0.00	1.00	5.00	1.00	9747.00	1.00
	Fancher Cave						
	Fish Pond Cave	0.00	1.00	5.00	1.00	1624.50	1.00

Species	Site	RWQP_05 Raw	RWQP_05 Scaled	RWQP Raw	RWQP Scaled	RWQH_01 Raw	RWQH_01 Scaled
	Fitton Cave	0.00	1.00	4.99	1.00	293222.25	0.99
	Fitton Spring Cave	0.00	1.00	4.99	1.00	293222.25	0.99
	Foushee Cave	0.00	1.00	4.95	0.99	19494.00	1.00
	Friday the 13th Cave	0.00	1.00	4.99	1.00	293222.25	0.99
	Green River Cave	0.00	1.00	5.00	1.00	23555.25	1.00
	Gunner Cave	0.00	1.00	5.00	1.00	142956.00	0.99
	Gustafson Cave	0.00	1.00	5.00	1.00	812.25	1.00
	Hammer Springs Cave	0.00	1.00	5.00	1.00	79600.50	1.00
	Hell Creek Cave	0.10	0.95	4.80	0.96	1645618.50	0.92
	Herald Hollow Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Hickory Creek Cave						
	Hidden Spring Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Hog Head Cave	0.00	1.00	5.00	1.00	73914.75	1.00
	Huchingson's Waterfall Cave						
	Hunter's Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Hurricane River Cave	0.00	1.00	5.00	1.00	41424.75	1.00
	Icebox Cave						
	Indian Rockhouse Cave	0.00	1.00	5.00	1.00	197376.75	0.99
	In-D-Pendants Cave	0.00	1.00	5.00	1.00	46298.25	1.00
	Janus Pit	0.00	1.00	5.00	1.00	0.00	1.00
	Jelico Hollow Cave	0.00	1.00	5.00	1.00	0.00	1.00
	John Eddings Cave	0.00	1.00	5.00	1.00	43861.50	1.00
	Lewis Spring Cave						
	Little Den Cave	0.00	1.00	4.99	1.00	293222.25	0.99
	Logan Cave	0.13	0.94	4.78	0.96	444300.75	0.98
	Major's Cave	0.00	1.00	4.75	0.95	2786829.75	0.86
	Mammoth Spring	0.00	1.00	4.95	0.99	692037.00	0.97

Species	Site	RWQP_05 Raw	RWQP_05 Scaled	RWQP Raw	RWQP Scaled	RWQH_01 Raw	RWQH_01 Scaled
	Martin Hollow Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Miner's Cave	0.27	0.87	4.83	0.97	445925.25	0.98
	Mr. Clean Cave	0.00	1.00	5.00	1.00	5685.75	1.00
	Mr. Griffin's Cave # 1	0.00	1.00	5.00	1.00	0.00	1.00
	Needles Cave	0.00	1.00	4.99	1.00	469480.50	0.98
	Nesbitt Spring Cave	0.00	1.00	5.00	1.00	17057.25	1.00
	Norfork Bat Cave	0.37	0.83	4.78	0.96	816311.25	0.96
	Old Joe Cave	0.18	0.92	4.88	0.98	1129027.50	0.94
	Omega Cave						
	Panther Mountain Cave						
	Pigeon Roost Cave	0.00	1.00	5.00	1.00	21930.75	1.00
	Potato Cave						
	Pregnant Nun Cave	0.00	1.00	5.00	1.00	126711.00	0.99
	Pretty Clean Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Reed Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Richardson Cave	0.00	1.00	5.00	1.00	141331.50	0.99
	Riley's Springbox	0.00	1.00	5.00	1.00	12996.00	1.00
	Rootville Cave	0.00	1.00	5.00	1.00	116964.00	0.99
	Rory Cave	0.00	1.00	5.00	1.00	30865.50	1.00
	Salamander Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Saltpeter Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Slick Rock Hollow Cave						
	Springhouse at Steel Creek Ranger Cabin	0.00	1.00	5.00	1.00	50359.50	1.00
	Steel Creek Campground Cave	0.00	1.00	5.00	1.00	103155.75	0.99
	Stillhouse Hollow Cave	0.00	1.00	5.00	1.00	60106.50	1.00
	Stovepipe Cave	0.00	1.00	5.00	1.00	9747.00	1.00
	Summer Cave	0.00	1.00	5.00	1.00	27616.50	1.00

Species	Site	RWQP_05 Raw	RWQP_05 Scaled	RWQP Raw	RWQP Scaled	RWQH_01 Raw	RWQH_01 Scaled
	Tom Allen's Cave	0.00	1.00	5.00	1.00	67416.75	1.00
	Tom Barnes Cave	0.00	1.00	5.00	1.00	5685.75	1.00
	Toney Bend Mine # 2	0.00	1.00	5.00	1.00	77163.75	1.00
	Tweet's Cave	0.00	1.00	5.00	1.00	4061.25	1.00
	Unnamed cave	0.00	1.00	5.00	1.00	812.25	1.00
	Unnamed caves at Devil's Knob Natural Area	0.00	1.00	5.00	1.00	0.00	1.00
	Van Dyke Spring Cave	0.00	1.00	4.99	1.00	293222.25	0.99
	Von Wadding's Memorial Cave	0.00	1.00	5.00	1.00	151890.75	0.99
	War Eagle Cave	0.00	1.00	4.99	1.00	508468.50	0.97
	War Eagle Cavern	0.00	1.00	4.99	1.00	198189.00	0.99
	Whippoorwill Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Willis Cave	0.00	1.00	4.99	1.00	293222.25	0.99
	Wolf Creek Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Wounded Knee Cave	0.00	1.00	5.00	1.00	2436.75	1.00
Lirceus bicuspidatus							
	Diamond Cave	0.00	1.00	5.00	1.00	105592.50	0.99
	Foushee Cave	0.00	1.00	4.95	0.99	19494.00	1.00
	Hell Creek Cave	0.10	0.95	4.80	0.96	1645618.50	0.92
	Hurricane River Cave	0.00	1.00	5.00	1.00	41424.75	1.00
Lirceus bidentatus							
	Unnamed seep 9 mi. SW of Harrison	0.00	1.00	5.00	1.00	86098.50	1.00
Stygobromus ozarkensis							
	Bear Hollow Cave	0.00	1.00	4.86	0.97	484101.00	0.98
	Blowing Springs Cave	0.00	1.00	4.96	0.99	752143.50	0.96
	Cave on Pond Above Black Bass Lake	0.27	0.88	4.84	0.97	380133.00	0.98
	Cave Springs Cave	0.77	0.64	0.92	0.18	20140551.00	0.00

Species	Site	RWQP_05 Raw	RWQP_05 Scaled	RWQP Raw	RWQP Scaled	RWQH_01 Raw	RWQH_01 Scaled
	Civil War Cave	0.17	0.92	4.73	0.95	3623447.25	0.82
	Dickerson Cave	0.00	1.00	5.00	1.00	160825.50	0.99
	Fitton Cave	0.00	1.00	4.99	1.00	293222.25	0.99
	Fitton Spring Cave	0.00	1.00	4.99	1.00	293222.25	0.99
	Hunter's Cave	0.00	1.00	5.00	1.00	0.00	1.00
	John Eddings Cave	0.00	1.00	5.00	1.00	43861.50	1.00
	Logan Cave	0.13	0.94	4.78	0.96	444300.75	0.98
	Needles Cave	0.00	1.00	4.99	1.00	469480.50	0.98
	Old Pendergrass Cave	0.04	0.98	4.49	0.90	10871966.25	0.46
	Pretty Clean Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Reed Cave	0.00	1.00	5.00	1.00	0.00	1.00
	Sherfield Cave	0.00	1.00	4.99	1.00	330585.75	0.98
	Spavinaw Creek Cave						
	War Eagle Cave	0.00	1.00	4.99	1.00	508468.50	0.97
	War Eagle Cavern	0.00	1.00	4.99	1.00	198189.00	0.99
	White River Below Beaver Dam	0.00	1.00	5.00	1.00	313528.50	0.98
	Withrow Springs Cave	0.00	1.00	4.99	1.00	508468.50	0.97
Typhlichthys subterraneus							
	Richardson Cave	0.00	1.00	5.00	1.00	141331.50	0.99
-	Unnamed well in Randolph County	-	-	-	-	-	-

Table Appendix E-7. Index values and scaled scores for RWQH 02 Raw through RWQ Scaled.

Species	Site	RWQH_02 Raw	RWQH_02 Scaled	RWQH Raw	RWQH Scaled	RWQ Raw	RWQ Scaled
Amblyopsis rosae							
	AGFC Nursery Pond on Beaver Lake	0.03	1.00	2.00	1.00	3.58	0.92
	Cave Springs Cave	20140551.00	0.00	0.00	0.00	1.17	0.30
	Civil War Cave	0.31	1.00	1.82	0.91	3.12	0.80
	Hewlitt's Spring Hole	2352276.00	0.88	1.77	0.88	2.82	0.73
	James-Ditto Cave	0.08	1.00	1.99	1.00	3.41	0.88
	Logan Cave	444300.75	0.98	1.96	0.98	2.90	0.75
	Monte Ne Sinkhole	0.15	1.00	1.98	0.99	3.62	0.93
	Mule Hole Sink	0.18	1.00	2.00	1.00	3.55	0.91
	Rootville Cave	0.06	1.00	1.99	1.00	3.66	0.94
	Tom Allen's Cave	0.03	1.00	2.00	1.00	3.62	0.93
Amnicola cora							
	Foushee Cave	19494.00	1.00	2.00	1.00	3.79	0.98
Bactrurus pseudomucronatus							
	Deep cistern 5.5 mi. S of Imboden	0.01	1.00	2.00	1.00	3.52	0.91
	Mansell Cave	0.00	1.00	2.00	1.00	3.60	0.93
Caecidotea ancyla							
	Bear Hollow Cave	484101.00	0.98	1.95	0.98	3.55	0.92
	Brewer Cave						
	Denny Cave	0.03	1.00	1.99	0.99	3.37	0.87
	Fitton Spring Cave	0.01	1.00	1.99	0.99	3.77	0.97
	Foushee Cave	19494.00	1.00	2.00	1.00	3.79	0.98
	Greasy Valley Cave	0.03	1.00	2.00	1.00	3.38	0.87
	Ivy Springs Cave	0.02	1.00	2.00	1.00	3.31	0.85
	Major's Cave	0.36	1.00	1.86	0.93	3.15	0.81
	Marshall Caves	0.18	1.00	1.99	1.00	3.52	0.91

Species	Site	RWQH_02 Raw	RWQH_02 Scaled	RWQH Raw	RWQH Scaled	RWQ Raw	RWQ Scaled
	Nesbitt Spring Cave	0.01	1.00	2.00	1.00	3.65	0.94
	Old Pendergrass Cave	10871966.25	0.46	0.92	0.46	2.63	0.68
	Pretty Clean Cave	0.00	1.00	2.00	1.00	3.75	0.97
	Rootville Cave	0.06	1.00	1.99	1.00	3.66	0.94
	Spavinaw Creek Cave						
	War Eagle Cave	0.06	1.00	1.97	0.99	3.59	0.92
	Withrow Springs Cave	0.06	1.00	1.97	0.99	3.59	0.92
Caecidotea dimorpha							
	Elm Cave	0.05	1.00	2.00	1.00	3.76	0.97
	Martin Hollow Cave	0.00	1.00	2.00	1.00	3.70	0.95
	Mr. Griffin's Cave # 1	0.00	1.00	2.00	1.00	3.87	1.00
	Nesbitt Spring Cave	0.01	1.00	2.00	1.00	3.65	0.94
	Riley's Springbox	0.01	1.00	2.00	1.00	3.64	0.94
	Stovepipe Cave	0.01	1.00	2.00	1.00	3.49	0.90
	Summer Cave	0.01	1.00	2.00	1.00	3.80	0.98
Caecidotea macropropoda							
	Fincher Cave	0.01	1.00	2.00	1.00	3.68	0.95
	Spring at Bradley Shelter	0.01	1.00	2.00	1.00	3.48	0.90
	Stormdrain Spring at University of Arkansas	0.93	1.00	1.91	0.96	3.27	0.84
	Watson Cave	0.03	1.00	2.00	1.00	3.35	0.86
Caecidotea salemensis							
	Deep cistern 5.5 mi. S of Imboden	0.01	1.00	2.00	1.00	3.52	0.91
Caecidotea steevesi							
	AGFC Nursery Pond on Beaver Lake	0.03	1.00	2.00	1.00	3.58	0.92
	Cave on Pond Above Black Bass Lake	0.10	1.00	1.98	0.99	3.69	0.95
	Old Spanish Treasure Cave	0.11	1.00	1.98	0.99	3.73	0.96

Species	Site	RWQH_02 Raw	RWQH_02 Scaled	RWQH Raw	RWQH Scaled	RWQ Raw	RWQ Scaled
	War Eagle Cave	0.06	1.00	1.97	0.99	3.59	0.92
	Withrow Springs Cave	0.06	1.00	1.97	0.99	3.59	0.92
Caecidotea stiladactyla							
	Arkansas Archaeological Survey Site #3BE352	0.10	1.00	1.99	1.00	3.51	0.90
	Bently Cave	0.38	1.00	1.99	1.00	3.71	0.96
	Big Mouth Cave						
	Brock Spring	0.13	1.00	1.97	0.99	3.20	0.83
	Bull Shoals Caverns	0.21	1.00	1.97	0.99	3.70	0.95
	Cal Cave	0.01	1.00	2.00	1.00	3.56	0.92
	Cave Mountain Cave	0.03	1.00	2.00	1.00	3.73	0.96
	Cave on North Boundary Trail	0.10	1.00	1.99	1.00	3.83	0.99
	Cave Springs Cave	20140551.00	0.00	0.00	0.00	1.17	0.30
	Cold Cave	0.29	1.00	1.99	1.00	3.51	0.90
	Covington's Cave						
	Dickerson Cave	0.03	1.00	1.99	1.00	3.52	0.91
	Eden Falls Cave	0.01	1.00	2.00	1.00	3.71	0.96
	Fish Pond Cave	0.00	1.00	2.00	1.00	3.65	0.94
	Fitton Cave	0.01	1.00	1.99	0.99	3.77	0.97
	Granny Parker's Cave						
	John Eddings Cave	0.04	1.00	2.00	1.00	3.77	0.97
	Laningham's Cave	0.01	1.00	2.00	1.00	3.56	0.92
	Middle Creek Spring Cave						
	Novack Spring Cave	0.01	1.00	2.00	1.00	3.71	0.96
	Old Joe Cave	0.20	1.00	1.94	0.97	3.57	0.92
	Sherfield Cave	0.02	1.00	1.98	0.99	3.84	0.99
	Simpson's Cave	0.01	1.00	2.00	1.00	3.43	0.88

Species	Site	RWQH_02 Raw	RWQH_02 Scaled	RWQH Raw	RWQH Scaled	RWQ Raw	RWQ Scaled
	Spring at Hogscald	0.03	1.00	1.99	1.00	3.73	0.96
	Spring at Sequoyah Woods	0.44	1.00	1.90	0.95	3.57	0.92
	Spring on Butler Creek Road	0.01	1.00	1.99	1.00	3.77	0.97
	Spring on North Boundary Trail	0.10	1.00	1.99	1.00	3.83	0.99
	Stillhouse Hollow Cave	0.11	1.00	2.00	1.00	3.61	0.93
	Tanyard Creek Nature Trail Cave	0.08	1.00	2.00	1.00	3.49	0.90
	Unnamed seep 4 mi. S of Boxley	0.00	1.00	2.00	1.00	3.78	0.97
	Unnamed seep 9 mi. SW of Harrison	0.01	1.00	2.00	1.00	3.71	0.96
	Unnamed spring 3.5 mi. S of Jasper	0.04	1.00	2.00	1.00	3.71	0.96
	War Eagle Cavern	0.03	1.00	1.99	1.00	3.75	0.97
	White River Below Beaver Dam	0.13	1.00	1.98	0.99	3.69	0.95
Cambarus aculabrum							
	Bear Hollow Cave	484101.00	0.98	1.95	0.98	3.55	0.92
	Brush Creek	2131344.00	0.89	1.79	0.89	2.86	0.74
	Logan Cave	444300.75	0.98	1.96	0.98	2.90	0.75
	Old Pendergrass Cave	10871966.25	0.46	0.92	0.46	2.63	0.68
Cambarus setosus							
	Blowing Cave	0.00	1.00	2.00	1.00	3.86	0.99
	Poke Cave	0.00	1.00	2.00	1.00	3.86	0.99
	Tom Allen's Cave	0.03	1.00	2.00	1.00	3.62	0.93
Cambarus zophonastes							
	Hell Creek Cave	1645618.50	0.92	1.84	0.92	3.42	0.88
	Nesbitt Spring Cave	0.01	1.00	2.00	1.00	3.65	0.94
	site in Yellville	0.26	1.00	1.85	0.93	3.30	0.85
Dendrocoelopsis americana							
	Brock Spring	0.13	1.00	1.97	0.99	3.20	0.83
	Granny Parker's Cave						

Species	Site	RWQH_02 Raw	RWQH_02 Scaled	RWQH Raw	RWQH Scaled	RWQ Raw	RWQ Scaled
	Steel Creek Campground Cave	0.03	1.00	1.99	1.00	3.77	0.97
	Watson Cave	0.03	1.00	2.00	1.00	3.35	0.86
Eurycea spelaea							
	Alexander Cave	547456.50	0.97	1.95	0.97	3.26	0.84
	Allen Cave						
	Back o' Beyond Cave	0.03	1.00	2.00	1.00	3.64	0.94
	Bald Scrappy Cave	0.02	1.00	2.00	1.00	3.73	0.96
	Bear Hollow Cave	484101.00	0.98	1.95	0.98	3.55	0.92
	Bear Pit	0.00	1.00	2.00	1.00	3.77	0.97
	Bell Cave						
	Bently Cave	0.38	1.00	1.99	1.00	3.71	0.96
	Big Mouth Cave						
	Big Spring Cave						
	Biology Cave	0.00	1.00	2.00	1.00	3.75	0.97
	Blanchard Springs Caverns	1799946.00	0.91	1.82	0.91	3.81	0.98
	Blowing Cave	0.00	1.00	2.00	1.00	3.86	0.99
	Blowing Spring Cave	0.00	1.00	2.00	1.00	3.88	1.00
	Blowing Springs Cave	0.31	1.00	1.96	0.98	3.69	0.95
	Blowing Springs Cave	0.00	1.00	2.00	1.00	3.67	0.95
	Blue Heaven Cave	0.02	1.00	1.99	1.00	3.63	0.94
	Bonanza Cave	0.00	1.00	2.00	1.00	3.78	0.97
	Bonanza Mine	0.00	1.00	2.00	1.00	3.79	0.98
	Breakdown Cave	0.04	1.00	1.99	1.00	3.83	0.99
	Brewer Cave						
	Bull Shoals Caverns	0.21	1.00	1.97	0.99	3.70	0.95
	Cave River Cave	0.00	1.00	2.00	1.00	3.76	0.97
	Cave Springs Cave	20140551.00	0.00	0.00	0.00	1.17	0.30

Species	Site	RWQH_02 Raw	RWQH_02 Scaled	RWQH Raw	RWQH Scaled	RWQ Raw	RWQ Scaled
	Chambers Hollow Cave	0.00	1.00	2.00	1.00	3.76	0.97
	Chilly Bowl Cave	0.00	1.00	2.00	1.00	3.66	0.94
	Chinn Springs Cave	0.03	1.00	1.98	0.99	3.70	0.95
	Congo Crawl						
	Coon Cave	0.06	1.00	2.00	1.00	3.62	0.93
	Copperhead Cave	0.01	1.00	2.00	1.00	3.64	0.94
	Corkscrew Cave	0.00	1.00	2.00	1.00	3.77	0.97
	Cosmic Caverns	0.02	1.00	1.99	1.00	3.62	0.93
	Crystal Dome Cave	0.05	1.00	1.99	0.99	3.44	0.89
	Cushman Cave	0.08	1.00	1.99	1.00	3.73	0.96
	Cyner Cave	0.01	1.00	1.99	1.00	3.75	0.97
	Davis Creek Cave						
	Dear Buster Cave	0.01	1.00	2.00	1.00	3.81	0.98
	Diamond Cave	0.02	1.00	1.99	1.00	3.78	0.97
	Dickerson Cave	0.03	1.00	1.99	1.00	3.52	0.91
	Eckel Cave	0.00	1.00	2.00	1.00	3.70	0.95
	Elm Cave	0.05	1.00	2.00	1.00	3.76	0.97
	Ennis Cave	0.00	1.00	2.00	1.00	3.67	0.95
	Fancher Cave						
	Fish Pond Cave	0.00	1.00	2.00	1.00	3.65	0.94
	Fitton Cave	0.01	1.00	1.99	0.99	3.77	0.97
	Fitton Spring Cave	0.01	1.00	1.99	0.99	3.77	0.97
	Foushee Cave	19494.00	1.00	2.00	1.00	3.79	0.98
	Friday the 13th Cave	0.01	1.00	1.99	0.99	3.77	0.97
	Green River Cave	0.01	1.00	2.00	1.00	3.52	0.91
	Gunner Cave	0.01	1.00	1.99	1.00	3.73	0.96
	Gustafson Cave	0.00	1.00	2.00	1.00	3.72	0.96

Species	Site	RWQH_02 Raw	RWQH_02 Scaled	RWQH Raw	RWQH Scaled	RWQ Raw	RWQ Scaled
	Hammer Springs Cave	0.01	1.00	2.00	1.00	3.87	1.00
	Hell Creek Cave	1645618.50	0.92	1.84	0.92	3.42	0.88
	Herald Hollow Cave	0.00	1.00	2.00	1.00	3.80	0.98
	Hickory Creek Cave						
	Hidden Spring Cave	0.00	1.00	2.00	1.00	3.56	0.92
	Hog Head Cave	0.01	1.00	2.00	1.00	3.80	0.98
	Huchingson's Waterfall Cave						
	Hunter's Cave	0.00	1.00	2.00	1.00	3.87	1.00
	Hurricane River Cave	0.01	1.00	2.00	1.00	3.80	0.98
	Icebox Cave						
	Indian Rockhouse Cave	0.02	1.00	1.99	1.00	3.78	0.97
	In-D-Pendants Cave	0.01	1.00	2.00	1.00	3.68	0.95
	Janus Pit	0.00	1.00	2.00	1.00	3.83	0.99
	Jelico Hollow Cave	0.00	1.00	2.00	1.00	3.77	0.97
	John Eddings Cave	0.04	1.00	2.00	1.00	3.77	0.97
	Lewis Spring Cave						
	Little Den Cave	0.01	1.00	1.99	0.99	3.77	0.97
	Logan Cave	444300.75	0.98	1.96	0.98	2.90	0.75
	Major's Cave	0.36	1.00	1.86	0.93	3.15	0.81
	Mammoth Spring	0.75	1.00	1.97	0.98	3.50	0.90
	Martin Hollow Cave	0.00	1.00	2.00	1.00	3.70	0.95
	Miner's Cave	0.12	1.00	1.98	0.99	3.73	0.96
	Mr. Clean Cave	0.00	1.00	2.00	1.00	3.76	0.97
	Mr. Griffin's Cave # 1	0.00	1.00	2.00	1.00	3.87	1.00
	Needles Cave	0.24	1.00	1.98	0.99	3.54	0.91
	Nesbitt Spring Cave	0.01	1.00	2.00	1.00	3.65	0.94
	Norfork Bat Cave	0.30	1.00	1.96	0.98	3.48	0.90

Species	Site	RWQH_02 Raw	RWQH_02 Scaled	RWQH Raw	RWQH Scaled	RWQ Raw	RWQ Scaled
	Old Joe Cave	0.20	1.00	1.94	0.97	3.57	0.92
	Omega Cave						
	Panther Mountain Cave						
	Pigeon Roost Cave	0.02	1.00	2.00	1.00	3.86	1.00
	Potato Cave						
	Pregnant Nun Cave	0.01	1.00	1.99	1.00	3.77	0.97
	Pretty Clean Cave	0.00	1.00	2.00	1.00	3.75	0.97
	Reed Cave	0.00	1.00	2.00	1.00	3.74	0.96
	Richardson Cave	0.09	1.00	1.99	1.00	3.76	0.97
	Riley's Springbox	0.01	1.00	2.00	1.00	3.64	0.94
	Rootville Cave	0.06	1.00	1.99	1.00	3.66	0.94
	Rory Cave	0.02	1.00	2.00	1.00	3.69	0.95
	Salamander Cave	0.00	1.00	2.00	1.00	3.69	0.95
	Saltpeter Cave	0.00	1.00	2.00	1.00	3.86	0.99
	Slick Rock Hollow Cave						
	Springhouse at Steel Creek Ranger Cabin	0.02	1.00	2.00	1.00	3.79	0.98
	Steel Creek Campground Cave	0.03	1.00	1.99	1.00	3.77	0.97
	Stillhouse Hollow Cave	0.11	1.00	2.00	1.00	3.61	0.93
	Stovepipe Cave	0.01	1.00	2.00	1.00	3.49	0.90
	Summer Cave	0.01	1.00	2.00	1.00	3.80	0.98
	Tom Allen's Cave	0.03	1.00	2.00	1.00	3.62	0.93
	Tom Barnes Cave	0.01	1.00	2.00	1.00	3.74	0.96
	Toney Bend Mine # 2	0.01	1.00	2.00	1.00	3.83	0.99
	Tweet's Cave	0.00	1.00	2.00	1.00	3.79	0.98
	Unnamed cave	0.00	1.00	2.00	1.00	3.69	0.95
	Unnamed caves at Devil's Knob Natural Area	0.00	1.00	2.00	1.00	3.86	0.99

Species	Site	RWQH_02 Raw	RWQH_02 Scaled	RWQH Raw	RWQH Scaled	RWQ Raw	RWQ Scaled
	Van Dyke Spring Cave	0.01	1.00	1.99	0.99	3.77	0.97
	Von Wadding's Memorial Cave	0.04	1.00	1.99	1.00	3.83	0.99
	War Eagle Cave	0.06	1.00	1.97	0.99	3.59	0.92
	War Eagle Cavern	0.03	1.00	1.99	1.00	3.75	0.97
	Whippoorwill Cave	0.00	1.00	2.00	1.00	3.77	0.97
	Willis Cave	0.01	1.00	1.99	0.99	3.77	0.97
	Wolf Creek Cave	0.00	1.00	2.00	1.00	3.84	0.99
	Wounded Knee Cave	0.00	1.00	2.00	1.00	3.83	0.99
Lirceus bicuspidatus							
	Diamond Cave	0.02	1.00	1.99	1.00	3.78	0.97
	Foushee Cave	19494.00	1.00	2.00	1.00	3.79	0.98
	Hell Creek Cave	1645618.50	0.92	1.84	0.92	3.42	0.88
	Hurricane River Cave	0.01	1.00	2.00	1.00	3.80	0.98
Lirceus bidentatus							
	Unnamed seep 9 mi. SW of Harrison	0.01	1.00	2.00	1.00	3.71	0.96
Stygobromus ozarkensis							
	Bear Hollow Cave	484101.00	0.98	1.95	0.98	3.55	0.92
	Blowing Springs Cave	0.31	1.00	1.96	0.98	3.69	0.95
	Cave on Pond Above Black Bass Lake	0.10	1.00	1.98	0.99	3.69	0.95
	Cave Springs Cave	20140551.00	0.00	0.00	0.00	1.17	0.30
	Civil War Cave	0.31	1.00	1.82	0.91	3.12	0.80
	Dickerson Cave	0.03	1.00	1.99	1.00	3.52	0.91
	Fitton Cave	0.01	1.00	1.99	0.99	3.77	0.97
	Fitton Spring Cave	0.01	1.00	1.99	0.99	3.77	0.97
	Hunter's Cave	0.00	1.00	2.00	1.00	3.87	1.00
	John Eddings Cave	0.04	1.00	2.00	1.00	3.77	0.97
	Logan Cave	444300.75	0.98	1.96	0.98	2.90	0.75

Species	Site	RWQH_02 Raw	RWQH_02 Scaled	RWQH Raw	RWQH Scaled	RWQ Raw	RWQ Scaled
	Needles Cave	0.24	1.00	1.98	0.99	3.54	0.91
	Old Pendergrass Cave	10871966.25	0.46	0.92	0.46	2.63	0.68
	Pretty Clean Cave	0.00	1.00	2.00	1.00	3.75	0.97
	Reed Cave	0.00	1.00	2.00	1.00	3.74	0.96
	Sherfield Cave	0.02	1.00	1.98	0.99	3.84	0.99
	Spavinaw Creek Cave						
	War Eagle Cave	0.06	1.00	1.97	0.99	3.59	0.92
	War Eagle Cavern	0.03	1.00	1.99	1.00	3.75	0.97
	White River Below Beaver Dam	0.13	1.00	1.98	0.99	3.69	0.95
	Withrow Springs Cave	0.06	1.00	1.97	0.99	3.59	0.92
Typhlichthys subterraneus							
	Richardson Cave	0.09	1.00	1.99	1.00	3.76	0.97
-	Unnamed well in Randolph County	-	-	-	-	-	-

Table Appendix E-8. Index values and scaled scores for VULN Raw through RVIA Scaled.

Species	Site	VULN Raw	VULN Scaled	SENS Raw	SENS Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
Amblyopsis rosae									
	AGFC Nursery Pond on Beaver Lake	88.33	0.33	1.26	0.86	79926	0.41	0.10	0.18
	Cave Springs Cave	110.49	0.16	0.47	0.32	134411	0.01	0.11	0.08
	Civil War Cave	104.25	0.21	1.02	0.70	91159	0.33	0.12	0.00
	Hewlitt's Spring Hole	100.72	0.24	0.97	0.66	99615	0.27	0.10	0.18
	James-Ditto Cave	113.04	0.15	1.03	0.71	28413	0.79	0.07	0.42
	Logan Cave	108.38	0.18	0.93	0.64	31431	0.77	0.07	0.43
	Monte Ne Sinkhole	71.25	0.46	1.39	0.96	117558	0.13	0.11	0.09
	Mule Hole Sink	120.70	0.09	1.00	0.69	127847	0.06	0.11	0.08

Species	Site	VULN Raw	VULN Scaled	SENS Raw	SENS Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Rootville Cave	105.07	0.21	1.15	0.79	17093	0.87	0.06	0.49
	Tom Allen's Cave	107.06	0.19	1.12	0.77	17539	0.87	0.06	0.48
Amnicola cora									
	Foushee Cave	73.32	0.45	1.42	0.98	17478	0.87	0.05	0.59
Bactrurus pseudomucronatus									
	Deep cistern 5.5 mi. S of Imboden	132.25	0.00	0.91	0.62	7098	0.95	0.04	0.64
	Mansell Cave	112.28	0.15	1.08	0.74	12955	0.90	0.05	0.58
Caecidotea ancyla									
	Bear Hollow Cave	86.95	0.34	1.26	0.87	49097	0.64	0.09	0.26
	Brewer Cave								
	Denny Cave	103.48	0.22	1.09	0.75	7480	0.94	0.05	0.60
	Fitton Spring Cave	83.52	0.37	1.34	0.92	6924	0.95	0.04	0.64
	Foushee Cave	73.32	0.45	1.42	0.98	17478	0.87	0.05	0.59
	Greasy Valley Cave	103.09	0.22	1.09	0.75	16014	0.88	0.05	0.58
	Ivy Springs Cave	79.47	0.40	1.25	0.86	7742	0.94	0.05	0.57
	Major's Cave	85.71	0.35	1.16	0.80	26637	0.80	0.06	0.49
	Marshall Caves	97.97	0.26	1.17	0.80	38521	0.72	0.09	0.29
	Nesbitt Spring Cave	96.42	0.27	1.21	0.83	7626	0.94	0.04	0.63
	Old Pendergrass Cave	82.05	0.38	1.06	0.73	40435	0.70	0.09	0.28
	Pretty Clean Cave	73.31	0.45	1.41	0.97	4515	0.97	0.04	0.67
	Rootville Cave	105.07	0.21	1.15	0.79	17093	0.87	0.06	0.49
	Spavinaw Creek Cave								
	War Eagle Cave	89.93	0.32	1.24	0.86	7899	0.94	0.05	0.60
	Withrow Springs Cave	89.93	0.32	1.24	0.86	8192	0.94	0.05	0.60
Caecidotea dimorpha									
	Elm Cave	81.17	0.39	1.36	0.93	6371	0.95	0.04	0.62
	Martin Hollow Cave	91.58	0.31	1.26	0.87	7785	0.94	0.04	0.64

Species	Site	VULN Raw	VULN Scaled	SENS Raw	SENS Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Mr. Griffin's Cave # 1	81.17	0.39	1.38	0.95	5166	0.96	0.05	0.60
	Nesbitt Spring Cave	96.42	0.27	1.21	0.83	7626	0.94	0.04	0.63
	Riley's Springbox	84.73	0.36	1.30	0.89	6583	0.95	0.05	0.58
	Stovepipe Cave	119.89	0.09	0.99	0.68	5592	0.96	0.05	0.62
	Summer Cave	80.24	0.39	1.37	0.95	3083	0.98	0.04	0.66
Caecidotea macropropoda									
	Fincher Cave	75.07	0.43	1.38	0.95	75017	0.45	0.08	0.36
	Spring at Bradley Shelter	91.06	0.31	1.21	0.83	24509	0.82	0.06	0.51
	Stormdrain Spring at University of Arkansas	108.26	0.18	1.02	0.70	123096	0.09	0.10	0.18
	Watson Cave	119.74	0.09	0.96	0.66	26767	0.80	0.06	0.51
Caecidotea salemensis									
	Deep cistern 5.5 mi. S of Imboden	132.25	0.00	0.91	0.62	7098	0.95	0.04	0.64
Caecidotea steevesi									
	AGFC Nursery Pond on Beaver Lake	88.33	0.33	1.26	0.86	79926	0.41	0.10	0.18
	Cave on Pond Above Black Bass Lake	70.98	0.46	1.41	0.97	12186	0.91	0.07	0.45
	Old Spanish Treasure Cave	78.03	0.41	1.37	0.94	21998	0.84	0.07	0.42
	War Eagle Cave	89.93	0.32	1.24	0.86	7899	0.94	0.05	0.60
	Withrow Springs Cave	89.93	0.32	1.24	0.86	8192	0.94	0.05	0.60
Caecidotea stiladactyla									
	Arkansas Archaeological Survey Site #3BE352	108.29	0.18	1.08	0.75	29800	0.78	0.06	0.46
	Bently Cave	87.26	0.34	1.30	0.89	59738	0.56	0.10	0.17
	Big Mouth Cave								
	Brock Spring	83.44	0.37	1.19	0.82	121801	0.10	0.10	0.17
	Bull Shoals Caverns	68.48	0.48	1.44	0.99	17354	0.87	0.06	0.51

Species	Site	VULN Raw	VULN Scaled	SENS Raw	SENS Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Cal Cave	82.00	0.38	1.30	0.89	11423	0.92	0.05	0.57
	Cave Mountain Cave	85.47	0.35	1.31	0.90	2347	0.98	0.03	0.74
	Cave on North Boundary Trail	88.64	0.33	1.32	0.91	12100	0.91	0.06	0.48
	Cave Springs Cave	110.49	0.16	0.47	0.32	134411	0.01	0.11	0.08
	Cold Cave	98.17	0.26	1.16	0.80	89160	0.34	0.12	0.04
	Covington's Cave								
	Dickerson Cave	109.18	0.17	1.08	0.74	16791	0.88	0.06	0.49
	Eden Falls Cave	79.42	0.40	1.36	0.93	2886	0.98	0.03	0.71
	Fish Pond Cave	87.40	0.34	1.28	0.88	27909	0.79	0.07	0.43
	Fitton Cave	83.52	0.37	1.34	0.92	6073	0.96	0.04	0.65
	Granny Parker's Cave								
	John Eddings Cave	77.84	0.41	1.38	0.95	5692	0.96	0.04	0.64
	Laningham's Cave	82.00	0.38	1.30	0.89	12271	0.91	0.05	0.58
	Middle Creek Spring Cave								
	Novack Spring Cave	79.42	0.40	1.36	0.93	3121	0.98	0.03	0.71
	Old Joe Cave	86.79	0.34	1.26	0.87	8412	0.94	0.06	0.53
	Sherfield Cave	82.25	0.38	1.37	0.94	2556	0.98	0.03	0.75
	Simpson's Cave	106.12	0.20	1.08	0.74	14219	0.90	0.05	0.56
	Spring at Hogscald	79.32	0.40	1.36	0.94	8843	0.93	0.06	0.49
	Spring at Sequoyah Woods	89.77	0.32	1.24	0.85	121524	0.10	0.10	0.18
	Spring on Butler Creek Road	76.29	0.42	1.40	0.96	26987	0.80	0.07	0.40
	Spring on North Boundary Trail	88.64	0.33	1.32	0.91	12037	0.91	0.06	0.48
	Stillhouse Hollow Cave	75.48	0.43	1.36	0.94	5838	0.96	0.04	0.64
	Tanyard Creek Nature Trail Cave	87.45	0.34	1.24	0.85	59837	0.56	0.10	0.17
	Unnamed seep 4 mi. S of Boxley	73.29	0.45	1.42	0.98	2296	0.98	0.03	0.76
	Unnamed seep 9 mi. SW of Harrison	70.30	0.47	1.43	0.98	22761	0.83	0.05	0.54
	Unnamed spring 3.5 mi. S of Jasper	68.72	0.48	1.44	0.99	5161	0.96	0.04	0.66

Species	Site	VULN Raw	VULN Scaled	SENS Raw	SENS Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	War Eagle Cavern	77.94	0.41	1.38	0.95	16349	0.88	0.07	0.41
	White River Below Beaver Dam	69.89	0.47	1.42	0.98	14396	0.89	0.07	0.43
Cambarus aculabrum									
	Bear Hollow Cave	86.95	0.34	1.26	0.87	49097	0.64	0.09	0.26
	Brush Creek	109.45	0.17	0.91	0.63	131559	0.03	0.10	0.15
	Logan Cave	108.38	0.18	0.93	0.64	31431	0.77	0.07	0.43
	Old Pendergrass Cave	82.05	0.38	1.06	0.73	40435	0.70	0.09	0.28
Cambarus setosus									
	Blowing Cave	98.82	0.25	1.25	0.86	24693	0.82	0.06	0.50
	Poke Cave	98.82	0.25	1.25	0.86	24002	0.82	0.06	0.51
	Tom Allen's Cave	107.06	0.19	1.12	0.77	17539	0.87	0.06	0.48
Cambarus zophonastes									
	Hell Creek Cave	81.87	0.38	1.26	0.87	7658	0.94	0.05	0.62
	Nesbitt Spring Cave	96.42	0.27	1.21	0.83	7626	0.94	0.04	0.63
	site in Yellville	83.41	0.37	1.22	0.84	11630	0.91	0.05	0.55
Dendrocoelopsis americana									
	Brock Spring	83.44	0.37	1.19	0.82	121801	0.10	0.10	0.17
	Granny Parker's Cave								
	Steel Creek Campground Cave	81.35	0.38	1.36	0.93	3644	0.97	0.04	0.69
	Watson Cave	119.74	0.09	0.96	0.66	26767	0.80	0.06	0.51
Eurycea spelaea									
	Alexander Cave	89.67	0.32	1.16	0.80	3793	0.97	0.04	0.68
	Allen Cave								
	Back o' Beyond Cave	92.87	0.30	1.24	0.85	4848	0.96	0.04	0.65
	Bald Scrappy Cave	93.52	0.29	1.25	0.86	6921	0.95	0.05	0.61
	Bear Hollow Cave	86.95	0.34	1.26	0.87	49097	0.64	0.09	0.26
	Bear Pit	78.12	0.41	1.38	0.95	5002	0.96	0.04	0.65

Species	Site	VULN Raw	VULN Scaled	SENS Raw	SENS Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Bell Cave								
	Bently Cave	87.26	0.34	1.30	0.89	59738	0.56	0.10	0.17
	Big Mouth Cave								
	Big Spring Cave								
	Biology Cave	92.66	0.30	1.27	0.87	5075	0.96	0.05	0.60
	Blanchard Springs Caverns	81.38	0.38	1.37	0.94	7286	0.95	0.05	0.62
	Blowing Cave	98.82	0.25	1.25	0.86	24693	0.82	0.06	0.50
	Blowing Spring Cave	78.82	0.40	1.40	0.97	2375	0.98	0.04	0.70
	Blowing Springs Cave	98.00	0.26	1.21	0.83	81295	0.40	0.11	0.11
	Blowing Springs Cave	77.52	0.41	1.36	0.94	12841	0.91	0.06	0.51
	Blue Heaven Cave	87.49	0.34	1.27	0.88	7821	0.94	0.05	0.59
	Bonanza Cave	96.19	0.27	1.25	0.86	10630	0.92	0.05	0.57
	Bonanza Mine	78.66	0.41	1.38	0.95	3697	0.97	0.04	0.66
	Breakdown Cave	86.65	0.34	1.33	0.92	7124	0.95	0.05	0.61
	Brewer Cave								
	Bull Shoals Caverns	68.48	0.48	1.44	0.99	17354	0.87	0.06	0.51
	Cave River Cave	75.39	0.43	1.40	0.96	6744	0.95	0.05	0.61
	Cave Springs Cave	110.49	0.16	0.47	0.32	134411	0.01	0.11	0.08
	Chambers Hollow Cave	94.36	0.29	1.25	0.86	28268	0.79	0.07	0.45
	Chilly Bowl Cave	66.97	0.49	1.44	0.99	15737	0.88	0.05	0.57
	Chinn Springs Cave	91.88	0.31	1.26	0.87	25020	0.82	0.06	0.50
	Congo Crawl								
	Coon Cave	71.97	0.46	1.39	0.96	3917	0.97	0.04	0.65
	Copperhead Cave	78.23	0.41	1.35	0.93	5359	0.96	0.04	0.65
	Corkscrew Cave	75.63	0.43	1.40	0.96	5539	0.96	0.04	0.65
	Cosmic Caverns	63.59	0.52	1.45	1.00	17695	0.87	0.05	0.56
	Crystal Dome Cave	84.35	0.36	1.25	0.86	22998	0.83	0.06	0.52

Species	Site	VULN Raw	VULN Scaled	SENS Raw	SENS Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Cushman Cave	90.97	0.31	1.27	0.88	9247	0.93	0.05	0.60
	Cyner Cave	93.66	0.29	1.26	0.87	5181	0.96	0.04	0.68
	Davis Creek Cave								
	Dear Buster Cave	84.82	0.36	1.34	0.92	3532	0.97	0.03	0.74
	Diamond Cave	91.23	0.31	1.28	0.88	4922	0.96	0.04	0.68
	Dickerson Cave	109.18	0.17	1.08	0.74	16791	0.88	0.06	0.49
	Eckel Cave	82.53	0.38	1.33	0.91	9824	0.93	0.07	0.42
	Elm Cave	81.17	0.39	1.36	0.93	6371	0.95	0.04	0.62
	Ennis Cave	85.81	0.35	1.30	0.89	5431	0.96	0.04	0.65
	Fancher Cave								
	Fish Pond Cave	87.40	0.34	1.28	0.88	27909	0.79	0.07	0.43
	Fitton Cave	83.52	0.37	1.34	0.92	6073	0.96	0.04	0.65
	Fitton Spring Cave	83.52	0.37	1.34	0.92	6924	0.95	0.04	0.64
	Foushee Cave	73.32	0.45	1.42	0.98	17478	0.87	0.05	0.59
	Friday the 13th Cave	83.52	0.37	1.34	0.92	5858	0.96	0.04	0.65
	Green River Cave	84.08	0.36	1.27	0.88	22375	0.84	0.06	0.52
	Gunner Cave	82.25	0.38	1.34	0.92	3462	0.97	0.04	0.65
	Gustafson Cave	82.28	0.38	1.34	0.92	4229	0.97	0.05	0.60
	Hammer Springs Cave	86.42	0.35	1.34	0.92	3506	0.97	0.04	0.68
	Hell Creek Cave	81.87	0.38	1.26	0.87	7658	0.94	0.05	0.62
	Herald Hollow Cave	74.98	0.43	1.41	0.97	7345	0.95	0.05	0.59
	Hickory Creek Cave								
	Hidden Spring Cave	80.30	0.39	1.31	0.90	4566	0.97	0.05	0.61
	Hog Head Cave	84.12	0.36	1.34	0.92	3819	0.97	0.03	0.74
	Huchingson's Waterfall Cave								
	Hunter's Cave	75.54	0.43	1.42	0.98	11586	0.91	0.06	0.53
	Hurricane River Cave	95.01	0.28	1.26	0.87	5913	0.96	0.04	0.66

Species	Site	VULN Raw	VULN Scaled	SENS Raw	SENS Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Icebox Cave								
	Indian Rockhouse Cave	82.12	0.38	1.35	0.93	4059	0.97	0.04	0.64
	In-D-Pendants Cave	82.28	0.38	1.33	0.91	5030	0.96	0.04	0.64
	Janus Pit	86.96	0.34	1.33	0.92	7093	0.95	0.05	0.62
	Jelico Hollow Cave	77.97	0.41	1.38	0.95	6074	0.96	0.05	0.59
	John Eddings Cave	77.84	0.41	1.38	0.95	5692	0.96	0.04	0.64
	Lewis Spring Cave								
	Little Den Cave	83.52	0.37	1.34	0.92	6168	0.95	0.04	0.65
	Logan Cave	108.38	0.18	0.93	0.64	31431	0.77	0.07	0.43
	Major's Cave	85.71	0.35	1.16	0.80	26637	0.80	0.06	0.49
	Mammoth Spring	87.18	0.34	1.24	0.85	7894	0.94	0.04	0.65
	Martin Hollow Cave	91.58	0.31	1.26	0.87	7785	0.94	0.04	0.64
	Miner's Cave	77.70	0.41	1.37	0.95	12711	0.91	0.06	0.49
	Mr. Clean Cave	95.03	0.28	1.25	0.86	7491	0.94	0.05	0.61
	Mr. Griffin's Cave # 1	81.17	0.39	1.38	0.95	5166	0.96	0.05	0.60
	Needles Cave	100.96	0.24	1.15	0.79	5581	0.96	0.05	0.57
	Nesbitt Spring Cave	96.42	0.27	1.21	0.83	7626	0.94	0.04	0.63
	Norfork Bat Cave	85.67	0.35	1.25	0.86	11297	0.92	0.06	0.52
	Old Joe Cave	86.79	0.34	1.26	0.87	8412	0.94	0.06	0.53
	Omega Cave								
	Panther Mountain Cave								
	Pigeon Roost Cave	87.94	0.34	1.33	0.92	25901	0.81	0.08	0.36
	Potato Cave								
	Pregnant Nun Cave	76.29	0.42	1.40	0.96	27147	0.80	0.07	0.41
	Pretty Clean Cave	73.31	0.45	1.41	0.97	4515	0.97	0.04	0.67
	Reed Cave	81.19	0.39	1.35	0.93	10276	0.92	0.05	0.58
	Richardson Cave	74.88	0.43	1.40	0.97	10642	0.92	0.08	0.34

Species	Site	VULN Raw	VULN Scaled	SENS Raw	SENS Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Riley's Springbox	84.73	0.36	1.30	0.89	6583	0.95	0.05	0.58
	Rootville Cave	105.07	0.21	1.15	0.79	17093	0.87	0.06	0.49
	Rory Cave	91.81	0.31	1.26	0.86	6795	0.95	0.04	0.64
	Salamander Cave	71.17	0.46	1.41	0.97	9892	0.93	0.05	0.56
	Saltpeter Cave	81.89	0.38	1.37	0.95	4395	0.97	0.05	0.60
	Slick Rock Hollow Cave								
	Springhouse at Steel Creek Ranger Cabin	79.92	0.40	1.37	0.94	4044	0.97	0.04	0.69
	Steel Creek Campground Cave	81.35	0.38	1.36	0.93	3644	0.97	0.04	0.69
	Stillhouse Hollow Cave	75.48	0.43	1.36	0.94	5838	0.96	0.04	0.64
	Stovepipe Cave	119.89	0.09	0.99	0.68	5592	0.96	0.05	0.62
	Summer Cave	80.24	0.39	1.37	0.95	3083	0.98	0.04	0.66
	Tom Allen's Cave	107.06	0.19	1.12	0.77	17539	0.87	0.06	0.48
	Tom Barnes Cave	85.02	0.36	1.32	0.91	4844	0.96	0.04	0.67
	Toney Bend Mine # 2	82.73	0.37	1.36	0.94	3666	0.97	0.04	0.65
	Tweet's Cave	93.22	0.30	1.27	0.88	3965	0.97	0.03	0.72
	Unnamed cave	101.57	0.23	1.18	0.81	7560	0.94	0.05	0.62
	Unnamed caves at Devil's Knob Natural Area	87.55	0.34	1.33	0.92	7254	0.95	0.05	0.59
	Van Dyke Spring Cave	83.52	0.37	1.34	0.92	6364	0.95	0.04	0.64
	Von Wadding's Memorial Cave	86.65	0.34	1.33	0.92	7034	0.95	0.05	0.61
	War Eagle Cave	89.93	0.32	1.24	0.86	7899	0.94	0.05	0.60
	War Eagle Cavern	77.94	0.41	1.38	0.95	16349	0.88	0.07	0.41
	Whippoorwill Cave	77.97	0.41	1.38	0.95	6932	0.95	0.05	0.59
	Willis Cave	83.52	0.37	1.34	0.92	6230	0.95	0.04	0.65
	Wolf Creek Cave	80.34	0.39	1.38	0.95	3458	0.97	0.03	0.74
	Wounded Knee Cave	83.77	0.37	1.35	0.93	5072	0.96	0.05	0.59
Lirceus bicuspidatus									

Species	Site	VULN Raw	VULN Scaled	SENS Raw	SENS Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	Diamond Cave	91.23	0.31	1.28	0.88	4922	0.96	0.04	0.68
	Foushee Cave	73.32	0.45	1.42	0.98	17478	0.87	0.05	0.59
	Hell Creek Cave	81.87	0.38	1.26	0.87	7658	0.94	0.05	0.62
	Hurricane River Cave	95.01	0.28	1.26	0.87	5913	0.96	0.04	0.66
Lirceus bidentatus									
	Unnamed seep 9 mi. SW of Harrison	70.30	0.47	1.43	0.98	22761	0.83	0.05	0.54
Stygobromus ozarkensis									
	Bear Hollow Cave	86.95	0.34	1.26	0.87	49097	0.64	0.09	0.26
	Blowing Springs Cave	98.00	0.26	1.21	0.83	81295	0.40	0.11	0.11
	Cave on Pond Above Black Bass Lake	70.98	0.46	1.41	0.97	12186	0.91	0.07	0.45
	Cave Springs Cave	110.49	0.16	0.47	0.32	134411	0.01	0.11	0.08
	Civil War Cave	104.25	0.21	1.02	0.70	91159	0.33	0.12	0.00
	Dickerson Cave	109.18	0.17	1.08	0.74	16791	0.88	0.06	0.49
	Fitton Cave	83.52	0.37	1.34	0.92	6073	0.96	0.04	0.65
	Fitton Spring Cave	83.52	0.37	1.34	0.92	6924	0.95	0.04	0.64
	Hunter's Cave	75.54	0.43	1.42	0.98	11586	0.91	0.06	0.53
	John Eddings Cave	77.84	0.41	1.38	0.95	5692	0.96	0.04	0.64
	Logan Cave	108.38	0.18	0.93	0.64	31431	0.77	0.07	0.43
	Needles Cave	100.96	0.24	1.15	0.79	5581	0.96	0.05	0.57
	Old Pendergrass Cave	82.05	0.38	1.06	0.73	40435	0.70	0.09	0.28
	Pretty Clean Cave	73.31	0.45	1.41	0.97	4515	0.97	0.04	0.67
	Reed Cave	81.19	0.39	1.35	0.93	10276	0.92	0.05	0.58
	Sherfield Cave	82.25	0.38	1.37	0.94	2556	0.98	0.03	0.75
	Spavinaw Creek Cave								
	War Eagle Cave	89.93	0.32	1.24	0.86	7899	0.94	0.05	0.60
	War Eagle Cavern	77.94	0.41	1.38	0.95	16349	0.88	0.07	0.41

Species	Site	VULN Raw	VULN Scaled	SENS Raw	SENS Scaled	RVIP Raw	RVIP Scaled	RVIA Raw	RVIA Scaled
	White River Below Beaver Dam	69.89	0.47	1.42	0.98	14396	0.89	0.07	0.43
	Withrow Springs Cave	89.93	0.32	1.24	0.86	8192	0.94	0.05	0.60
Typhlichthys subterraneus									
	Richardson Cave	74.88	0.43	1.40	0.97	10642	0.92	0.08	0.34
-	Unnamed well in Randolph County	-	-	-	-	-	-	-	-

Table Appendix E-9. Index values and scaled scores for RVIX Raw through THREAT Scaled.

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
Amblyopsis rosae							
	AGFC Nursery Pond on Beaver Lake	0.05	0.03	0.62	0.23	1.09	0.56
	Cave Springs Cave	0.13	0.08	0.17	0.06	0.38	0.20
	Civil War Cave	0.07	0.04	0.37	0.14	0.84	0.43
	Hewlitt's Spring Hole	0.09	0.05	0.50	0.18	0.85	0.43
	James-Ditto Cave	0.02	0.01	1.23	0.45	1.16	0.59
	Logan Cave	0.16	0.10	1.29	0.48	1.11	0.57
	Monte Ne Sinkhole	0.07	0.04	0.26	0.10	1.06	0.54
	Mule Hole Sink	0.08	0.05	0.18	0.07	0.76	0.39
	Rootville Cave	0.01	0.01	1.37	0.51	1.30	0.66
	Tom Allen's Cave	0.21	0.13	1.48	0.55	1.32	0.68
Amnicola cora							
	Foushee Cave	0.31	0.18	1.64	0.61	1.58	0.81
Bactrurus pseudomucronatus							
	Deep cistern 5.5 mi. S of Imboden	0.04	0.03	1.62	0.60	1.22	0.63
	Mansell Cave	0.38	0.23	1.72	0.63	1.37	0.70
Caecidotea ancyla							

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Bear Hollow Cave	0.11	0.07	0.96	0.35	1.22	0.63
	Brewer Cave						
	Denny Cave	0.32	0.19	1.73	0.64	1.39	0.71
	Fitton Spring Cave	0.30	0.18	1.77	0.65	1.57	0.81
	Foushee Cave	0.31	0.18	1.64	0.61	1.58	0.81
	Greasy Valley Cave	0.18	0.11	1.57	0.58	1.33	0.68
	Ivy Springs Cave	0.02	0.01	1.53	0.56	1.43	0.73
	Major's Cave	0.03	0.02	1.32	0.48	1.29	0.66
	Marshall Caves	0.14	0.08	1.08	0.40	1.20	0.62
	Nesbitt Spring Cave	0.27	0.16	1.73	0.64	1.47	0.75
	Old Pendergrass Cave	0.13	0.08	1.06	0.39	1.12	0.57
	Pretty Clean Cave	0.07	0.04	1.68	0.62	1.59	0.82
	Rootville Cave	0.01	0.01	1.37	0.51	1.30	0.66
	Spavinaw Creek Cave						
	War Eagle Cave	0.19	0.11	1.66	0.61	1.47	0.75
	Withrow Springs Cave	0.04	0.02	1.56	0.58	1.43	0.73
Caecidotea dimorpha							
	Elm Cave	0.08	0.05	1.62	0.60	1.53	0.79
	Martin Hollow Cave	0.37	0.22	1.80	0.66	1.53	0.79
	Mr. Griffin's Cave # 1	0.06	0.04	1.60	0.59	1.54	0.79
	Nesbitt Spring Cave	0.27	0.16	1.73	0.64	1.47	0.75
	Riley's Springbox	0.12	0.07	1.60	0.59	1.48	0.76
	Stovepipe Cave	0.08	0.05	1.63	0.60	1.29	0.66
	Summer Cave	0.82	0.49	2.13	0.79	1.73	0.89
Caecidotea macropropoda							
	Fincher Cave	0.05	0.03	0.83	0.31	1.26	0.65
	Spring at Bradley Shelter	0.32	0.19	1.52	0.56	1.39	0.71

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Stormdrain Spring at University of Arkansas	0.01	0.01	0.28	0.10	0.81	0.41
	Watson Cave	0.04	0.02	1.33	0.49	1.15	0.59
Caecidotea salemensis							
	Deep cistern 5.5 mi. S of Imboden	0.04	0.03	1.62	0.60	1.22	0.63
Caecidotea steevesi							
	AGFC Nursery Pond on Beaver Lake	0.05	0.03	0.62	0.23	1.09	0.56
	Cave on Pond Above Black Bass Lake	0.09	0.06	1.42	0.52	1.50	0.77
	Old Spanish Treasure Cave	0.06	0.04	1.29	0.48	1.42	0.73
	War Eagle Cave	0.19	0.11	1.66	0.61	1.47	0.75
	Withrow Springs Cave	0.04	0.02	1.56	0.58	1.43	0.73
Caecidotea stiladactyla							
	Arkansas Archaeological Survey Site #3BE352	0.09	0.05	1.29	0.48	1.22	0.63
	Bently Cave	0.03	0.02	0.74	0.27	1.17	0.60
	Big Mouth Cave						
	Brock Spring	0.05	0.03	0.31	0.11	0.94	0.48
	Bull Shoals Caverns	0.18	0.11	1.49	0.55	1.54	0.79
	Cal Cave	0.72	0.43	1.92	0.71	1.60	0.82
	Cave Mountain Cave	0.05	0.03	1.76	0.65	1.55	0.80
	Cave on North Boundary Trail	0.30	0.18	1.57	0.58	1.48	0.76
	Cave Springs Cave	0.13	0.08	0.17	0.06	0.38	0.20
	Cold Cave	0.02	0.01	0.39	0.15	0.95	0.48
	Covington's Cave						
	Dickerson Cave	0.12	0.07	1.44	0.53	1.28	0.65
	Eden Falls Cave	0.91	0.55	2.24	0.82	1.76	0.90
	Fish Pond Cave	0.08	0.05	1.28	0.47	1.35	0.69

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Fitton Cave	0.07	0.04	1.64	0.61	1.53	0.78
	Granny Parker's Cave						
	John Eddings Cave	0.69	0.41	2.01	0.74	1.69	0.87
	Laningham's Cave	0.76	0.45	1.94	0.72	1.61	0.82
	Middle Creek Spring Cave						
	Novack Spring Cave	0.71	0.43	2.12	0.78	1.71	0.88
	Old Joe Cave	0.23	0.14	1.61	0.59	1.46	0.75
	Sherfield Cave	0.13	0.08	1.81	0.67	1.61	0.82
	Simpson's Cave	0.01	0.01	1.46	0.54	1.28	0.66
	Spring at Hogscald	0.02	0.01	1.44	0.53	1.47	0.75
	Spring at Sequoyah Woods	0.26	0.16	0.44	0.16	1.02	0.52
	Spring on Butler Creek Road	0.29	0.18	1.37	0.51	1.47	0.75
	Spring on North Boundary Trail	0.22	0.13	1.52	0.56	1.47	0.75
	Stillhouse Hollow Cave	0.26	0.16	1.76	0.65	1.58	0.81
	Tanyard Creek Nature Trail Cave	0.08	0.05	0.77	0.28	1.14	0.58
	Unnamed seep 4 mi. S of Boxley	0.10	0.06	1.80	0.66	1.64	0.84
	Unnamed seep 9 mi. SW of Harrison	0.10	0.06	1.43	0.53	1.51	0.77
	Unnamed spring 3.5 mi. S of Jasper	0.06	0.04	1.66	0.61	1.60	0.82
	War Eagle Cavern	0.04	0.02	1.32	0.49	1.43	0.73
	White River Below Beaver Dam	0.07	0.04	1.37	0.50	1.48	0.76
Cambarus aculabrum							
	Bear Hollow Cave	0.11	0.07	0.96	0.35	1.22	0.63
	Brush Creek	0.01	0.01	0.18	0.07	0.69	0.36
	Logan Cave	0.16	0.10	1.29	0.48	1.11	0.57
	Old Pendergrass Cave	0.13	0.08	1.06	0.39	1.12	0.57
Cambarus setosus							
	Blowing Cave	0.87	0.52	1.85	0.68	1.54	0.79

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Poke Cave	0.73	0.44	1.77	0.65	1.51	0.77
	Tom Allen's Cave	0.21	0.13	1.48	0.55	1.32	0.68
Cambarus zophonastes							
	Hell Creek Cave	0.77	0.46	2.02	0.75	1.61	0.83
	Nesbitt Spring Cave	0.27	0.16	1.73	0.64	1.47	0.75
	site in Yellville	0.02	0.01	1.48	0.54	1.38	0.71
Dendrocoelopsis americana							
	Brock Spring	0.05	0.03	0.31	0.11	0.94	0.48
	Granny Parker's Cave						
	Steel Creek Campground Cave	0.22	0.13	1.80	0.66	1.60	0.82
	Watson Cave	0.04	0.02	1.33	0.49	1.15	0.59
Eurycea spelaea							
	Alexander Cave	0.09	0.06	1.71	0.63	1.43	0.73
	Allen Cave						
	Back o' Beyond Cave	0.44	0.27	1.88	0.69	1.54	0.79
	Bald Scrappy Cave	0.63	0.37	1.93	0.71	1.58	0.81
	Bear Hollow Cave	0.11	0.07	0.96	0.35	1.22	0.63
	Bear Pit	0.92	0.55	2.17	0.80	1.75	0.90
	Bell Cave						
	Bently Cave	0.03	0.02	0.74	0.27	1.17	0.60
	Big Mouth Cave						
	Big Spring Cave						
	Biology Cave	0.03	0.02	1.58	0.58	1.46	0.75
	Blanchard Springs Caverns	0.19	0.11	1.68	0.62	1.56	0.80
	Blowing Cave	0.87	0.52	1.85	0.68	1.54	0.79
	Blowing Spring Cave	0.87	0.52	2.21	0.81	1.78	0.91
	Blowing Springs Cave	0.08	0.05	0.56	0.21	1.04	0.53

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Blowing Springs Cave	0.56	0.33	1.75	0.65	1.58	0.81
	Blue Heaven Cave	0.10	0.06	1.59	0.59	1.46	0.75
	Bonanza Cave	1.38	0.82	2.31	0.85	1.71	0.88
	Bonanza Mine	0.03	0.02	1.65	0.61	1.56	0.80
	Breakdown Cave	0.23	0.14	1.69	0.62	1.54	0.79
	Brewer Cave						
	Bull Shoals Caverns	0.18	0.11	1.49	0.55	1.54	0.79
	Cave River Cave	0.79	0.48	2.04	0.75	1.71	0.88
	Cave Springs Cave	0.13	0.08	0.17	0.06	0.38	0.20
	Chambers Hollow Cave	0.25	0.15	1.39	0.51	1.38	0.71
	Chilly Bowl Cave	0.10	0.06	1.52	0.56	1.55	0.79
	Chinn Springs Cave	0.00	0.00	1.32	0.49	1.35	0.69
	Congo Crawl						
	Coon Cave	0.30	0.18	1.81	0.67	1.62	0.83
	Copperhead Cave	0.11	0.07	1.68	0.62	1.55	0.79
	Corkscrew Cave	0.41	0.24	1.85	0.68	1.65	0.84
	Cosmic Caverns	0.06	0.04	1.47	0.54	1.54	0.79
	Crystal Dome Cave	0.00	0.00	1.36	0.50	1.36	0.70
	Cushman Cave	0.26	0.16	1.70	0.62	1.50	0.77
	Cyner Cave	0.51	0.31	1.95	0.72	1.59	0.81
	Davis Creek Cave						
	Dear Buster Cave	1.47	0.88	2.59	0.96	1.88	0.96
	Diamond Cave	0.19	0.11	1.76	0.65	1.53	0.79
	Dickerson Cave	0.12	0.07	1.44	0.53	1.28	0.65
	Eckel Cave	0.27	0.16	1.51	0.56	1.47	0.75
	Elm Cave	0.08	0.05	1.62	0.60	1.53	0.79
	Ennis Cave	0.25	0.15	1.76	0.65	1.54	0.79

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Fancher Cave						
	Fish Pond Cave	0.08	0.05	1.28	0.47	1.35	0.69
	Fitton Cave	0.07	0.04	1.64	0.61	1.53	0.78
	Fitton Spring Cave	0.30	0.18	1.77	0.65	1.57	0.81
	Foushee Cave	0.31	0.18	1.64	0.61	1.58	0.81
	Friday the 13th Cave	0.48	0.29	1.90	0.70	1.62	0.83
	Green River Cave	0.13	0.08	1.43	0.53	1.40	0.72
	Gunner Cave	0.24	0.15	1.77	0.65	1.57	0.81
	Gustafson Cave	0.23	0.14	1.70	0.63	1.55	0.79
	Hammer Springs Cave	0.21	0.13	1.78	0.66	1.58	0.81
	Hell Creek Cave	0.77	0.46	2.02	0.75	1.61	0.83
	Herald Hollow Cave	0.50	0.30	1.83	0.68	1.65	0.84
	Hickory Creek Cave						
	Hidden Spring Cave	0.07	0.04	1.61	0.59	1.50	0.77
	Hog Head Cave	1.18	0.71	2.42	0.89	1.81	0.93
	Huchingson's Waterfall Cave						
	Hunter's Cave	0.85	0.51	1.96	0.72	1.70	0.87
	Hurricane River Cave	0.06	0.03	1.65	0.61	1.48	0.76
	Icebox Cave						
	Indian Rockhouse Cave	0.99	0.59	2.20	0.81	1.74	0.89
	In-D-Pendants Cave	0.44	0.26	1.86	0.69	1.60	0.82
	Janus Pit	0.14	0.08	1.65	0.61	1.52	0.78
	Jelico Hollow Cave	0.51	0.30	1.85	0.68	1.63	0.84
	John Eddings Cave	0.69	0.41	2.01	0.74	1.69	0.87
	Lewis Spring Cave						
	Little Den Cave	0.34	0.20	1.80	0.67	1.59	0.81
	Logan Cave	0.16	0.10	1.29	0.48	1.11	0.57

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Major's Cave	0.03	0.02	1.32	0.48	1.29	0.66
	Mammoth Spring	0.03	0.02	1.61	0.59	1.45	0.74
	Martin Hollow Cave	0.37	0.22	1.80	0.66	1.53	0.79
	Miner's Cave	0.25	0.15	1.55	0.57	1.52	0.78
	Mr. Clean Cave	0.52	0.31	1.87	0.69	1.55	0.79
	Mr. Griffin's Cave # 1	0.06	0.04	1.60	0.59	1.54	0.79
	Needles Cave	0.11	0.06	1.60	0.59	1.38	0.71
	Nesbitt Spring Cave	0.27	0.16	1.73	0.64	1.47	0.75
	Norfork Bat Cave	0.09	0.05	1.49	0.55	1.41	0.72
	Old Joe Cave	0.23	0.14	1.61	0.59	1.46	0.75
	Omega Cave						
	Panther Mountain Cave						
	Pigeon Roost Cave	0.92	0.55	1.72	0.63	1.55	0.79
	Potato Cave						
	Pregnant Nun Cave	0.08	0.05	1.25	0.46	1.42	0.73
	Pretty Clean Cave	0.07	0.04	1.68	0.62	1.59	0.82
	Reed Cave	0.26	0.16	1.66	0.61	1.54	0.79
	Richardson Cave	0.11	0.07	1.33	0.49	1.46	0.75
	Riley's Springbox	0.12	0.07	1.60	0.59	1.48	0.76
	Rootville Cave	0.01	0.01	1.37	0.51	1.30	0.66
	Rory Cave	0.18	0.11	1.70	0.63	1.49	0.76
	Salamander Cave	0.14	0.08	1.56	0.58	1.55	0.79
	Saltpeter Cave	1.23	0.74	2.31	0.85	1.80	0.92
	Slick Rock Hollow Cave						
	Springhouse at Steel Creek Ranger Cabin	0.06	0.04	1.70	0.63	1.57	0.80
	Steel Creek Campground Cave	0.22	0.13	1.80	0.66	1.60	0.82

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Stillhouse Hollow Cave	0.26	0.16	1.76	0.65	1.58	0.81
	Stovepipe Cave	0.08	0.05	1.63	0.60	1.29	0.66
	Summer Cave	0.82	0.49	2.13	0.79	1.73	0.89
	Tom Allen's Cave	0.21	0.13	1.48	0.55	1.32	0.68
	Tom Barnes Cave	0.12	0.07	1.71	0.63	1.54	0.79
	Toney Bend Mine # 2	0.24	0.15	1.77	0.65	1.59	0.82
	Tweet's Cave	0.60	0.36	2.05	0.75	1.63	0.84
	Unnamed cave	0.05	0.03	1.60	0.59	1.40	0.72
	Unnamed caves at Devil's Knob Natural Area	0.88	0.53	2.07	0.76	1.68	0.86
	Van Dyke Spring Cave	0.46	0.28	1.87	0.69	1.61	0.83
	Von Wadding's Memorial Cave	0.87	0.52	2.08	0.77	1.68	0.86
	War Eagle Cave	0.19	0.11	1.66	0.61	1.47	0.75
	War Eagle Cavern	0.04	0.02	1.32	0.49	1.43	0.73
	Whippoorwill Cave	0.00	0.00	1.54	0.57	1.52	0.78
	Willis Cave	0.40	0.24	1.85	0.68	1.60	0.82
	Wolf Creek Cave	1.67	1.00	2.71	1.00	1.95	1.00
	Wounded Knee Cave	0.55	0.33	1.88	0.69	1.62	0.83
Lirceus bicuspidatus							
	Diamond Cave	0.19	0.11	1.76	0.65	1.53	0.79
	Foushee Cave	0.31	0.18	1.64	0.61	1.58	0.81
	Hell Creek Cave	0.77	0.46	2.02	0.75	1.61	0.83
	Hurricane River Cave	0.06	0.03	1.65	0.61	1.48	0.76
Lirceus bidentatus							
	Unnamed seep 9 mi. SW of Harrison	0.10	0.06	1.43	0.53	1.51	0.77
Stygobromus ozarkensis							
	Bear Hollow Cave	0.11	0.07	0.96	0.35	1.22	0.63

Species	Site	RVIX Raw	RVIX Scaled	RVI Raw	RVI Scaled	THREAT Raw	THREAT Scaled
	Blowing Springs Cave	0.08	0.05	0.56	0.21	1.04	0.53
	Cave on Pond Above Black Bass Lake	0.09	0.06	1.42	0.52	1.50	0.77
	Cave Springs Cave	0.13	0.08	0.17	0.06	0.38	0.20
	Civil War Cave	0.07	0.04	0.37	0.14	0.84	0.43
	Dickerson Cave	0.12	0.07	1.44	0.53	1.28	0.65
	Fitton Cave	0.07	0.04	1.64	0.61	1.53	0.78
	Fitton Spring Cave	0.30	0.18	1.77	0.65	1.57	0.81
	Hunter's Cave	0.85	0.51	1.96	0.72	1.70	0.87
	John Eddings Cave	0.69	0.41	2.01	0.74	1.69	0.87
	Logan Cave	0.16	0.10	1.29	0.48	1.11	0.57
	Needles Cave	0.11	0.06	1.60	0.59	1.38	0.71
	Old Pendergrass Cave	0.13	0.08	1.06	0.39	1.12	0.57
	Pretty Clean Cave	0.07	0.04	1.68	0.62	1.59	0.82
	Reed Cave	0.26	0.16	1.66	0.61	1.54	0.79
	Sherfield Cave	0.13	0.08	1.81	0.67	1.61	0.82
	Spavinaw Creek Cave						
	War Eagle Cave	0.19	0.11	1.66	0.61	1.47	0.75
	War Eagle Cavern	0.04	0.02	1.32	0.49	1.43	0.73
	White River Below Beaver Dam	0.07	0.04	1.37	0.50	1.48	0.76
	Withrow Springs Cave	0.04	0.02	1.56	0.58	1.43	0.73
Typhlichthys subterraneus							
	Richardson Cave	0.11	0.07	1.33	0.49	1.46	0.75
-	Unnamed well in Randolph County	-	-	-	-	-	-

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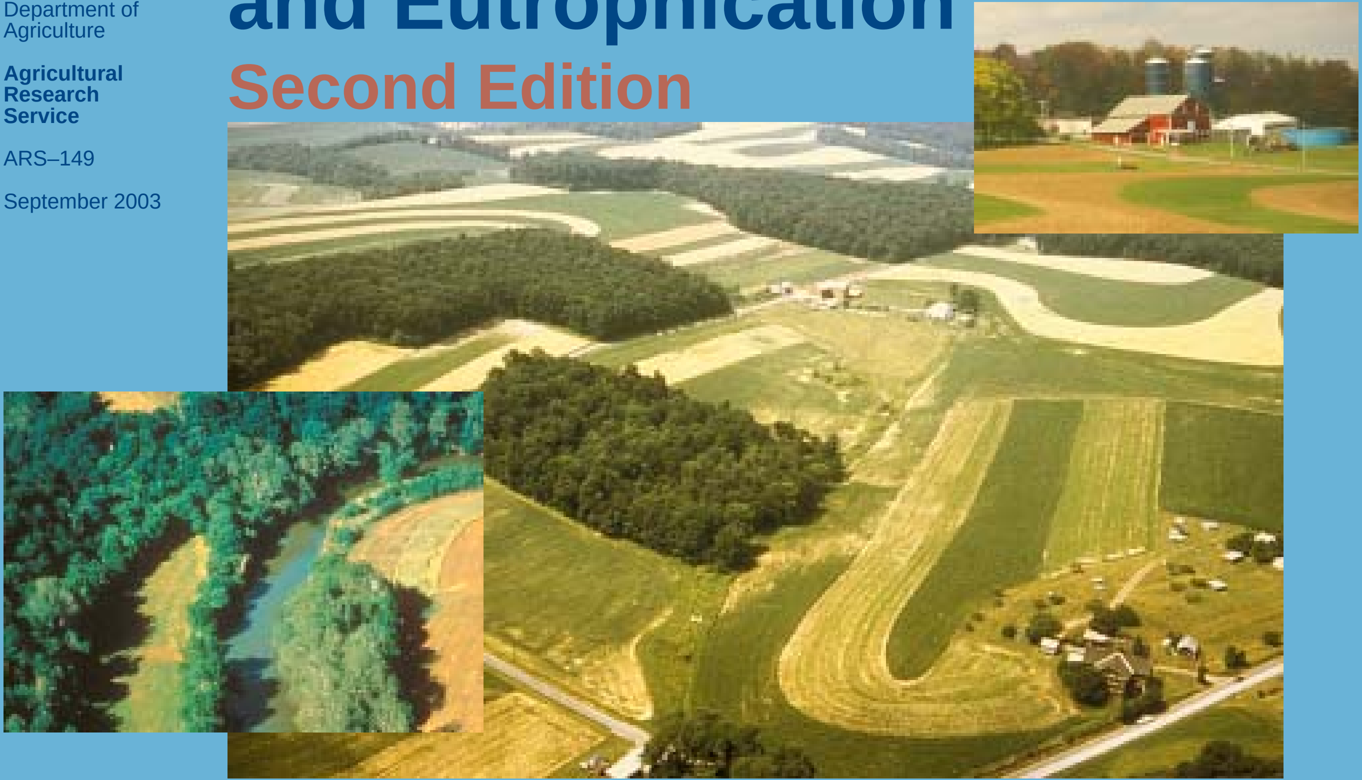
Agricultural Phosphorus and Eutrophication

Second Edition



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Agricultural Phosphorus and Eutrophication

Second Edition

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Abstract

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Inputs of phosphorus (P) are essential for profitable crop and livestock agriculture. However, P export in watershed runoff can accelerate the eutrophication of receiving fresh waters. The rapid growth and intensification of crop and livestock farming in many areas has created regional imbalances in P inputs in feed and fertilizer and P output in farm produce. In many of these areas, soil P has built up to levels in excess of crop needs and now has the potential to enrich surface runoff with P.

The overall goal of our efforts to reduce P losses from agriculture to water should be to increase P use-efficiency, balance P inputs in feed and fertilizer into a watershed with P output in crop and animal produce, and manage the level of P in the soil. Reducing P loss in agricultural runoff may be brought about by source and transport control strategies. This includes refining feed rations, using feed additives to increase P absorption by animals, moving manure from surplus to deficit areas, finding alternative uses for manure, and targeting conservation practices, such as reduced tillage, buffer strips, and cover crops, to critical areas of P export from a watershed. In these critical areas, high P soils coincide with parts of the landscape where surface runoff and erosion potential are high.

Keywords: eutrophication, fertilizer, phosphorus, P input, P output, runoff

While supplies last, copies of this publication may be obtained at no cost from USDA–ARS, Pasture Systems & Watershed Management Research Unit, Curtin Road, University Park, PA 16802–3702.

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Agricultural Phosphorus and Eutrophication

Introduction

Eutrophication

Phosphorus (P) is an essential element for plant and animal growth and its input has long been recognized as necessary to maintain profitable crop and animal production. Phosphorus inputs can also increase the biological productivity of surface waters by accelerating eutrophication. Eutrophication is the natural aging of lakes or streams brought on by nutrient enrichment. This process can be greatly accelerated by human activities that increase nutrient loading rates to water.

Eutrophication has been identified as the main cause of impaired surface water quality (U.S. Environmental Protection Agency 1996). Eutrophication restricts water use for fisheries, recreation, industry, and drinking because of increased growth of undesirable algae and aquatic weeds and the oxygen shortages caused by their death and decomposition. Associated periodic surface blooms of cyanobacteria (blue-green algae) occur in drinking water supplies and may pose a serious health hazard to animals and humans. Recent outbreaks of the dinoflagellate *Pfiesteria piscicida* in the eastern United States, and Chesapeake Bay tributaries in particular, have been linked to excess nutrients in affected waters. Neurological damage in people exposed to the highly toxic, volatile chemical produced by these algae has dramatically increased public awareness of eutrophication and the need for solutions (Burkholder and Glasgow 1997).

Eutrophication of most fresh water around the world is accelerated by P inputs (Schindler 1977, Sharpley et al. 1994). Although nitrogen (N) and carbon (C) are also essential to the growth of aquatic biota, most attention has focused on P inputs because of the difficulty in controlling the exchange of N and C between the atmosphere and water and the fixation of atmospheric N by some blue-green algae. Therefore, P is often the limiting element, and its control is of prime importance in reducing the accelerated eutrophication of fresh waters. When salinity increases, as in estuaries, N generally becomes the element controlling aquatic productivity. However, in Delaware’s inland bays (coastal estuaries), nitrate-N leaching has elevated N concentrations to the point where P is now the limiting factor in eutrophication.

Figure 1. Watersheds with a high potential for soil and water degradation from manure P (Adapted from Kellogg and Lander 1999).

Lake water concentrations of P above 0.02 ppm generally accelerate eutrophication. These values are an order of magnitude lower than P concentrations in soil solution critical for plant growth (0.2 to 0.3 ppm), emphasizing the disparity between critical lake and soil P concentrations and the importance of controlling P losses to limit eutrophication.

Agricultural Production

Confined animal operations are now a major source of agricultural income in several states. Animal manure can be a valuable resource for improving soil structure and increasing vegetative cover, thereby reducing surface runoff and erosion potential. However, the rapid growth and intensification of crop and animal farming in many areas has created regional and local imbalances in P inputs and outputs. On average, only 30 percent of the fertilizer and feed P input to farming systems is output in crops and animal produce. Therefore, when averaged over the total usable agricultural land area in the United States, an annual P surplus of 30 lb/acre exists (National Research Council 1993). This has led to P applications in excess of crop removal, soil P accumulations, and an increased risk of P loss in runoff (Kellogg and Lander 1999) (fig. 1).

Before World War II, farming communities tended to be self-sufficient in that enough feed was produced locally and recycled to meet animal requirements. After World War II, increased fertilizer use in crop production fragmented farming systems, creating specialized crop and animal operations that efficiently coexist in different regions within and among countries. Since farmers did not need to rely on manures as nutrient sources (the primary source until fertilizer production and distribution became less expensive), they could spatially separate grain and animal production. Today, less than a third of the grain produced is fed on farms where it is grown (Lanyon 2000) resulting in a major one-way transfer of P from grain-producing to animal-producing areas.

Table 1. Farming system and P balance

	Farming system			
P	**Crop***	**Dairy†**	**Poultry‡**	**Hogs§**
Input	- - - - - - - - - - - - - - - -	lb P/acre/yr	- - - - - - - - - - - - - -	
Fertilizer	20	10	0	0
Feed	0	20	1,375	95
Output	–18	–13	– 365	-60
Balance	+2	+17	+1,010	+35

SOURCE: Lanyon and Thompson (1996) and Bacon et al. (1990).

* 75-acre cash crop farm growing corn and alfalfa.

† 100-acre dairy farm with 65 dairy holsteins averaging 14,500 lb milk/cow/yr, 5 dry cows, and 35 heifers. Crops were corn for silage and grain, alfalfa, and rye for forage.

‡ 30-acre poultry farm with 74,000 layers; output includes 335 lb P/acre/yr in eggs, 20 lb P/acre/yr sold in crops (corn and alfalfa), and 10 lb P/acre/yr manure exported from the farm.

§ 75-acre farm with 1,280 hogs, output includes 40 lb P/acre/yr manure exported from the farm.

The potential for P surplus at the farm scale can increase when farming systems change from cropping to intensive animal production, since P inputs become dominated by feed rather than fertilizer. With a greater reliance on imported feeds, only 27 percent of the P in purchased feed for a 74,000-layer operation on a 30-acre farm in Pennsylvania could be accounted for in farm outputs (table 1). This nutrient budget clearly shows that the largest input of nutrients to a poultry farm and, therefore, the primary source of any on-farm nutrient excess, is in animal feed. Annual P surpluses of 80 to 110 lb/acre/yr were estimated by Sims (1997) for a typical poultry grain farm in Delaware. This scenario is consistent with other concentrated animal production operations, including dairy and hogs.

Phosphorus accumulation on farms has built up soil P to levels that often exceed crop needs. Today, there are serious concerns that agricultural runoff (surface and subsurface) and erosion from high P soils may be major contributing factors to surface water eutrophication. Agricultural runoff is all water draining from an area (field or watershed) including surface runoff, subsurface flow, leaching, and tile drainage processes. Phosphorus loss in agricultural runoff is not of economic importance to farmers because it generally amounts to only 1 or 2 percent of the P applied. However, P loss can lead to significant off-site economic impacts, which in some cases occur many miles from P sources. By the time these water-quality impacts are manifest, remedial strategies are difficult and expensive to implement; they cross political and regional boundaries; and because of P loading, improvement in water quality will take a long time.

Nitrogen-based management has been practiced and advocated by farm advisers for many years. Farmers are only now becoming aware of P issues. Many are confused and feel that science has misled them or let them down by not emphasizing the P management issues. Therefore, the research community must do a better job of transferring and translating its findings to the agricultural community as a whole. For example, we must be able to show where P is coming from, how much P in soil and water is too much, and how and where these inputs and losses can be reduced in order to develop agricultural resource management systems that sustain production, environmental quality, and farming communities.

In this publication, P is in its elemental form, rather than as P_2O_5, which is commonly used in fertilizer analysis. The conversion factor from P to P_2O_5 is 2.29. When discussing plant available forms of soil P, as determined by soil testing laboratories, we will refer to them as “soil test P” (ppm or mg/kg) and identify in each case the specific method of analysis used. Based on a 6-inch soil depth containing 2 million pounds of soil, the conversion factor for ppm to lb P/acre is 2. For more detailed information on the methods used for soil P testing, how they were developed, and why they vary among regions see Fixen and Grove (1990), Pierzynski (2000), Sharpley et al. (1994, 1996), and Sims (1998).

Soil Phosphorus

Soil P exists in organic and inorganic forms, but these are not discrete entities with indistinct forms occurring (fig. 2). Organic P consists of undecomposed residues, microbes, and organic matter in the soil. Inorganic P is usually associated with Al, Fe, and Ca (aluminum, iron, and calcium, respectively) compounds of varying solubility and availability to plants. Phosphorus has to be added to most soils so that there are adequate levels for opti-

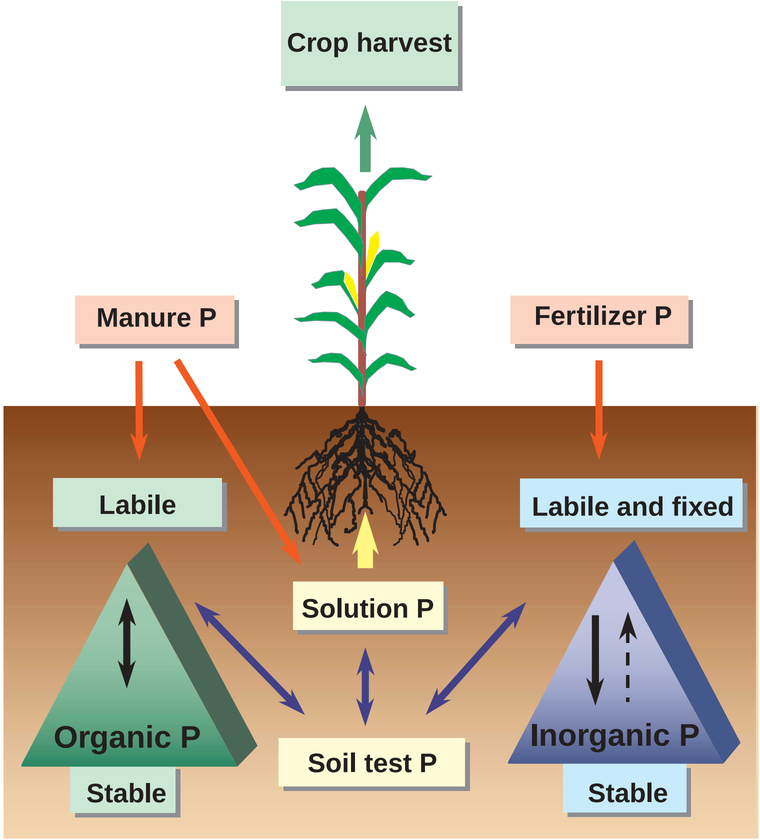


Figure 2. The phosphorus cycle in soil

mum crop growth and yield. However, P can be rapidly fixed in relatively insoluble forms and therefore be unavailable to plants, depending on soil pH and type (Al, Fe, and Ca content). Converting stable forms of soil P to labile or available forms usually occurs too slowly to meet crop P requirements (fig. 2). As a result, soil P tests were developed to determine the amount of plant-available P in soil and from this how much P as fertilizer or manure should be added to meet desired crop yield goals.

In most soils, the P content of surface horizons is greater than that of the subsoil because of sorption of added P, greater biological activity, cycling of P from roots to aboveground plant biomass, and more organic material in surface layers (fig. 3). In reduced tillage systems, fertilizers and manures are

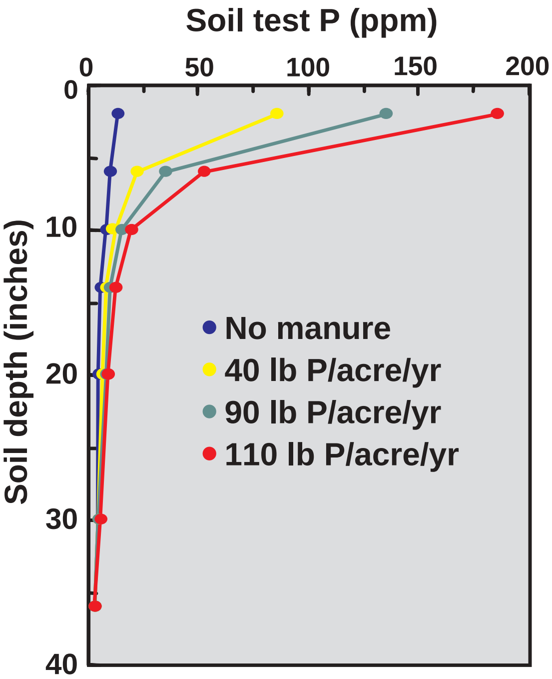


Figure 3. Soil test P (as Mehlich–3 P) accumulates at the surface with repeated application of P for 10 years. Note that typical fertilizer P applications for a corn crop in Oklahoma with a medium soil test P (20 to 40 ppm Mehlich–3 P) is about 20 lb P/acre. (Adapted from Sharpley et al. 1984.)

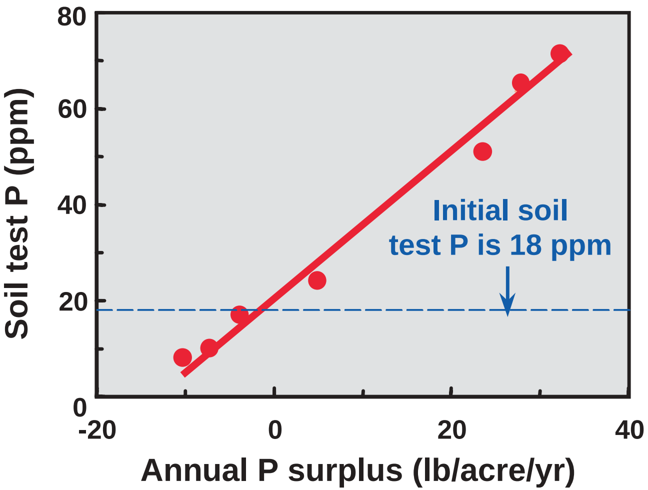


Figure 4. Increase in soil test P from applying more P than a crop needs each year (as Bray–I P). A negative surplus indicates crop and soil removal. (Adapted from a 25-year study by Barber 1979.)

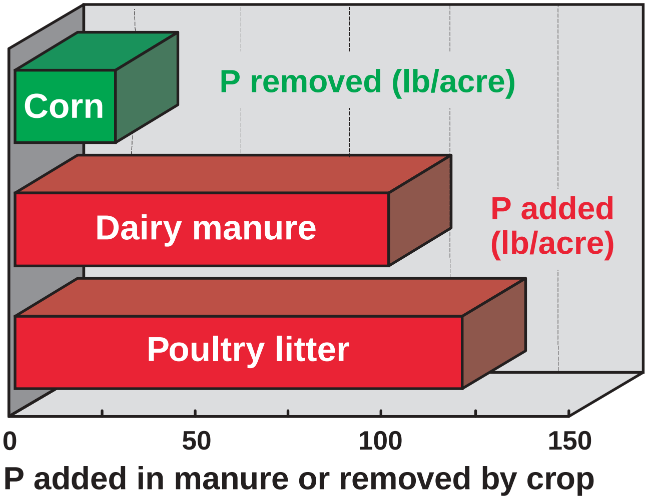
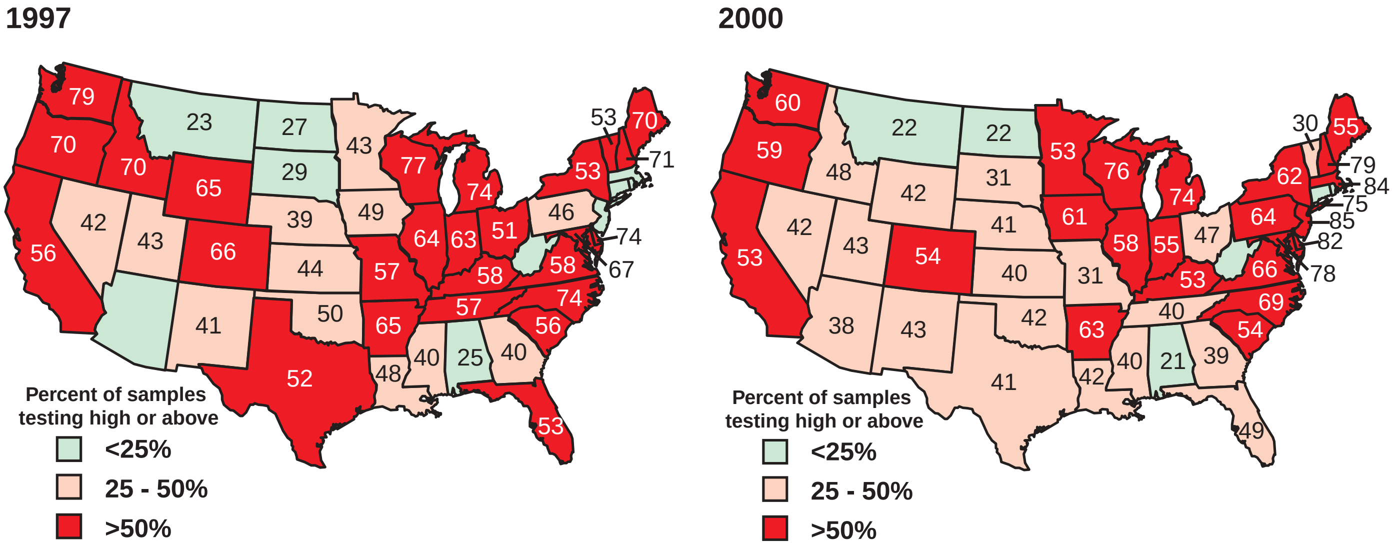


Figure 5. Applying manure to meet crop N needs (about 200 lb available N/acre) adds much more P than corn crop needs.

not incorporated or they are incorporated only to shallow depths, thereby exacerbating P buildup in the top 2 to 5 inches of soil. In some situations, P can easily move through the soil, as we will discuss later.

Continual long-term application of fertilizer or manure at levels exceeding crop needs will increase soil P levels (fig. 4). In many areas of intensive, confined animal production, manures are normally applied at rates designed to meet crop N requirements but to avoid groundwater quality problems created by leaching of excess N. This often results in a buildup of soil test P above amounts sufficient for optimal crop yields. As illustrated in figure 5, the amount of P added in



North American average of 47% soils testing medium or below for P

Figure 6. A survey of agricultural soils analyzed by state soil test laboratories in 1997 and 2000 shows a regional buildup of soil test P near P-sensitive waters (Fixen 1998, Fixen and Roberts 2000).

average applications of dairy manure (8 to 10 tons/acre and 0.5 percent P) and poultry litter (4 tons/acre and 1.5 percent P) are considerably greater than what is removed in harvested crops; the result is an accumulation of soil P.

In 2000, several state soil test laboratories reported that the majority of agricultural soils analyzed had soil test P levels in the high or above categories, which require little or no P fertilization. It is clear from figure 6 that high soil P levels are a regional problem, because the majority of agricultural soils in several states still test medium or low. For example, most Great Plains soils still require P for optimum crop yields. Unfortunately, problems associated with high soil P are aggravated by the fact that many of these agricultural soils are located in states with sensitive water bodies, such as the Great Lakes, Lake Champlain, the Chesapeake and Delaware Bays, Lake Okeechobee, the Everglades, and other fresh water bodies (fig. 6).

Distinct areas of general P deficit and surplus exist within states and regions. For example, soil test summaries for Delaware reveal the magnitude and localization of high soil test P levels that can occur in areas dominated by intensive animal production (fig. 7). From 1992 to 1996 in Sussex County, Delaware, with its high concentration of poultry operations, 87 percent of fields tested had optimum (25 to 50 ppm) or excessive soil test P (>50 ppm), as determined by Mehlich–1; whereas, in New Castle County, with only limited animal production, 72 percent of fields tested were rated as low (<13 ppm) or medium (13 to 25 ppm).

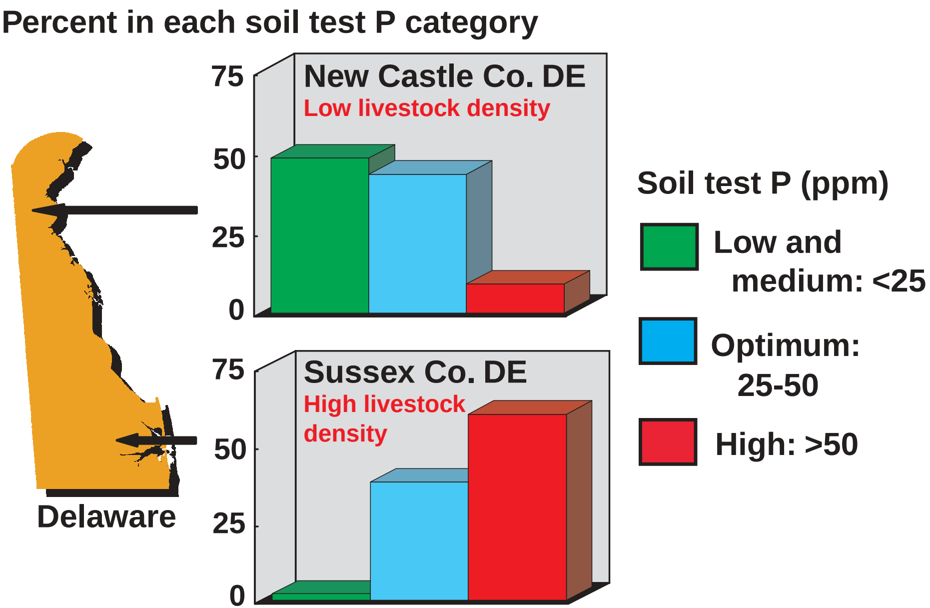


Figure 7. Elevated soil test P levels (as Mehlich–1 P) are usually localized in areas of confined animal operations.

Though rapidly built up by applications of P, available soil P decreases slowly once further applications are stopped. Therefore, the determination of how long soil test P will remain above crop sufficiency levels is of economic and environmental importance to farmers who must integrate manure P into sustainable nutrient management systems. For example, if a field has a high potential to enrich agricultural runoff with P because of excessive soil P, how long will it be before crop uptake will lower soil P levels so that manure can be applied again without increasing the potential for P loss? McCollum (1991) estimated that without further P additions, 16 to 18 years of corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] production would be needed to deplete soil test P (Mehlich–3 P) (Mehlich 1984) in a Portsmouth fine sandy loam from 100 ppm to the agronomic threshold level of 20 ppm.

The Loss of Phosphorus in Agricultural Runoff

The term “agricultural runoff” encompasses two processes that occur in the field—surface runoff and subsurface flow. In reality these can be vague terms for describing very dynamic processes. For example, surface or overland flow can infiltrate into a soil during movement down a slope, move laterally as interflow, and reappear as surface flow. In this publication, agricultural runoff refers to the total loss of water from a watershed by all surface and subsurface pathways.

Forms and Processes

The loss of P in agricultural runoff occurs in sediment-bound and dissolved forms (fig. 8). Sediment P includes P associated with soil particles and organic material eroded during flow events and constitutes about 80 percent of P transported in surface runoff from most cultivated land (Sharpley et al. 1992). Surface runoff from grass, forest, or noncultivated soils carries little sediment and is, therefore, generally dominated by dissolved P (about 80 percent of P loss). This dissolved form comes from the release of P from soil and plant material (fig. 8). This release occurs when rainfall or irrigation water interacts with a thin layer of surface soil (1 to 2 inches) and plant material before leaving the field as surface runoff (Sharpley 1985). Most dissolved P is immediately

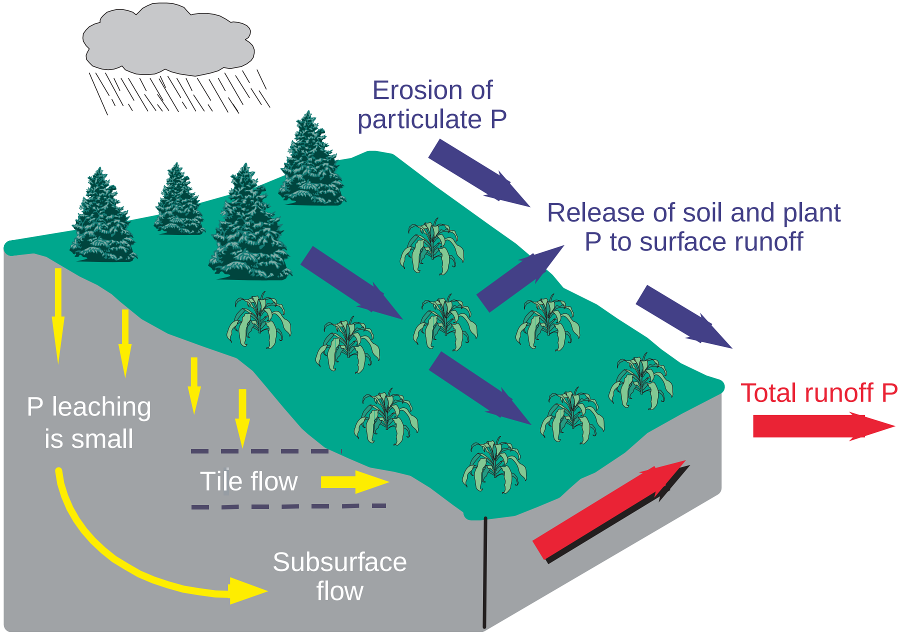


Figure 8. Phosphorus can be released from soil and plant material to surface and subsurface runoff water or lost by erosion.

available for biological uptake. Sediment P is not readily available, but it can be a long-term source of P for aquatic biota (Ekholm 1994, Sharpley 1993).

In most watersheds, P export occurs mainly in surface runoff, rather than subsurface flow. However, in some regions, notably the Coastal Plains and Florida, as well as fields with subsurface drains, P can be transported in drainage waters. Generally, the concentration of P in water percolating through the soil profile is low because of P fixation by P-deficient subsoils. Exceptions occur in sandy, acid organic, or peaty soils with low P fixation or holding capacities and in soils where the preferential flow of water can occur rapidly through macropores and earthworm holes (Bengston et al. 1992, Sharpley and Syers 1979, Sims et al. 1998).

Irrigation, especially furrow irrigation, can significantly increase the potential for soil and water contact and therefore can increase P loss by both surface runoff and erosion in return flows. Furrow irrigation exposes unprotected surface soil to the erosive effect of water movement. The process of irrigation also has the potential to greatly increase the land area that can serve as a potential source for P movement, a fact that is especially important in the western United States.

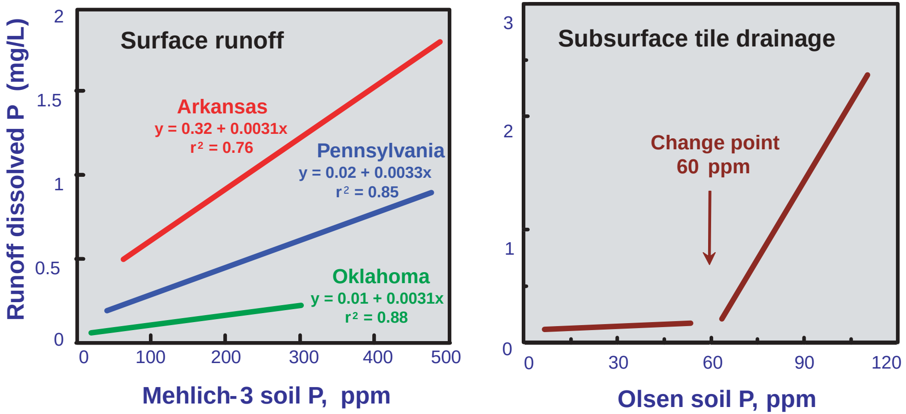


Figure 9. Effect of soil P on the dissolved P concentration of surface runoff from several pasture watersheds (adapted from Sharpley et al. 2001) and subsurface tile drainage from Broadbalk fields. (Adapted from Heckrath et al. 1995.)

The Dependence of Agricultural Runoff P on Soil P

Many studies report that the loss of dissolved P in surface runoff depends on the P content of surface soil (fig. 9). In a review of several studies, Sharpley et al. (1996) found that the relationship between surface runoff P and soil P varies with management. Relationship slopes were flatter for grass (4.1 to 7.0, mean 6.0) than for cultivated land (8.3 to 12.5, mean 10.5), but the slopes were too variable to allow use of a single or average relationship to recommend P amendments based on water-quality criteria. Clearly, several soil and land management factors influence the relationship between dissolved P in surface runoff and soil P.

All in all, the loss of P in subsurface flow, as well as surface runoff, is linked to soil P concentration. Heckrath et al. (1995) found that soil test P (Olsen P) greater than 60 ppm in the plow layer of a silt loam caused the dissolved P concentration in tile drainage water to increase dramatically (0.15 to 2.75 mg/L) (fig. 9). They postulated that this level (60 ppm), which is well above that needed by major crops for optimum yield, is a critical point above which the potential for P movement through the soil profile greatly increases (Ministry of Agriculture, Food and Fisheries 1994). Similar studies suggest that this change point can vary threefold as a function of site hydrology, relative drainage volumes, and soil P release characteristics (Sharpley and Syers 1979).

These and similar studies compared agricultural runoff P to soil P using traditional soil test methods that estimate plant availability of soil P. While these studies show promise in describing the relationship between the level of soil P and surface runoff P, they are limited for several reasons. First, soil test extraction methods were developed to estimate the plant availability of soil P and may not accurately reflect soil P release to surface or subsurface runoff water. Second, although dissolved P is an important water-quality variable, it represents only the dissolved portion of P readily available for aquatic plant growth. It does not reflect fixed soil P that can become available with changing chemistry in anaerobic conditions.

The final concern is with sampling depth. It is generally recommended that soil samples be collected to plow depth, usually 6 to 8 inches for routine evaluation of soil fertility. However, it is the surface inch or two in direct contact with runoff that is important when using soil testing to estimate P loss. Consequently, different sampling procedures may be necessary when using a soil test to estimate the potential for P loss. To overcome these concerns, approaches are being developed that provide a more theoretically sound estimate, than traditional agronomic chemical extractants do, of the amount of P in soil that can be released to runoff water and the amount of algal-available P in runoff (Pierzynski 2000, Sharpley 1993).

An approach, developed in the Netherlands by Breeuwsma and Silva (1992) to assess P leaching potential, is to determine soil P saturation (percent saturation = available P/maximum P fixation). This approach is based on the fact that, as P saturation or the amount of fixed P increases, more P is released from soil to surface runoff or leaching water. This method is used to limit the loss of P in surface and ground waters. A critical P saturation of 25 percent has been established for Dutch soils as the threshold value above which the potential for P movement in surface and ground waters becomes unacceptable.

Remediation

The overall goal to reduce P loss from agriculture to water should increase the efficiency of P use by balancing P inputs in feed and fertilizer into a watershed with P outputs in crop and animal produce and managing the level of P in the soil. Reducing P loss in agricultural runoff may be brought about by source and transport control strategies. The transport of P from agricultural land in surface runoff and erosion has been reduced; however, much less attention has been directed toward source management.

When looking at management to minimize the environmental impact of P, there are several important factors that must be considered. To cause an environmental problem, there must be a source of P (that is, high soil levels, manure or fertilizer applications, etc.) and it must be transported to a sensitive location (that is, for leaching, runoff, erosion, etc.). Problems occur where these two come together. A high P source with little opportunity for transport may not constitute an environmental threat. Likewise, a situation where there is a high potential for transport but no source of P to move is also of little threat. Management should focus on the areas where these two conditions intersect. These areas are called “critical source areas” (fig. 10).

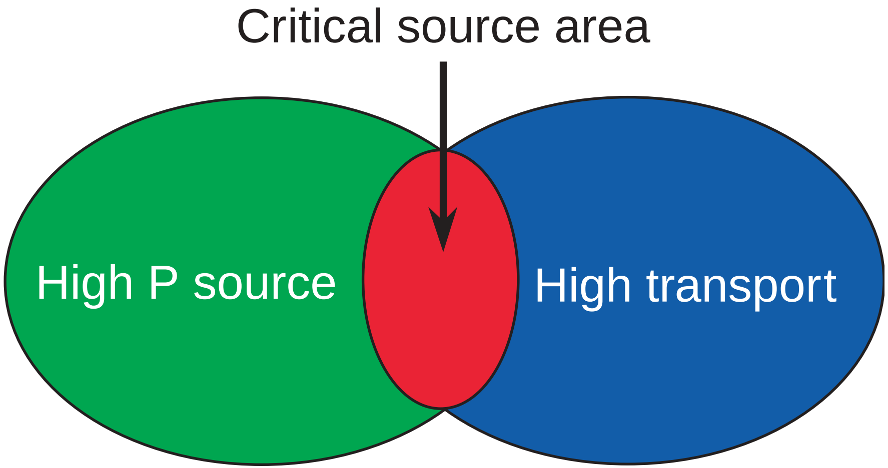


Figure 10. Critical source areas for P loss from a watershed occur where areas of high soil P and transport potential coincide.

Source Management

Reducing off-farm inputs of P in feed

Manipulation of dietary P intake by animals may help balance farm P input and output in animal operations because feed inputs are often the major cause of P surplus (table 1). Morse et al. (1992) recorded a 17-percent reduction in P excretion when the daily P intake of dairy cows was reduced from 82 to 60 g/day. The U.S. National Research Council (2001) recommends dietary P levels for animal production and dairy cows that range between 0.32 and 0.38 percent P, depending on milk yields (table 2). Dietary P in excess of these recommendations can be decreased without harming production or animal health. In fact, Wu et al. (2001) found essentially all P fed in excess of 0.32 percent was excreted by high-producing dairy cows (table 2).

Table 2. Dairy cattle feed recommendations, milk production, fecal P excretion, and losses of P in surface runoff after land application of manure

Dietary P level	Milk production[1]	P excreted[1]	Runoff dissolved P[2]	
%	kg/day	g P/day	ppm	g/ha
0.31	42.4	43	0.30	7
0.39	38.7	66	N.D.[3]	N.D.
0.47	39.4	88	2.84	79

SOURCE: Adapted from Wu et al. (2001).

SOURCE: Adapted from Ebeling et al. (2002). The high P diet in this study was 0.49% P.

N.D. No data available from this study.

The potential effect of overfeeding P to dairy cows and land when applying manure on runoff P was demonstrated by Ebeling et al. (2002). When cows had 0.31 and 0.47 percent P in their diets and the manure (0.48 and 1.28 percent P, respectively) was applied to silt loams covered with corn residues in Wisconsin, runoff P increased dramatically from 7 to 79 g/ha (table 2).

Clearly, amounts of excreted P can be reduced by carefully matching dietary P inputs to animal requirements. As P requirements can change during an animal's life cycle, including lactation in dairy cows for example, further gains in decreasing P excretion may be made by periodically changing dietary P levels.

It is common to supplement poultry and hog feed with mineral forms of P because of the low digestibility of phytin, the major P compound in grain. This supplementation contributes to P enrichment of manures and litters. Enzyme additives for animal feed are being tested to increase the efficiency of P uptake from grain during digestion. Development of such enzymes that would be cost-effective in terms of animal weight gain may reduce the P content of manure. One method is to use phytase, an enzyme that enhances the efficiency of P recovery from phytin in grains fed to poultry and hogs. Another promising method is to develop grain varieties that are lower in phytin.

A third method is to increase the quantity of P in corn that is available to animals by reducing the amount of phytate produced by corn. This would decrease phytate-P, which contributes as much as 85 percent of P in corn grain, and increase inorganic P concentrations in grain. Ertl et al. (1998) manipulated the genes controlling phytate formation in corn and showed that the use of low-phytate corn in poultry feed can increase the availability of P and other phytate-bound minerals and proteins and reduce P excretion.

Soil P management and estimating threshold levels for environmental risk assessment

The long-term use of commercial fertilizers has increased the P status of many agricultural soils to optimum or excessive levels. The goal of P fertilization was to remove soil P supply as a limitation to agricultural productivity; however, for many years actions taken to achieve this goal did not consider the environmental consequences of P loss from soil to water. The constraint on P buildup in soils from commercial fertilizer use was usually economic, with most farmers recognizing that soil tests for P accurately indicated when to stop applying fertilizer P. Some "insurance" fertilization has always occurred, particularly in high-value crops, such as vegetables, tobacco, and sugarcane. However, the use of commercial fertilizers alone would not be expected to grossly overfertilize soils because farmers would cease applying fertilizer P when it became unprofitable. Today's dilemma is caused by the realization that soils considered optimum in soil test P (or perhaps only slightly overfertilized) from a crop produc-

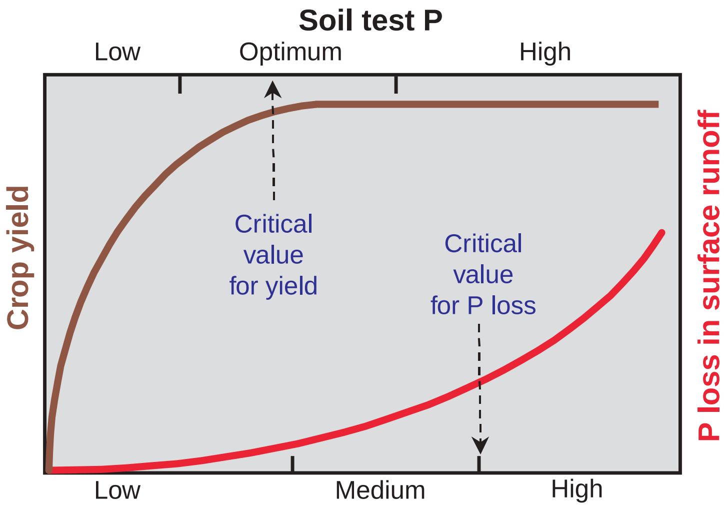


Figure 11. As soil P increases, so does crop yield and the potential for P loss in surface runoff. The interval between the critical soil P value for yield and runoff P will be important for P management.

tion perspective may still provide environmentally significant quantities of soluble and sediment P in surface runoff and erosion.

Environmental concern has forced many states to consider developing recommendations for P applications and watershed management based on the potential for P loss in agricultural runoff. A major difficulty is the identification of a threshold soil test P level to estimate when soil P becomes high enough to result in unacceptable P enrichment of agricultural runoff. Table 3 gives examples from several states, along with agronomic threshold concentrations for comparison.

Environmental threshold levels range from less than 2 times (Maine and Michigan) to 4 times (Pennsylvania and Texas) the agronomic thresholds.

Soil test results for environmental purposes must be interpreted carefully. The comments given on soil test reports—low, medium, optimum, high, and so forth—were established based on the expected response of a crop to P. However, one cannot assume a direct relationship between the soil test calibration for crop response to P and runoff enrichment potential. In other words, one cannot accurately project that a soil test level above an expected crop response level exceeds crop needs and is therefore potentially polluting. What will be crucial in terms of managing P based in part on soil test levels will be the interval between the critical or threshold soil P value for crop yield and runoff P (fig. 11).

Table 3. Threshold soil test P values and P management recommendations

State	Threshold values, ppm Agronomic	Environmental	Soil test P method	Management recommendations to protect water quality
Arkansas	50	150	Mehlich-3	*Above 150 ppm P:* add no P, provide buffers next to streams, overseed pastures with legumes to aid P removal, and provide constant soil cover to minimize erosion.
Colorado	15*	20	Olsen	*Above 20 ppm P:* use P index.
Delaware	50	150	Mehlich-3	*Above 150 ppm P:* develop P-based nutrient management plan (for example, P addition not to exceed crop removal) or use P index.
Idaho	40	40	Olsen	*Above 40 ppm P:* addition not to exceed crop removal and plan required to decrease soil test P to < 40 ppm and minimize transport potential.
Kansas	50	200	Mehlich-3	*Above 200 ppm P:* no P addition regardless of P index rating.
Maine	20	20	Morgan	*Row crops > 20 ppm soil P:* addition not to exceed crop removal for highly erodible soils or soil in P sensitive watershed. *Sod crop:* P addition not to exceed crop removal if soil test P is > 5 times crop removal.
Maryland	25	75	Mehlich-1	*Use P index > 75 ppm P:* soils with high index must reduce or eliminate P additions.

Table 3. Threshold soil test P values and P management recommendations (continued)

State	Threshold values, ppm		Soil test P method	Management recommendations to protect water quality
	Agronomic	Environmental		
Michigan	40	75 and 150	Bray-1	*75 to 150 ppm P:* P addition not to exceed crop removal. *Above 150 ppm P:* apply no P until soil text P is < 150 ppm P.
Ohio	40	150	Bray-1	*Above 40 ppm P:* no fertilizer P addition. *Above 150 ppm P:* apply no P until soil test P is < 150 ppm P.
Oklahoma	30	130 and 200	Mehlich-3	*Non-nutrient limited watershed 130 to 200 ppm P* - half P rate and adopt measures to decrease runoff and erosion; *> 200 ppm P* - P addition not to exceed crop removal. *Nutrient limited watershed 60 to 130 ppm P* - half P rate; *> 130 ppm P* - add no P. *Slope – 8 to 15%* halve P rate: *> 15%* add no P.
Pennsylvania	50	200	Mehlich-3	*Above 200 ppm P and < 150 ft from stream:* use P index.
Texas	44	200	Texas A&M	*Above 200 ppm P:* addition not to exceed crop removal.
Wisconsin	30	100	Bray-1	*50 to 100 ppm P:* P addition not to exceed crop removal. *Above 100 ppm P:* P additions must be < crop removal or use P index to determine if P additions are restricted.
In Your Area				

SOURCE: Adapted from Lory and Scharf 2000, Sharpley et al. 1996.
*AB-DTPA is ammonium bicarbonate – diethylelenetriaminepentaacetic acid (Pierzynski 2000).

There is reluctance on the part of most soil testing programs to establish upper threshold limits for soil test P. Reasons range from the fact that soil tests were not originally designed or calibrated for environmental purposes to an unjustified reliance upon soil test P alone by environmental regulatory agencies. Refusing to participate in the debate on the appropriateness of critical limits for soil test P is extremely shortsighted and may force others with less expertise to set the limits that are so important to the soil testing and agricultural community. A foresighted stance acknowledges that agronomically based soil tests can play a role in environmental management of soil P but are only a first step in a more comprehensive approach. This awareness will enhance the credibility of soil testing programs and improve the contribution they make to the agricultural community.

Manure management

Farm advisers and resource planners are recommending that P content of manure and soil be determined by soil test laboratories before land application of manure. This is important because without such determinations, farmers and their advisers tend to underestimate the nutritive value of manure. Soil test results can also demonstrate the positive and negative long-term effects of manure use and the time required to build up or deplete soil nutrients. For instance, soil tests can help a farmer identify the soils in need of P fertilization, those where moderate manure applications may be made, and fields where no manure applications need to be made for crop yield response.

Commercially available manure amendments, such as slaked lime or alum, can reduce ammonia (NH_3) volatilization, leading to improved animal health and weight gains; reduce the solubility of P in poultry litter by several orders of magnitude; and decrease dissolved P, metal, and hormone concentrations in surface runoff (Moore and Miller 1994, Moore et al. 1995, Nichols et al. 1997). Also, the dissolved P concentration (11 mg/L) of surface runoff from fescue treated with alum-amended litter was much lower than that from fescue treated with unamended litter (83 mg/L) (Shreve et al. 1995). Perhaps the most important benefit of manure amendments for air and water quality would be an increase in the N:P ratio of manure via reduced N loss because of NH_3 volatilization. An increased N:P ratio of manure would more closely match crop N and P requirements.

A mechanism should be established to facilitate movement of manures from surplus to deficit areas. At the moment, manures are rarely transported more than 10 miles from where they are produced. However, mandatory transport of manure from farms with surplus nutrients to neighboring farms where nutrients are needed faces several significant obstacles. First, it must be shown that manure-rich farms are unsuitable for manure application based on soil properties, crop nutrient requirements, hydrology, actual P movement, and sensitive water bodies. Then, it must be shown that the recipient farms are more suitable for manure application. The greatest success with redistribution of manure nutrients is likely to occur when the general goals of nutrient management set by a national (or state) government are supported by consumers, local governments, the farm community, and the animal industry. This may initially require incentives to facilitate subsequent transport of manures from one area to another. Again, this may be a short-term alternative if N-based management is used to apply the transported manures. If this happens, soil P in areas receiving manures may become excessive in 3 to 5 years.

Innovative methods are being used by some farmers to transport manure. For example, grain or feed trucks and railcars are transporting dry manure back to the grain source area instead of returning empty (Collins et al. 1988). In Delaware, a local poultry trade organization has established a manure bank network that puts manure-needy farmers in contact with manure-rich poultry growers. Even so, large-scale transportation of manure from producing to non-manure-producing areas is not occurring.

Composting, another potential tool, may also be considered a management tool to improve manure distribution. Although it tends to increase the P concentration of manures, composting reduces the volume of manures and therefore transportation costs. Additional markets are also available for composted materials. As the value of clean water and the cost of sustainable manure management is realized, it is expected that alternative entrepreneurial uses for manure will be developed, become more cost-effective, and create expanding markets.

Transport Management

Phosphorus loss via surface runoff and erosion may be reduced by conservation tillage and crop residue management, buffer strips, riparian zones, terracing, contour farming tillage, cover crops, and impoundments (settling basins). Basically, these practices reduce the impact of rainfall on the soil surface, reduce runoff volume and velocity, reduce sediment transport, and increase soil resistance to erosion. None of these measures, however, should be relied on as the sole or primary practice to reduce P losses in agricultural runoff.

Most of these practices are generally more efficient at reducing sediment P than dissolved P. Several researchers report little decrease in lake productivity with reduced P inputs following implementation of conservation measures (Gray and Kirkland 1986, Knuuttila et al. 1994, McDowell et al. 2002). Many times, the impact of remedial measures used to help improve poor water quality will be slow because lake and stream sediments can be a long-term source of P in waters even after inputs from agriculture are reduced. Therefore, immediate action may be needed to reduce future problems.

Targeting Remediation

Threshold soil P levels are being proposed to guide P management recommendations. In most cases, agencies that seek these levels hope to uniformly apply a threshold value to areas and states under their domain. However, it is too simplistic to use threshold soil P levels as the sole criterion to guide P management and P applications. For example, adjacent fields having similar soil test P levels but differing susceptibilities to surface runoff and erosion, due to contrasting topography and management, should not have similar P management recommendations. Also, it has been shown that in some agricultural watersheds, 90 percent of annual algal-available P export from watersheds comes from only 10 percent of the land area during a few relatively large storms (Pionke et al. 1997). For example, more than 75 percent of annual water discharge from watersheds in Ohio (Edwards and Owens 1991) and Oklahoma (Smith et al. 1991) occurred during one or two severe storms. These events contributed over 90 percent of annual total P export (0.2 and 5.6 lb/acre/yr in Ohio and Oklahoma, respectively). Therefore, threshold soil P values will have little meaning unless they are used in conjunction with an estimate of a site’s potential for surface runoff and erosion.

A sounder approach advocated by researchers and an increasing number of advisers is to link areas of surface runoff and high soil P content in a watershed (fig. 12).

Soil test P >100 ppm

Areas most vulnerable to P loss

Area of high transport potential

Integrated P and N management

Figure 12. Identifying P loss vulnerability (high soil test P and transport potential) to more effectively target measures to reduce P export in surface runoff from watersheds.

Preventing P loss is now taking on the added dimension of defining, targeting, and remediating source areas of P where high soil P levels coincide with high surface runoff and erosion potentials. This approach addresses P management at multifield or watershed scales. Furthermore, a comprehensive P management strategy must address down-gradient water-quality impacts, such as the proximity of P-sensitive waters. Conventionally applied remediations may not produce the desired results and may prove to be an inefficient and costly approach to the problem if this source-area perspective to target application of P fertility, surface runoff, and erosion control technology is not used.

The concept of a simple P index has been developed by a group of research scientists with diverse expertise as a screening tool for use by field staffs, watershed planners, and farmers to rank the vulnerability of fields as sources of P loss in surface runoff (Lemunyon and Gilbert 1993). The index accounts for and ranks transport and source factors controlling P loss in surface and subsurface runoff, delineating sites where the risk of P movement is expected to be higher than that of others (table 4).

Site vulnerability to P loss in surface runoff is assessed by selecting rating values for a variety of source and transport factors. Source factors of the P index are based on soil test P and fertilizer and manure rate, method, and timing of application. The correction factor of 0.2 for soil test P is based on field data that showed a five-fold greater concentration of dissolved P in surface runoff with an increase in mineral fertilizer or manure, compared to an equivalent increase in Mehlich-3 P (Sharpley and Tunney 2000).

To calculate transport potential for each site, erosion, surface runoff, leaching potential, and connectivity values were first summed. A relative transport potential was determined by dividing this summed value by 22, which is the value corresponding to *high* transport potential (erosion is 7, surface runoff is 8, leaching potential is 0, and connectivity is 8). This normalization process assumes that when a site's full transport potential is realized, the transport factor is 1 or greater. Transport factors less than 1 represent a fraction of the maximum potential.

A P index value, representing cumulative site vulnerability to P loss, is obtained by multiplying the summed transport and source

Table 4. The P indexing approach using Pennsylvania's index version from July 2001

Transport Factors						**Your field**
Erosion	Soil loss *(ton/A/yr)*					
Runoff potential	0 Very low	2 Low	4 Medium	6 High	8 Very high	
Sub-surface drainage	0 None		1 Some		2* Patterned	
Contributing distance	0 > 500 ft	2 500 to 350 ft	4 350 to 250 ft	6 250 to 150 ft	8 < 150 ft	
Transport sum = Erosion + Runoff potential + Sub-surface drainage + Contributing distance						
Modified connectivity	0.7 Riparian buffer- applies to distance < 150 ft.		1.0 Grassed waterway or none		1.1 Direct connection-applies to distance > 150 ft.	
Transport factor = Modified connectivity x (Transport sum/22)						
Phosphorus index value = 2 x Source factor x Transport factor						

*As an example, indices for other states can be found on the National Phosphorus Research Project's home page at http://pswmru.arsup.psu.edu/

†Or rapid permeability soil near a stream.

(cont.)–

Table 4. The P indexing approach using Pennsylvania's index version from July 2001 (cont.)

Source Factors						**Your field**
Soil test			Soil test P (ppm P)			
			Soil test rating = 0.20 Soil test P (ppm P)*			
Fertilizer P rate			Fertilizer P (lb P_2O_5/acre)			
Fertilizer application method	0.2 Placed or injected 2" or more deep	0.4 Incorporated < 1 week	0.6 Incorporated > 1 week or not incorporated April – October	0.8 Incorporated > 1 week or not incorporated Nov. – March	1.0 Surface applied to frozen or snow-covered soil	
			Fertilizer rating = Rate x Method			
Manure P rate			Manure P (lb P_2O_5/acre)			
Manure application method	0.2 Placed or injected 2" or more deep	0.4 Incorporated < 1 week	0.6 Incorporated > 1 week or not incorporated April – October	0.8 Incorporated > 1 week or not incorporated Nov. – March	1.0 Surface applied to frozen or snow-covered soil	
Manure P availability	0.5 Treated manure/Biosolids		0.8 Dairy		1.0 Poultry/Swine	
			Manure rating = Rate x Method x Availability			

factors. Index values are normalized so that the break between *high* and *very high* categories is 100. In most indices, this simply requires multiplying the index value by 2. The P index value for a site can then be used to categorize the site's vulnerability to P loss (table 5).

The index is a tool for field personnel to identify agricultural areas or management practices that have the greatest potential to accelerate eutrophication. It can be used to identify management options available to land users and will allow them flexibility in developing remedial strategies. The first step is to determine the P index for soils adjacent to sensitive waters and prioritize the efforts needed to reduce P losses. Then, management options appropriate for soils with different P index ratings can be implemented. General recommenda-

Table 5. General interpretation of the P index

P index	Rating	General interpretation
< 60	**Low**	**Low** potential for P loss. If current farming practices are maintained, there is a low risk of adverse impacts on surface waters.
60 to 80	**Medium**	**Medium** potential for P loss. The chance for adverse impacts on surface waters exists, and some remediation should be taken to minimize the risk of P loss.
80 to 100	**High**	**High** potential for P loss and adverse impacts on surface waters. Soil and water conservation measures and P management plans are needed to minimize the risk of P loss.
> 100	**Very high**	**Very high** potential for P loss and adverse impacts on surface waters. All necessary soil and water conservation measures and a P management plan must be implemented to minimize the P loss.

↖ **Your Field** ↗

tions are given in table 6; however, P management is very site specific and requires a well-planned, coordinated effort among farmers, extension agronomists, and soil conservation specialists.

Making Management Decisions

Farm N inputs can usually be more easily balanced with plant uptake than P inputs can, particularly where confined animal operations exist. In the past, separate strategies for either N or P were developed and implemented at farm or watershed scales. Because N and P have different chemistry and flow pathways through soils and watersheds, these narrowly targeted strategies often conflict and lead to compromised water quality. For example, manure application based on crop N requirements to minimize nitrate leaching to groundwater often results in excess soil P and enhances potential P losses in surface runoff. In contrast, reducing surface runoff losses of P via conservation tillage can increase water infiltration into the soil profile and enhance nitrate leaching.

For P, a primary strategy is to minimize surface runoff and particulate transport. In most cases, decreasing P loss by plant cover, crop residues, tillage and planting along contours, and buffer zones also decreases nitrate loss. Some exceptions are practices that promote water infiltration, which tend to increase leaching, and tillage practices that do not incorporate P fertilizers and manures into the soil. No-till is commonly recommended as a conservation measure for cropland that is eroding. Conversion to no-till is followed by loss of soil and total N and P in surface runoff and increased nitrate leaching and algal-available P transport (Sharpley and Smith 1994).

Nitrogen losses can occur from any location in a watershed, so remedial strategies for N can be applied to the whole watershed. Phosphorus losses usually occur from areas prone to surface runoff; therefore, the most effective P strategy would be to (1) avoid excessive soil P buildup in the whole watershed and thereby limit losses in subsurface flow and (2) use more stringent measures for the most vulnerable sites to minimize loss of P in surface runoff.

Development of sound remedial measures should consider these conflicting impacts of conservation practices on resultant water quality. Clearly, a technically sound framework must be developed that includes critical sources of N and P

Table 6. Management options to minimize nonpoint - source pollution of surface waters by soil P

Phosphorus index	Management options
< 60 (Low)	***Soil testing:*** Test soils for P at least every 3 years to monitor buildup or decline in soil P. ***Soil conservation:*** Follow good soil conservation practices. Consider effects of changes in tillage practices or land use on potential for increased transport of P from site. ***Nutrient management:*** Consider effects of any major changes in agricultural practices on P loss *before* implementing them on the farm. Examples include increasing the number of animal units on a farm or changing to crops with a high demand for fertilizer P.
60 to 80 (Medium)	***Soil testing:*** Test soils for P at least every 3 years to monitor buildup or decline in soil P. Conduct a more comprehensive soil testing program in areas identified by the P index as most sensitive to P loss by surface runoff, subsurface flow, and erosion. ***Soil conservation:*** Implement practices to reduce P loss by surface runoff, subsurface flow, and erosion in the most sensitive fields (that is, reduced tillage, field borders, grassed waterways, and improved irrigation and drainage management). ***Nutrient management:*** Any changes in agricultural practices may affect P loss; carefully consider the sensitivity of fields to P loss before implementing any activity that will increase soil P. Avoid broadcast applications of P fertilizers and apply manures only to fields with low P index values.

(cont.)

Table 6. Management options to minimize nonpoint - source pollution of surface waters by soil P (cont.)

Phosphorus index	Management options
80 to 100 (High)	***Soil testing:*** A comprehensive soil testing program should be conducted on the entire farm to determine fields that are most suitable for further additions of P. For fields that are excessive in P, estimates of the time required to deplete soil P to optimum levels should be made for use in long-range planning. ***Soil conservation:*** Implement practices to reduce P loss by surface runoff, subsurface flow, and erosion in the most sensitive fields (that is, reduced tillage, field borders, grassed waterways, and improved irrigation and drainage management). Consider using crops with high P removal capacities in fields with high P index values. ***Nutrient management:*** In most situations involving fertilizer P, only a small amount used in starter fertilizers is needed. Manure may be in excess on the farm and should only be applied to fields with lower P index values. A long-term P management plan should be considered.
> 100 (Very high)	***Soil testing:*** For fields that are excessive in P, estimate the time required to deplete soil P to optimum levels for use in long-range planning. Consider using new soil testing methods that provide more information on environmental impact of soil P. ***Soil conservation:*** Implement practices to reduce P loss by surface runoff, subsurface flow, and erosion in the most sensitive fields (that is, reduced tillage, field borders, grassed waterways, and improved irrigation and drainage management). Consider using crops with high P removal capacities in fields with high P index values. ***Nutrient management:*** Fertilizer and manure P should not be applied for 3 years or more. A comprehensive, long-term P management plan must be developed and implemented for an entire crop rotation.

export from agricultural watersheds so that optimal strategies at farm and watershed scales can be implemented to best manage N and P.

Summary

The overall goal to reduce P losses from agriculture should be to balance off-farm inputs of P in feed and fertilizer with outputs in products and to manage soils in ways that retain crop nutrient resources. Source and transport control strategies can provide the basis for increasing P-use efficiency in agricultural systems.

Future advisory programs should reinforce the fact that all fields do not contribute equally to P export from watersheds. Most P export comes from only a small portion of the watershed as a result of relatively few storms. Although soil P content is important in determining the concentration of P in agricultural runoff, surface runoff and erosion potential often override soil levels in determining P export. If water or soil do not move from a field or below the root zone, then P will not move. Clearly, management systems will be most effective if targeted to the hydrologically active source areas in a watershed that operate during a few major storms.

Manure management recommendations will have to account for site vulnerability to surface runoff and erosion, as well as soil P content, because not all soils and fields have the same potential to transfer P to surface runoff and leaching. As a result, threshold soil P levels should be indexed against P transport potential, with lower values for P source areas than for areas not contributing to water export.

Phosphorus applications at recommended rates can reduce P loss in agricultural runoff via increased crop uptake and cover. It is of vital importance that management practices be implemented to minimize soil P buildup in excess of crop requirements, reduce surface runoff and erosion, and improve capability to identify fields that are major sources of P loss to surface waters.

Overall—

- management systems should balance P inputs and outputs at farm and watershed scales;
- source and transport controls should target and identify critical source areas of P export from watersheds; and
- farmers should link threshold soil P levels that guide manure applications with site vulnerability to P loss.

Consideration of all these factors will be needed to develop extension and demonstration projects that educate farmers, the animal industry, and the general public about what is actually involved in ensuring clean water. It is hoped this will help overcome the common misconception that diffuse or nonpoint sources are too difficult, costly, or variable to control or target substantial reductions (fig. 13).

Efforts to implement defensible remedial strategies that minimize P loss from agricultural land will require interdisciplinary research involving soil scientists, hydrologists, agronomists, limnologists, and animal scientists. Development of guidelines to implement such strategies will also require consideration of the socioeconomic and political impacts of any management changes on rural and urban communities and of the mechanisms by which change can be achieved in a diverse and dispersed community of land users.

Figure 13. Several *myths* about P still exist:

- Most management practices are permanent solutions. In most cases the only permanent solution to reducing P losses is balancing farm and watershed P inputs and outputs.

- Soils are infinite sinks for P. Research shows that soils cannot indefinitely fix applied P. Continued applications of P beyond crop requirements, a common scenario where organic wastes have been heavily used in agriculture, are a major cause of soil P saturation.

- Crop N requirements should drive manure management. Basing manure management on mature N and crop N needs can lead to undesirably high P applications due to the unfavorable N:P ratios of most manures and crop requirements.

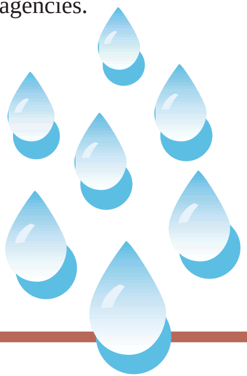
- Phosphorus does not move through the soil. While most P losses occur with surface runoff, P may move through soils with combinations of low P-fixing capacities, with preferential flow (or subsurface drains), or high soil test P contents.

- Erosion control will stop P losses in runoff. Erosion control is not the sole answer; reduction of dissolved P loss in runoff can only be achieved by minimizing P loss at the source and implementing practices that reduce total P in runoff.

- By controlling point sources we can solve water quality problems. Although point source inputs have been reduced in many areas, nonpoint source inputs now contribute to a greater share of water quality problems.

- Phosphorus management strategies can be universally applied. All fields and water bodies are not created equal; management plans for P and best management practices must be tailored to site vulnerability to P loss and proximity of P-sensitive waters.

- We don't know enough about agricultural P. We know a lot about how P reacts with soil and is transferred to runoff, but we have not adequately disseminated this information to land users and state and Federal agencies.



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Site ID: BC 1	Date	Time collected	Ortho P	TP	Ammonia-N	Nitrate-N	TN	TSS	DOC	E. coli	Total Coliform	Alkalinity	pH	Chloride	Conductivty	Total dissolved soilds	Notes
Description: Field 1, H flume	4/4/2014	9:20	0.181	0.638	0.25	0.106	2.08	207.0	14.7	--	--						
PQL different than what is																	
listed below is in ()	5/9/2014	10:25	0.079	0.312	0.17	0.209	1.63	125.9	9.6	--	--						63 samples/error: no liquid detected; only ~300 mL of sample
PQLs:	5/13/2014	9:48	0.190	0.366	0.10	0.126	1.33	42.1	10.2	--	--						63 samples/15420 gal; had enough for full sample
Ammonia = 0.09	5/28/2014	9:55	0.235	0.310	0.00	0.000	0.00	56.1	164.7	--	--						53 samples/17600 gal; only ~300 mL of sample
E. coli = 1	6/24/2014	10:06	0.228	0.498	0.18	0.114	2.39	23.2	20.15	--	--						7 samples/1440 gal
Total Coliform = 1	6/27/2014	9:35	1.166	1.374	0.10	0.333	1.18	12.3	7.80	--	--						100 samples/41380 gal
Nitrate = 0.01	7/25/2014	10:26	0.648	0.794	0.16	0.388	1.65	5.6	8.84	--	--						34 samples/4920 gal
Ortho P = 0.006	10/14/2014	9:55	0.529	0.746	0.98	0.698	2.89	65.7	9.46	--	--						8 samples/970 gal
TN = 0.04	3/25/2015	1:20	0.143	0.346	0.41	0.216	2.68	65.5	15.65					0.436	49.1	29.1	32 samples/4642.1 gal
TP = 0.01	5/8/2015	1:00	0.525	0.714	0.16	0.475	2.19	16.9	13.28					2.085	48.7	53.6	84 samples/12510 gal
TSS = 9.2	5/11/2015	1:30	0.251	0.386	0.09	0.055	0.86	44.4	6.31					0.363	24.2	26.0	100 samples/53438.7 gal
DOC = 0.2	5/18/2015	10:58	0.208	0.512	0.54	0.410	3.59	53.7	26.12					1.702	100.3	108.0	7 samples/960 gal
	5/26/2015	12:09	0.245	0.432	0.20	0.174		37.8	11.28					1.361	42.0	41.6	41 samples/6010 gal
	7/7/2015	1:25	0.387	0.444	0.23	0.345	1.30	4.9	8.32					7.114	49.0	39.8	100 samples/20060 gal
	10/13/2016	1:10	0.940	1.231	0.130	0.335	2.360	59.000	16.670					2.582	57.0	72.500	26 samples/3754.74 gal

ID	Description	Notes	Latitude
BC 1	Field 1		35 55’ 06.42”
BC 2	Field 5a		35 56’03.01”
BC 3	Field 12		35 54’ 13.57”
BC 4	Culvert		35 55’ 25.89”
BC 5	Spring		35 54’ 57.06”
BC 6	Upstream	furthest upstream off NCR 6310	35 53’ 32.28”
BC 7	Downstream 1	furthest downstream where NCR 6330 crosses big creek, upstream of crossing	35 56’ 18.98”
BC 8	Dry Creek		
BC 9	Left Fork		35 5’”48.04”
Site 4	Middle	middle; where NCR 6335 bridge crosses Big Creek, downstream of bridge	
Site 5	Below Barn	below the hog barn on Big Creek, downstream of bridge	
W1	House well		35 55’ 19.24”
T1	Trench below lagoc	T1=lagoon trench south	35 55’ 21.39”
T2	Trench below lagoc	T2=lagoon trench north	35 55’ 27.02”

Longitude	Elevation, ft
93 03’ 38.34”	984
93 04’ 25.85”	778
93 04’ 04.76”	838
93 04’ 14.94”	824
93 03’ 34.64”	977
93 04’ 06.38”	857
93 04’ 21.81”	769
93 04” 02.02”	760
93 04’ 23.04”	896
93 04’ 19.93”	883
93 04’ 22.71”	915

Date:						
Collected by:						
ID	**Description**	**Time:**	**ISCO or Grab**	**# of samples/gallons**	**ISCO collection date**	**Notes**
BC 1	Field 1					
BC 2	Field 5a					
BC 3	Field 12					
BC 4	Culvert					
BC 5	Spring					
BC 6	Upstream					furthest upstream off NCR 6310
BC 7	Downstream 1					furthest downstream where NCR 6330 crosses big creek, upstream of crossing
BC 8	Dry Creek					
Site 4	Middle					middle; where NCR 6335 bridge crosses Big Creek, downstream of bridge
Site 5	Below Barn					below the hog barn on Big Creek, downstream of bridge
W1	House well					
T1/T2						T1=lagoon trench south, T2=lagoon trench north

		**See separate spreadsheet for a printable blank data sheet*					

Site ID: BC 2

Description: Field 5a

PQL different than what is listed below is in ()

PQLs:
Ammonia = 0.09
E. coli = 1
Total Coliform = 1

Nitrate = 0.01
Ortho P = 0.006
TN = 0.04
TP = 0.01
TSS = 9.2
DOC = 0.2

Date	Time collected	Ortho P	TP	Ammonia-N
6/27/2014	11:22	0.506	0.656	0.06
7/25/2014	11:05	0.625	0.754	0.09
10/13/2014	10:48	0.707	0.926	0.36
3/26/2015	12:30	0.813	1.330	0.39
5/11/2015	12:25	0.248	0.968	0.26
7/7/2015	6:15	0.094	0.448	0.13
3/31/2016	12:02	1.154	1.352	0.27
5/10/2016	12:26	1.114	1.458	1.69

Nitrate-N	TN	TSS	DOC	E. coli	Total Coliform	Alkalinity	pH
0.000	0.53	39.7	5.82	--	--		
0.000	0.61	9.0	5.81	--	--		
0.068	0.91	38.1	5.34	--	--		
0.225	2.59	72.3					
0.127	1.50	44.4	8.58				
0.172	1.01	261.3	4.38				
0.302	1.67	26.5	32.74				
2.894	6.35	79.9	12.82	22820.0	>241920		

Chloride	Conductivty	Total dissolved soilds	Notes
			100 samples/20630 gal
			27 samples/2000 gal
			100 samples/11720 gal
1.965	79.4	113.1	100 samples/42742.9 gal
1.073	60.3	74.0	100 samples/5158670 gal
1.874	215.0	114.0	100 samples/155650 gal
1.861	115.0	90.0	100 samples/139510 gal
0.161	79.4	72.5	5 samples/153.2 gal

Site ID: BC 3	Date	Time collected	Ortho P	TP	Ammonia-N
Description: Field 12	5/8/2015	12:38	0.675	0.956	0.14
PQL different than what is listed below is in ()	5/11/2015	1:00	0.194	0.364	0.09
	7/7/2015	4:35	0.796	0.910	0.13
	3/10/2016	12:41	0.411	0.522	1.17
	5/10/2016	1:08	0.370	0.666	0.12

PQLs:
Ammonia = 0.09
E. coli = 1
Total Coliform = 1
Nitrate = 0.01
Ortho P = 0.006
TN = 0.04
TP = 0.01
TSS = 9.2
DOC = 0.2

Nitrate-N	TN	TSS	DOC	E. coli	Total Coliform	Alkalinity
0.303	1.82	57.0	16.00			
0.135	0.83	36.7	7.03			
0.567	1.58	29.0	7.67			
0.85	4.49	621.5	12.58			
0.062	1.03	96.7	6.92	6630.0	>241920	

pH	Chloride	Conductivty	Total dissolved soilds	Notes
	2.193	116.4	98.0	
	0.771	120.1	68.2	
	0.984	70.7	46.4	
	0.690	43.9	70.0	
	0.349	30.5	57.5	

Base or storm	Ortho P	TP	Ammonia-N	Nitrate-N	TN	TSS	DOC	E. coli
storm, grab	0.009	0.028	0.05	0.643	0.63	1.0	0.7	19.3
base, grab	0.007	0.028	0.00	0.610	0.62	11.0	1.2	260.2
storm, grab	0.004	0.042	0.03	0.685	0.81	3.3	4.9	--
base, grab	0.009	0.020	0.03	0.484	0.54	2.1	1.1	44.3
storm, grab	0.026	0.262	0.46	0.845	2.36	908.8	6.5	--
storm	0.011	0.022	0.04	0.466	0.53	2.5	2.7	70.8
storm, ISCO (BC4-a)	0.003	0.016	0.03	0.463	0.49	4.7	1.8	8.5
storm, grab (BC4-b)	0.007	0.032	0.03	0.483	0.56	1.9	2.0	547.5
base, grab	0.004	0.012	0.03	0.451	0.50	1.0	0.0	47.9
base, grab	0.005	0.010	0.03	0.448	0.50	1.5	0.6	90.5
storm, ISCO (BC4-b)	0.010	0.290	0.61	0.939	2.33	847.6	4.7	--
storm, grab (BC4-a)	0.007	0.060	0.12	0.509	0.70	5.1	2.6	307.6
base, grab	0.008	0.020	0.08	0.522	0.55	0.8	0.3	204.6
storm, grab	0.011	0.020	0.10	0.799	0.85	1.7	0.2	517.2
storm, ISCO	0.005	0.090	0.68	4.562	7.16	2096.3	4.09	--
storm, grab	0.017	0.022	0.03	0.550	0.60	1.7	0.83	--
storm, ISCO	0.023	0.054	0.37	0.759	2.89	1252.1	6.96	--
base, grab								
storm, ISCO	0.006	0.032	0.06	0.601	0.67	16.8	0.56	--
storm, ISCO	0.016	1.018	0.98	0.875	2.69	2642.0	5.09	--
storm, grab	0.017	0.042	0.20	1.204	1.23	4.9	1.03	1732.9
storm, ISCO	0.004	0.068	0.08	0.996	1.37	11.2	3.28	--
storm, grab								
storm, ISCO	0.021	0.04	0.04	1.161	1.11	8.2	1.11	

Total Coliform	Alkalinity	pH
365.4		
>2419.2		
--		
517.2		
--		
770.1		
195.6		
4320.0		
>2419.2		
4790.0		
--		
10760.0		
5940.0		
14830.0		
--		
--		
--		
--		
--		
30760.0		
--		

Site ID: BC 5	Date	Time collected	Ortho P	TP	Ammonia-N	Nitrate-N	TN	TSS	DOC	E. coli	Total Coliform	Alkalinity	pH
Description: Spring	9/20/2013	10:50	0.006	0.020	0.03	0.384	0.50	4.7		72.7	5040.0		
Previously "Site 1"	9/24/2013	10:30	0.004	0.024	0.00	0.122	0.35	50.0		8.5	>2419.6		
	10/1/2013	9:45	0.001	0.162	0.00	0.108	0.41	89.2		4.1	920.8		
PQLs:	10/9/2013	9:00	0.011	0.054	0.00	0.088	0.28	29.1		3.1	1413.6		
Ammonia = 0.01	10/15/2013	11:13	0.010	0.250	0.15	0.086	0.58	66.9		1401.0	19863.0		
E. coli = 1	10/22/2013	10:10	0.005	0.086	0.10	0.307	0.53	36.4		1732.9	>2419.6		
Total Coliform = 1	10/31/2013	11:00	0.003	0.404	0.14	0.321	1.02	400.9		90.7	32550.0		
Nitrate = 0.03	11/6/2013	8:35	0.013	0.130	0.10	0.062	0.72	21.2		8570.0	34480.0		
Ortho P = 0.01	11/12/2013	10:56	0.006	0.022	0.05	2.449	2.61	8.9		47.9	2750.0		
TN = 0.03	11/19/2013	9:20	0.007	0.022	0.02	3.063	3.06	4.4		579.4	9880.0		
TP = 0.01	11/26/2013	10:35	0.007	0.018	0.00	1.690	1.70	4.5		85.7	1553.1		
TSS = 7.5	12/3/2013	8:30	0.007	0.046	0.04	1.048	1.37	26.9		25.0	1986.3		
DOC = 0.6	12/17/2013	9:35	0.007	0.042	0.05	0.367	0.65	2.0		248.1	2419.2		
	1/2/2014	10:45	0.006	0.024	0.05	3.240	3.48	0.5			*		
	1/7/2014	10:10	0.0080	0.024	0.00	2.2305	2.39	1.3		20.9	1413.6		
	1/14/2014	11:35	0.010	0.042	0.00	1.974	2.09	2.3		24.3	1732.9		
	1/21/2014	8:10	0.008	0.006	0.02	2.107	2.10	0.9		5.2	613.1		
	1/29/2014	10:20	0.009	0.024	0.00	0.851	0.86	1.4	7.10	3.1	325.5		
	2/13/2014	8:30	0.009	0.024	0.00	0.654	0.73	5.1	24.70	<1	461.1		
	2/19/2014	9:15	0.006	0.020	0.02	0.574	0.62	0.8	0.47	1.0	365.4		
	2/27/2014	10:40	0.007	0.106	0.06	0.594	0.82	70	5.1	<1	307.6		
Some PQLs are different starting on this date	3/10/2014	10:30	0.006	0.048	0.02	0.372	0.53	19.9	3.8 (0.6)	6.3	517.2		
PQLs:	3/18/2014	12:08	0.011	0.026	0.00	0.902	0.99	1.7	2.5	21.1	>2419.2		
Ammonia = 0.09	3/26/2014	10:40	0.010	0.026	0.01	1.003	1.13	3.0	1.4	8.4	980.4		
E. coli = 1	3/29/2014	9:40	0.006	0.044	0.00	0.288	0.51	3.3	8.1	--	--		
Total Coliform = 1	4/2/2014	11:15	0.011	0.020	0.00	0.604	0.67	0.6	2.1	3.10	307.6		
Nitrate = 0.01	4/4/2014	9:07	0.014	0.052	0.02	0.393	0.59	3.9	4.9	--	--		
Ortho P = 0.006	4/8/2014	9:15	0.016	0.018	0.00	0.532	0.59	0.7	4.7	74.9	488.4		
TN = 0.04	4/14/2014	9:47	0.006	0.038	0.01	0.432	0.54	0.9	4.4	172.2	>2419.2		
TP = 0.01	4/22/2014	9:40	0.013	0.020	0.00	0.586	0.66	1.7	0.9	11.0	>2419.2		
TSS = 9.2	5/1/2014	10:09	0.007	0.012	0.00	0.505	0.57	1.4	1.0	52.1	1986.3		
DOC = 0.2	5/8/2014	1:00	0.009	0.020	0.00	0.386	0.48	11.1	1.0	8.6	5560.0		
	5/9/2014	10:05	0.009	0.030	0.02	0.161	0.36	5.8	4.0	--	--		
	5/13/2014	9:33	0.008	0.062	0.06	0.249	0.45	3.8	4.3	435.2	7280.0		
	5/19/2014	1:17	0.007	0.018	0.00	0.639	0.70	3.7	0.8	27.5	>2419.2		
	5/28/2014	9:34	0.010	0.036	0.00	0.353	0.58	7.3	2.8	1986.3	16740.0		
	6/5/2014	1:03	0.022	0.030	0.08	0.350	0.46	4.5	0.9	33.2	4280.0		
	6/9/2014	9:06	0.009	0.048	0.15	0.163	0.39	7.2	5.15	770.1	173290.0		
	6/19/2014	9:10	0.008	0.024	0.06	0.320	0.43	3.7	0.20	28.8	2419.2		
	6/24/2014	9:46	0.007	0.046	0.04	0.201	0.38	4.8	5.14	10810.0	275.5		
	6/27/2014	10:03	0.012	0.010	0.00	0.378	0.51	3.3	3.86	--	--		
	7/1/2014	9:46	0.013	0.022	0.04	0.547	0.68	11.3	1.22	87.8	3990.0		
	7/7/2014	9:28	0.009	0.132	0.33	0.352	0.66	18.7	2.97	10190.0	111990.0		
	7/15/2014	9:33	0.005	0.014	0.01	0.353	0.43	2.7	1.39	129.6	2810.0		
	7/18/2014	12:34	0.012	0.022	0.07	0.410	0.49	1.9	0.83	--	--		
	7/23/2014	10:27	0.015	0.024	0.05	0.342	0.37	2.5	1.42	14.6	1413.6		

	8/12/2014	10:09	0.009	0.032	0.03	0.217	0.26	7.0	0.56	40.4	>2419.2		
	8/20/2014	10:28	0.010	0.036	0.00	0.285	0.45	7.5	1.09	307.6	40830.0		
	8/26/2014	11:38	0.007	0.078	0.05	0.256	0.42	38.6	0.35	51.2	4650.0		
	9/3/2014	10:24	0.008	0.022	0.00	0.227	0.37	10.9	0.61	1870.0	21430.0		
	9/11/2014	11:48	0.004	0.012	0.00	0.564	0.65	1.3	0.16	35.4	7440.0		
	9/18/2014	10:42	0.007	0.200	0.17	0.170	0.6	54.7	3.12	12590.0	81640.0		
	9/23/2014	1:05	0.001	0.024	0.00	0.253	0.37	6.7	0.93	201.4	2750.0		
	9/30/2014	10:56	0.002	0.138	0.00	0.256	0.63	81.8	0.53	135.4	13960.0		
	10/8/2014	10:24	0.001	0.050	0.00	0.218	0.41	22.1	0.64	88.4	7330.0		
	10/13/2014	9:38	0.071	0.126	0.12	0.083	0.62	46.5	6.55	19350.0	198630.0		
	10/22/2014	10:24	0.006	0.058	0.00	0.402	0.59	26.1	0.87	1046.2	5210.0		
	10/30/2014	11:30	0.000	0.048	0.04	0.360	0.58	23.5	0.61	110.0	3950.0		
	11/5/2014	9:29	0.013	0.088	0.11	0.145	0.5	13.4	3.91	579.4	11530		
	11/12/2014	10:22	0.011	0.024	0	0.095	0.16	0	0.5	65	3310		
	11/24/2014	9:39	0.007	0.014	0	0.271	0.48	4.1	4.71	40.2	>2419.2		
	12/4/2014	10:49	0.007	0.024	0	0.317	0.5	2.3	5.57	5.2	1119.9		
	12/9/2014	10:00	0.008	0.024	0	0.295	0.48	2.3	4.26	18.9	1203.3		
	12/15/2014	12:17	0.016	0.11	0.09	0.07	0.58	5.9	9.21	28.5	1299.7		

Site ID: BC 6	Date	Time collected	ISCO or Grab	Grab Storm	Lab Sample No.	Ortho P	TP
Description: Upstream of all sites	9/12/2013	10:45	Grab		140203-03	0.016	0.030
Previously "Site 2"	9/20/2013	11:15	Storm	after rain	140221-02	0.009	0.022
PQL different than what is listed below is in ()	9/24/2013	10:45	Grab		140228-02	0.021	0.140
PQLs:	10/1/2013	10:00	Grab		140235-02	0.011	0.038
Ammonia = 0.01	10/9/2013	9:30	Grab		140261-02	0.016	0.034
E. coli = 1	10/15/2013	12:24	Storm	storm high flow	140266-02	0.018	0.026
Total Coliform = 1	10/22/2013	10:30	Storm	storm	140275-02	0.014	0.034
Nitrate = 0.03	10/31/2013	10:45	Grab		140289-02	0.012	0.032
Ortho P = 0.01	11/6/2013	9:00	Grab		140295-02	0.032	0.074
TN = 0.03	11/12/2013	11:35	Grab		140312-02	0.011	0.010
TP = 0.01	11/19/2013	9:45	Grab		140320-02	0.010	0.026
TSS = 7.5	11/26/2013	10:45	Grab		140331-02	0.013	0.018
DOC = 0.6	12/3/2013	8:45	Grab		140334-02	0.007	0.012
	12/17/2013	10:00	Storm	after snow melt	140344-02	0.010	0.036
	1/2/2014	10:55	Grab		1/2/2014	0.009	0.022
	1/7/2014	10:20	Grab		1/7/2014	0.014	0.022
	1/14/2014	12:15	Grab		1/14/2014	0.008	0.028
	1/21/2014	8:30	Grab		1/21/2014	0.009	0.010
	1/29/2014	10:40	Grab		1/29/2014	0.007	0.028
	2/13/2014	8:50	Grab		2/13/2014	0.009	0.016
	2/19/2014	10:17	Grab		2/19/2014	0.008	0.018
	2/27/2014	11:03	Grab		2/27/2014	0.008	0.022
Some PQLs are different starting on this date	3/10/2014	10:55	Grab	base/snow melt	3/10/2014	0.005	0.026
PQLs:	3/18/2014	12:48	Storm	storm	3/18/2014	0.010	0.038
Ammonia = 0.09	3/26/2014	10:22	Grab		3/26/2014	0.010	0.024
E. coli = 1	3/29/2014	10:00	Storm	storm, grab	3/29/2014	0.006	0.042

Total Coliform = 1	4/2/2014	10:14	Grab		4/2/2014	0.011	0.026
Nitrate = 0.01	4/4/2014	9:40	Storm	storm, grab	4/4/2014	0.012	0.056
Ortho P = 0.006	4/8/2014	10:25	Storm	storm, grab	4/8/2014	0.012	0.026
TN = 0.04	4/14/2014	11:17	Storm	storm, grab	4/14/2014	0.005	0.034
TP = 0.01	4/22/2014	10:21	Grab		4/22/2014	0.074	0.888
TSS = 9.2	5/1/2014	10:29	Grab		5/1/2014	0.006	0.018
DOC = 0.2	5/8/2014	12:45	Grab		5/8/2014	0.013	0.020
	5/9/2014	10:42	Storm	storm, grab	5/9/2014	0.008	0.030
	5/13/2014	10:38	Storm	storm, grab	5/13/2014	0.008	0.062
	5/19/2014	12:11	Grab		5/19/2014	0.006	0.024
	5/28/2014	11:06	Storm	storm, grab	5/28/2014	0.007	0.022
	6/5/2014	12:50	Grab		6/5/2014	0.012	0.022
	6/9/2014	10:22	Storm	storm, grab	6/9/2014	0.006	0.030
	6/19/2014	9:55	Grab		6/19/2014	0.008	0.028
	6/24/2014	12:17	Storm	storm, grab	6/24/2014	0.014	0.056
	6/27/2014	11:53	Storm	6/26/2014, 4:52	6/27/2014	0.007	0.014
	7/1/2014	11:40	Grab		7/1/2014	0.011	0.010
	7/7/2014	11:00	Storm	storm, grab	7/7/2014	0.009	0.040
	7/15/2014	10:20	Grab		7/15/2014	0.010	0.046
	7/18/2014	12:09	ISCO	7/15/2014, 18:52	7/18/2014	0.006	0.032
	7/18/2014	12:13	Grab	storm, grab (BC6-b)	7/18/2014	0.012	0.028
	7/23/2014	12:21	Grab		7/23/2013	0.021	0.020
	7/25/2014	11:30	Storm	7/23/2014, 15:41	7/25/2014	0.081	0.476
	7/25/2014	11:33	Storm	storm, grab (BC6-b)	7/25/2014	0.010	0.036
	7/31/2014	10:56	Storm	storm, grab	7/31/2014	0.015	0.022
	8/12/2014	10:52	Grab		8/12/2014	0.012	0.026
	8/20/2014	11:23	Grab		8/20/2014	0.014	0.040
	8/26/2014	12:08	Grab		8/26/2014	0.005	0.064
	9/3/2014	11:15	Storm	storm, grab	9/3/2014	0.010	0.030
	9/11/2014	12:56	Storm	storm, grab	9/11/2014	0.001	0.040
	9/18/2014	11:25	Storm	storm, grab	9/18/2014	0.006	0.024
	9/23/2014	12:45	Grab		9/23/2014	0.003	0.022
	9/30/2014	12:20	Grab		9/30/2014	0.002	0.032

	10/8/2014	12:11	Grab		10/8/2014	0.003	0.052
	10/13/2014	10:07	Storm	10/11/2014	10/13/2014	0.005	0.072
	10/13/2014	10:11	Storm	storm, grab (BC6-b)	10/13/2014	0.069	0.200
	10/22/2014	11:56	Grab		10/22/2014	0.010	0.026
	10/30/2014	9:53	Grab		10/30/2014	0.005	0.016
	11/5/2014	11:31	Storm	storm, grab	11/5/2014	0.018	0.032
	11/12/2014	10:38	Grab		11/12/2014	0.012	0.036
	11/24/2014	10:34	Storm	storm, grab	11/24/2014	0.013	0.013
	12/4/2014	11:10	Grab		12/4/2014	0.011	0.022
	12/9/2014	10:33	Storm	storm, grab	12/9/2014	0.011	0.024
	12/15/2014	12:28	Storm	storm, grab	12/15/2014	0.026	0.07
	12/22/2014	12:05	Grab		12/22/2014	0.010	0.028
	1/8/2015	11:25	Grab		1/8/2015	0.009	0.022
	1/14/2015	11:45	Grab		1/14/2015	0.012	0.032
	1/21/2015	11:52	Grab		1/21/2015	0.008	0.018
	1/29/2015	11:45	Grab		1/29/2015	0.006	0.060
	2/3/2015	11:40	Grab		2/3/2015	0.006	0.022
	2/10/2015	11:05	Grab		2/10/2015	0.009	0.012
	2/26/2015	11:36	Grab		2/26/2015	0.006	0.024
	3/3/2015	11:50	Grab		3/3/2015	0.006	0.026
	3/11/2015	12:30	Storm	storm, grab	3/11/2015	0.005	0.026
	3/19/2015	12:00	Grab		3/19/2015	0.007	0.024
	3/25/2015	1:30	Grab		3/25/2015	0.006	0.028
	3/26/2015	1:10	Grab		3/26/2015	0.013	0.064
	4/2/2015	12:15	Grab		4/2/2015	0.007	0.040
	4/9/2015	12:30	Grab		4/9/2015	0.011	0.042
	4/15/2015	12:23	Storm	storm,grab	4/15/2015	0.007	0.040
	4/20/2015	12:40	ISCO		4/20/2015		
	4/23/2015	1:00	Grab		4/23/2015	0.007	0.032
	4/29/2015	11:53	Grab		4/29/2015	0.010	0.020
	5/4/2015		Grab		5/4/2015	0.008	0.026
	5/7/2015	11:43	Grab		5/7/2015	0.008	0.032
	5/8/2015	1:25	Grab		5/8/2015	0.134	0.354

	5/11/2015	11:28	Storm	storm,grab	5/11/2015	0.004	0.074
	5/14/2015	12:28	Grab		5/14/2015	0.011	0.046
	5/18/2015	11:57	Storm	storm,grab	5/18/2015	0.007	0.034
	5/26/2015	1:20	Grab		5/26/2015	0.012	0.044
	6/4/2015	12:00	Grab			0.008	0.026
	6/8/2015	12:26	Grab		6/8/2015	0.010	0.030
	6/17/2015	10:10	Grab		6/17/2015	0.009	0.036
	6/22/2015	12:15	Storm	storm,grab	6/22/2015	0.010	0.030
	6/29/2015	12:30	Storm	storm,grab	6/29/2015	0.354	0.524
	7/9/2015	12:25	Grab		7/9/2015	0.013	0.048
	7/16/2015	12:15	Grab		7/16/2015	0.010	0.024
	7/23/2015	11:15	Storm	storm,grab	7/23/2015	0.009	0.026
	7/30/2015	12:17	Grab		7/30/2015	0.014	0.024
	8/6/2015	11:36	Storm	storm,grab	8/6/2015	0.009	0.028
	8/13/2015	12:06	Grab		8/13/2015	0.013	0.018
	8/20/2015	11:17	Storm	storm,grab	8/20/2015	0.006	2.956
	8/27/2015	12:37	Grab		8/27/2015	0.005	0.028
	9/2/2015	11:50	Grab			0.007	0.042
	9/16/2015	12:06	Grab			0.004	0.024
	9/24/2015	11:30	Grab			0.006	0.078
	11/12/2015	12:26	Grab			0.015	0.022
	11/18/2015	11:50	Grab			0.013	0.046
	12/2/2015	1:22	Grab			0.010	0.020
	12/14/2015	1:00	Grab			0.009	0.034
	12/22/2015	12:38	Grab			0.010	0.020
	1/5/2016	1:00	Grab			0.008	0.026
	1/25/2016	12:10	Grab			0.010	0.022
	2/10/2016	11:15	Grab			0.005	0.016
	2/24/2016	12:16	Grab			0.014	0.052
	3/10/2016	1:13	Grab			0.012	0.048
	3/16/2016	12:35	Grab			0.008	0.034
	3/24/2016	12:50	Grab			0.011	0.032
	3/31/2016	12:45	Grab			0.008	0.042

	4/4/2016	12:50	Grab			0.008	0.026
	4/20/2016	1:20	Grab			0.003	0.020
	4/28/2016	1:00	Grab			0.009	0.012
	5/2/2016	2:29	Grab			0.006	0.018
	5/10/2016	12:50	Grab			0.007	0.044
	5/18/2016	1:08	Grab			0.007	0.016
	5/26/2016	1:08	Grab			0.007	0.030
	6/2/2016	12:26	Grab			0.007	0.018
	6/7/2016	12:16	Grab			0.013	0.018
	6/15/2016	12:40	Grab			0.007	0.010
	6/22/2016	12:20	Grab			0.008	0.016
	6/29/2016	11:37	Grab			0.006	0.029
	7/6/2016	7:41	Grab			0.009	0.023
	8/16/2016	12:16	Grab			0.009	0.031
	8/24/2016	12:40	Grab			0.004	0.014
	8/30/2016	12:35	Grab			0.003	0.020
	9/7/2016	9:03	Grab			0.007	0.020
	9/15/2016	11:20	Grab			0.012	0.011
	9/28/2016	12:26	Grab			0.008	0.016
	10/5/2016	12:01	Grab			0.009	0.020
	10/13/2016	12:46	Grab			0.015	0.026
	10/20/2016	12:03	Grab			0.010	0.021
	10/27/2016	11:50	Grab			0.010	0.021
	11/3/2016	11:10	Grab			0.003	0.031
	11/10/2016	11:33	Grab			0.011	0.013
	11/17/2016	11:40	Grab			0.009	0.020
	11/21/2016	11:15	Grab			0.010	0.019
	11/29/2016	12:48	Grab			0.008	0.026
	12/14/2016	11:58	Grab			0.009	0.017
	1/5/2017		Grab			0.009	0.014

Date	Ammonia-N	Nitrate-N	TN	TSS	DOC	E. coli	Total Coliform	Alkalinity	pH	Chloride
9/12/2013	0.06	0.367	0.50	3.0		6.3	2419.2			
9/20/2013	0.03	0.247	0.36	1.1		80.9	9870.0			
9/24/2013	0.03	0.444	2.20	17.9		38.9	1119.9			
10/1/2013	0.02	0.236	0.34	2.2		7.5	1299.7			
10/9/2013	0.03	0.497	0.73	7.1		10.8	2419.6			
10/15/2013	0.03	1.024	1.03	1.1		759.0	2419.2			
10/22/2013	0.03	0.345	0.32	0.3		186.0	299.0			
10/31/2013	0.03	0.242	0.32	1.1		65.7	1986.3			
11/6/2013	0.03	0.432	0.61	4.7		4080.0	28510.0			
11/12/2013	0.03	0.169	0.22	1.0		45.0	1986.3			
11/19/2013	0.03	0.123	0.22	0.7		435.2	2400.0			
11/26/2013	0.03	0.135	0.14	0.4		77.1	1203.3			
12/3/2013	0.03	0.152	0.25	0.5		26.5	435.2			
12/17/2013	0.06	0.180	0.27	1.2		248.1	2419.2			
1/2/2014	0.01	0.223	0.25	0.7						
1/7/2014	0.02	0.204	0.27	0.8		66.3	307.6			
1/14/2014	0.01	0.156	0.25	0.3		151.5	980.4			
1/21/2014	0.03	0.130	0.22	1.0		55.7	290.9			
1/29/2014	0.03	0.125	0.15	0.6	2.20	10.9	248.1			
2/13/2014	0.03	0.107	0.15	0.9	8.50	68.9	238.2			
2/19/2014	0.03	0.048	0.10	0.4	0.09	111.9	325.5			
2/27/2014	0.02	0.066	0.22	2.1	1.6	29.5	209.8			
3/10/2014	0.06	0.086	0.12	0.9	1.4	52.1	275.5			
3/18/2014	0.08	0.186	0.24	2.1	1.2	50.4	435.2			
3/26/2014	0.03	0.118	0.19	0.6	0.8	43.5	517.2			
3/29/2014	0.06	0.067	0.14	2.1	2.1					

4/2/2014	0.03	0.053	0.09	1.0	0.5	60.5	613.1			
4/4/2014	0.05	0.105	0.19	3.3	2.3					
4/8/2014	0.02	0.090	0.13	0.8	1.4	110.6	1299.7			
4/14/2014	0.04	0.101	0.17	3.7	2.1	387.3	3090.0			
4/22/2014	0.03	0.004	0.09	1.2	0.5	126.6	1203.3			
5/1/2014	0.03	0.070	0.09	1.9	1.0	96.0	3050.0			
5/8/2014	0.06	0.087	0.09	1.2	0.9	57.3	5120.0			
5/9/2014	0.03	0.072	0.10	1.5	0.7					
5/13/2014	0.03	0.096	0.23	10.1	2.9	920.8	13130.0			
5/19/2014	0.05	0.103	0.16	1.9	0.5	133.3	2419.2			
5/28/2014	0.03	0.124	0.10	2.1	0.7	290.9	15760.0			
6/5/2014	0.01	0.136	0.14	1.2	1.0	307.6	18500.0			
6/9/2014	0.03	0.176	0.19	3.3	1.95	410.6	2419.2			
6/19/2014	0.09	0.154	0.22	0.3	0.3	36.4	3790.0			
6/24/2014	0.03	0.219	0.27	4.3	2.63	28510.0	980.4			
6/27/2014	0.01	0.117	0.14	5.1	3.34					
7/1/2014	0.09	0.171	0.19	1.9	0.70	238.2	3640.0			
7/7/2014	0.03	0.266	0.28	3.9	1.08	1732.9	69100.0			
7/15/2014	0.04	0.215	0.30	5.2	1.73	686.7	26130.0			
7/18/2014	0.04	0.004	0.20	4.4	1.83					
7/18/2014	0.03	0.200	0.19	1.5	0.66					
7/23/2014	0.05	0.103	0.13	1.3	1.13	142.1	2419.2			
7/25/2014	0.09	0.004	0.86							
7/25/2014	0.05	0.087	0.11	2.6	1.21					
7/31/2014	0.03	0.116	0.13	1.2	0.76	275.5	6370.0			
8/12/2014	0.03	0.108	0.13	1.7	0.30	98.8	1986.3			
8/20/2014	0.03	0.214	0.32	8.3	0.52	88.4	3000.0			
8/26/2014	0.09	0.075	0.42	6.5	1.21	3.1	4370.0			
9/3/2014	0.04	0.303	0.52	5.3	0.67	270.0	8570.0			
9/11/2014	0.06	0.198	0.53	6.2	2.28	2419.2	81640.0			
9/18/2014	0.02	0.555	0.66	3.7	0.69	365.4	11720.0			
9/23/2014	0.02	0.152	0.27	3.5	0.82	9.7	2419.2			
9/30/2014	0.01	0.172	0.46	6.1	1.09	5.2	4320.0			

10/8/2014	0.04	0.125	0.53	8.7	1.61	24.6	4260.0			
10/13/2014	0.03	0.124	0.46	20.8	3.36					
10/13/2014	0.10	0.147	0.55	28.4	4.59	20140.0	173290.0			
10/22/2014	0.03	0.123	0.15	0.6	0.61	67.6	2430.0			
10/30/2014	0.03	0.114	0.12	0.5	0.44	31.8	2419.2			
11/5/2014	0.03	0.103	0.18	0.7	1.22	214.3	5040			
11/12/2014	0.03	0.065	0.1	0.5	0.4	57.3	3130			
11/24/2014	0.03	0.097	0.11	0.7	2.15	72.7	2419.2			
12/4/2014	0.03	0.103	0.13	0.7	2.94	45.7	1850			
12/9/2014	0.01	0.057	0.09	0.5	1.6	36.4	1986.3			
12/15/2014	0.06	0.067	0.26	21.6	3.17					
12/22/2014	0.06	0.096	0.12	0.9	1.05	155.3	1046.2			
1/8/2015	0.03	0.187	0.21	2.3	1.41	30.9	547.5	36	7.3	1.80
1/14/2015	0.03	0.135	0.19	1.1	3.02	88.2	727.0			2.09
1/21/2015	0.03	0.089	0.12	1.1	0.95	70.3	579.4	48	7.6	1.85
1/29/2015	0.03	0.065	0.21	2.2	1.71	727.0	1413.6			2.09
2/3/2015	0.03	0.051	0.28	1.1	2.69	4.1	1203.3	54	7.74	2.40
2/10/2015	0.03	0.056	0.09	0.7	1.04	1119.1	2419.2			2.51
2/26/2015	0.03	0.100	0.13	0.6	1.20	47.9	687.7	40	7.59	1.98
3/3/2015	0.02	0.048	0.11	2.3	1.50					2.08
3/11/2015	0.02	0.118	0.16	2.1	3.38	34.5	579.4	30	7.79	1.88
3/19/2015	0.04	0.111	0.20	1.7	2.53	42.6	866.4			1.55
3/25/2015	0.02	0.056	0.16	2.9	1.36	125.9	2419.2	42	8.01	1.77
3/26/2015	0.06	0.090	0.30	11.4	3.71	547.5	5200.0			1.33
4/2/2015	0.02	0.045	0.14	3.1	3.61	166.9	2419.2	42	8.0	1.57
4/9/2015	0.04	0.066	0.18	13.1	2.13	86.0	2650.0			1.73
4/15/2015	0.03	0.090	0.16	3.5	3.24	648.8	4040.0	36	7.7	1.38
4/20/2015										
4/23/2015	0.03	0.083	0.18	4.0	5.11	104.6	2419.2			1.65
4/29/2015	0.03	0.082	0.13	2.7	1.58	58.3	1732.4	50	8.1	1.56
5/4/2015	0.03	0.083	0.11	2.3	2.93	38.6	>2419.2			1.40
5/7/2015	0.01	0.110	0.16	7.5	10.16	77.6	3280.0			1.80
5/8/2015	0.16	0.340	1.12	51.4	9.30					1.63

5/11/2015	0.04	0.004	0.24	4.5	4.31			24	7.5	1.55
5/14/2015	0.02	0.177	0.23	2.8	1.35	145.5	2470.0			1.20
5/18/2015	0.02	0.110	0.15	5.2	1.29	137.6	2419.2			1.10
5/26/2015	0.04	0.080	0.20	6.4	1.50	275.5	5610.0	28	7.7	1.08
6/4/2015	0.03	0.083	0.11	2.3	2.93	38.6	>2419.2			
6/8/2015	0.06	0.058	0.24	4.5	3.63	866.4	2780.0	60	8.2	2.03
6/17/2015	0.03	0.050	0.16	3.5	2.83	435.2	13130.0			1.51
6/22/2015	0.01	0.042	0.05	2.9	0.99	78.0	4960.0	40	8.2	1.36
6/29/2015	0.37	0.226	1.64	11	11.32					1.74
7/9/2015	0.02	0.087	0.18	6.8	2.75	201.4	10140.0	32	7.69	1.53
7/16/2015	0.02	0.065	0.15	0.5	1.91	41.3	52.0			1.33
7/23/2015	0.02	0.096	0.18	1.3	0.97	93.3	7490.0	78	7.89	1.63
7/30/2015	0.00	0.101	0.15	0.9	1.61	27.2	2880.0			1.75
8/6/2015	0.00	0.147	0.24	1.8	3.37	488.4	13540.0	100	7.7	1.84
8/13/2015	0.04	0.124	0.16	0.3	4.32	13.4	2460.0			1.91
8/20/2015	0.03	0.108	2.64	4.7	7.71	2010.0	51720.0	108	7.3	2.15
8/27/2015	0.04	0.084	0.28	2.9	4.3	104.6	7710			2.11
9/2/2015	0.07	0.047	0.39	3.37	5.5	46.4	9070	122	7.1	2.498
9/16/2015	0.000	0.104	0.3	4.62	2.1	50.4	3590	132	7.6	3.046
9/24/2015	0.000	0.000	0.41	5.92	14.8	17.1	4570			2.743
11/12/2015	0.000	0.127	0.22	0.9	2.51	117.8	2620	104	8	2.125
11/18/2015	0.06	0.229	0.41	4	2.55	517.2	5810			1.355
12/2/2015	0.03	0.135	0.22	1.4	0.98	55.6	1986.3			1.518
12/14/2015	0.05	0.181	0.27	4.1	4.10	410.6	4080.0	26.0	7.5	1.212
12/22/2015	0.00	0.092	0.14	0.4	0.94	50.4	648.8	56.0	8.3	1.784
1/5/2016	0.00	0.158	0.20	0.5	0.95	67.7	648.8	40.0	7.5	1.338
1/25/2016	0.00	0.068	0.09	1.1	1.52	16.9	290.9	46.0	8.2	1.5
2/10/2016	0.00	0.048	0.11	0.5	1.11	14.5	178.5	54.0	8.6	1.692
2/24/2016	0.00	0.099	0.28	6.1	3.32	1203.3	7330.0	66.0	7.2	1.197
3/10/2016	0.13	0.08	0.20	8.6	2.66	770.1	>2419.2	38.0	7.6	1.268
3/16/2016	0.00	0.06	0.13	0.4	1.10	52.9	579.4	38.0	6.7	1.252
3/24/2016	0.06	0.040	0.14	4.5	1.60			46.0	7.7	1.825
3/31/2016	0.08	0.100	0.22	6.1	2.49	186.0	>2419.2	30.0	7.3	0.933

4/4/2016	0.00	0.065	0.08	1.7	0.71	8.3	648.8	40.0	7.4	1.2
4/20/2016	0.00	0.047	0.06	1.9	0.61	185.0	1299.7	58.0	8.0	1.4
4/28/2016	0.00	0.035	0.12	1.2		58.6	648.8	66.0	8.1	1.4
5/2/2016	0.00	0.039	0.10	6.7	1.76	185.0	2419.2	38.0	7.7	1.150
5/10/2016	0.01	0.070	0.20	6.1	3.10	613.1	4480.0	32.0	7.6	0.914
5/18/2016	0.00	0.043	0.13	1.4	1.00	85.5	1299.7	48.0	8.0	1.228
5/26/2016	0.00	0.056	0.12	4.2	1.56	238.2	5290.0	76.0	7.8	1.045
6/2/2016	0.00	0.046	0.13	4.1	1.8	224.7	1986.3	68.0	7.9	1.298
6/7/2016	0.06	0.131	0.14	1.3	2.8	120.1	2720.0	58.0	8.1	2.722
6/15/2016	0.00	0.097	0.15	1.6	0.02	69.1	2310.0	72.0	8.3	1.471
6/22/2016	0.02	0.237	0.33	2.3	0.20	455.0	547.5	88.0	8.1	1.695
6/29/2016	0.06	0.186	0.34	4.6	0.92	55.4	9888.0	110.0	7.4	2.176
7/6/2016	0.00	0.221	0.27	5.9	0.66	387.3	12230.0	106.0	7.5	1.821
8/16/2016	0.03	0.089	0.23	4.6	3.14	248.9	9330.0	40.0	7.7	1.092
8/24/2016	0.03	0.046	0.14	2.0	1.08	72.3	2620.0	54.0	8.3	1.513
8/30/2016	0.00	0.042	0.13	1.7	1.37	102.5	5210.0	64.0	8.2	1.088
9/7/2016	0.01	0.113	0.21	1.9	1.89	195.6	5380.0	82.0	7.9	1.601
9/15/2016	0.00	0.119	0.21	3.2	6.12	ND	ND	98.0	8.0	1.287
9/28/2016	0.01	0.128	0.21	1.0	1.33	9330.0	2310.0	84.0	8.1	1.804
10/5/2016	0.00	0.120	0.25	2.1	2.85	770.1	13170.0	94.0	7.9	1.831
10/13/2016	0.00	0.147	0.28	2.7	2.32	3590.0	46110.0		7.8	2.540
10/20/2016	0.00	0.076	0.13	1.1	4.43	3730.0	16640.0		7.9	2.017
10/27/2016	0.00	0.046	0.14	1.1	5.87	517.2	5450.0		8.0	2.139
11/3/2016	0.01	0.071	0.20	2.1	6.81	22.6	3010.0		7.6	2.330
11/10/2016	0.01	0.073	0.12	1.0	2.29	53.7	>2419.2		8.0	2.446
11/17/2016	0.00	0.057	0.13	0.6	1.84	58.1	3270.0		8.0	2.455
11/21/2016	0.00	0.125	0.17	1.3	0.68	178.9	3840.0		8.0	2.314
11/29/2016	0.01	0.063	0.12	2.1	2.38	235.9	3790.0			2.087
12/14/2016	0.03	0.064	0.08	0.9	4.43	67.6	2650.0		8.3	2.140
1/5/2017	0.02	0.059	0.09	0.7	0.66	52.0	2419.2		8.8	2.264

Date	Conductivty	Total dissolved		
9/12/2013				
9/20/2013				
9/24/2013				
10/1/2013				
10/9/2013				
10/15/2013				
10/22/2013				
10/31/2013				
11/6/2013				
11/12/2013				
11/19/2013				
11/26/2013				
12/3/2013				
12/17/2013				
1/2/2014				
1/7/2014				
1/14/2014				
1/21/2014				
1/29/2014				
2/13/2014				
2/19/2014				
2/27/2014				
3/10/2014				
3/18/2014				
3/26/2014				
3/29/2014				

4/2/2014				
4/4/2014				
4/8/2014				
4/14/2014				
4/22/2014				
5/1/2014				
5/8/2014				
5/9/2014				
5/13/2014				
5/19/2014				
5/28/2014				
6/5/2014				
6/9/2014				
6/19/2014				
6/24/2014				
6/27/2014				
7/1/2014				
7/7/2014				
7/15/2014				
7/18/2014				
7/18/2014				
7/23/2014				
7/25/2014				
7/25/2014				
7/31/2014				
8/12/2014				
8/20/2014				
8/26/2014				
9/3/2014				
9/11/2014				
9/18/2014				
9/23/2014				
9/30/2014				

10/8/2014				
10/13/2014				
10/13/2014				
10/22/2014				
10/30/2014				
11/5/2014				
11/12/2014				
11/24/2014				
12/4/2014				
12/9/2014				
12/15/2014				
12/22/2014				
1/8/2015	90	71.6		
1/14/2015	105	49.1		
1/21/2015	121	71.1		
1/29/2015	140	71.3		
2/3/2015	129	71.1		
2/10/2015	132	67.6		
2/26/2015	107	56.4		
3/3/2015	112	58.9		
3/11/2015	85	269.3		
3/19/2015	98	58.0		
3/25/2015	110	67.6		
3/26/2015	115	64.4		
4/2/2015	110	76.0		
4/9/2015	116	74.9		
4/15/2015	91	63.8		
4/20/2015				
4/23/2015	95	60.4		
4/29/2015	85	54.3		
5/4/2015	123	70.7		
5/7/2015	157	88.4		
5/8/2015	131	110.0		

5/11/2015	143	79.3		
5/14/2015	107	56.2		
5/18/2015	90	58.4		
5/26/2015	78	55.3		
6/4/2015				
6/8/2015	149	111.3		
6/17/2015	128	70.2		
6/22/2015	114	64.9		
6/29/2015	55	49.8		
7/9/2015	90	64.7		
7/16/2015	161	78.9		
7/23/2015	180	50.2		
7/30/2015	224	113.3		
8/6/2015	218	75.3		
8/13/2015	210	121.6		
8/20/2015	219	120.0		
8/27/2015	240	131.3		
9/2/2015	262	129.3		
9/16/2015	272	151.3		
9/24/2015	271	149.3		
11/12/2015	228	115		
11/18/2015	83.6	55.6		
12/2/2015	82.6	100.0		
12/14/2015	63.2	50.0		
12/22/2015	107.3	50.0		
1/5/2016	101.8	62.5		
1/25/2016	115.3	65.0		
2/10/2016	140.7	60.0		
2/24/2016	102.1	97.5		
3/10/2016	84.5	60.0		
3/16/2016	88.3	52.5		
3/24/2016	103.3	56.5		
3/31/2016	65.8	235.0		

4/4/2016	86.9	55.0		
4/20/2016	125.7	65.0		
4/28/2016	134.8	72.5		
5/2/2016	83.7	52.5		
5/10/2016	67.6	57.5		
5/18/2016	102.8	57.5		
5/26/2016	78.4	50.0		
6/2/2016	105.4	75.0		
6/7/2016	128.3	77.5		
6/15/2016	150.3	77.5		
6/22/2016	182.3	112.5		
6/29/2016	203.0	112.5		
7/6/2016	212.0	117.5		
8/16/2016	88.1	60.0		
8/24/2016	121.7	95.0		
8/30/2016	143.3	70.0		
9/7/2016	176.0	97.5		
9/15/2016	206.0	111.1		
9/28/2016	217.0	113.3		
10/5/2016	230.0	110.0		
10/13/2016	222.0	242.5		
10/20/2016	215.0	117.8		
10/27/2016	299.0	117.5		
11/3/2016	260.0			
11/10/2016	233.0			
11/17/2016	272.0			
11/21/2016	101.0			
11/29/2016				
12/14/2016	129.0			
1/5/2017	142			

Site ID: BC 7	Date	Time collected	Base or storm	Ortho P	TP	Ammonia-N	Nitrate-N	TN
Description: Downstream 1	9/12/2013	1:00	Grab	0.010	0.022	0.04	0.396	0.62
Previously "Site 3"	9/20/2013	12:50	Storm	0.013	0.022	0.05	0.442	0.53
PQL different than what is listed below is in ()	9/24/2013	12:40	Grab	0.007	0.028	0.01	0.511	0.58
PQLs:	10/1/2013	10:55	Grab	0.009	0.034	0.02	0.514	0.65
Ammonia = 0.01	10/9/2013	10:20	Grab	0.006	0.038	0.03	0.618	0.77
E. coli = 1	10/15/2013	1:34	Storm	0.067	0.316	0.20	0.677	1.07
Total Coliform = 1	10/22/2013	11:20	Grab	0.012	0.020	0.04	0.723	0.76
Nitrate = 0.03	10/31/2013	10:30	Storm	0.012	0.024	0.03	0.443	0.45
Ortho P = 0.01	11/6/2013	10:00	Grab	0.041	0.154	0.12	0.286	0.60
TN = 0.03	11/12/2013	1:35	Grab	0.011	0.010	0.03	0.242	0.31
TP = 0.01	11/19/2013	10:55	Grab	0.009	0.024	0.02	0.172	0.28
TSS = 7.5	11/26/2013	11:45	Grab	0.013	0.016	0.03	0.231	0.24
DOC = 0.6	12/3/2013	9:35	Grab	0.006	0.012	0.03	0.225	0.28
	12/17/2013	10:50	Storm	0.008	0.032	0.03	0.325	0.43
	1/2/2014	11:50	Grab	0.012	0.036	0.03	0.485	0.54
	1/7/2014	11:10	Grab	0.015	0.028	0.03	0.413	0.46
	1/14/2014	1:15	Grab	0.008	0.026	0.05	0.310	0.39
	1/21/2014	9:05	Grab	0.010	0.014	0.01	0.301	0.36
	1/29/2014	11:00	Grab	0.007	0.024	0.03	0.282	0.28
	2/13/2014	9:10	Grab	0.009	0.014	0.03	0.241	0.28
	2/19/2014	11:30	Grab	0.007	0.016	0.03	0.109	0.17
	2/27/2014	12:22	Grab	0.007	0.014	0.03	0.112	0.16
Some PQLs are different starting on this date	3/10/2014	12:15	Grab	0.004	0.026	0.04	0.12	0.21

PQLs:	3/18/2014	1:03	Storm	0.014	0.040	0.06	0.316	0.38
Ammonia = 0.09	3/26/2014	11:31	Grab	0.011	0.026	0.03	0.254	0.30
E. coli = 1	3/29/2014	10:35	Storm	0.008	0.038	0.03	0.125	0.19
Total Coliform = 1	4/2/2014	12:11	Grab	0.010	0.024	0.03	0.108	0.14
Nitrate = 0.01	4/4/2014	10:08	Storm	0.016	0.052	0.05	0.155	0.32
Ortho P = 0.006	4/8/2014	9:05	Storm	0.014	0.024	0.03	0.170	0.23
TN = 0.04	4/14/2014	9:35	Storm	0.007	0.050	0.08	0.140	0.25
TP = 0.01	4/22/2014	9:25	Grab	0.020	0.024	0.01	0.133	0.17
TSS = 9.2	5/1/2014	9:58	Grab	0.007	0.008	0.05	0.119	0.11
DOC = 0.2	5/8/2014	1:13	Grab	0.008	0.028	0.03	0.163	0.55
	5/9/2014	9:52	Storm	0.008	0.018	0.03	0.152	0.17
	5/13/2014	9:22	Storm	0.010	0.086	0.07	0.133	0.38
	5/19/2014	1:30	Grab	0.008	0.018	0.03	0.111	0.14
	5/28/2014	9:16	Storm	0.008	0.020	0.03	0.221	0.21
	6/5/2014	1:16	Grab	0.012	0.026	0.05	0.219	0.28
	6/9/2014	8:51	Storm	0.006	0.026	0.02	0.256	0.26
	6/19/2014	8:55	Grab	0.010	0.020	0.03	0.246	0.32
	6/24/2014	9:27	Storm	0.009	0.068	0.05	0.245	0.35
	6/27/2014	12:17	Storm	0.017	0.022	0.01	0.379	0.42
	7/1/2014	9:30	Grab	0.012	0.012	0.03	0.335	0.40
	7/7/2014	9:12	Storm	0.010	0.034	0.03	0.398	0.40
	7/15/2014	11:32	Grab	0.009	0.050	0.03	0.270	0.40
	7/18/2014	10:45	Storm	0.014	0.030	0.09	0.292	0.30
	7/23/2014	10:09	Grab	0.019	0.032	0.09	0.280	0.31
	7/25/2014	9:55	Storm	0.013	0.040	0.03	0.196	0.29
	7/31/2014	9:32	Storm	0.018	0.030	0.03	0.250	0.30
	8/12/2014	9:54	Grab	0.012	0.036	0.04	0.232	0.23
	8/20/2014	10:14	Grab	0.011	0.032	0.01	0.319	0.37
	8/26/2014	11:14	Grab	0.013	0.018	0.01	0.398	0.46
	9/3/2014	9:39	Storm	0.015	0.018	0.03	0.500	0.6

Streambed manipulation began around the week of September 15, 2014, upstream and downstream of the NC 6335 bridge across Big Creek.	9/11/2014	11:30	Storm	0.010	0.024	0.04	0.476	0.52
	9/18/2014	9:54	Storm	0.013	0.028	0.02	0.523	0.61
	9/23/2014	10:59	Grab	0.010	0.026	0.02	0.442	0.53
	9/30/2014	9:57	Grab	0.011	0.032	0.01	0.444	0.57
	10/8/2014	9:31	Grab	0.009	0.028	0.03	0.474	0.57
	10/14/2014	9:21	Storm	0.110	0.450	0.23	0.257	1.03
	10/14/2014	9:31	Storm	0.015	0.058	0.05	0.379	0.51
	10/22/2014	10:09	Grab	0.011	0.028	0.03	0.380	0.47
	10/30/2014	11:47	Grab	0.006	0.016	0.03	0.368	0.42
	11/5/2014	9:10	Storm	0.014	0.023	0.03	0.353	0.48
	11/12/2014	9:27	Grab	0.012	0.026	0.03	0.217	0.31
	11/24/2014	9:23	Storm	0.014	0.016	0.03	0.297	0.38
	12/4/2014	10:35	Grab	0.013	0.024	0.03	0.264	0.33
	12/9/2014	9:38	Storm	0.013	0.022	0.03	0.179	0.23
	12/15/2014	12:09	Storm	0.013	0.044	0.04	0.162	0.33
	12/22/2014	11:00	Grab	0.011	0.052	0.03	0.175	0.24
	1/8/2015	10:53	Grab	0.011	0.024	0.03	0.376	0.39
	1/14/2015	11:15	Grab	0.011	0.020	0.03	0.388	0.34
	1/21/2015	11:05	Grab	0.010	0.026	0.06	0.370	0.3
	1/29/2015	1:20	Grab	0.009	0.020	0.04	0.168	0.27
	2/3/2015	10:50	Grab	0.009	0.018	0.03	0.140	0.09
	2/10/2015	10:25	Grab	0.011	0.010	0.03	0.143	0.23
	2/26/2015	10:34	Grab	0.008	0.026	0.02	0.200	0.25

	3/3/2015	10:55	Grab	0.007	0.028	0.03	0.138	0.23
	3/11/2015	11:20	Storm	0.007	0.030	0.02	0.209	0.27
	3/19/2015	11:13	Grab	0.009	0.028	0.04	0.234	0.35
	3/25/2015	11:30	Grab	0.008	0.036	0.04	0.162	0.29
	3/26/2015	1:35	Grab	0.013	0.076	0.06	0.144	0.41
	4/2/2015	1:30	Grab	0.007	0.042	0.02	0.139	0.22
	4/9/2015	12:50	Grab	0.010	0.048	0.03	0.157	0.25
	4/15/2015	12:40	ISCO	0.009	0.048	0.03	0.166	0.26
	4/23/2015	12:15	Grab	0.007	0.032	0.03	0.162	0.25
	4/29/2015	12:13	Grab	0.012	0.018	0.03	0.189	0.98
	5/4/2015		Grab	0.009	0.034	0.03	0.184	0.23
	5/7/2015	12:05	Grab	0.009	0.034	0.03	0.267	0.36
	5/8/2015	1:25	Grab	0.195	0.544	0.27	0.292	1.20
	5/11/2015	12:47	Storm	0.031	0.530	0.11	0.071	1.12
	5/14/2015	12:47	Storm	0.015	0.050	0.02	0.326	0.39
	5/18/2015	12:17	Storm	0.009	0.040	0.03	0.201	0.25
	5/26/2015	1:32	Grab	0.045	0.200	0.11	0.096	0.20
	6/1/2015	1:15	Storm	0.006	0.050	0.05	0.109	0.25
	6/8/2015	1:12	Grab	0.009	0.022	0.05	0.185	0.27
	6/17/2015	12:49	Grab	0.007	0.034	0.03	0.106	0.23
	6/22/2015	12:55	Storm	0.009	0.032	0.04	0.136	0.16
	7/7/2015	19:45	Storm	0.275	0.380	0.22	0.204	1.03
	7/9/2015	12:55	Grab	0.014	0.050	0.03	0.117	0.24
	7/16/2015	12:54	Grab	0.011	0.030	0.03	0.195	0.33
	7/23/2015	12:40	Storm	0.011	0.028	0.02	0.198	0.31
	7/30/2015	12:50	Grab	0.012	0.022	0.02	0.268	0.38
	8/6/2015	12:22	Storm	0.010	0.028	0.03	0.406	0.52
	8/13/2015	1:01	Grab	0.011	0.024	0.03	0.384	0.50
	8/20/2015	11:49	Storm	0.015	0.022	0.03	0.491	0.53
	8/27/2015	1:20	Grab	0.013	0.024	0.03	0.45	0.54
	9/2/15	12:19	Grab	0.010	0.020	0.01	0.449	0.55
	9/10/15	12:59	Grab	0.008	0.028	0.02	0.464	0.58
	9/16/15	12:24	Grab	0.009	0.030	0.01	0.404	0.62

	9/24/15	12:07	Grab	0.009	0.018	0.00	0.449	0.56
	9/30/15	11:50	Grab	0.008	0.022	0.01	0.472	0.66
	10/8/15	11:20	Grab	0.005	0.020	0.02	0.517	0.60
	10/14/15	11:28	Grab	0.010	0.056	0.03	0.603	0.76
	10/22/15	12:15	Grab	0.008	0.018	0.07	0.548	0.69
	10/28/15	11:56	Grab	0.009	0.032	0.03	0.544	0.78
	11/4/15	12:03	Grab	0.010	0.038	0.00	0.607	0.76
	11/12/15	12:03	Grab	0.013	0.044	0.00	0.439	0.64
	11/18/15	11:25	Grab	0.017	0.050	0.09	0.334	0.56
	12/2/2015	11:57	Grab	0.012	0.022	0.02	0.266	0.39
	12/14/2015	12:30	Grab	0.012	0.048	0.07	0.235	0.38
	12/22/2015	11:02	Grab	0.011	0.020	0.00	0.245	0.32
	1/5/2016	11:40	Grab	0.011	0.026	0.00	0.419	0.46
	1/25/2016	11:00	Grab	0.011	0.022	0.00	0.213	0.24
	2/10/2016	11:04	Grab	0.005	0.016	0.00	0.198	0.24
	2/24/2016	10:52	Grab	0.015	0.058	0.00	0.142	0.37
	3/10/2016	10:51	Grab	0.010	0.044	0.11	0.12	0.25
	3/16/2016	11:23	Grab	0.006	0.028	0.01	0.17	0.24
	3/24/2016	11:35	Storm	0.011	0.024	0.00	0.106	0.20
	3/31/2016	10:45	Grab	0.011	0.056	0.08	0.156	0.33
	4/4/2016	11:48	Grab	0.010	0.026	0.00	0.176	0.20
	4/20/2016	11:42	Grab	0.004	0.018	0.00	0.152	0.20
	4/28/2016	11:30	Grab	0.010	0.012	0.00	0.154	0.27
	5/2/2016	11:43	Grab	0.008	0.016	0.00	0.075	0.16
	5/10/2016	10:58	Grab	0.011	0.060	0.01	0.101	0.31
	5/18/2016	11:10	Grab	0.009	0.020	0.02	0.117	0.25
	5/26/2016	11:30	Grab	0.009	0.036	0.00	0.094	0.20
	6/2/2016	11:04	Grab	0.006	0.018	0.00	0.106	0.20
	6/7/2016	11:10	Grab	0.012	0.018	0.04	0.123	0.19
	6/15/2016	11:25	Grab	0.008	0.050	0.05	0.181	0.42
	6/22/2016	10:23	Grab	0.015	0.028	0.04	0.327	0.44
	6/29/2016	10:41	Grab	0.010	0.021	0.03	0.395	0.47
	7/6/2016	6:26	Grab	0.010	0.023	0.01	0.461	0.43

	7/13/2016	7:33	Grab	0.006	0.017	0.00	0.365	0.43
	7/20/2016	7:39	Grab	0.005	0.024	0.00	0.356	0.44
	7/27/2016	7:21	Grab	0.007	0.027	0.00	0.423	0.47
	8/3/2016	7:43	Grab	0.013	0.014	0.00	0.221	0.29
	8/16/2016	10:41	Grab	0.011	0.039	0.03	0.161	0.33
	8/24/2016	10:53	Grab	0.005	0.016	0.00	0.122	0.22
	8/24/2016	11:03	Storm	0.000	0.109	0.01	0.002	0.42
	8/30/2016	11:10	Grab	0.004	0.020	0.00	0.116	0.21
	9/7/2016	7:38	Grab	0.008	0.059	0.01	0.265	0.46
	9/15/2016	10:45	Grab	0.014	0.016	0.01	0.312	0.42
	9/28/2016	11:12	Grab	0.011	0.017	0.01	0.293	0.42
	10/5/2016	10:07	Grab	0.014	0.043	0.02	0.413	0.58
	10/13/2016	10:29	Grab	0.033	0.066	0.02	0.614	0.88
	10/20/2016	10:48	Grab	0.014	0.030	0.03	0.327	0.39
	10/27/2016	10:42	Grab	0.014	0.021	0.01	0.291	0.36
	11/3/2016	9:36	Grab	0.008	0.022	0.03	0.388	0.47
	11/10/2016	10:38	Grab	0.011	0.021	0.02	0.419	0.48
	11/17/2016	10:43	Grab	0.011	0.020	0.01	0.412	0.49
	11/21/2016	10:05	Grab	0.012	0.021	0.01	0.466	0.52
	11/29/2016	11:30	Grab	0.007	0.027	0.00	0.146	0.23
	12/14/2016	11:03	Grab	0.013	0.024	0.02	0.199	0.27
	1/5/2017		Grab	0.012	0.019	0.04	0.257	0.31

Date	TSS	DOC	E. coli	Total Coliform	Alkalinity	pH	Chloride	Conductivty	Total dissolved soilds	
9/12/2013	1.7		16.1	2419.2						
9/20/2013	1.1		547.5	17230.0						
9/24/2013	1.5		5.2	2419.2						
10/1/2013	3.6		2620.0	10810.0						
10/9/2013	13.6		27.5	3450.0						
10/15/2013	101.1		1334.0	19863.0						
10/22/2013	0.7		86.5	292.0						
10/31/2013	1.4									
11/6/2013	28.4		3500.0	43520.0						
11/12/2013			24.0	2419.2						
11/19/2013	1.0		193.5	4410.0						
11/26/2013	1.2		35.9	2419.2						
12/3/2013	0.5		12.0	2419.2						
12/17/2013	2.1		148.3	2419.2						
1/2/2014	0.8									
1/7/2014	0.2		18.3	325.5						
1/14/2014	0.5		95.9	1299.7						
1/21/2014	0.5		131.3	410.6						
1/29/2014		2.00	<1	275.0						
2/13/2014	0.4	11.30	9.8	290.9						
2/19/2014	0.3	0.01	8.5	272.3						
2/27/2014	0.6	1.10	2.00	547.5						
3/10/2014	6.1	1.2 (0.6)	27.8	579.4						

3/18/2014	3.4	1.7	78.8	866.4						
3/26/2014	1.2	0.7	21.8	866.4						
3/29/2014	2.5	2.2	--	--						
4/2/2014	0.8	0.6	29.5	1553.1						
4/4/2014	6.3	2.7	--	--						
4/8/2014	2.2	1.5	155.3	1413.6						
4/14/2014	8.7	3.1	613.1	5210.0						
4/22/2014	1.6	0.6	66.3	2419.20						
5/1/2014	1.5	0.9	62.4	3990.0						
5/8/2014	4.7	1	19.9	14760.0						
5/9/2014	2.1	0.6	--	--						
5/13/2014	19.4	5.6	1553.1	29090.0						
5/19/2014	2.0	0.3	53.7	4220.0						
5/28/2014	1.9	0.7	209.8	8390.0						
6/5/2014	4.3	0.8	201.4	13330.0						
6/9/2014	4.3	1.33	517.2	11690.0						
6/19/2014	0.9	0.33	61.3	4960.0						
6/24/2014	7.2	3.81	24950.0	1046.2						
6/27/2014	5.5	1.26	--	--						
7/1/2014	5.6	0.87	129.6	17890.0						
7/7/2014	3.5	0.67	649.8	15760.0						
7/15/2014	9.1	1.92	816.4	27550.0						
7/18/2014	2.6	0.77	--	--						
7/23/2014	3.7	1.12	95.9	6010.0						
7/25/2014	5.9	1.30	--	--						
7/31/2014	3.3	0.77	224.7	23590.0						
8/12/2014	8.3	0.40	125.0	9870.0						
8/20/2014	3.4	0.44	69.7	7380.0						
8/26/2014	1.4	0.22	19.7	5120.0						
9/3/2014	3.5	0.09	65.7	4040.0						

9/11/2014	1.5	0.24	980.4	15970.0						
9/18/2014	2.1	0.33	579.4	11530.0						
9/23/2014	2.7	0.50	47.1	2620.0						
9/30/2014	1.9	0.45	85.7	2560.0						
10/8/2014	2.1	0.45	56.3	5630						
10/14/2014	171.2	4.77								
10/14/2014	7.0	2.30	1203.3	20120.0						
10/22/2014	2.0	0.59	200.0	4350.0						
10/30/2014	1.8	0.42	20.1	2330.0						
11/5/2014	2.1	0.78	153.9	4190						
11/12/2014	1.2	0.39	14.6	4350						
11/24/2014	1.5	2.11	14.8	2419.2						
12/4/2014	1.5	2.98	7.4	2990						
12/9/2014	1.1	1.42	35	2650						
12/15/2014	4.3	1.87								
12/22/2014	1.5	1.14	55.6	980.0						
1/8/2015	2.5	1.22	42.6	980.4	64	7.6	2.02	144	89.3	
1/14/2015	1	2.03	25.6	613.1			2.76	166	79.8	
1/21/2015	1	1.60	37.4	613.1	84	7.6	2.44	191	91.1	
1/29/2015	1.3	1.50	19.9	1046.2			2.51	205	109.1	
2/3/2015	4.1	2.66	1.0	547.5	88	7.7	2.82	196	103.3	
2/10/2015	1	1.15	7.4	1553.1			3.01	204	105.5	
2/26/2015	0.8	1.17	48.7	866.4	66	7.8	2.27	162	88.0	

3/3/2015	1.3	1.50					2.39	170	80.0	
3/11/2015	1.8	1.44	66.3	770.1	52	7.8	2.02	128	77.3	
3/19/2015	2.8	2.87	71.7	1119.9			1.75	148	84.9	
3/25/2015	5	1.41	547.5	3410	64	7.8	2.07	158	88.7	
3/26/2015	14.1	3.94	816.4	4960			1.46	83	78.7	
4/2/2015	2.5	2.71	121.1	1986.3	68	8.1	1.95	163	103.0	
4/9/2015	19.7	1.82	47.2	1986.3			2.08	168	100.4	
4/15/2015	4.4	2.67	344.8	2920.0	56	7.8	1.54	130	82.0	
4/23/2015	2.6	2.51	65.7	2419.2			1.81	142	81.0	
4/29/2015	2.1	1.64	58.6	1986.3	80	8.0	2.15	150	97.3	
5/4/2015	1.7	2.64	24.7	2419.2			1.84	185	101.1	
5/7/2015	4.5	7.70	27.8	2280.0			2.50	225	125.8	
5/8/2015	113.2	7.47					1.73	149	130.9	
5/11/2015	277.5	8.48			36	7.5	1.06	103	80.2	
5/14/2015	6.1	1.16	128.1	4370.0			1.55	150	58.7	
5/18/2015	6.1	1.47	185.0	6770.0			1.25	137	89.1	
5/26/2015	94.7	4.57			46	7.7	1.20	125	93.3	
6/1/2015	13.7	1.80					1.44	163	86.9	
6/8/2015	0.9	2.66	57.4	4640.0	94	8.0	2.14	216	141.3	
6/17/2015	2.3	2.92	344.8	20980.0			1.76	204	106.5	
6/22/2015	2.9	1.15	36.8	5040.0	76	7.9	1.55	177	79.3	
7/7/2015	19.1	7.91					1.63	116	77.6	
7/9/2015	8.8	2.32	275.5	10760.0	50	7.7	1.50	124	72.2	
7/16/2015	0.5	1.35	11.8	6310.0			1.84	223	111.8	
7/23/2015	0.8	1.06	16.8	4870.0	108	7.8	2.18	248	122.0	
7/30/2015	1.9	2.16	11.9	6500.0			2.31	286	142.9	
8/6/2015	1.7	3.06	40.2	10390.0	154	7.6	2.78	283	159.1	
8/13/2015	4.0	3.74	24.0	3310.0			2.83	287	156.0	
8/20/2015	2.2	5.94	39.3	66.3	142	7.2	3.01	300	153.3	
8/27/2015	2.5	4.43	137.4	5730			2.83	301	166.9	
9/2/15	3.2	4.80	20.3	6630.0	146	7.5	3.134	322.0	159.6	
9/10/15	4.0	2.90	66.3	5470.0			3.468	309.0	172.7	
9/16/15	4.6	1.40	6.2	4800.0	152	7.4	3.871	310.0	169.3	

9/24/15	5.6	1.20	29.9	7540.0			3.460	308.0	168.3	
9/30/15	5.4	4.50	31.7	5290.0	148	7.6	3.979	322.0	174.5	
10/8/15	1.5	1.62	21.3	12360.0			3.424	344.0	179.8	
10/14/15	12.4	1.33	7.3	8164.0	16	7.8	3.715	362.0	181.0	
10/22/15	2.3	3.64	17.8	3140.0			3.450	362.0	168.8	
10/28/15	1.7	3.91	35.0	6700.0	164	7.8	3.398	351.0	168.3	
11/4/15	1.7	3.79	23.1	2880.0			4.047	358.0	181.0	
11/12/15	6.9	2.14	75.9	>2419.2	128	7.9	2.801	281.0	152.0	
11/18/15	4.5	2.88	435.2	14550.0			1.552	119.5	77.8	
12/2/2015	1.6	0.94	48.0	9600.0			1.864	126.9	68.9	
12/14/2015	11.2	3.24	325.5	4520.0	38.0	7.7	1.262	92.6	70.0	
12/22/2015	1.0	1.12	31.8	980.4	70.0	7.7	1.994	157.3	82.5	
1/5/2016	0.1	1.13	40.8	648.8	60.0	7.5	2.172	157.5	92.5	
1/25/2016	0.7	1.29	8.6	365.4	80.0	8.0	2.0	191.1	95.0	
2/10/2016	0.9	0.99	4.1	218.7	94.0	8.0	2.359	214.0	102.5	
2/24/2016	8.3	3.99	1986.3	6500.0	80.0	7.5	1.482	155.7	110.0	
3/10/2016	6.2	2.28	298.7	>2419.2	54.0	7.3	1.481	126.1	80.0	
3/16/2016	0.9	1.17	81.3	>2419.2	60.0	7.1	1.500	137.6	75.0	
3/24/2016	3.9	1.29			68.0	7.3	1.827	156.8	79.0	
3/31/2016	12.4	2.67	365.0	>2419.2	48.0	7.3	1.043	95.9	50.0	
4/4/2016	1.9	0.98	77.6	1046.2	66.0	7.4	1.6	138.6	80.0	
4/20/2016	1.2	0.74	38.4	2920.0	92.0	7.3	1.9	187.0	105.0	
4/28/2016	1.5		36.4	2149.2	100.0	7.7	2.1	199.1	107.5	
5/2/2016	2.0	1.50	178.9	4720.0	60.0	7.8	1.197	130.5	87.5	
5/10/2016	11.6	2.95	1203.3	7490.0	44.0	7.6	0.856	93.5	75.0	
5/18/2016	1.2	0.98	107.1	>2419.2	74.0	7.8	1.482	154.5	82.5	
5/26/2016	4.6	1.75	547.5	3640.0	34.0	7.7	0.941	114.1	72.5	
6/2/2016	1.4	1.8	104.6	3410.0	48.0	8.0	1.447	154.8	100.0	
6/7/2016	1.5	1.94	73.8	2980.0	88.0	7.8	1.698	176.8	97.5	
6/15/2016	25.4	0.38	33.2	4740.0	108.0	7.9	2.525	205.0	115.0	
6/22/2016	14.9	0.00	46.4	4570.0	120.0	7.8	2.406	230.0	145.0	
6/29/2016	2.5	0.46	41.3	6310.0	132.0	7.5	2.971	259.0	322.5	
7/6/2016	2.1	0.47	39.3	8570.0	136.0	7.4	2.960	262.0	157.5	

7/13/2016	4.3	1.12	129.6	8390.0	130.0	7.4	2.549	289.0	137.5	
7/20/2016	5.1	3.93			138.0	7.7	2.726	305.0	145.0	
7/27/2016	2.3	1.62	140.8	17260.0	134.0	7.5	2.599	286.0	150.0	
8/3/2016	3.2	3.46	115.3	9320.0	144.0	7.9	1.845	258.0	137.5	
8/16/2016	8.1	2.94	178.2	17820.0	60.0	7.7	1.255	128.9	82.5	
8/24/2016	3.2	0.85	72.8	7030.0	84.0	7.8	1.368	174.8	97.5	
8/24/2016	66.9	5.89					1.152	122.8	97.5	
8/30/2016	1.7	1.19	30.1	5200.0	88.0	7.8	1.435	193.5	97.5	
9/7/2016	25.4	1.39	30.9	4790.0	112.0	7.9	2.143	240.0	125.0	
9/15/2016	2.9	5.38	ND	ND	126.0	7.9	1.918	265.0	137.8	
9/28/2016	1.6	2.15	7120.0	5210.0	124.0	7.8	2.272	281.0	142.2	
10/5/2016	29.3	3.00	547.1	11690.0	122.0	7.8	2.708	288.0	140.0	
10/13/2016	9.6	3.90	4640.0	129970.0		7.6	2.799	258.0	152.5	
10/20/2016	2.1	3.11	387.3	5690.0		7.2	2.791	314.0	157.8	
10/27/2016	2.1	7.91	45.5	6440.0		7.6	2.805	304.0	150.0	
11/3/2016	1.7	6.07	1732.9	5200.0		7.2	3.074	313.0		
11/10/2016	0.7	2.15	22.6	5040.0		7.8	3.330	311.0		
11/17/2016	2.5	1.37	18.5	>2419.2		7.8	3.203	366.0		
11/21/2016	1.3	1.23	26.9	>2419.2		7.8	3.272	139.0		
11/29/2016	4.4	2.11	387.3	7380.0			2.481			
12/14/2016	1.3	2.05	5.2	>2419.2		7.8	**2.597**	206.0		
1/5/2017	1.3	0.55	5.2	1986.3		8.1	**5.692**	220.0		

Date		Notes		Date
9/12/2013		> because turning all cells when undiluted, but dilution coming out too low		9/12/2013
9/20/2013				9/20/2013
9/24/2013		> because turning all cells when undiluted, but dilution coming out too low		9/24/2013
10/1/2013				10/1/2013
10/9/2013				10/9/2013
10/15/2013		moved sample point up river slightly, before large spring flows in		10/15/2013
10/22/2013				10/22/2013
10/31/2013		TN low .023 but below PQL		10/31/2013
11/6/2013				11/6/2013
11/12/2013		TP low .001 but below PQL		11/12/2013
11/19/2013				11/19/2013
11/26/2013				11/26/2013
12/3/2013				12/3/2013
12/17/2013				12/17/2013
1/2/2014		*no bacteria results; WQ tech locked out because lock changed & unable to read results		1/2/2014
1/7/2014				1/7/2014
1/14/2014				1/14/2014
1/21/2014				1/21/2014
1/29/2014		TN low .002, but below PQL		1/29/2014
2/13/2014				2/13/2014
2/19/2014				2/19/2014
2/27/2014				2/27/2014
3/10/2014				3/10/2014

3/18/2014		storm event on 3/16		3/18/2014
3/26/2014				3/26/2014
3/29/2014		storm event on 3/28; no bacteria because samples collected on a Saturday		3/29/2014
4/2/2014				4/2/2014
4/4/2014		storm event on 4/3/14		4/4/2014
4/8/2014		storm event on 4/6/14-4/7/14		4/8/2014
4/14/2014		storm event on 4/13/14		4/14/2014
4/22/2014				4/22/2014
5/1/2014				5/1/2014
5/8/2014				5/8/2014
5/9/2014		storm event on 5/8/14		5/9/2014
5/13/2014		storm event on 5/12/14		5/13/2014
5/19/2014				5/19/2014
5/28/2014		storm event on 5/27/14		5/28/2014
6/5/2014				6/5/2014
6/9/2014		storm events on 6/7/14-6/8/14		6/9/2014
6/19/2014				6/19/2014
6/24/2014		scattered storms 6/21-6/23		6/24/2014
6/27/2014		storm event on 6/25/14		6/27/2014
7/1/2014				7/1/2014
7/7/2014		rain event on 7/7/14		7/7/2014
7/15/2014				7/15/2014
7/18/2014		rain event on 7/17/14		7/18/2014
7/23/2014				7/23/2014
7/25/2014		rain event on 7/23/14		7/25/2014
7/31/2014		rain event on 7/30/14-7/31/14		7/31/2014
8/12/2014				8/12/2014
8/20/2014				8/20/2014
8/26/2014				8/26/2014
9/3/2014		storm event on 9/2/14		9/3/2014

9/11/2014		storm event on 9/10-9/11		9/11/2014
9/18/2014		storm event 9/17-9/18		9/18/2014
9/23/2014				9/23/2014
9/30/2014				9/30/2014
10/8/2014				10/8/2014
10/14/2014		18 samples/7.7 Mgal; rain event on 10/11/14-10/14/14		10/14/2014
10/14/2014				10/14/2014
10/22/2014				10/22/2014
10/30/2014				10/30/2014
11/5/2014		rain event on 11/4/14		11/5/2014
11/12/2014				11/12/2014
11/24/2014		rain event on 11/22/14-11/23/14		11/24/2014
12/4/2014				12/4/2014
12/9/2014		rain event on 12/5/2014		12/9/2014
12/15/2014		rain event on 12/14/14		12/15/2014
12/22/2014				12/22/2014
1/8/2015				1/8/2015
1/14/2015				1/14/2015
1/21/2015				1/21/2015
1/29/2015				1/29/2015
2/3/2015				2/3/2015
2/10/2015				2/10/2015
2/26/2015				2/26/2015

3/3/2015				3/3/2015
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3/25/2015				3/25/2015
3/26/2015				3/26/2015
4/2/2015				4/2/2015
4/9/2015				4/9/2015
4/15/2015				4/15/2015
4/23/2015				4/23/2015
4/29/2015				4/29/2015
5/4/2015				
5/7/2015				5/7/2015
5/8/2015				5/8/2015
5/11/2015				5/11/2015
5/14/2015				5/14/2015
5/18/2015				5/18/2015
5/26/2015				5/26/2015
6/1/2015				
6/8/2015				
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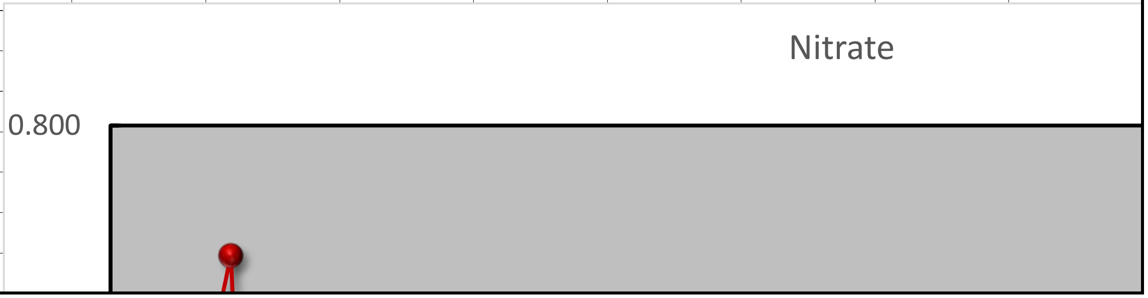
12/14/2016				
1/5/2017				

Date	**Nitrate**											
9/12/2013	0.396											
9/20/2013	0.442											
9/24/2013	0.511											
10/1/2013	0.514											
10/9/2013	0.618											
10/15/2013	0.677											
10/22/2013	0.723											
10/31/2013	0.443											
11/6/2013	0.286											
11/12/2013	0.242											
11/19/2013	0.172											
11/26/2013	0.231											
12/3/2013	0.225											
12/17/2013	0.325											
1/2/2014	0.485											
1/7/2014	0.413											
1/14/2014	0.310											
1/21/2014	0.301											
1/29/2014	0.282											
2/13/2014	0.241											
2/19/2014	0.109											
2/27/2014	0.112											
3/10/2014	0.12											

3/18/2014	0.316
3/26/2014	0.254
3/29/2014	0.125
4/2/2014	0.108
4/4/2014	0.155
4/8/2014	0.170
4/14/2014	0.140
4/22/2014	0.133
5/1/2014	0.119
5/8/2014	0.163
5/9/2014	0.152
5/13/2014	0.133
5/19/2014	0.111
5/28/2014	0.221
6/5/2014	0.219
6/9/2014	0.256
6/19/2014	0.246
6/24/2014	0.245
6/27/2014	0.379
7/1/2014	0.335
7/7/2014	0.398
7/15/2014	0.270
7/18/2014	0.292
7/23/2014	0.280
7/25/2014	0.196
7/31/2014	0.250
8/12/2014	0.232
8/20/2014	0.319
8/26/2014	0.398
9/3/2014	0.500



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9/18/2014	0.523
9/23/2014	0.442
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10/8/2014	0.474
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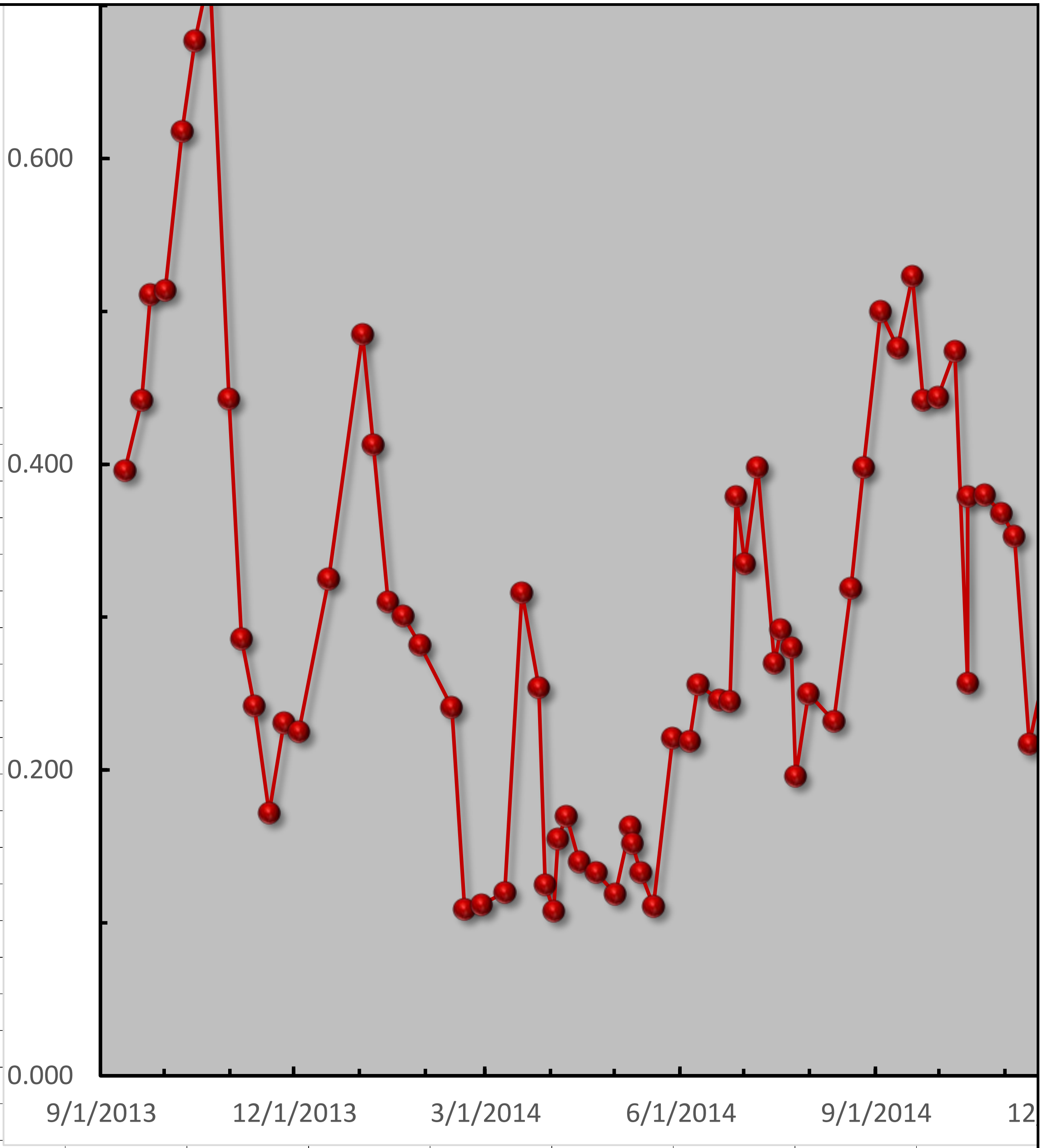
10/14/2014	0.379
10/22/2014	0.380
10/30/2014	0.368
11/5/2014	0.353
11/12/2014	0.217
11/24/2014	0.297
12/4/2014	0.264
12/9/2014	0.179
12/15/2014	0.162
12/22/2014	0.175
1/8/2015	0.376
1/14/2015	0.388
1/21/2015	0.370
1/29/2015	0.168
2/3/2015	0.140
2/10/2015	0.143
2/26/2015	0.200



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3/11/2015	0.209											
3/19/2015	0.234											
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4/2/2015	0.139											
4/9/2015	0.157											
4/15/2015	0.166											
4/23/2015	0.162											
4/29/2015	0.189											
5/4/2015												
5/7/2015	0.267											
5/8/2015	0.292											
5/11/2015	0.071											
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	0.251											
	0.238											
	0.071											
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	0.113											

Date					
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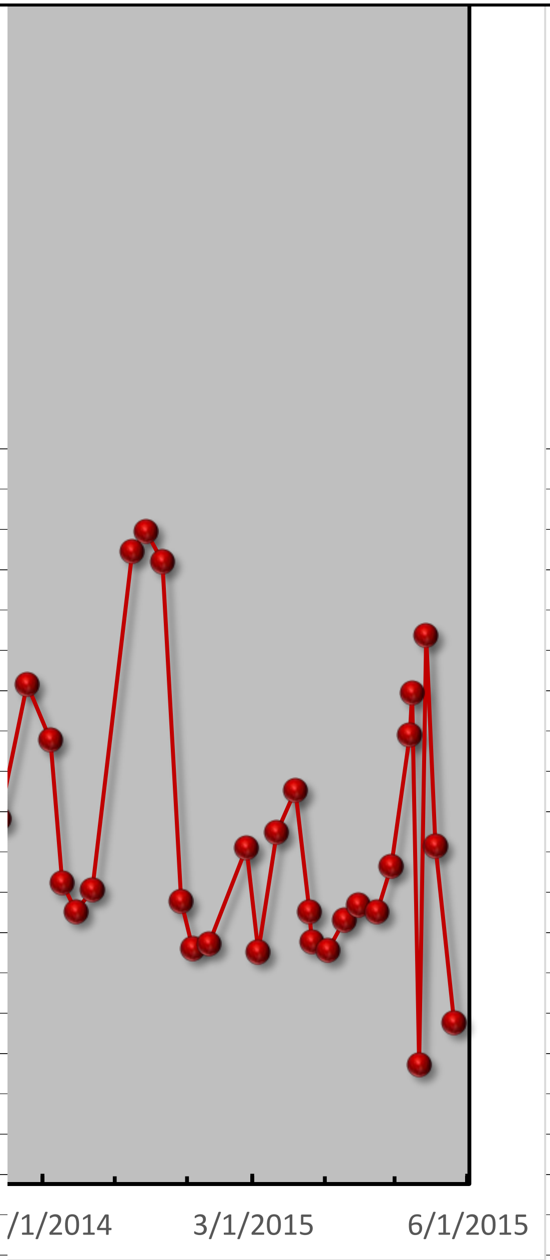

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6/1/2015					
6/8/2015					
6/17/2015					
6/22/2015					
7/7/2015					
7/9/2015					
7/16/2015					
7/23/2015					
7/30/2015					
8/6/2015					
8/13/2015					
8/20/2015					
8/27/2015					
9/2/15					
9/10/15					
9/16/15					

9/24/15					
9/30/15					
10/8/15					
10/14/15					
10/22/15					
10/28/15					
11/4/15					
11/12/15					
11/18/15					
12/2/2015					
12/14/2015					
12/22/2015					
1/5/2016					
1/25/2016					
2/10/2016					
2/24/2016					
3/10/2016					
3/16/2016					
3/24/2016					
3/31/2016					
4/4/2016					
4/20/2016					
4/28/2016					
5/2/2016					
5/10/2016					
5/18/2016					
5/26/2016					
6/2/2016					
6/7/2016					
6/15/2016					
6/22/2016					
6/29/2016					
7/6/2016					

7/13/2016					
7/20/2016					
7/27/2016					
8/3/2016					
8/16/2016					
8/24/2016					
8/24/2016					
8/30/2016					
9/7/2016					
9/15/2016					
9/28/2016					
10/5/2016					
10/13/2016					
10/20/2016					
10/27/2016					
11/3/2016					
11/10/2016					
11/17/2016					
11/21/2016					
11/29/2016					
12/14/2016					
1/5/2017					

Site ID: BC 8

Description: Dry Creek; bridge on NCR 6310 on Dry Creek just upstream of where Dry Creek enters Big Creek

PQL different than what is listed below is in ()

PQLs:
Ammonia = 0.09
E. coli = 1
Total Coliform = 1
Nitrate = 0.01
Ortho P = 0.006
TN = 0.04
TP = 0.01
TSS = 9.2
DOC = 0.2

Date	Time collected	Collected by	Base or storm
11/12/14	10:44	PW	base, grab
11/24/14	12:55	PW	base grab
12/4/14	11:05	PW, TG	base, grab
12/15/14	12:31	PW, TG	storm, grab
12/22/14	12:11		base, grab
1/8/15			n/a
7/30/15	15:20		
8/13/15	15:30		
4/28/16	4/29/2016 15:17		

Ortho P	TP	Ammonia-N	Nitrate-N	TN	TSS	DOC	E. coli
0.011	0.036	0	0.117	0.2	2.7	0.53	7.4
0.015	0.034	0	0.151	0.21	2.3	2.35	7.4
0.012	0.03	0.01	0.167	0.21	0.7	2.3	27.8
0.011	0.03	0.03	0.071	0.15	1.4	1.01	
0.014	0.036	0	0.132	0.18	0.5	1.1	100
0.008	0.020	0.04	0.221	0.37	2.3	2.60	30.3
0.007	0.016	0.03	0.192	0.52	1.4	4.50	13.2
0.010	0.012	0.00	0.152	0.27	1.0		14.8

Total Coliform	Alkalinty	pH	Chloride	Conductivity	total dissolved solids
>2419.2					
1046.2					
1553.1					
			rain event on 12/14/14		
860					
8160.0			3.373	305.0	131.3
4810.0			3.849	272.0	158.2
3050.0	120.0	8.0	2.9	243.0	130.0

Site ID: BC 9

Description: Dry Creek; bridge on NCR 6310 on Dry Creek just upstream of where Dry Creek enters Big Creek

PQL different than what is listed below is in ()

PQLs:

Ammonia = 0.09

E. coli = 1

Total Coliform = 1

Nitrate = 0.01

Ortho P = 0.006

TN = 0.04

TP = 0.01

TSS = 9.2

DOC = 0.2

Date	Time collected	ISCO Collection Date	Ortho P
5/4/2015		Grab	0.008
5/14/2015	12:57	Grab	0.015
5/18/2015	12:29	Grab	0.011
5/26/2015	1:45	Grab	0.014
6/8/2015	1:25	Grab	0.006
6/17/2015	1:01	Grab	0.005
6/22/2015	1:10	Grab	0.011
7/9/2015	1:15	Grab	0.015
7/16/2015	1:03	Grab	0.010
7/23/2015	1:02	Grab	0.009
8/6/2015	12:37	Grab	0.007
8/20/2015	12:04	Grab	0.009
8/27/2015	1:30	Grab	0.008
9/2/2015	12:30	Grab	0.007
9/10/2015	1:10	Grab	0.006
9/16/2015	12:36	Grab	0.006
9/24/2015	12:18	Grab	0.007
9/30/2015	11:42	Grab	0.007
10/8/2015	11:10	Grab	0.003
10/14/2015	11:17	Grab	0.009
10/22/2015	12:05	Grab	0.008
10/28/2015	11:46	Grab	0.007
11/4/2015	11:54	Grab	0.007
11/12/2015	11:54	Grab	0.005
11/18/2015	11:15	Grab	0.020
12/2/2015	11:40	Grab	0.014
12/14/2015	12:20	Grab	0.014
12/22/2015	10:48	Grab	0.013
1/5/2016	11:30	Grab	0.013
1/25/2016	10:48	Grab	0.010
2/10/2016	11:29	Grab	0.003
2/24/2016	10:38	Grab	0.015
3/10/2016	10:38	Grab	0.013

3/16/2016	11:13	Grab	0.009
3/24/2016	11:25	Grab	0.013
3/31/2016	10:33	Grab	0.013
4/4/2016	11:38	Grab	0.009
4/20/2016	11:30	Grab	0.005
5/2/2016	11:24	Grab	0.009
5/10/2016	10:35	Grab	0.011
5/18/2016	10:57	Grab	0.010
5/26/2016	11:20	Grab	0.010
6/2/2016	10:52	Grab	0.007
6/7/2016	10:50	Grab	0.009
6/15/2016	11:15	Grab	0.009
6/22/2016	10:08	Grab	0.008
6/29/2016	10:25	Grab	0.006
7/6/2016	6:08	Grab	0.006
7/13/2016	7:15	Grab	0.005
7/20/2016	7:25	Grab	0.005
7/27/2016	7:02	Grab	0.004
8/3/2016	7:28	Grab	0.007
8/16/2016	10:28	Grab	0.012
8/24/2016	10:40	Grab	0.004
8/30/2016	11:00	Grab	0.005
9/7/2016	7:23	Grab	0.006
9/15/2016	10:32	Grab	0.011
9/28/2016	11:00	Grab	0.006
10/5/2016	9:54	Grab	0.009
10/13/2016	10:16	Grab	0.091
10/20/2016	10:20	Grab	0.008
10/27/2016	10:27	Grab	0.008
11/3/2016	9:14	Grab	0.004
11/10/2016	10:18	Grab	0.005
11/17/2016	10:20	Grab	0.005
11/21/2016	9:40	Grab	0.004
11/29/2016	11:20	Grab	0.004
12/14/2016	10:45	Grab	0.007
1/5/2017		Grab	0.006

TP	Ammonia-N	Nitrate-N	TN	TSS	DOC	E. coli	Total Coliform
0.022	0.00	0.145	0.19	2.1	3.15	38.9	2560.0
0.038	0.02	0.321	0.38	3.3	1.36	83.3	2690.0
0.040	0.04	0.209	0.29	4.1	1.90	167.4	8300.0
0.048	0.04	0.139	0.29	6.1	2.41	344.8	8880.0
0.024	0.02	0.102	0.23	1.1	2.78	32.7	4550.0
0.026	0.04	0.112	0.22	2.8	1.62	26.2	8550.0
0.030	0.02	0.147	0.18	2.5	1.59	35.4	5910.0
0.058	0.04	0.138	0.31	11.4	2.67	387.3	12670.0
0.042	0.01	0.181	0.28	0.9	1.64	21.6	9330.0
0.028	0.04	0.239	0.40	1.4	1.21	35.4	8360.0
0.026	0.04	0.310	0.47	1.2	3.16	217.8	8130.0
0.028	0.04	0.306	0.42	2.3	5.12	48.8	3930.0
0.024	0.02	0.218	0.33	2	3.79	7.4	3010
0.020	0.03	0.109	0.33	1.67	3.8	26.9	5290.0
0.026	0.00	0.198	0.34	4.09	2.5	21.6	7230.0
0.032	0.00	0.146	0.48	2.49	1.3	38.2	6333.0
0.016	0.01	0.098	0.20	3.08	0.6	31.3	3410.0
0.018	0.00	0.082	0.20	4.98	1.2	18.3	5940.0
0.020	0.02	0.069	0.15	1.5	1.58	59.8	3640.0
0.022	0.01	0.078	0.16	2.2	1.28	9.8	1986.3
0.018	0.00	0.069	0.13	1.9	3.57	3.1	1732.9
0.024	0.02	0.060	0.24	1.9	2.90	61.3	3410.0
0.018	0.00	0.072	0.18	0.7	3.98	77.6	>2419.2
0.016	0.00	0.215	0.34	1.1	2.50	25.6	3360.0
0.062	0.08	0.432	0.73	7.4	3.72	686.7	23590.0
0.024	0.01	0.302	0.43	1.6	1.36	66.9	1986.3
0.056	0.06	0.298	0.50	10.8	3.92	410.6	6010.0
0.020	0.00	0.267	0.35	0.1	1.36	26.5	1299.7
0.028	0.00	0.427	0.48	0.7	1.51	34.1	686.7
0.024	0.00	0.198	0.25	1.0	1.30	21.1	435.2
0.012	0.00	0.175	0.24	0.8	1.15	7.4	209.8
0.088	0.00	0.249	0.63	15.6	5.07	2780.0	14390.0
0.046	0.01	0.15	0.38	8.7	2.64	367.3	2750.0

0.032	0.00	0.19	0.26	0.3	1.45	35.9	980.4
0.048	0.09	0.186	0.39	10.7	2.65		
0.056	0.09	0.199	0.40	11.9	2.59	172.0	3640.0
0.022	0.00	0.131	0.17	1.5	0.87	44.8	1119.9
0.020	0.00	0.157	0.21	2.1	0.84	35.0	6160.0
0.020	0.00	0.095	0.20	1.9	2.30	172.6	3640.0
0.072	0.02	0.121	0.37	17.2	3.35	980.4	8230.0
0.016	0.01	0.139	0.27	1.4	1.54	60.1	2620.0
0.048	0.02	0.123	0.24	10.6	2.66	461.1	6890.0
0.022	0.00	0.117	0.22	1.4	1.40	44.1	1986.3
0.016	0.04	0.124	0.19	0.8	2.08	31.8	3180.0
0.012	0.01	0.198	0.29	2.0	0.94	63.1	8860.0
0.018	0.05	0.220	0.37	2.1	0.70	37.9	676.0
0.023	0.03	0.251	0.35	2.0	0.94	23.5	5200.0
0.02	0.04	0.271	0.36	2.7	0.96	248.1	12590.0
0.017	0.00	0.172	0.29	1.9	0.85	95.9	12360.0
0.013	0.00	0.197	0.76	2.3	2.21		
0.021	0.00	0.255	0.35	3.6	1.79	920.8	15000.0
0.016	0.00	0.212	0.32	2.4	2.21	101.4	7430.0
0.082	0.07	0.118	0.30	19.5	3.64	201.4	14550.0
0.013	0.00	0.045	0.13	1.5	1.62	43.5	6690.0
0.021	0.02	0.157	0.28	2.7	2.00	111.2	17850.0
0.021	0.00	0.151	0.24	2.8	1.58	27.5	10170.0
0.014	0.01	0.132	0.25	2.2	5.35		
0.011	0.02	0.101	0.22	1.8	1.31	2530.0	3410.0
0.023	0.01	0.130	0.29	2.8	2.38	285.1	17820.0
0.203	0.04	1.071	1.74	24.2	9.30	14010.0	>241920.0
0.026	0.01	0.146	0.27	1.3	3.95	33.5	17890.0
0.016	0.02	0.132	0.26	1.9	7.76	48.8	9340.0
0.026	0.03	0.117	0.26	1.5	9.24	33.1	7380.0
0.013	0.01	0.161	0.23	4.1	2.07	7.4	2560.0
0.011	0.00	0.195	0.26	0.5	1.77	15.8	2400.0
0.011	0.01	0.239	0.31	0.4	3.35	11.9	2419.2
0.014	0.00	0.191	0.28	1.1	1.97	57.6	>2419.2
0.017	0.02	0.144	0.21	0.9	3.77	13.4	2419.2
0.011	0.03	0.229	0.26	0.7	0.85	6.2	1732.9

Alkalinity	pH	Chloride	Conductivty	Total dissolved soilds
		2.433	231.0	126.9
		2.073	212.0	118.2
		1.960	201.0	109.6
		1.840	196.3	113.8
		2.785	264.0	166.0
		2.576	252.0	136.0
		1.982	220.0	115.8
		1.984	193.7	119.8
		2.548	281.0	160.0
		3.037	307.0	123.8
		3.721	272.0	162.0
		3.897	279.0	147.3
		3.546	281	154.4
		3.732	285.0	150.2
		4.121	273.0	147.1
		5.830	289.0	159.1
		4.141	286.0	163.8
		3.826	287.0	163.0
		3.865	295.0	154.3
		4.622	318.0	159.5
		4.370	292.0	150.0
		4.451	296.0	146.8
		4.922	296.0	140.5
		3.389	326.0	161.8
		1.920	172.5	102.2
		2.443	171.4	124.4
		1.680	129.3	102.5
92.0	8.1	2.712	211.0	107.5
85.0	7.6	2.552	209.0	115.0
96.0	8.3	2.7	235.0	120.0
112.0	8.3	3.045	246.0	122.5
80.0	7.5	2.045	188.3	122.1
76.0	8.0	1.952	179.7	105.0

126.0	7.5	2.086	194.5	110.0
100.0	7.6	2.833	233.0	121.5
66.0	7.5	1.479	136.3	60.0
90.0	7.6	1.8	184.6	105.0
114.0	7.7	2.7	235.0	130.0
90.0	8.0	1.606	187.4	100.0
66.0	7.8	1.157	137.4	102.5
102.0	8.0	2.000	211.0	117.5
52.0	7.7	1.526	166.0	97.5
104.0	8.0	2.208	219.0	130.0
108.0	8.0	2.206	239.0	130.0
126.0	7.9	2.022	247.0	125.0
130.0	8.0	3.166	260.0	162.5
134.0	7.8	3.885	264.0	150.0
136.0	7.6	3.429	268.0	157.5
		3.219	451.0	150.0
138.0	7.8	3.104	287.0	155.0
132.0	7.7	3.369	274.0	155.0
122.0	7.8	2.828	308.0	160.0
96.0	7.9	1.509	196.5	122.5
112.0	8.0	1.636	239.0	132.5
130.0	7.9	1.869	193.5	135.0
130.0	8.0	2.604	288.0	152.5
130.0	7.9	2.341	280.0	153.3
130.0	8.0	2.546	293.0	148.9
124.0	7.9	3.036	287.0	140
	7.7	3.351	224.0	162.5
	7.3	3.877	340.0	168.9
	7.5	3.767	326.0	172.5
	7.1	3.866	326.0	
	7.9	4.183	323.0	
	7.9	4.04	371.0	
	7.8	4.092	362.0	
		2.801		
	7.8	3.117	242	
	8.4	3.803	247	

Site: 4	Date	Time collected	Base or storm	Ortho P	TP	Ammonia-N	Nitrate-N	TN
Description: Upstream of barn, where NCR 6335 bridge crosses Big Creek, downstream of bridge	9/12/2013	11:15	base	0.010	0.032	0.05	0.356	0.54
Coordinates:	9/20/2013	11:40	after rain	0.015	0.024	0.04	0.356	0.42
4a 35° 55' 34" N 93° 3' 55" W	9/24/2013	11:00	base	0.007	0.024	0.00	0.330	0.41
4b 35° 54' 57" N 93° 3' 56" W	10/1/2013	10:15	base	0.006	0.032	0.03	0.235	0.40
PQL different than what is listed below is in ()	10/9/2013	9:45	base	0.016	0.030	0.00	0.385	0.53
PQLs:	10/15/2013	12:47	storm high flow	0.019	0.036	0.06	0.839	0.99
Ammonia = 0.01	10/22/2013	10:45	storm	0.016	0.024	0.03	0.575	0.60
E. coli = 1	10/31/2013	10:15	base	0.007	0.044	0.04	0.246	0.38
Total Coliform = 1	11/6/2013	9:10	base	0.020	0.038	0.00	0.184	0.27
Nitrate = 0.03	11/12/2013	12:15	base	0.012	0.014	0.09	0.221	0.33
Ortho P = 0.01	11/19/2013	10:05	base	0.011	0.028	0.00	0.175	0.32
TN = 0.03	11/26/2013	11:06	base	0.014	0.016	0.00	0.190	0.20
TP = 0.01	12/3/2013	9:00	base	0.009	0.012	0.00	0.210	0.28
TSS = 7.5	12/17/2013	10:10	after snow melt	0.011	0.032	0.02	0.379	0.48
DOC = 0.6	1/2/2014	11:10	base	0.012	0.024	0.00	0.437	0.47
	1/7/2014	10:30	base	0.017	0.022	0.00	0.363	0.43
	1/14/2014	11:50	base	0.008	0.030	0.03	0.211	0.73
	1/21/2014	8:20	base	0.010	0.010	0.01	0.211	0.28
	1/29/2014	10:30	base	0.007	0.024	0.01	0.195	0.24
	2/13/2014	8:40	base	0.011	0.014	0.00	0.135	0.23
	2/19/2014	9:30	base	0.009	0.018	0.00	0.070	0.15
	2/27/2014	11:40	base	0.008	0.016	0.00	0.084	0.11
Some PQLs are different starting on this date	3/10/2014	11:40	base/snow melt	0.007	0.020	0.04	0.096	0.13
PQLs:	3/18/2014	12:20	storm	0.012	0.040	0.04	0.238	0.76
Ammonia = 0.09	3/26/2014	10:32	base	0.011	0.024	0.00	0.170	0.22
E. coli = 1	3/29/2014	9:50	storm, grab	0.007	0.036	0.00	0.087	0.16
Total Coliform = 1	4/2/2014	10:21	base, grab	0.012	0.028	0.00	0.075	0.11

Nitrate = 0.01	4/4/2014	9:30	storm, grab	0.013	0.044	0.04	0.084	0.21
Ortho P = 0.006	4/8/2014	9:58	storm, grab	0.012	0.024	0.02	0.103	0.16
TN = 0.04	4/14/2014	10:38	storm, grab	0.009	0.040	0.06	0.111	0.19
TP = 0.01	4/22/2014	10:10	base, grab	0.009	0.022	0.01	0.092	0.10
TSS = 9.2	5/1/2014	10:19	base, grab	0.007	0.014	0.04	0.096	0.10
DOC = 0.2	5/8/2014	12:53	base, grab	0.008	0.016	0.01	0.121	0.14
	5/9/2014	11:22	storm, grab	0.008	0.020	0.06	0.102	0.10
	5/13/2014	10:05	storm, grab	0.008	0.074	0.06	0.113	0.30
	5/19/2014	1:10	base, grab	0.008	0.020	0.00	0.000	0.10
	5/28/2014	10:13	storm, grab	0.007	0.020	0.03	0.154	0.14
	6/9/2014	9:34	storm, grab	0.006	0.034	0.00	0.213	0.31
	6/19/2014	9:24	base, grab	0.009	0.026	0.10	0.180	0.25
	6/24/2014	10:17	storm, grab	0.010	0.052	0.04	0.228	0.30
	6/27/2014	10:10	storm, grab	0.017	0.026	0.02	0.248	0.29
	7/1/2014	10:22	base, grab	0.011	0.024	0.02	0.296	0.36
	7/7/2014	9:38	storm, grab	0.013	0.040	0.00	0.322	0.33
	7/15/2014	10:10	base, grab	0.013	0.048	0.04	0.245	0.34
	7/18/2014	12:42	storm, grab	0.013	0.028	0.03	0.249	0.25
	7/23/2014	10:53	base, grab	0.018	0.026	0.04	0.217	0.21
	7/25/2014	10:39	storm, grab	0.012	0.034	0.04	0.134	0.19
	7/31/2014	10:29	storm, grab	0.016	0.022	0.06	0.195	0.32
	8/12/2014	10:21	base, grab	0.015	0.024	0.01	0.162	0.18
	8/20/2014	10:39	base, grab	0.015	0.030	0.00	0.229	0.22
Site went dry 8/26/14; Started flowing again after rain event on 10/11/14-10/14/14	10/13/2014	9:51	storm, grab	0.060	0.230	0.18	0.197	0.63
	10/22/2014	10:46	base, grab	0.009	0.022	0.00	0.236	0.26
Streambed manipulation began around the week of September 15, 2014, upstream and downstream of the NC 6335 bridge across Big Creek.	10/30/2014	11:22	base, grab	0.005	0.014	0	0.122	0.16
	11/5/2014	9:41	storm, grab	0.013	0.018	0	0.191	0.23
	11/12/2014	10:29	base, grab	0.008	0.034	0.01	0.304	0.52

	11/24/2014	9:46	storm, grab	0.01	0.01	0	0.129	0.18
	12/4/2014	10:56	base, grab	0.011	0.022	0	0.128	0.17
	12/9/2014	10:17	base, grab	0.012	0.026	0	0.122	0.2
	12/15/2014	12:22	storm, grab	0.019	0.028	0.02	0.065	0.15

Site: 4	TSS	DOC	E. coli	Total Coliform					
Description: Upstream of barn, where NCR 6335 bridge crosses Big Creek, downstream of bridge	5.8		4.1	4040.0					
Coordinates:	1.2		1203.3	26130.0					
4a 35° 55' 34" N 93° 3' 55" W	1.6		42.0	>2419.6					
4b 35° 54' 57" N 93° 3' 56" W	6.7		81.6	5200.0					
PQL different than what is listed below is in ()	6.2		193.5	4730.0					
PQLs:	2.1		472.0	8664.0					
Ammonia = 0.01	1.2		410.6	11190.0					
E. coli = 1	2.3		261.3	6310.0					
Total Coliform = 1	2.5		579.4	13330.0					
Nitrate = 0.03	1.4		36.4	1732.9					
Ortho P = 0.01	0.3		172.3	>2419.2					
TN = 0.03	0.7		248.9	1986.3					
TP = 0.01	0.3		29.2	547.5					
TSS = 7.5	0.7		157.6	>2419.2					
DOC = 0.6	0.3		*	*					
	0.3		24.3	344.8					
	0.9		238.2	920.8					
	0.3		51.2	488.4					
	0.0	2.10	28.2	290.9					
	0.9	9.10	31.4	260.2					
	0.5	0.10	45.5	235.9					
	0.3	1.2	14.8	160.7					
Some PQLs are different starting on this date	1.3	1.3 (0.6)	59.4	547.5					
PQLs:	3.1	1.2	63.7	648.8					
Ammonia = 0.09	0.5	0.5	48.7	579.4					
E. coli = 1	1.5	2.3	--	--					
Total Coliform = 1	0.7	1.4	12.1	1732.1					

Nitrate = 0.01	5.2	2.6	--	--					
Ortho P = 0.006	2.1	1.2	179.3	1299.7					
TN = 0.04	5.0	3.1	517.2	2980.0					
TP = 0.01	0.8	0.5	95.9	>2419.2					
TSS = 9.2	2.2	0.4	73.8	4310.0					
DOC = 0.2	1.4	0.9	34.1	5760.0					
	2.0	0.7	--	--					
	11.8	5.7	1046.2	15290.0					
	1.5	0.5	95.9	4710.0					
	1.9	0.7	198.9	12660.0					
	3.9	2.66	1119.9	29870.0					
	0.1	0.40	49.6	5120.0					
	30.1	2.45	17270.0	1046.2					
	3.5	0.54	--	--					
	2.1	0.78	78.5	22420.0					
	3.7	0.67	2419.2	48840.0					
	7.8	1.98	1119.9	26130.0					
	2.1	0.68	--	--					
	1.8	1.08	344.8	5540.0					
	2.7	1.31	--	--					
	0.8	0.75	461.1	10710					
	1.5	0.28	83.0	2419.2					
	3.5	0.32	12.1	2310.0					
Site went dry 8/26/14; Started flowing again after rain event on 10/11/14-10/14/14	0.8	3.10	15530.0	241920.0					
	0.5	0.66	200.0	3180.0					
Streambed manipulation began around the week of September 15, 2014, upstream and downstream of the NC 6335 bridge across Big Creek.	2.3	0.49	28.8	2720					
	0.6	0.68	201.4	6130					
	3.9	0.73	64.4	1986.3					

	1.5	2.61	20.1	1986.3					
	0.7	1.79	8.5	2419.2					
	1.1	1.79	<1.0	1850					
	1.9	1.85							

Site: 5	Date	Time collected	Base or storm	Ortho P	TP	Ammonia-N	Nitrate-N	TN	TSS
Description: Downstream of barn, across field	9/12/2013	11:50	base	0.019	0.026	0.05	0.632	0.78	1.2
Coordinates:	9/20/2013	12:20	after rain	0.024	0.032	0.06	0.757	0.85	1.3
35° 56' 1" N 93° 4' 21" W	9/24/2013	12:20	base	0.017	0.032	1.77	0.790	0.82	0.7
PQL different than what is listed below is in ()	10/1/2013	10:35	base	0.018	0.032	0.00	0.837	0.92	1.1
PQLs:	10/9/2013	10:00	base	0.017	0.020	0.00	0.868	0.89	0.4
Ammonia = 0.01	10/15/2013	13:13	storm high flow	0.033	0.244	0.12	1.280	1.44	89.2
E. coli = 1	10/22/2013	11:00	storm	0.016	0.022	0.00	0.786	0.77	0.1
Total Coliform = 1	10/31/2013	10:00	base	0.018	0.022	0.11	0.519	0.66	0.9
Nitrate = 0.03	11/6/2013	9:45	base	0.040	0.164	0.12	0.413	0.67	32.9
Ortho P = 0.01	11/12/2013	13:03	base	0.012	0.012	0.00	0.295	0.34	0.5
TN = 0.03	11/19/2013	10:35	base	0.011	0.028	0.00	0.231	0.34	0.5
TP = 0.01	11/26/2013	11:30	base	0.014	0.018	0.03	0.300	0.33	1.3
TSS = 7.5	12/3/2013	9:15	base	0.010	0.018	0.00	0.295	0.35	0.6
DOC = 0.6	12/17/2013	10:30	after snow melt	0.008	0.032	0.03	0.393	0.50	1.6
	1/2/2014	11:25	base	0.012	0.024	0.00	0.543	0.58	0.8
	1/7/2014	10:50	base	0.015	0.022	0.00	0.497	0.54	1.1
	1/14/2014	12:50	base	0.008	0.028	0.02	0.332	0.43	0.5
	1/21/2014	8:45	base	0.011	0.012	0.01	0.339	0.45	1.0
	Decided to quit sampling this site								

Site: 5	DOC	E. coli	Total Coliform		
Description: Downstream of barn, across field		1.0	488.4		
Coordinates:		218.7	2430.0		
35° 56' 1" N 93° 4' 21" W		41.7	816.4		
PQL different than what is listed below is in ()		18.5	648.8		
PQLs:		29.2	1986.3		
Ammonia = 0.01		959.0	12997.0		
E. coli = 1		150.0	2419.2		
Total Coliform = 1		13.5	218.7		
Nitrate = 0.03		3180.0	36090.0		
Ortho P = 0.01		21.1	1046.2		
TN = 0.03		238.2	2419.2		
TP = 0.01		39.9	613.1		
TSS = 7.5		248.1	686.7		
DOC = 0.6		127.4	2419.2		
		*	*		
		21.1	290.9		
		156.5	1119.9		
		49.6	249.9		

Site ID: W1

Description: House/barn well

PQL different than what is listed below is in ()

PQLs:
Ammonia = 0.09
E. coli = 1
Total Coliform = 1
Nitrate = 0.01
Ortho P = 0.006
TN = 0.04
TP = 0.01
TSS = 9.2
DOC = 0.2

Well was turned off at the sampling location since 10/30/2014

Discontinue grab until well is turned
Well turned on 3/19/2005

Date	Time collected	Ortho P	TP
4/2/2014	9:30	0.014	0.024
4/2/2014	9:30	0.014	0.020
4/22/2014	11:00	0.008	0.022
5/1/2014	10:49	0.012	0.012
5/8/2014	12:34	0.008	0.010
5/13/2014	10:13	0.008	0.020
5/19/2014	12:46	0.011	0.016
5/28/2014	10:35	0.009	0.012
6/5/2014	11:37	0.008	0.028
6/9/2014	9:54	0.005	0.016
6/19/2014	9:32	0.009	0.028
6/24/2014	10:47	0.006	0.036
7/1/2014	11:18	0.009	0.006
7/7/2014	9:51	0.007	0.020
7/15/2014	10:46	0.009	0.012
7/23/2014	11:19	0.013	0.016
8/12/2014	10:37	0.009	0.020
8/20/2014	10:53	0.010	0.020
8/26/2014	11:56	0.008	0.022
9/3/2014	10:40	0.011	0.008
9/11/2014	12:43	0.006	0.010
9/18/2014	11:06	0.009	0.014
9/23/2014	12:27	0.006	0.018
9/30/2014	11:10	0.007	0.012
10/8/2014	11:01	0.006	0.018
10/13/2014	11:00	0.005	0.016
10/22/2014	11:11	0.007	0.016
11/24/2014	9:53	0.01	0.014
3/19/2015	11:13	0.009	0.020
3/25/2015	12:20	0.007	0.016
4/2/2015	12:48	0.008	0.030
4/9/2015	12:00	0.011	0.026
4/15/2015	11:58	0.008	0.022
4/23/2015	11:35	0.008	0.082
4/29/2015	11:23	0.010	0.006
5/4/2015		0.012	0.022
5/7/2015	11:23	0.008	0.022

5/11/2015	12:15	0.009	0.038
5/18/2015	11:20	0.008	0.018
5/26/2015	12:43	0.013	0.020
6/8/2015	11:36	0.008	0.018
6/17/2015	11:47	0.010	0.028
6/22/2015	10:45	0.010	0.032
7/9/2015	12:07	0.011	0.024
7/16/2015	12:28	0.012	0.024
7/23/2015	12:23	0.015	0.030
7/30/2015	11:58	0.013	0.014
8/6/2015	10:37	0.010	0.018
8/13/2015	11:53	0.025	0.012
8/20/2015	10:52	0.012	0.018
8/27/2015	12:20	0.012	0.018
9/2/2015	11:30	0.012	0.016
9/10/2015	11:56	0.010	0.018
9/16/2015	11:52	0.009	0.020
9/24/2015	11:19	0.009	0.012
9/30/2015	12:43	0.009	0.016
10/8/2015	12:15	0.008	0.020
10/14/2015	12:10	0.012	0.020
10/22/2015	1:10	0.010	0.014
10/28/2015	12:55	0.008	0.016
11/4/2015	12:41	0.010	0.016
11/12/2015	12:42	0.009	0.012
11/18/2015	12:50	0.009	0.014
12/2/2015	1:38	0.011	0.014
12/14/2015	1:38	0.011	0.010
12/22/2015	12:25	0.010	0.016
1/5/2016	12:44	0.008	0.020
1/25/2016	11:42	0.012	0.020
2/10/2016	12:03	0.007	0.014
2/24/2016	11:53	0.010	1.000
3/10/2016	12:03	0.011	0.020
3/16/2016	12:22	0.009	0.022
3/24/2016	12:34	0.012	0.014
3/31/2016	11:49	0.010	0.018
4/4/2016	12:35	0.011	0.018
4/20/2016	12:52	0.005	0.014
4/28/2016	12:31	0.011	0.008
5/2/2016	1:27	0.009	0.016
5/10/2016	12:08	0.009	0.008
5/18/2016	12:50	0.009	0.010
5/26/2016	12:51	0.009	0.012
6/2/2016	12:06	0.008	0.018
6/7/2016	12:00	0.011	0.014

	6/15/2016	12:15	0.008	0.008
	6/22/2016	11:38	0.009	0.008
	6/29/2016	11:12	0.008	0.014
	7/6/2016	7:18	0.009	0.013
	7/13/2016	8:34	0.005	0.011
	7/20/2016	8:30	0.007	0.009
	7/27/2016	8:14	0.006	0.010
Well Off 8/3/2016				
	10/13/2016		0.008	0.010
	10/20/2016		0.009	0.020
	10/27/2016		0.009	0.010
	11/3/2016		0.004	0.010
	11/10/2016		0.005	0.009
	11/17/2016	11:10	0.006	0.010
	11/21/2016	10:40	0.007	0.011
	11/29/2016	12:36	0.004	0.011
	12/14/2016	11:30	0.010	0.014
	1/5/2017	12:47	0.008	0.014

Ammonia-N	Nitrate-N	TN	TSS	DOC	E. coli	Total Coliform	Alkalinity	pH
0.00	0.500	0.50	0.1	0.8	7.5	117.2		
0.04	0.498	0.49	0.3	0.7	--	--		
0.00	0.494	0.55	0.3	0.0	9.8	770.1		
0.08	0.467	0.52	0.7	0.5	<1	116.9		
0.18	0.440	0.68	0.3	1.4	<1	<1		
0.06	0.458	0.49	0.5	0.5	<1	18.9		
0.03	0.489	0.49	0.2	0.4	11.0	123.6		
0.06	0.495	0.51	0.1	0.3	<1	<1		
0.12	0.444	0.59	0.0	1.4	<1	<1		
0.14	0.501	0.57	0.2	0.90	<1	<1		
0.06	0.442	0.57	0.0	0.33	<1	<1		
0.03	0.504	0.53	0.2	0.61	<1	<1		
0.22	0.446	0.67	0.4	0.80	<1.0	<1		
0.11	0.483	0.57	0.2	0.50	<1	<1		
0.08	0.476	0.60	0.4	0.70	<1.0	<1		
0.26	0.469	0.67	0.2	0.70	<1.0	<1		
0.20	0.418	0.62	0.5	0.35	<1.0	<1		
0.15	0.412	0.61	0.3	0.28	<1.0	<1		
0.26	0.378	0.66	0.4	0.18	<1.0	<1		
0.17	0.475	0.68	2.9	0.02	56.3	59.1		
0.00	0.495	0.52	0.3	0.00	<1.0	<1		
0.01	0.494	0.52	0.0	0.00	35.0	6940		
0.00	0.494	0.53	0.5	0.33	8.5	866.4		
0.00	0.501	0.56	0.3	0.17	2.0	43.5		
0.03	0.486	0.54	1.1	0.19	1.0	69.1		
0.00	0.496	0.56	0.3	0.23	28.1	2750		
0.00	0.497	0.5	0.2	0.24	5.2	81.3		
0	0.452	0.57	1.9	2.81	<1.0	5.2		
0.02	0.467	0.55	1.2	4.93	1.0	31.1		
0.00	0.450	0.52	1.9	0.29	18.5	30.1		
0.00	0.477	0.50	0.7	6.05	39.3	9060.0		
0.00	0.499	0.50	1.5	0.74	4.1	325.5		
0.02	0.475	0.60	1.2	3.72	9.6	80.9		
0.00	0.496	0.53	1.4	1.69	18.5	35.0		
0.00	0.517	0.51	0.7	2.26	248.1	5040.0		
0.02	0.561	0.52	1.3	6.07	<1.0	14.6		
0.01	0.512	0.49	0.0	2.86	3.1	59.4		

0.02	0.541	0.55	4.2	0.89				
0.00	0.529	0.53	0.9	0.90	5.2	13.4		
0.00	0.514		2.7	0.87	9.5	2419.2		
0.27	0.475	0.82	0.7	6.67	<1.0	<1		
0.03	0.466	0.52	0.06	3.08	488.4	15390.0		
0.02	0.459	0.43	0.4	1.85	27.2	1732.9		
0.01	0.423	0.48	2.0	1.69	9.8	4160.0		
0.01	0.471	0.47	0.0	4.00	2.0	727.0		
0.00	0.442	0.52	1.0	0.89	8.5	35.0		
0.02	0.466	0.51	0.3	0.90	1.0	7.4		
0.04	0.482	0.52	0.5	3.33	920.8	21870.0		
0.03	0.498	0.58	0.5	6.15	4.1	228.2		
0.00	0.545	0.56	0.9	6.63	1.0	29.5		
0	0.599	0.61	1.6	3.66	1	61.3		
0.00	0.607	0.64	2.72	1.9	110.6	14210.0		
0.00	0.576	0.60	3.21	0.3	8.6	727.0		
0.00	0.559	0.60	2.58	0.2	1.0	148.3		
0.00	0.543	0.58	7.72	0.3	<1.0	24.6		
0.00	0.499	0.60	4.20	0.5	<1.0	2.0		
0.02	0.518	0.53	0.5	1.54	<1.0	<1		
0.00	0.490	0.63	0.3	0.94	<1.0	<1		
0.04	0.478	0.50	0.4	1.93	<1.0	2.0		
0.01	0.391	0.54	0.0	2.40	<1.0	<1		
0.00	0.468	0.54	0.0	2.62	<1.0	<1		
0.00	0.501	0.55	0.3	3.71	<1.0	<1		
0.00	0.464	0.59	0.4	0.48	<1.0	<1		
0.02	0.480	0.60	0.9	1.38	1.0	1.0		
0.00	0.545	0.57	0.1	10.15	<1.0	1.0		
0.00	0.534	0.59	0.3	1.40	<1.0	<1.0		
0.00	0.528	0.57	0.9	1.08	<1.0	1.0		
0.00	0.602	0.55	0.5	2.36	<1.0	<1		
0.00	0.542	0.56	0.1	0.63	<1.0	<1.0		
0.00	0.582	0.55	1.3	2.63	<1.0	<1.0		
0.02	0.56	0.59	0.9	1.19	<1.0	<1.0		
0.00	0.55	0.55	0.0	1.55	<1.0	<1		
0.00	0.565	0.65	0.2	2.72				
0.00	0.556	0.62	0.2	3.93	1.0	26.2		
0.00	0.466	0.48	0.0	0.94	<1.0	1.0		
0.00	0.598	0.50	0.5	0.47	1.0	1.0		
0.00	0.481	0.57	0.3		<1.0	<1		
0.00	0.551	0.56	0.1	1.94	<1.0	<1		
0.00	0.533	0.56	0.5	4.39	<1.0	24.9		
0.00	0.488	0.64	0.4	0.95	<1.0	<1.0		
0.00	0.564	0.57	0.7	0.93	1.0	7.4		
0.00	0.597	0.62	0.7	0.99	<1.0	<1.0		
0.03	0.500	0.58	0.1	3.06	<1.0	<1.0		

0.00	0.506	0.59	0.7	0.00	<1.0	<1.0	
0.00	0.545	0.58	0.5	0.00	<1.0	<1.0	
0.00	0.569	0.56	0.0	0.23	<1.0	<1.0	
0.00	0.874	0.96	1.0	0.73	<1.0	13.5	
0.00	0.627	0.63	0.5	0.09	<1.0	<1.0	
0.02	0.594	0.70	0.1	0.14			
0.00	0.650	0.67	0.1	1.41	<1.0	<1.0	
0.01	1.166	1.23	0.6	1.35	<1.0	23.3	
0.02	0.739	0.79	0.1	4.56	<1.0	19.7	7.6
0.01	0.664	0.74	0.9	8.95	<1.0	5.2	7.9
0.02	0.719	0.75	0.4	9.48	1.0	2.0	7.6
0.00	0.574	0.68	0.1	2.16	<1.0	1.0	7.6
0.01	0.660	0.71	0.3	1.57	<1.0	1.0	7.6
0.00	0.675	0.75	0.4	1.37	<1.0	<1.0	7.5
0.00	0.598	0.68	0.4	2.67	<1.0	<1.0	
0.03	0.678	0.7	0.3	6.19	<1.0	<1.0	7.4
0.04	0.610	0.66	0.3	0.3	<1.0	<1.0	7.8

Chloride	Conductivty	Total dissolved soilds
4.79	458	232.2
5.27	453	221.6
4.91	453	256.0
5.10	419	242.2
5.02	426	240.9
4.83	414	237.3
4.96	436	226.4
5.08	458	243.6
5.10	452	238.2

5.19	484	234.7
4.82	481	178.0
5.02	488	249.6
7.09	437	246.4
5.13	493	234.0
5.17	481	240.2
5.86	481	240.7
5.38	495	254.9
5.42	481	234.0
5.85	499	251.8
5.74	449	233.8
4.89	448	240.0
4.65	427	234.0
4.81	441	245.1
4.989	465.0	239.8
5.206	447.0	233.3
4.878	448.0	236.2
5.191	448.0	236.8
7.307	446.0	236.3
5.782	455.0	250.3
5.235	461.0	230.0
5.845	453.0	241.0
4.837	456.0	234.0
5.159	455.0	239.3
5.590	458.0	237.0
4.657	458.0	231.1
5.557	422.0	253.3
4.545	460.0	245.0
5.455	458.0	242.5
4.855	439	215.0
5.278	462	242.5
5.273	468	215.0
5.237	447	242.5
5.366	458	237.5
4.993	482	240.0
5.265	484	219.0
5.023	409	220.0
4.735	414	210.0
5.475	417	227.5
4.671	417	247.5
5.316	441	237.5
5.234	411	237.5
4.450	420	232.5
5.649	426	220.0
5.450	409	182.5
4.670	416	220.0

4.394	414	242.5
5.173	424	260.0
5.557	432	172.5
5.811	391	237.5
5.021	561	220.0
5.561	447	230.0
5.230	467	227.5
6.988	476.0	245
6.421	495.0	244.4
6.132	501.0	142.5
5.560	479.0	
5.858	473.0	
5.655	544.0	
5.576	209.0	
5.721		
5.365	411.0	
5.371	421	

Site ID: T1

Description: Lagoon trench; T1 is south end pipe

PQL different than what is listed below is in ()

PQLs:
Ammonia = 0.09
E. coli = 1

Total Coliform = 1
Nitrate = 0.01
Ortho P = 0.006
TN = 0.04
TP = 0.01
TSS = 9.2
DOC = 0.2

Date	Time collected	Ortho P	TP
8/22/2014	14:06	0.007	0.008
9/4/2014	11:36	0.004	0.003
9/11/2014	12:35	0.001	0.018
10/13/2014	11:15	0.000	0.024
11/5/2014	10:25	0.004	0.012
12/22/2014	11:45	0.005	0.018
1/8/2015	12:00	0.005	0.022
1/14/2015	12:40	0.005	0.012
1/21/2015			
1/29/2015			
2/3/2015			
2/10/2015			
2/26/2015	11:15	0.004	0.028
3/3/2015	11:30	0.003	0.024
3/11/2015	12:10	0.003	0.014
3/19/2015	11:30	0.003	0.012
3/25/2015	12:30	0.003	0.008
3/26/2015	12:55	0.004	0.026
4/2/2015	12:54	0.003	0.028
4/9/2015	12:10	0.006	0.018
4/15/2015	12:10	0.003	0.020
4/23/2015	11:48	0.003	0.034
5/11/2015	12:25	0.003	0.060
5/14/2015	12:05	0.005	0.042
5/18/2015	12:55	0.002	0.020
5/26/2015	12:55	0.007	0.012
6/22/2015	10:30	0.005	0.048
7/9/2015	12:00	0.007	0.030
11/18/2015	12:28	0.005	0.030
12/2/2015	12:48	0.006	0.008
12/14/2015	1:30	0.004	0.012
12/22/2015	12:14	0.005	0.010
1/5/2016	12:13	0.003	0.016
2/24/2016	11:36	0.005	0.014
3/10/2016	11:50	0.005	0.036
3/16/2016	12:01	0.003	0.032
3/24/2016	12:20	0.008	0.016
3/31/2016	11:40	0.004	0.018
5/10/2016	11:55	0.002	0.016

5/18/2016	12:05	0.006	0.006
5/26/2016	12:38	0.008	0.006
6/2/2016	11:35	0.002	0.018
8/16/2016	11:40	0.005	0.006
8/24/2016	12:05	0.000	0.019

Ammonia-N	Nitrate-N	TN	TSS	DOC	E. coli	Total Coliform	Alkalinity	pH
0.00	0.523	0.69	5.7	1.79	--	--		
0.04	0.937	1.22	3.7	0.68	--	--		
0.03	1.580	1.86	1.0	0.54	1.0	57940		
0.00	1.251	1.46	71.4	0.83	15650.0	61310		
0.02	1.54	1.67	0.9	0.37				
0.00	0.881	0.83	6.1	1.09	<1.0	630		
0.00	0.769	0.75	4.7	0.88	1	13130		
0.01	0.658	0.63	0.5	0.45	<1.0	727		
0.01	0.712	0.76	46.0	0.60	<1.0	41063.0		
0.00	0.867	0.89	14.9	0.95	ND	ND		
0.07	0.989	0.97	0.3	2.00	<1.0	>2419.2		
0.01	0.849	0.93	0.0	3.11	1.0	275.5		
0.00	0.838	0.88	0.2	0.59	<1.0	410.6		
0.02	0.904	1.00	15.4	0.69	<1.0	1553.1		
0.02	0.865	0.87	0.3	3.34	1.1	308.6		
0.00	0.790	0.83	0.8	2.99	<1.0	187.2		
0.00	0.857	0.93	1.3	4.29	<1.0	3180.0		
0.00	0.877	0.97	1.2	1.18	3.1	2690.0		
0.02	0.916	0.97	27.6	1.78				
0.02	0.904	0.94	29.9	1.20	81.6	1732.9		
0.00	0.897	0.93	0.3	1.28	32.3	1732.9		
0.01	0.752	0.90	1.0	0.78	272.3	11060.0		
0.07	0.653	0.76	47.3	1.86	21.1	1986.3		
0.00	0.520	0.62	7.1	2.52	63.7	12330.0		
0.02	0.264	0.52	1.9	1.74	65.7	17930.0		
0.00	0.218	0.33	1.3	1.10	6.3	5810.0		
0.00	0.299	0.36	1.1	3.44	8.4	10460.0		
0.00	0.157	0.20	0.3	0.89	1.0	435.2		
0.00	0.243	0.29	0.9	1.11	1.0	209.8		
0.00	0.345	0.39	2.1	1.53	<1.0	9070.0		
0.10	0.26	0.45	3.5	2.87	2419.2	16690.0		
0.02	0.33	0.37	0.0	1.23	101.7	290.9		
0.00	0.208	0.20	2.8	1.33				
0.00	0.347	0.49	5.5	4.76	4.1	2419.2		
0.00	0.228	0.30	3.9	2.91	13.9	>2419.2		

0.00	0.169	0.22	0.1	0.54	2.0	5200.0		
0.00	0.217	0.23	1.4	1.29	1.0	4260.0		
0.00	0.124	0.30	8.8	3.01	26.5	393.0		
0.02	0.130	0.17	0.2	2.14	93.4	48840.0		
0.03	0.033	0.30	8.3	1.99	21.8	3450.0		

Chloride	Conductivty	Total dissolved soilds
2.01	154	103.6
2.81	166	81.8
2.08	171	78.4
2.11	177	86.7
1.95	193	114.0
1.70	209	109.3
2.13	238	105.1
1.64	209	120.2
1.94	261	151.3
1.99	260	154.0
1.80	260	146.7
2.06	231	132.7
2.09	262	126.5
1.86	299	156.5
1.57	346	173.1
1.65	297	146.0
1.99	341	169.8
2.63	342	167.8
1.147	151.9	86.7
1.471	162.0	108.9
1.593	157.2	92.5
1.695	179.5	95.0
1.605	160.9	82.5
1.163	162.2	102.5
1.019	173.7	117.5
1.451	226.0	120.0
1.732	229.0	99.0
1.280	167.9	100.0
1.122	226.0	130.0

1.653	234.0	125.0
1.421	262.0	142.5
1.229	320	192.5
2.051	293	130.0
1.259	318	170.0

Site ID: T2

Description: Lagoon trench; T2 is north end pipe

PQL different than what is listed below is in ()

PQLs:

Ammonia = 0.09

E. coli = 1

Total Coliform = 1

Nitrate = 0.01

Ortho P = 0.006

TN = 0.04

TP = 0.01

TSS = 9.2

DOC = 0.2

Date	Time collected	Ortho P	TP	Ammonia-N
9/11/2014	12:29	0.000	0.010	0.03
10/13/2014	11:10	0.001	0.116	0.33
11/5/2014	10:14	0.004	0.032	0.03
3/11/2015	12:15	0.003	0.056	0.04
3/19/2015	11:35	0.004	0.062	0.09
3/26/2015	12:50	0.004	0.126	0.13
5/11/2015	12:35	0.003	0.042	0.05
5/26/2015	1:00	0.007	0.112	0.04
12/14/2015		0.003	0.026	0.10
2/24/2016		0.005	0.066	0.13
3/10/2016	11:46	0.005	0.054	0.14
3/31/2016	11:35	0.006	0.040	0.06
4/4/2016	12:26	0.004	0.012	0.00
5/10/2016	11:45	0.002	0.038	0.00
5/26/2016		0.003	0.034	0.00
8/16/2016	11:50	0.004	0.036	0.05

Nitrate-N	TN	TSS	DOC	E. coli	Total Coliform	Alkalinity	pH	Chloride
2.033	2.31	3.2	0.70	81.3	27,550.0			
1.714	2.73	11.1	4.14	920.8	>241920			
3.375	3.65	33.1	0.87					
1.443	1.59	1.2	3.51	<1.0	>2419.2			1.77
1.036	1.42	1.9	5.12	5.2	>2419.2			1.04
0.873	1.44	22.2	4.63	105.4	6,950.0			0.78
0.553	0.76	8.8	3.44					0.41
1.190		131.9	1.23	69.7	>2419.2			0.93
6.473	7.40	1.6	5.56	33.6	29,090.0			1.001
6.298	7.02	9.7	4.27	30.1	18,720.0			0.992
1.72	2.35	6.8	6.77	613.1	34,480.0			0.349
2.800	3.54	20.9	9.29	7.4	10,810.0			0.424
0.236	0.25	0.0	0.85	1.0	>2419.2			1.4
1.706	2.18	5.2	3.72	38.7	1,553,310.0			0.405
0.832	1.14	2.6	3.81	816.4	198,630.0			0.359
0.344	0.99	1.5	8.98	290.9	198630.0			0.597

Conductivty	Total dissolved soilds
159	140.8
168	104.9
135	160.9
165	88.5
284	141.3
148.2	110.0
143.6	122.5
106.8	80.0
134.5	87.5
192.1	107.5
196.5	115.0
220.0	115.0
219	117.5

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ORIGINAL ARTICLE

Characterization of the karst hydrogeology of the Boone Formation in Big Creek Valley near Mt. Judea, Arkansas—documenting the close relation of groundwater and surface water

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Abstract The Boone Formation has been generalized as a karst aquifer throughout northern Arkansas, although it is an impure limestone. Because the formation contains from 50 to 70 % insoluble chert, it is typically covered with a mantle of regolith, rocky clay, and soil which infills and masks its internal fast-flow pathways within the limestone facies. This paper describes continuous monitoring of precipitation, water levels in wells, and water levels in streams (stream stage) in Big Creek Valley upstream from its confluence with the Buffalo National River to characterize the nearly identical timing response of relevant components of the hydrologic budget and to clearly establish the karstic nature of this formation. Although the complete hydrographs of streams and wells are not identical in the study area, lag time between precipitation onset and water-level response in wells and streams is rapid and essentially indistinguishable from one another. The spikey nature of the stream hydrographs reflects low storage, high transmissivity, and rapid draining of the upper zones of the karst aquifer, whereas the longer-term, plateau-like draining in the lower zones reflects groundwater perching on chert layers that feed low-yield springs and seeps through lower storage and lower permeability flow paths. Groundwater drainage to thin terrace and alluvial deposits with intermediate hydraulic attributes overlying the Boone Formation also shows rapid drainage to Big Creek, consistent with karst hydrogeology, but with high precipitation peaks retarded by slower recession in the alluvial and terrace deposits as the stream peaks move downstream.

Keywords Mantled karst · Concentrated animal feeding operations · Buffalo National River · Ozarks · Lag time · Hydrologic budget

Introduction

The Boone Formation (hereafter referred to as the Boone) occurs throughout northern Arkansas with a physiographic range approximating that of the Springfield Plateau (Fig. 1). Although this geologic unit encompasses about 35 % of the land area of the northern two tiers of Arkansas counties, site-specific details of its hydrogeology are only generally understood, and its water-transmitting capacity and its ability to attenuate contamination have not been well documented other than to reference the entire area as a mantled karst (Aley 1988; Aley and Aley 1989; Imes and Emmett 1994; Adamski et al. 1995; Funkhouser et al. 1999; Braden and Ausbrooks 2003; Mott 2003; Hobza et al. 2005; Leh et al. 2008; Gouzie et al. 2010; Brahana 2011; Kosic et al. 2015). Given this general consensus, there exists a claim by some that lack of obvious karst topography at air-photo scales and map resolutions is evidence that karst in the outcrop of the Boone does not exist.

The Boone is a relatively thick unit (about 110 m) with variable lithology, including limestone, chert, and thin shaley limestone layers. The soluble limestone of the Boone contrasts with the highly insoluble, brittle chert,

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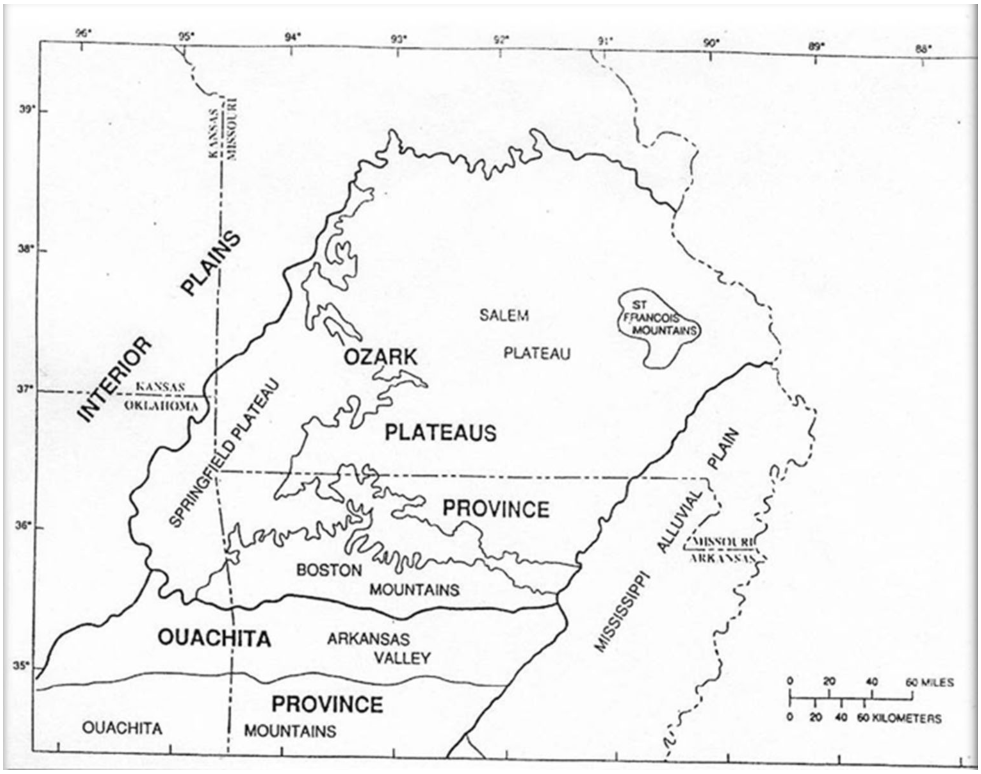


Fig. 1 Location of the Springfield Plateau physiographic province on the southern and northwestern margins of the Ozark Plateaus, midcontinent USA

which can occupy as much as 70 % of the entire thickness of this formation. For the most part, the Boone contains no less than 50 % chert, except in its upper and lower pure limestone measures (Liner 1979). The Boone is nearly flat-lying, and has numerous, interbedded limestone layers forming couplets with thin, areally continuous chert layers through much of its middle and lower sections (Fig. 2). Brittle fracturing, a result of about 200 m of total uplift in the distal, far-field of the Ouachita orogeny has allowed groundwater to chemically weather and karstify the formation (Liner 1978; Hudson 2000; Brahana 2012).

The physical attributes of the chert at a regional scale provide near-uniform thickness (Fig. 3), but in the field under close, non-magnified inspection, contact boundaries between the chert and limestone reflect thickening and thinning that one would expect in soft, non-indurated sediment, typically on the order of several centimeters, whereas individual chert layers typically extend continuously for kilometers with approximately similar thickness; different layers can be thinner than 5 cm, and as thick as 30 cm. The low permeability of the chert results in segregation and vertical isolation of parts of the groundwater flow system, which typically has been developed only in the limestone layers where the rock has been dissolved and karstified. The systematic orthogonal jointing resulting from the uplift and the long duration of weathering near the land surface are responsible for introduction of aggressive recharge and dissolution.

A significant land-use change occurred in 2013 that involved the permitting and construction of a concentrated animal feeding operation (CAFO) near Big Creek, slightly more than 10 km upstream from the Buffalo National River near the town of Mt. Judea, Arkansas. The CAFO, a 6500-head facility for farrowing sows and piglets, was permitted to be constructed on the Boone Formation. In addition to the large structures housing the swine, two lagoons approximately one acre each were included as temporary holding facilities for urine, feces, wash water from the operation, and about 600 acres of pasture land for spreading the waste were also approved; all on land underlain by the Boone Formation, or in the valleys with thin alluvial deposits directly overlying the Boone (Fig. 4; Braden and Ausbrooks 2003).

The CAFO permitting process, approved by the Arkansas Department of Environmental Quality (ADEQ), did not include any study of groundwater or study of karst, and many landowners living in Big Creek Valley and many more who use the shallow Boone aquifer for stock and domestic water supply and the Buffalo National River to canoe, kayak, fish and to swim were concerned about the risk for similar environmental and water-quality problems occurring on this river that had occurred elsewhere (Funkhouser et al. 1999; Varnell and Brahana 2003; Palmer 2007; Gurian-Sherman 2008; Brahana et al. 2014; Kosic et al. 2015). The waste generated from 6500 hogs at a facility of this size exceeds more than 2 million gallons per

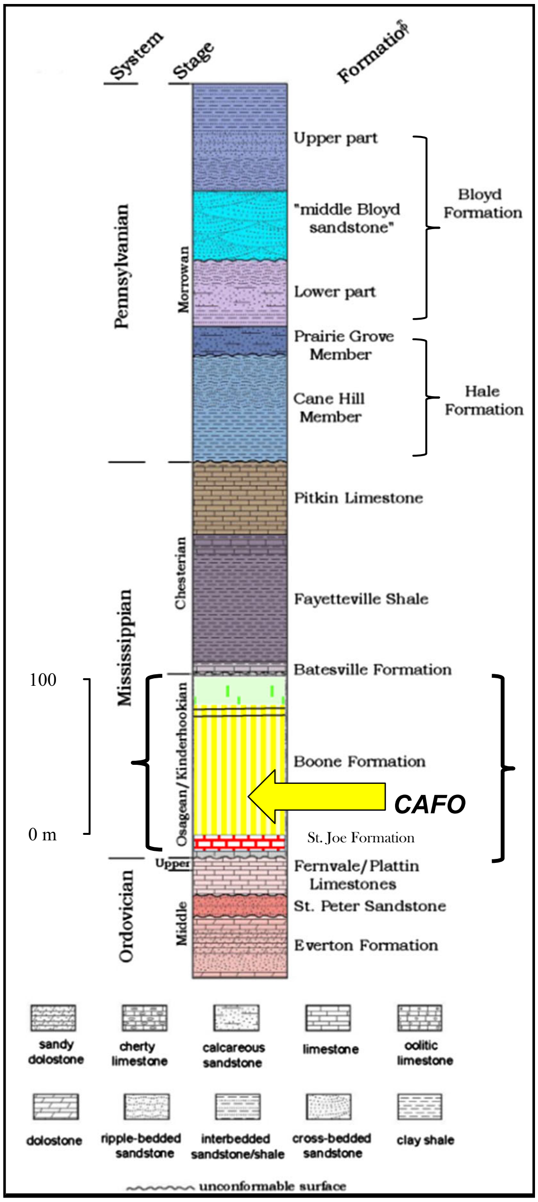


Fig. 2 Stratigraphy in the vicinity of Big Creek and Mt. Judea, in Newton County, Arkansas, showing geologic formations exposed in Big Creek Valley, a major tributary to the Buffalo National River. Emphasis in this research is on the Boone Formation, and particularly the chert-rich interval bracketed and highlighted in *yellow* directly beneath the relatively pure limestone and oolitic facies (Short Creek Oolite) highlighted in *green*, and directly overlying the relatively pure limestone of the lowermost 10 m (St. Joe Formation) shown in *red*. The CAFO and its waste-spreading fields mostly lie within the lower half of the Boone Formation, which in Big Creek Valley may be overlain directly by creek alluvium and terrace deposits

year, requiring that the waste be continually removed to avoid overfilling the waste lagoons (Pesta 2012). Pig feces and urine spread on pasture land overlying karst has generated significant concern that the CAFO will create health problems for the many tourists who utilize the river, as well as many of the downstream landowners who use the groundwater for domestic and stock water supplies. Canoeists are particularly concerned because much of the drainage area of Big Creek has been karstified, which means that contaminated water with concentrated pig waste can move rapidly underground with little or no attenuation, and resurface in Big Creek or springs that drain the spreading fields that lie along the Buffalo. Insofar as the swimmers, fishermen, and canoeists cannot escape primary contact with this river, which has been classified as an Extraordinary Resource Waters (ERW), this research was undertaken as part of a sequence of karst hydrogeologic studies to fill in the gaps that were not addressed in the original permitting and approval process.

Purpose and scope

The objective of this report is to investigate the relation of the groundwater and surface water in Big Creek and Left Fork of Big Creek drainages by comparing continuous, long-term responses of water levels in wells and in Big Creek and Left Fork of Big Creek in response to precipitation in the study area. The underlying justification is to determine the time difference (lag time) between precipitation on the land surface and the rise of hydraulic head in wells and the rise in stream stage. Fast flow and coincidence of lag time in wells and surface water in response to precipitation events are key indicators of underlying karst hydrogeology and document the justification that the wells shown represent useful sites for the introduction of fluorescent dyes to trace groundwater movement and document groundwater velocity in the Boone aquifer in the study area. The geographic scope of this paper is limited to the area atop a 6500-head factory pig CAFO, including the waste-storage lagoons, the structures housing the pigs, and the spreading fields where waste from the lagoons is applied on the land surface (Fig. 4).

Study area

The south and north boundaries of this study extend from an east–west line slightly upstream (south) of the spreading fields to downstream where an east–west line intersects the confluence of Left Fork of Big Creek and Big Creek (Fig. 4). The eastern boundary of the study area is the upper contact of the Batesville Sandstone with the Fayetteville Shale on the eastern side of Big Creek Valley, and the western boundary is the upper contact of the Batesville Sandstone with the Fayetteville Shale on the western side of Big Creek Valley (Fig. 4).

Geologic setting

The rock formations exposed at land surface in Big Creek basin are Paleozoic sedimentary rocks, with lithologies that

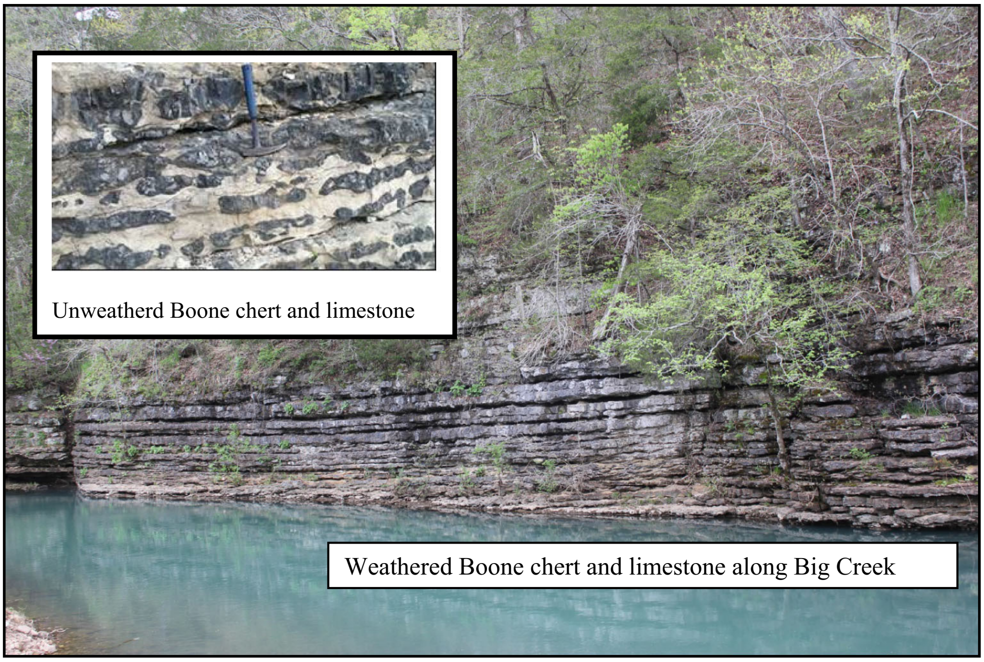
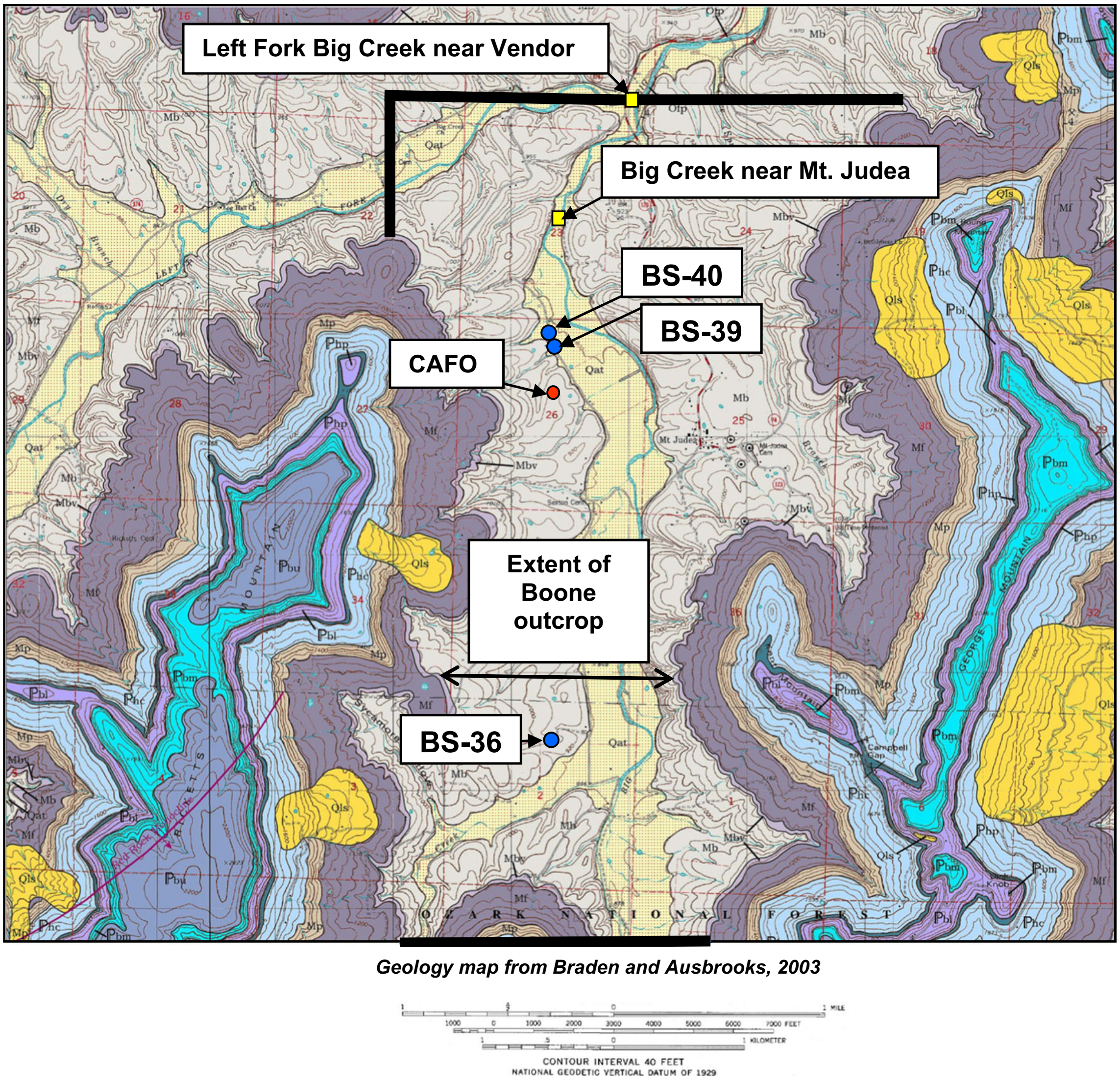


Fig. 3 Dissolution within limestone layers of the chert/limestone couplets creates an effective mantled karst in the middle to lower part of the Boone Formation in Big Creek and throughout northern Arkansas. Groundwater moving along these bedding planes has been measured by dye tracing to travel about 500–800 m per day under natural hydraulic gradients, with little or no attenuation of contaminants. The photo *inset* in the *upper left corner* shows unweathered *light gray* limestone separated between *dark gray* chert layers

range from terrigenous shales and sandstones that cap the hills and ridges in the upper part of the valley near the topographic divides to relatively pure carbonates near the confluence of Big Creek with the Buffalo National River (Fig. 2). Stratigraphically, these rocks encompass slightly less than 600 m, from the Upper Bloyd sandstones of Pennsylvanian age to the Everton Formation of Ordovician age (Braden and Ausbrooks 2003). These rocks were deposited in a range of different environments. For the Boone Formation, the interval of greatest interest to this study, the environments of deposition were mostly very shallow to deep water marine, for the St. Joe Formation. The recurring sequence of limestone and chert as couplets is thought to be derived from periodic expulsion of volcanic ash that was deposited on a very shallow marine carbonate-rock forming platform. Volcanoes are thought to have expelled the ash from south of the exposed core of the Ouachita Mountains, where the northern part of the South American plate subducted beneath the North American plate. When volcanism and ash production were intense, areal deposition of ash over broad regions of a shallow ocean overwhelmed carbonate production (which never ceased), generating the siliceous material that formed the chert. When the volcanoes were quiescent, carbonate production proceeded unimpeded, and limestone sediments were produced. Lithification, induration, and diagenesis produced rocks from the sediment, and uplift, fracturing, and weathering eroded the rocks into the landscape we see today, leaving the rock record seen now in the stratigraphic column (Fig. 2).

Oblique plate closure of the Ouachita orogeny from east to west resulted in approximately 200 m of uplift in the study area (Hudson 2000), reflected in the higher elevations occurrence of stratigraphic intervals in Newton County (Fanning 1994), and the requirement for rappeling into caves overlying some of the deep basement faults in the region that would otherwise be horizontal entrances further east or west (Fanning 1994; Tennyson et al. 2008). Most of the tectonic grain of the region is nearly flat-lying, with large-scale structures such as monoclines grading into faults being the only common feature, and brittle fractures, joints, and faults being the most common deformation types. Dips throughout most of this part of the region are less than 3°, except near major faults, where dips as large as 7°–10° may be found (Hudson 2000).

Physiographically, the chert in the Boone facilitates the formation of an undulating plateau surface, which extends across northern Arkansas from east to west. The outcrop pattern widens and curves back toward the northeast to form a prominent plateau (Fig. 1) named for Springfield, Missouri. Although the geologic nomenclature changes as one crosses the state line from Arkansas into Missouri (Boone becomes Burlington, Keokuk, and Elsie Formations), the lithologies remain the same. Whole-rock percentage of chert declines from south to north, and the continuity of the thin chert layers ceases, with the



Geology map from Braden and Ausbrooks, 2003

Fig. 4 Areal geology of the study area, showing wells (*blue* and *red circles*), stream gaging stations (*red squares*), and boundaries of the area under discussion (*black bars* on the north, northwest, and south margins). Precipitation gages were installed at BS-36 and Big Creek near Mt. Judea. The Boone Formation is shown on the map in gray with Mb symbols. This study was not granted access to the CAFO "House Wells". *Notes* [Qat, Alluvium and terrace deposits along Big Creek and Left Fork of Big Creek; Mf, Fayetteville Shale; Mbv, Batesville Formation; Mb, Boone Formation; Other geologic units (labeled M and P as first letter are younger geologic units beyond the scope of this study). Qat directly overlies the Boone Formation in the valleys and is in direct hydrogeologic connection with the Boone.]

dominance of discontinuous chert nodules along bedding planes being more prevalent in Missouri rather than continuous chert layers, which are dominant in Arkansas.

Methodology

The approach to measuring and documenting the precise timing of water-level response of groundwater and stream levels in response to precipitation follows the hydrologic methodology of the U.S. Geological Survey (Straub and Parmar 1998; Sauer and Turnipseed 2010). Water level in surface water is called stream stage, which is a measure of the depth of the stream at a resistant rock layer, a "control" that lies within the stream bed and is difficult to erode. Typically, the physical determination for a wide range of variable flow conditions of a stream is measured using Doppler flow methods, and these are compared with stage to create a stage–discharge relation. For this study, the interest is strictly in the water level in the stream, and its timing as compared to hydraulic-head response and timing in the wells.

Stream stage in this study is drawn from two surface-water stations measured by the U.S. Geological Survey, Site 07055790, Big Creek near Mt. Judea, Arkansas, and Site 07055792, Left Fork of Big Creek near Vendor,

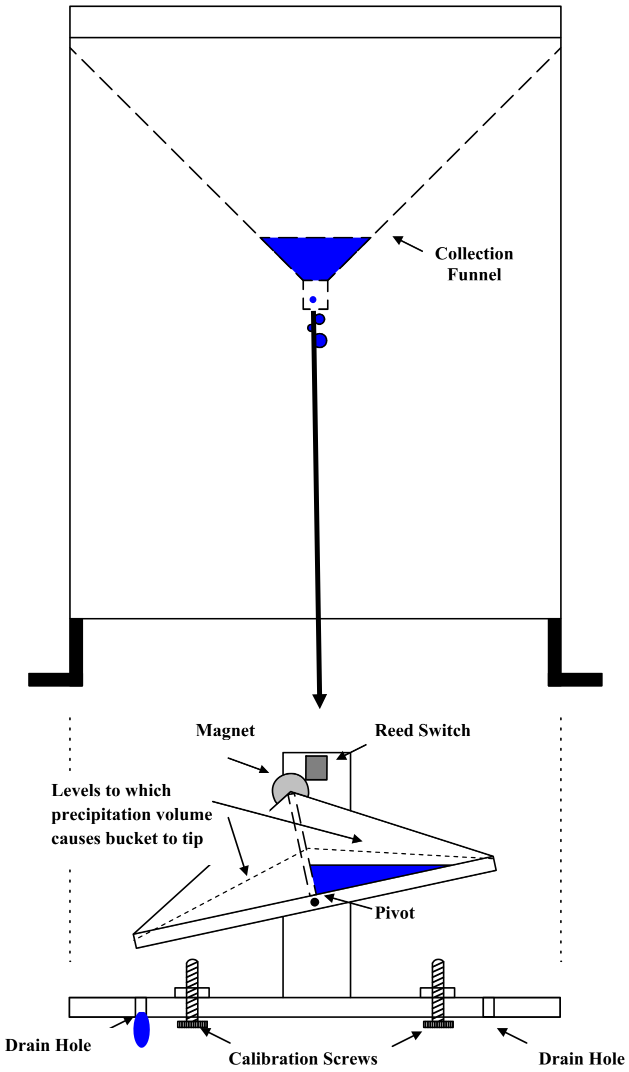


Fig. 5 Internal schematic showing the operation of the tipping-bucket portion of the rain gage, which is centered beneath a narrow funnel (beneath *blue* water drop at the *top of the figure*). When the rainfall reaches 0.04 mm (0.01 inch) of rain, the weight causes the rocker arm to pivot, moving the magnet past the reed switch, which is recorded to the nearest second by cable to the Campbell CR 10× data recorder (Fig. 6). A summation of the number of tips provides the magnitude of the precipitation event, and the time interval provides the duration of the event from start to finish. Data are downloaded from the data recorder to a laptop computer in the field, and processed with data downloaded from transducers which are installed below the water level in wells, and the stream-stage records, which are measured in time increments of every 5 min

Arkansas. In the case of surface-water station Site 07055790, Big Creek near Mt. Judea (Fig. 4), the control is composed of chert in the lower Boone. In the case of surface-water station Site 07055792, Left Fork of Big Creek near Vendor (Fig. 4), the control is the St. Joe Formation (Fig. 2), a relatively pure limestone (Big Creek Research and Extension Team 2015).

Fig. 6 Pressure transducer, which measures the height of the water column above the pressure sensor, shown by the *red arrow* on the left side of the figure above. This field instrument is also equipped with a temperature thermistor, which measures the temperature of the groundwater. Under most conditions, the transducer is hung vertically in the well by a cable through the cap, identified by the *green arrow*. Water level and temperature data are stored internally in the instrument at a predetermined time interval, typically every 5 min. Data are downloaded periodically by removing the instrument from the well, unscrewing the water-tight cap and connecting it to an optical reader interface attached to a field laptop. Once downloading is complete, the instrument is reset, reinstalled in the well, and the water level is measured with an electric tape to verify the exact water level. The entire process is documented in a field notebook to facilitate data interpretation

Precipitation, which in the study area is dominantly rainfall, was measured at well BS-36 using a tipping-bucket rain gage (Texas Electronics Model TE 525), an electronic weather station with a very accurate clock and a fulcrum-balanced seesaw arrangement of two small buckets on either side of the pivot (Fig. 5). The two buckets are manufactured within accurate tolerances to ensure that they hold an exact amount of precipitation, typically 0.24 mm. The tipping-bucket assembly is located underneath the rain collector, which funnels the precipitation vertically downward to the buckets. As rainfall fills one bucket, it becomes unbalanced and tips down, emptying itself as the other bucket pivots into place for the next filling. The action of each tipping event moves a magnet past a switch, activating the electronic circuitry to transmit the count of the number of tips to a digital datalogger (Campbell CR 10×),

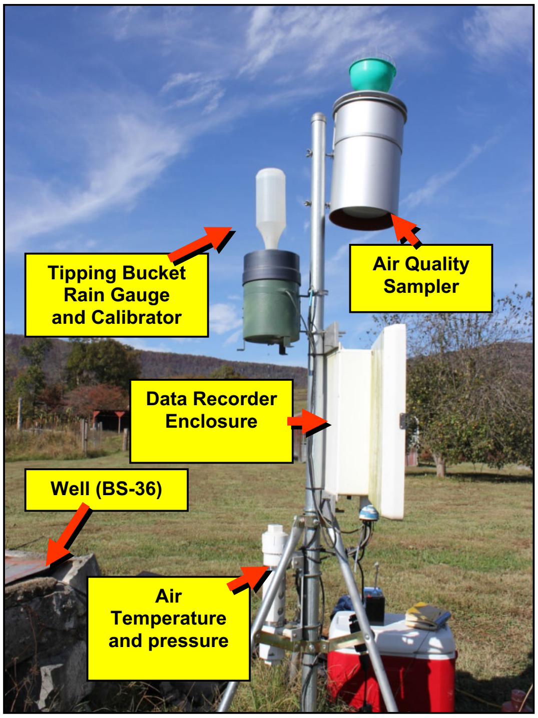


Fig. 7 Data collection equipment at BS-36, a site that is surrounded on three sides by spreading fields that receive waste from the hog CAFO. The instruments used in this research measure rainfall intensity and duration (tipping-bucket rain gage), and air temperature and pressure, which is used to calibrate the transducer which measures changes in the water level in well BS-36 in response to rainfall. The transducer is not shown in this image, but the data it collects are electronically transmitted to the data recorder every 15 min, and these data are plotted with the exact timing and amount of the rain. Data are stored digitally in the recorder, which is locked inside the enclosure which is shown. The air quality sampler is part of another experiment, and those data are not discussed in this research. Connections to the transducer are made by cable down the inside of the well. Figure 6 shows the view down the well

recording each event as 0.25 mm of rainfall with an accurate time. Rainfall data from the datalogger were totaled for the same 15-min interval as stream stage and hydraulic-head data from the transducers.

The design and accurate functioning requires that the rain gage be level, accomplished by centering a bubble level. Calibration of the rain gage to 0.24 mm per bucket tip was accomplished using the Novalynx Corporation model 260-2595 Rain Gage Calibrator following the Texas Electronics field calibration method. Replication of precipitation accuracy involved utilizing two rain gages in the basin reported by the U.S. Geological Survey (http://waterdata.usgs.gov/ar/nwis/rt).

Hydraulic head (groundwater level) and temperature were measured using transducers (Fig. 6) at the three groundwater sites within the study area (Fig. 4), but temperature data were not available for the streamflow or precipitation sites. Although temperature data can be very important in groundwater and spring characterization studies, the missing temperature records from the stream and precipitation data were considered to be ancillary to this study and are thus not discussed. Site details for the wells, BS-36 (Figs. 7, 8, 9), BS-39 (Fig. 10), and BS-40 (Fig. 11), reflect well construction, well dimensions, and equipment placement within each well. Transducers record the pressure exerted by the weight of the water above their sensor, using a non-vented water-level logger encapsulated in a polypropylene housing and placed below the water surface in wells. The logger, a HOBO U20L-004 is a research-grade instrument manufactured by Onset Computer Corporation and was used to continuously measure and record water level and temperature with a 0.1 % measurement accuracy. A second identical device was secured at land surface (Fig. 7) to measure air pressure and temperature; parameters necessary for correcting the effect of air pressure changes to compute the precise hydraulic head of the groundwater in the well. Post-processing of the groundwater data allowed for matching the hydraulic head of the groundwater with the precipitation data, which in turn were time synchronized with the USGS stream-stage data.

Fig. 8 View looking down well BS-36, which shows the groundwater reflected as a bright spot of light at a depth of 10.15 m below the top of the well. Cables and wires allow data to be communicated from below the water surface to the data recorder (Fig. 7). Hand-dug wells are not uncommon in the Big Creek area, and provide a glimpse into a bygone era when they were created by pick and shovel as the well digger was lowered by rope and pulley down to a level where he encountered water. Dug wells have to be wide enough to allow the well digger to fit inside the borehole, and this one is 0.46 m in diameter. When the well digger has reached the level where water moves into the well to a depth that hopefully does not dry up during droughts, his digging is completed. The walls of the borehole are often lined with sandstone or chert rock slabs that keep soil and other debris from falling into the well. Dug wells are an excellent means for hydrogeologists to gain direct measurement into the water that is flowing underground

Verification of transducer accuracy in each well followed standard USGS procedures (Shuter and Teasdale

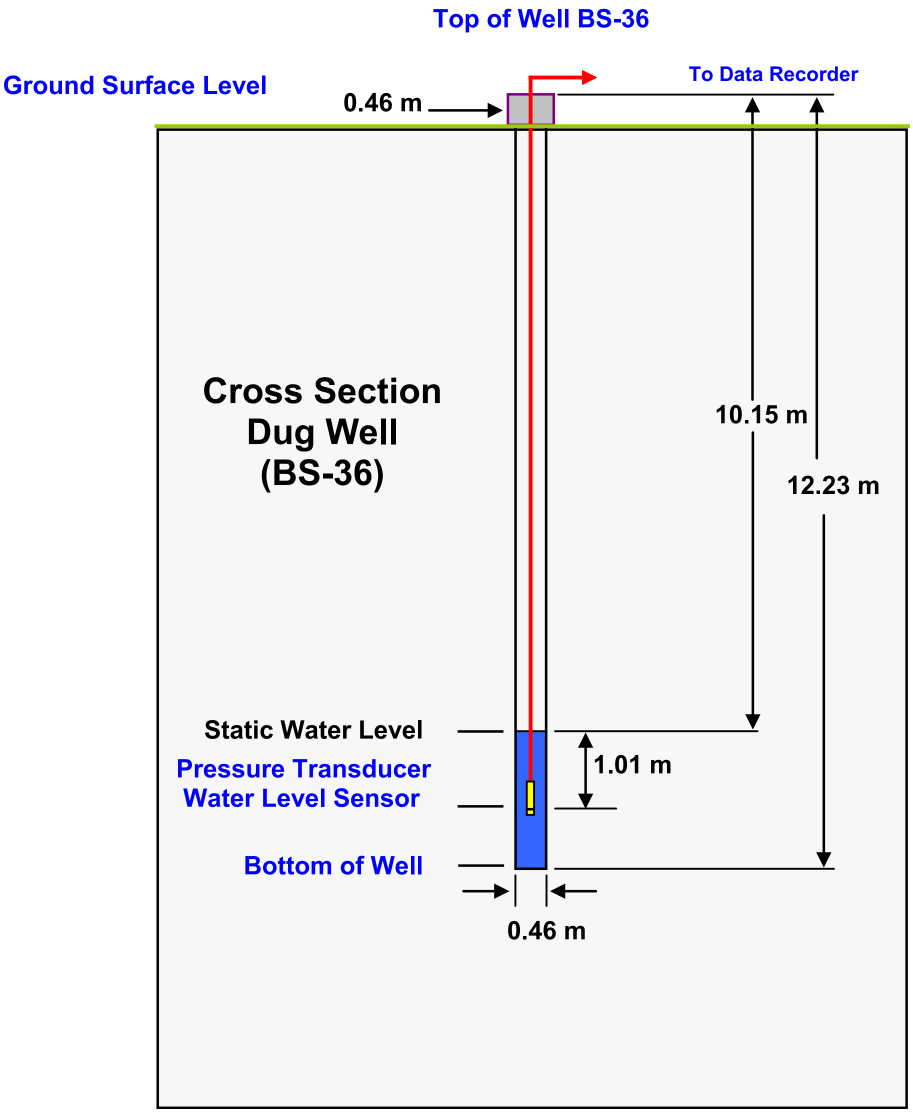


Fig. 9 Cross section showing a geologically prepared view of well BS-36 with distances carefully measured using a steel tape accurate to 1 mm. The pressure transduce, shown as the *yellow cylinder* at the bottom of the *red* cable, accurately measures water level in the water at the bottom of the well in response to rainfall. The transducer actually measures the height of the water above it, which is accurate to a fraction of a mm. The transducer also has a thermistor (temperature), and a very accurate clock built into it, so that data collected can be compared to the accurate clock of the rain gage. The resulting hydrograph (plot of water level vs. time) of the well can be compared to the timing of the rainfall to assess how long it takes the water on the surface to infiltrate into the well, which is an excellent indicator of how well developed and open the karst is in this area. Well BS-36 was chosen because it represents groundwater that occurs in the limestone/chert couplets that are shown in Fig. 3. The diagram is not drawn to scale

1989; Taylor and Alley 2001; Freeman et al. 2004) and was measured using both steel and electric water-level tapes during site visits, approximately every 3 weeks. As a further quality assurance/quality control determination, hydraulic-head data in BS-36 were replicated using a Druck (Model PDCR 1830 (mv) 5 psi) pressure transducer connected to a Campbell Scientific CR 10× Datalogger. The datalogger sampled every 5 min, and data were post-processed to convert to hydraulic head averaged over a 15-minute interval.

Results

Hydrographs of two surface-water gaging stations for the month of May 2015 are shown in Fig. 12. The hydrographs show the stage (stream level rise and fall) on the *vertical axis* plotted against time on the *horizontal axis*. Precipitation is shown by the vertical lines that are plotted along the bottom axis of the graph based on the duration and intensity of precipitation events. The scale for the stream responses is shown on the *left side* of the *y*-axis, and the scale for the precipitation is shown on the *right side* of the *y*-axis. Time is shown on the *x*-axis of the plot, along the bottom of the graph. The timing of the causes (precipitation) and effects (stream-stage response) on the graph allows for a rapid visual assessment of the difference between precipitation initiation and stream-stage increase, a difference called the lag time. In Fig. 12, the lag time was less than an hour in all cases, indicating that the stream levels started rising essentially no later than an hour after the precipitation started.

Hydrographs of three groundwater wells for the month of May 2015 are shown in Fig. 13. The hydrographs show the hydraulic head on the vertical axis plotted against time

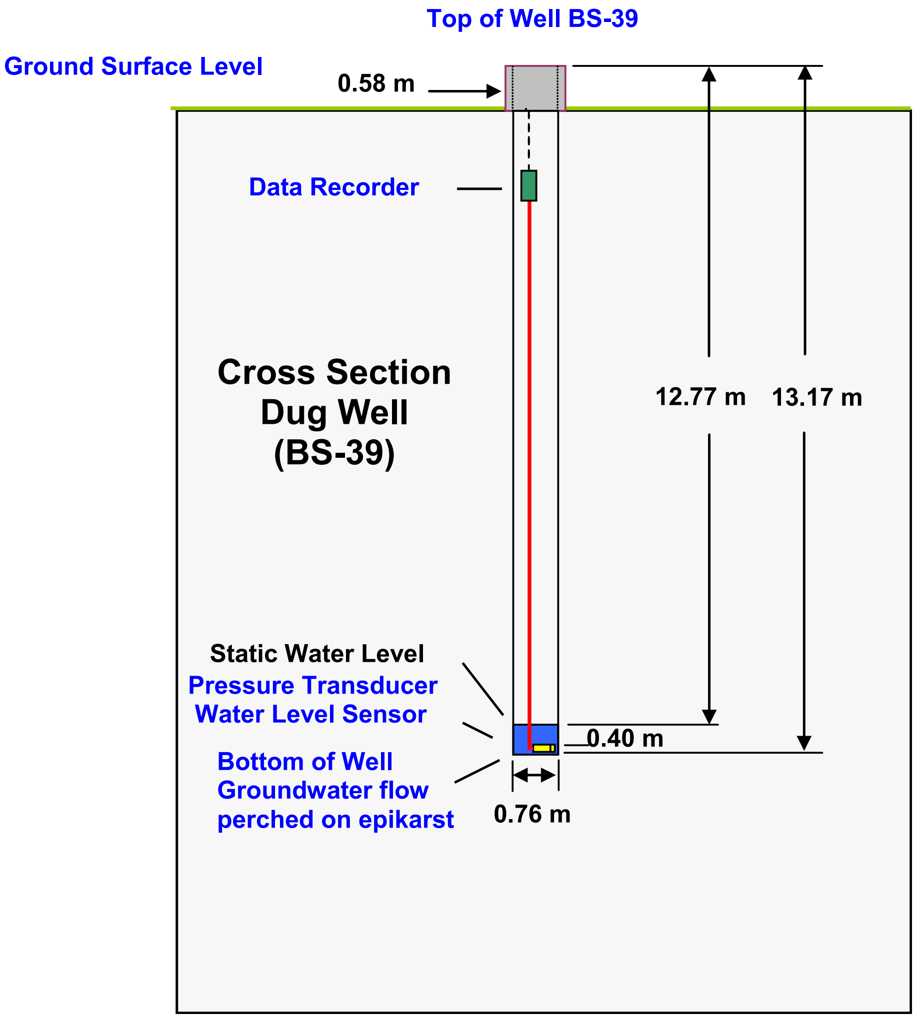


Fig. 10 Cross section showing a second type of hand-dug well, BS-39, which is located on the top of the epikarst, the weathered zone of karst rock that lies directly below the regolith and alluvium in the valley across the county road from the CAFO property. Well-completion methods are similar to those used in BS-36, with the borehole stacked with sandstone and chert rock slabs to protect the completed well from collapse, just as BS-36 was. The diagram is not drawn to scale

on the horizontal axis. As in Fig. 12, precipitation is shown by the vertical lines along the bottom axis of the graph, and the scale of hydraulic head is presented as it was the surface-water graphs. For the three groundwater wells, time lag was essentially identical to the time lag of the surface-water stage, indicating that groundwater levels started rising no later than an hour after precipitation started.

Rapid response of the groundwater level is an indicator that karst conditions facilitate rapid flow of precipitation into the ground. The magnitude of the water-level increases can be caused by several factors including: variation of permeability or porosity of the aquifer materials; variation in storage as the groundwater moves downgradient; variation in karstification in the limestone/chert couplet interval of the Boone (BS-36); variations in the epikarst (upper eroded zone) at the top of the Boone (BS-39); and variations in Big Creek alluvium and terrace deposits (BS-40) that directly overlie the Boone in Big Creek Valley (Braden and Ausbrooks 2003).

Figure 14 provides a compilation of Figs. 12 and 13 in the study area, showing the nearly identical lag times of all water-level responses of wells and streams for the time interval from May 1, 2015, through June 2, 2015.

For the period of record, from May 1, 2015, through early June, 2015, 10 storms of varying intensity were recorded. Hydrograph records of the wells and streams indicate that water level rises rapidly after the onset of precipitation in Big Creek and contiguous basins, with little delay (less than an hour) between the wells and the streams (Figs. 13, 14, 15). This coincidence of the start of water-level rise in the hydrographs reflects the close relation of surface and ground water. The time to maximum crest of each hydrograph, however, indicates the duration the water takes to move laterally below ground through aquifers to the hydrologic drains. Variations in time-to-crest of each of the hydrographs indicate details of the rainfall intensity and variations in the underground flow system, including permeability, prestorm water levels and hydrologic conditions, rainfall distribution, flow constrictions or constraints for intervening flow paths, and degree of karstification.

The sites included: BS-36 is a (hand-dug) well open to the epikarst in the upland on the Boone slightly less than

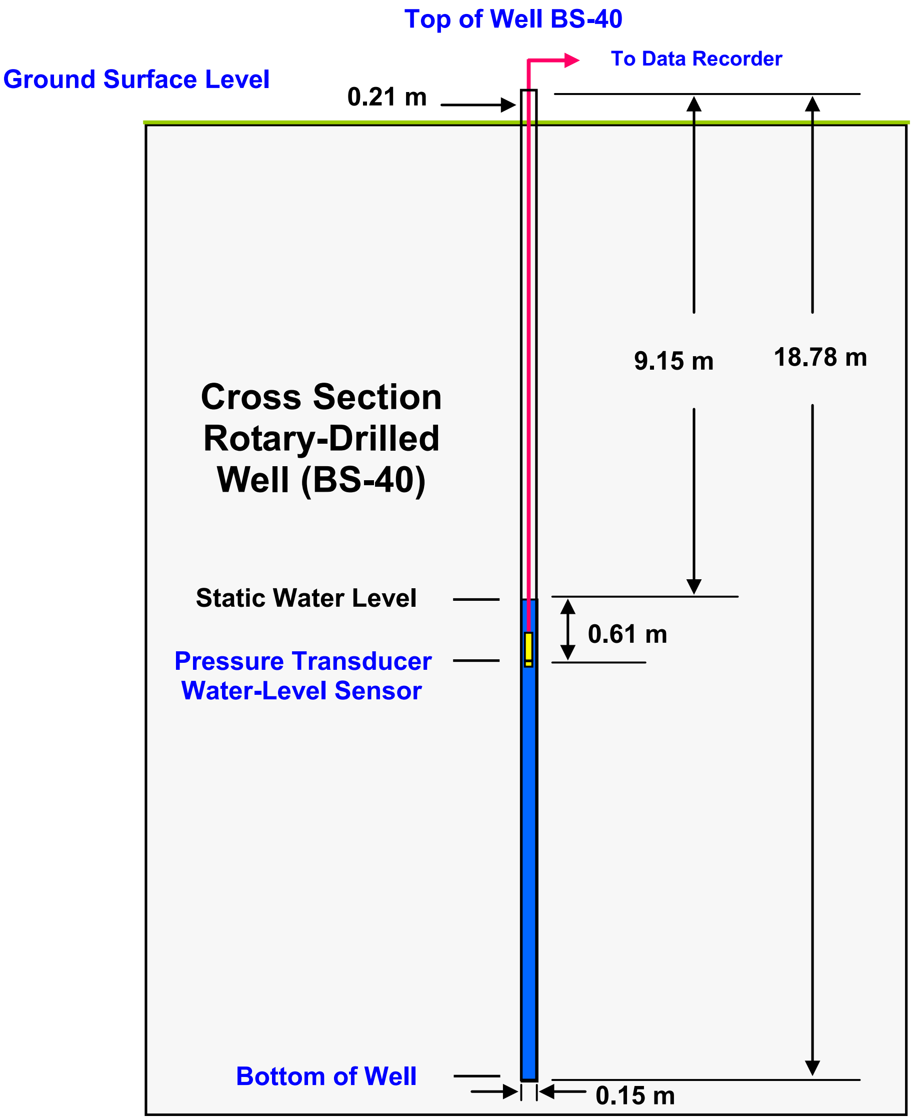


Fig. 11 Cross section of the third type of well in the study area, BS-40, which was constructed by a rotary drilling method. This is a more modern and effective means of well-drilling, and is capable of completing wells into hard, indurated, competent rock. The diameter of wells completed by rotary drilling are significantly smaller than hand-dug wells, and the completion methods are distinctly different. Instead of a stacked rock casing, these types of wells are lined with PVC or steel pipe, and the interval the driller leaves open to the borehole has holes, openings, a screened interval, or nothing (an open hole, if the rock will stay open when the drill bit is removed). Various types of casing with narrower slots or openings than the sediment size protect finer-grained materials from being drawn into the well. Well BS-40 was drilled in rocks shown as Qat, part of the sand, gravel and clay deposited by Big Creek. The diagram is not drawn to scale

2.7 km along an azimuth of 1° east of south from the south corner of the southern hog barn; BS-39 is a (hand-dug) well open to the epikarst near the boundary of the upland and the Big Creek alluvial plain slightly less than 425 m along an azimuth of 3° east of north from the northern corner of the northern hog barn; BS-40 is a (rotary drilled) well open to the Big Creek alluvium within the Big Creek alluvial plain about 520 m from the northern corner of the northern hog barn along an azimuth of 4° east of north; surface-water USGS Station 07055790, Big Creek near Mt. Judea, AR; and surface-water USGS Station 07055792, Left Fork Big Creek near Vendor, AR (Fig. 16).

Although the onset of water-level rise in response to precipitation for the stations above was considered to be coincident, variations in time-to-crest of the hydrographs from each site for the period of record showed a progression through time, generalized from fastest to slowest as:

1. USGS Station 07055790, Big Creek near Mt. Judea, AR (tie)
2. USGS Station 07055792, Left Fork Big Creek near Vendor, AR (tie)
3. BS-36
4. BS-40 (slight difference)
5. BS-39 (slight difference)

Considering the storm of 5/11 and 5/12 (Figs. 13, 14, 15), which generated the greatest precipitation for the period of record, time-to-crest for wells BS-40 ad BS-39 was greatest. Because the hydrographs of the surface-water stations were already in recession, high stream base level decreased rapidly, owing to high transmissivity of the surface streams as compared to groundwater, and the delay in time-to-crest seen in the hydrograph of BS-40 took longer to discharge existing water already in the system. The exact cause of the

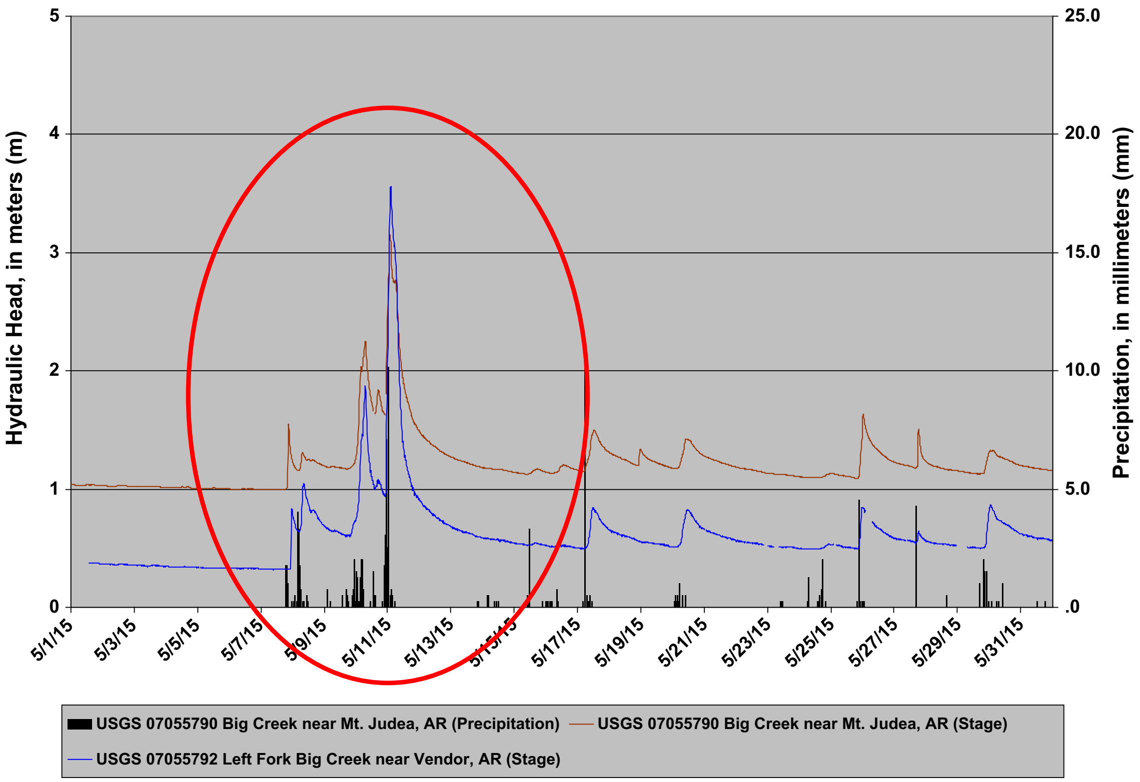


Fig. 12 Hydrographs of two surface-water gaging stations run by the U.S. Geological Survey in Big Creek Valley, Left Fork of Big Creek near Vendor, AR, and Big Creek near Mt. Judea, AR, for the month of May 2015. The hydrographs show the stage (stream level rise and fall) on the *vertical axis* plotted against time on the *horizontal axis*. Precipitation is shown by the *vertical lines* that are precisely plotted based on the duration and intensity of precipitation events. The scale for the stream responses is shown on the *left side* of the *y*-axis, and the scale for the precipitation is shown on the *right side* of the *y*-axis. The timing of the causes (precipitation) and effects (stream-stage response) can be subtracted, and is called the lag time. In this case, the time lag was zero, indicating that the stream levels rose essentially as soon as the precipitation started

delayed time-to-crest is not known at this time. Water level in BS-39 appeared to be controlled by BS-40, reflected in Fig. 14 for storms of 5/9, 5/11, 5/17, 5/20, 5/26, 5/27, and 5/30. For the most part, the peaks are similar, but BS-40 appears to reach time-to-crest slightly sooner than BS-39. We interpret this response to reflect the short-term, temporal base level created by increased flow in the Big Creek alluvium, which slows draining from BS-39. The implication of rapid draining is a further indicator of karst drainage, which is characterized by rapid loss of base flow. Data for the storms of record in the study area indicate only minor (1–3 days) gains of baseflow to streams during droughts resulting from the alluvial component of the system.

The hydrograph of well BS-36 generally crested rapidly, prior to the time-to-crest of Big Creek and Left Fork of Big Creek (Fig. 14). We interpret this as a reflection of the drainage basin size that contributes to BS-36 as being relatively small and flow distances being generally short, typically less than 1 km. In the cherty part of the Boone in upland settings, chert perches shallow water levels that recede with variable rates depending on the karstification of the interbedded limestone.

The hydrograph of well BS-36 for 8^{+} months during the interval from January 23, 2015, through August 27, 2015, showing the control of chert layers on groundwater recession is shown in Fig. 15. Zone A is confined at its base by a hydrologic break at a depth of about 1.67 m above the bottom of the well. The limestone interval above this depth appears to have well-developed secondary karst on the base of the chert, as reflected by the steep recessional limb above 1.67 m indicative of rapid draining. A chert layer (Break 1) is interpreted as inhibiting upward water-level rise for 11 major precipitation events for this time interval, and where the spillover occurs into Zone A for 4 of these events, the rapid water-level declines reflect the effectiveness with which the karst above Break 1 allows the rapid outflow of the added groundwater. Zones B and C reflect active vertical fluctuation of the water level through this interval, with water-level declines of about 0.3 m in several days after precipitation events. Break 2 at about 1.43 m above the bottom of the well is interpreted as a permeability break, likely not a chert layer but lithologically controlled by a very thin interval. The bases for this determination are: a)

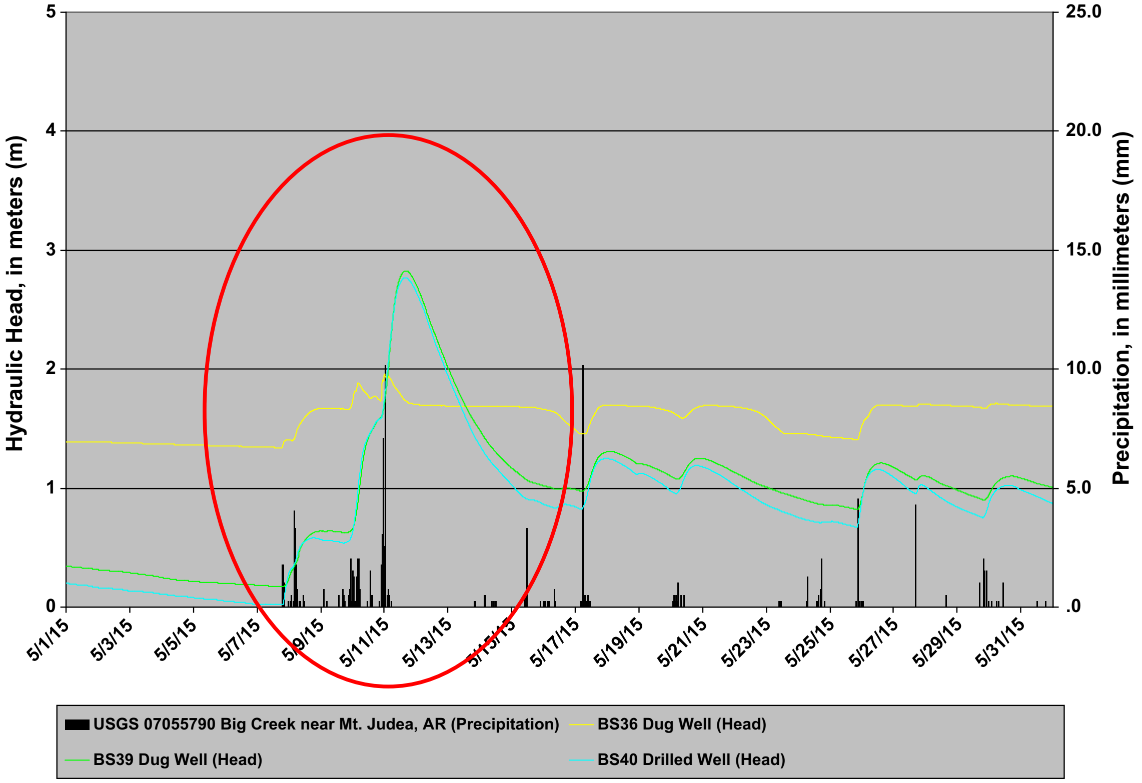


Fig. 13 Hydrographs of three groundwater wells, BS-36, BS-39, and BS-40 for the month of May 2015. The hydrographs show the groundwater level (rise and fall) on the *vertical axis* plotted against time on the *horizontal axis*. As in Fig. 12, precipitation is shown by the *vertical lines* and the scales for the figures are presented in the same locations. The timing of the causes (precipitation) and effects (groundwater-level response) can be subtracted, and is called the lag time. In this case, the time lag was essentially zero, indicating that groundwater levels started rising as soon as the precipitation started. The magnitude of the water-level increases is a reflection of the change in storage as the groundwater moves downgradient, and varies for different hydrologic settings in the Boone Formation (BS-36), the epikarst at the top of the Boone (BS-39), and the Big Creek alluvium and terrace deposits (BS-40) that lie above the Boone in Big Creek Valley

2 hydrograph rises terminate at Break 2; b) 3 hydrograph recessions terminate against this very thin layer; and c) 6 distinct breaks in recessional gradient occur at Break 2. Break 3, which occurs at 1.37 m above the bottom of well BS-36, is thought to represent the lowermost chert layer in the well that perches the slow-flow component of the karst groundwater until essentially all water in the well has been dissipated. The remarkably level groundwater surface for about 75 % of the total hydrograph record is consistent with the interpretation that the lower 1.37 m in this well was created as a cistern. This cistern is an effective storage zone that does not intersect any well-developed karstified zones in the well-bore. In this vertical interval, flow recedes very slowly until the next precipitation event generates a groundwater-level rise. This slowest recession rate, which drains the cistern at a rate about 0.15 m per month, is reflected in slow drainage to low-level seeps and springs along poorly developed, low-permeability karst flow paths. Three of these perched, low-discharge springs are known to be within about one hundred meters south and east of well BS-36 (Fig. 16).

The sequence of selected springs encircling well BS-36 is demonstrable karst discharge features from the middle portion of the Boone that contains limestone/chert couplets (Fig. 2) and deserve discussion in conjunction with hydraulic head in this aquifer (Fig. 15). Springs and seeps from this interval are common (Braden and Ausbrooks 2003). When extreme precipitation events occur, such as are shown when the hydraulic head in BS-36 is elevated into zone A (Fig. 15), lateral groundwater flow becomes confined by the overlying chert layers and produces ephemeral high-level artesian springs. The photograph in Fig. 16 shows one of these springs, which flowed after a storm of more than 250 mm over the course of several days in mid-May, 2015. Multiple springs became active during this time, some spouting more than 0.3 m above land surface at the point of resurgence. Deposited around the outflow of these springs were piles of angular chert gravel (several cm in diameter) which had been washed out of the aquifer by rapid groundwater flow. These gravel clasts had not traveled far in the subsurface, based on the angularity of the chert, but they obviously were moved by a fast-flow

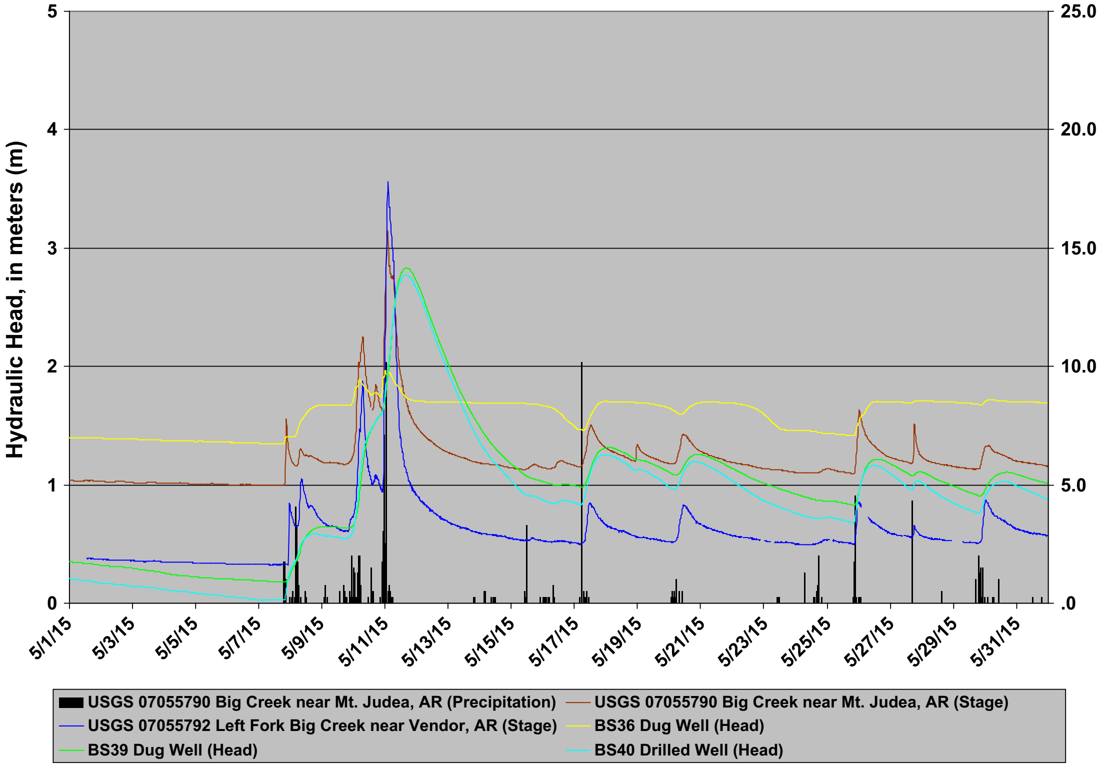


Fig. 14 Compilation of precipitation, and surface-water stage from Big Creek at Mt. Judea, Arkansas, and Left Fork of Big Creek near Vendor, Arkansas, and groundwater levels in Big Creek drainage basin at wells BS-36, BS-39, and BS-40, showing the nearly identical lag times of all water-level responses of wells and streams. The *hydrographs* shown represent the time interval from May 1, 2015 through June 2, 2015

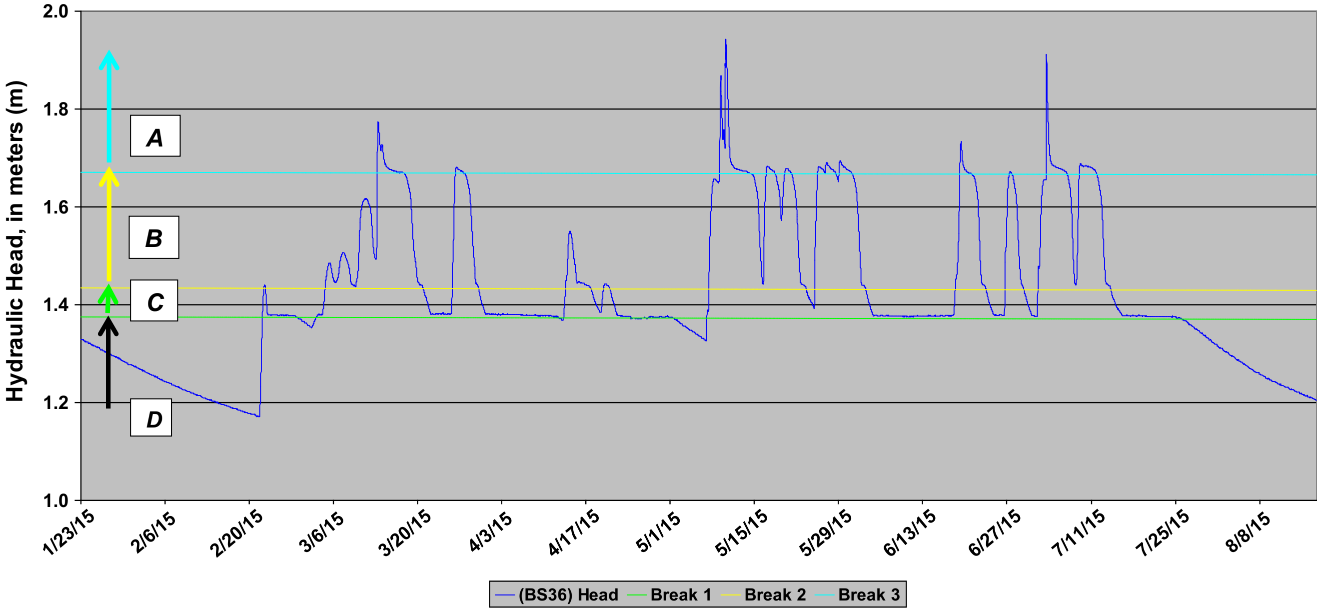


Fig. 15 Hydrograph of well BS-36 for 8^+ months during the interval from January 23, 2015 through August 17, 2015, showing the control of chert layers on groundwater recession. Four hydrologic zones are identified by 3 breaks in the plot of water level over the time of the hydrograph, and indicate that the presence of karst hydrogeology in this well surrounded by CAFO spreading field

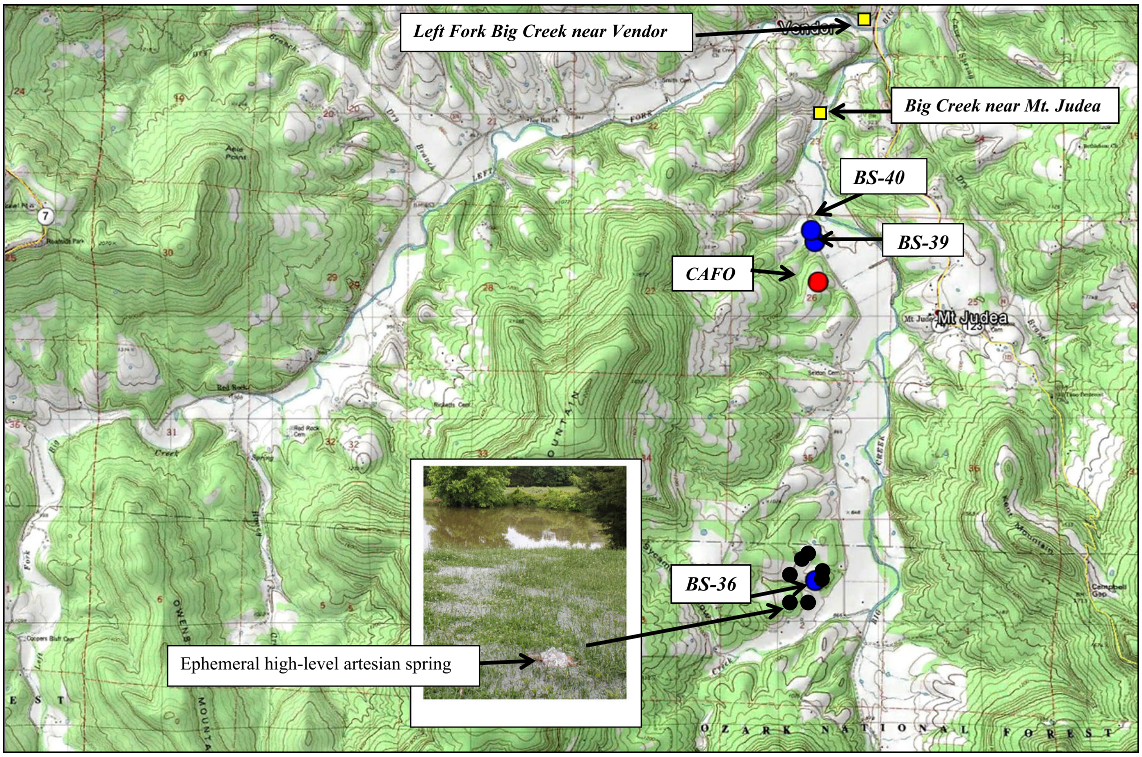


Fig. 16 Shaded topographic relief of the study area showing data collection sites. Surface-water sites are provided by the U.S. Geological Survey and are shown in *yellow*; groundwater sites are shown in *blue*; ephemeral springs, both artesian and perched that surround well BS-36 are shown as *black circles*; the CAFO is shown as a *red circle*

component of a karst aquifer because their size required continuous flow pathways large enough to allow gravel-sized particles and large flow volumes to be transported through. As is typical of karst aquifers, flow from these springs receded quickly, typically by much less than 24 h.

The hydrogeologic response of the springs described above is similar to others in Big Creek basin, and in fact, throughout the area of occurrence of the Boone. For example, many of the springs within the study area were found to be multi-orifice during an initial karst inventory, with numerous resurgences along near-horizontal bedding planes in karstified limestone lying between chert layers. Insofar as these springs were visited multiple times, during a wide range of variable groundwater levels, it became obvious that upper-level resurgences ceased flowing during droughts, establishing overflow/underflow conditions that were controlled by anisotropic permeability zones. Such findings are not unexpected in karst (Winter et al. (1998), Palmer 2007), and they serve as supporting evidence that the Boone is a karst aquifer.

Conclusions

This study provides continuous monitoring of precipitation, hydraulic head in wells, and stream stage in Big Creek Valley upstream from its confluence with the Buffalo National River to characterize the nearly identical timing of the response of these components of the hydrologic budget and to determine the karst nature of the Boone. Not only is the timing of stream-stage increase almost identical to groundwater-level rise in the streams and springs of the study area, but documented dissolution features of varying scales clearly indicate that the lack of obvious karst topography at air-photo scales is not a good indication that karst hydrogeology does not exist.

Although the complete hydrographs of streams and wells are not identical in the study area, lag time between precipitation onset and water-level response in wells and streams is rapid and indicates essentially indistinguishable from one another. The spikey nature of the stream hydrographs reflects low storage, high transmissivity, and rapid draining of the upper zones of the karst aquifer, whereas the longer-term, plateau-like draining in the lower zones reflects groundwater perching on chert layers that feed low-yield springs and seeps through lower storage and lower permeability flow paths. Groundwater drainage to thin terrace and alluvial deposits with intermediate hydraulic attributes overlying the Boone also shows rapid drainage to Big Creek, consistent with lateral input from karst sources, but with high precipitation peaks retarded by slower recession in the alluvial and terrace deposits as flow moves downstream.

Fast flow and coincidence of lag time in wells and surface water in response to precipitation events are key indicators of underlying karst hydrogeology. These data document the justification that the wells shown are useful and meaningful sites for the introduction of fluorescent dyes to trace groundwater movement and document groundwater velocity in the Boone aquifer in the study area. Insofar as karst occurs, and insofar as karst hydrogeology is heterogenous, dye-trace input sources that utilize dug wells in mantled karst are entirely justified, and the results of the dye tracing in wells at differing water levels are a meaningful and effective way to characterize the complexity of the groundwater flow system, which in this area shows multiple levels of variably karstified flow paths.

As discussed previously, the recurring and areally continuous chert layers in the limestone/chert couplets of the Boone provide a mantle that masks much of the underlying structure of the groundwater drainage from land surface or above. Groundwater flow follows the laws of physics. This means it flows from high energy (hydraulic head) to lower energy, following the path of least resistance. In the Boone, the path of least resistance is the karst fast-flow pathways in the pure limestones, be they thin-bedded and separated by chert, as in the middle part of the formation, or be they thicker bedded with obvious openings at land surface, as in the purer carbonate lithologies of the upper Boone and the St. Joe Formation.

Acknowledgments We are most grateful to Patagonia Environmental Grants Program for funding a portion of travel expenses for this project, to the Buffalo River Watershed Alliance for maintenance of the Patagonia Award, to Ann Mesrobian, Ginny Masullo, and Marti Olesen for editorial and verification review, and to four anonymous donors who contributed funds for partial travel and equipment expenses. Three local landowners and farmers in Big Creek Valley allowed us access to their wells and unlimited access to their property, and we are most grateful for their assistance and kindness. Finally, we sincerely thank two anonymous peer reviewers for this journal who made meaningful suggestions that improved this paper.

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MEMORANDUM OF AGREEMENT
BETWEEN THE
BOARD OF TRUSTEES OF THE UNIVERSITY OF ARKANSAS SYSTEM
FOR AND ON BEHALF OF THE
UNIVERSITY OF ARKANSAS SYSTEM-DIVISION OF AGRICULTURE
AND THE
ARKANSAS DEPARTMENT OF ENVIRONMENTAL QUALITY

THIS MEMORANDUM OF AGREEMENT (hereinafter referred to as "MOA") is made and entered into between the Board of Trustees of the University of Arkansas System for and on behalf of the University of Arkansas System-Division of Agriculture (hereinafter referred to as "University") and the Arkansas Department of Environmental Quality (hereinafter referred to as "ADEQ" or the "Department").

WITNESSETH:

WHEREAS, ADEQ is an agency of the State of Arkansas vested with authority to administer environmental regulatory programs, and ADEQ's mission is to protect, enhance, and restore the natural environment for the well-being of all Arkansans; and

WHEREAS, one of the many duties of ADEQ is to issue permits for certain livestock operations, including confined animal feeding operations (hereinafter referred to as "CAFOs"); and

WHEREAS, pursuant to its statutory duties and in compliance with applicable state and federal environmental laws and regulations, ADEQ issued a general permit for CAFOs operating in the state; and

WHEREAS, the first facility permitted under the new general permit for CAFOs is C&H Hog Farm located in the Buffalo River watershed in Newton County; and

WHEREAS, the Buffalo River, designated as the nation's first national river, is unquestionably a scenic and environmental treasure and the maintenance of its natural beauty and pristine water is recognized as important to all citizens of the state; and

WHEREAS, out of concern for protecting the Buffalo River and its tributaries, the Governor has taken the extraordinary step of seeking authorization from the Legislature for $340,510.00 to conduct additional testing in areas on or near the permitted CAFO, C&H Hog Farm, in the Buffalo River watershed; and

WHEREAS, the University of Arkansas System-Division of Agriculture has professionals with expertise in soil and water monitoring and the design and implementation of best practices relevant to the compliance of farm operations to state and federal laws;

NOW, THEREFORE, in furtherance of ADEQ's mission to protect the environment and administer regulatory programs, University and ADEQ agree as follows:

I. Scope of Agreement

A. University agrees to:

1. Undertake and complete a study of the potential for water quality impacts within the Buffalo River watershed from animal wastes produced by the permitted CAFO, C&H Hog Farm, and its operations within the watershed. University shall designate individuals with professional qualifications and expertise sufficient to design and implement such study, including but not limited to best placement for monitoring wells, sampling and testing as necessary for a thorough and informed analysis. This study shall be for the review and consideration of ADEQ and other state officials. Although carried out for the use and benefit of ADEQ and to inform its ultimate performance of its regulatory functions, the study shall be funded and conducted independently of ADEQ and shall meet the requirements of an independent study conducted by professionals in the field of water quality.

2. Provide ADEQ with a Project Plan and time line for the implementation and completion of the water quality study as described herein.

3. Provide ADEQ with quarterly written reports due each quarter of each year this Agreement remains in effect, beginning with the first report due on or before January 31, 2014, the second report due on or before March 31, 2014 and continuing quarterly ending with the final report which will contain conclusions and recommendations, due on or before June 30, 2019. The quarterly reports shall be in a format approved mutually by ADEQ and University, and, at a minimum, shall include a summary of all Project Plan activities performed by University during the preceding quarter.

4. Seek additional funding from appropriate sources as needed for completion of the study in accordance with the Project Plan.

B. ADEQ agrees to:

1. Assist University with obtaining access to conduct the study if access is denied by any property owner.

2. Assist and support University's independent study as appropriate through the sharing of relevant data and information available to ADEQ.

II. Term

This Agreement shall become effective as soon as signed by both parties and shall remain in force until June 30, 2019, unless terminated earlier in accordance with other provisions herein.

III. Termination

A. This Agreement may be terminated by mutual consent of the parties, or by one party upon thirty (30) days written notice.

B. In the event the State of Arkansas fails to appropriate funds or make monies available for any fiscal year covered by the term of this Agreement, then this Agreement shall be automatically terminated on the last day of the fiscal year for which funds were appropriated or monies made available for such purposes.

IV. Amendment

Amendments to this Agreement may be proposed by either party upon written notice to the other party, and such amendments shall become effective as soon as signed by both parties hereto.

V. Notices

Any notices required hereunder shall be addressed as follows:

To ADEQ:

Teresa Marks, Director
Arkansas Dept. of Environmental Quality
5301 Northshore Dr.
North Little Rock, AR 72118-5317
Tel. (501) 682-0959
Fax (501) 682-0798

With a copy to:

Tammera Harrelson, Chief Counsel
Arkansas Dept. of Environmental Quality
5301 Northshore Dr.
North Little Rock, AR 72118-5317
Tel. (501) 682-0886
Fax (501) 682-0891

To UNIVERSITY:

Dr. Mark Cochran
Vice President for Agriculture
University of Arkansas System
Division of Agriculture
2404 N. University Ave.
Little Rock, AR 72207-3608
Tel. (501) 686-2540
Fax (501) 686-2543

With a copy to:

University of Arkansas System
Attn: Office of General Counsel
2404 North University Avenue
Little Rock, AR 72207-3608
Tel. (501) 686-2520
Fax (501) 686-2517

VI. Miscellaneous:

A. The officials executing this Agreement hereby represent and warrant that they have full and complete authority to act on behalf of University and ADEQ, respectively, and that the terms and provisions hereof constitute valid and enforceable obligations of each.

B. This Agreement shall be interpreted and construed in accordance with the laws of the State of Arkansas.

C. No transfer or assignment of this Agreement, or any part thereof or interest therein, shall be made unless all of the parties first approve such transfer or assignment in writing.

D. This Agreement constitutes the entire agreement between the parties. There are no understandings, agreements, or representations, oral or written, not specified within this Agreement.

BOARD OF TRUSTEES OF THE UNIVERSITY OF ARKANSAS SYSTEM FOR AND ON BEHALF OF THE UNIVERSITY OF ARKANSAS DIVISION OF AGRICULTURE

By: Ann Kemp
Ann KempVice-President
for Administration

Dated this 5 day of Sept., 2013.

ARKANSAS DEPARTMENT OF ENVIRONMENTAL QUALITY

By: Teresa Marks
Teresa Marks, Director

Dated this 6th day of Sept., 2013.

Geochemical Processes and Controls Affecting Water Quality of the Karst Area of Big Creek near Mt. Judea, Arkansas

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[9]*Woodward Clyde Consulting Group (retired); ADEQ (retired), Little Rock, AR 72118*
[10]*Tyson Foods, Inc. (Retired), Fayetteville, AR 72701*
[11]*Department of Biological and Agricultural Engineering (Retired), University of Arkansas, Fayetteville, AR 72701*
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Running Title: Geochemical Processes and Controls Affecting Water Quality of the Karst Area of Big Creek near Mt. Judea

Abstract

Karst regions typically are considered to be vulnerable with respect to various land-use activities, owing to the intimate association of surface and groundwater and lack of contaminant attenuation provided by most karst aquifers. Inasmuch as the soluble rocks of the karst landscape can be dissolved to create large, rapid-flow zones that compete successfully with surface streams, groundwater and subsurface flow represent a much larger component of the hydrologic budget in karst regions than in areas where non-soluble rocks predominate. Karst areas typically are distinguished by being unique, but some general approaches can be applied to characterize the hydrology of the area. These approaches include an evaluation of the degree of karstification, the hydrologic attributes of the groundwater flow system, the baseline water quality, the time-of-travel through the karst flow system, and the general flux moving through the system. The nature of potential contaminants and their total mass and range of concentrations are critical to understanding the potential environmental risk.

This study describes the characterization of the baseline water quality of the shallow karst Boone aquifer and surface streams and springs to determine major processes and controls affecting water quality in the region, and to assess 2 years of waste spreading. Parameters evaluated include major constituents, contaminants and their breakdown products from the industrial operation of a concentrated animal-feeding operation (CAFO) on Big Creek, the indicator pathogen, *E. coli*, dissolved oxygen, selected trace metals, and other ancillary water-quality attributes that are directly observable in the environment. Determination of pre-CAFO water quality was accomplished by sampling approximately 40 sites that included wells, springs, and streams.

Introduction

The recent (2012) Arkansas Department of Environmental Quality (ADEQ) issuance of a permit for a CAFO near Big Creek, slightly more than 10 kilometers (km) upstream from the Buffalo National River near the town of Mt. Judea, Arkansas (Figure 1), made Arkansas citizens aware of the potential for the CAFO to introduce solutes and pathogens that could degrade surface and groundwater in the area. The initial permit did not consider or discuss groundwater or karst, nor did it establish baseline water quality.

The waste generated from 6,503 hogs exceeds more than 7.5 million liters per year, and it must be continually removed to avoid overfilling the waste lagoons. Pig feces and urine spread on pasture land overlying karst has generated significant concern that the CAFO will create health problems for the many tourists who utilize the Buffalo, as well as many of the downstream landowners in Big Creek valley who use the groundwater for domestic and stock water supplies. Canoeists and swimmers are particularly concerned because much of the drainage area of Big Creek has been karstified, which means that contaminated water with concentrated pig waste can move rapidly through open voids in the subsurface with little or no attenuation, and resurface in Big Creek, Left Fork Big Creek, or springs that drain the impacted area that lie downgradient. The main drain of this highly interactive groundwater/surface water system is the Buffalo National River (BNR on Figure 1). Insofar as the canoeists and swimmers cannot escape direct contact with river waters of the Buffalo (an Extraordinary Resource Water), citizen concerns seem warranted, and served as justification for conducting this study.

Physical Setting of the Study Area

Hydrologically, the study area includes the drainage basin of Big Creek including the waste-spreading fields of the CAFO, and the region surrounding site 30 on Left Fork of Big Creek (LFBC on Figure 1) which has been shown by dye tracing to receive groundwater flow beneath the topographic divide separating the two surface-drainage basins. The Boone Formation (from the base of the Batesville Formation to the bottom of the St. Joe Formation) is shown in Figures 1 and 2 as the light gray color in the central and northwest parts of the study area. The study area lies completely within Newton County.

The Boone Formation occurs across northern Arkansas in a broad outcrop band coincides with the Springfield Plateau physiographic province. This formation becomes karstified during weathering to facilitate groundwater capture of surface water, including the Mt. Judea area. Although this geologic unit encompasses about 35 percent of the land area of the northern two tiers of Arkansas counties, specific details of its hydrogeology are only generally documented in the literature. and its water-transmitting capacity and its ability to attenuate contamination has seldom been discussed other than to reference the entire area as a mantled karst (Aley 1988, Aley and Aley 1989, Imes and Emmett 1994, Adamski et al. 1995, Funkhouser et al. 1999, Braden and Ausbrooks 2003, Mott 2003, Hobza et al. 2005, Brahana et al. 2011, Kosič et al. 2015). Given this general cursory treatment, there exists a faulty claim that lack of obvious karst topography at air-photo scales is evidence that karst in the outcrop of the Boone Formation does not exist. The claim is inaccurate.

The Boone Formation is a relatively thick unit, about 110 meters (m) with variable lithology, including limestone, chert, and minor thin shaley limestone layers. The soluble limestone of the Boone contrasts with the highly insoluble, brittle chert, which can occupy as much as 70 percent of the entire thickness of this formation. For the most part, the Boone contains no less than 50 percent chert, except in its upper and lower pure-limestone measures (Liner 1978). The Boone Formation is nearly flat-lying, and has numerous, thin interbedded limestone layers forming couplets with thin, areally continuous chert layers through much of its middle and lower sections of the formation (Hudson and Murray 2003). Brittle fracturing, a result of about 200 meters of total uplift in the distal, far-field of the Ouachita orogeny has allowed groundwater to chemically weather and karstify the formation (Liner 1978, Brahana et al. 2014).

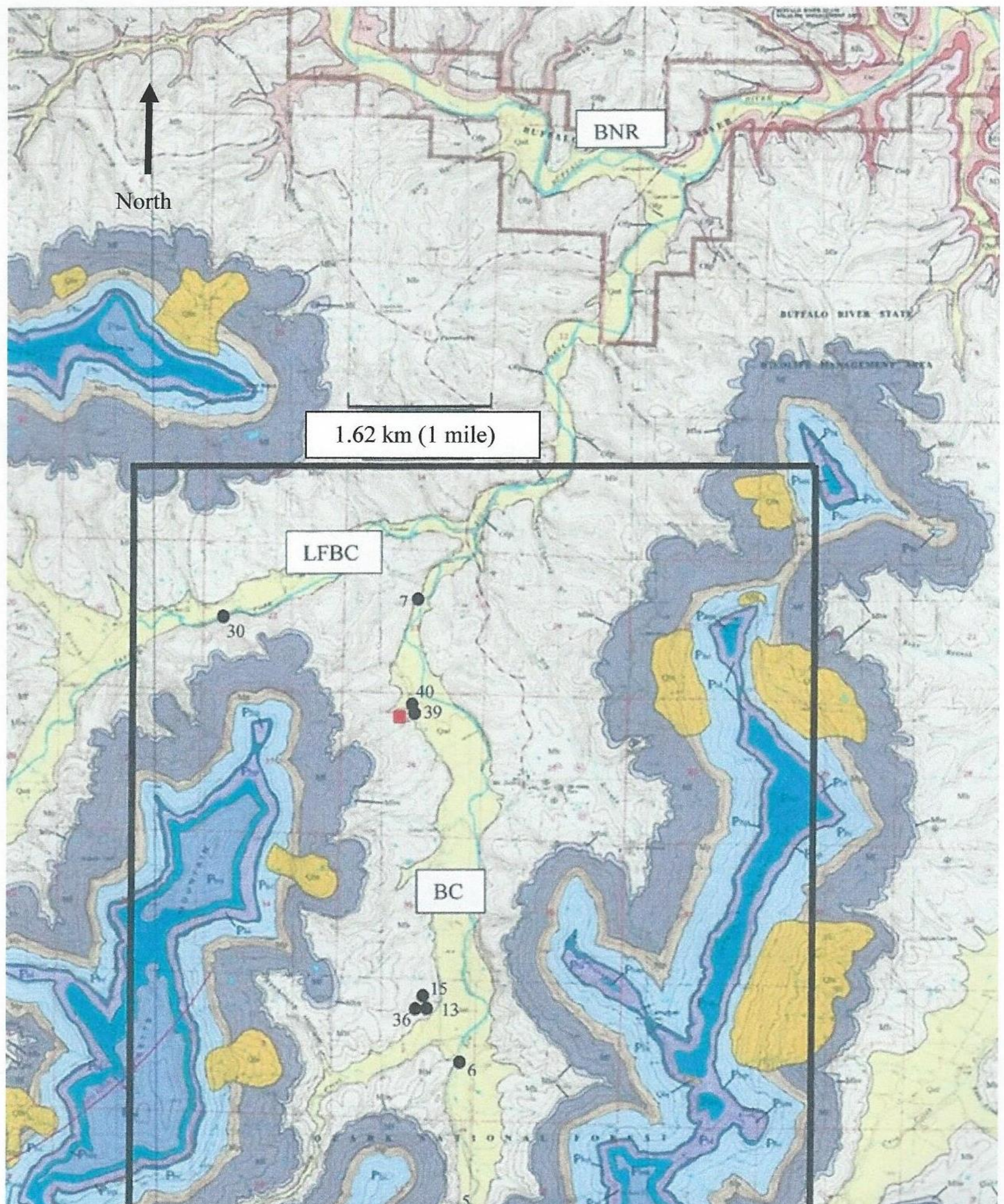
The physical attributes of the chert at a regional scale appears to be near-uniform thickness, but in the field under close, non-magnified inspection, contact boundaries between the chert and limestone reflect thickening and thinning that one would expect in soft, non-indurated sediment, typically on the order of several centimeters. Whereas individual chert layers may possess similar thickness, different layers vary significantly, with some of the thicker chert units greater than 30 centimeters (cm). The limestone lithologies in this interval range from less than 10 cm to several m.

The low permeability of the chert results in segregation and vertical isolation in this part of the groundwater flow system, which typically has been developed only in the limestone layers where the rock has been dissolved and karstified. The systematic orthogonal jointing resulting from the uplift and the long duration of weathering near the land surface are responsible for introduction of aggressive recharge and dissolution from the land surface to the hydrologically connected groundwater (Adamski et al. 1995, Davis et al. 2000, Funkhouser et al. 1999, Brahana et al. 2011).

Problem to Be Addressed

Significant land-use changes from a CAFO on karst required an accurate characterization of groundwater flow and the establishment of baseline water quality. Defining geochemical processes and controls was an essential first step in addressing these data gaps.

The CAFO is comprised of a 6,503-head facility for 2500 farrowing sows, 4000 piglets, and 3 boars; it was permitted to be constructed on the Boone Formation. In addition to the large structures housing the swine, two lagoons approximately one acre each were



The geologic base map is from Braden and Ausbrooks (2003). Topographic base map is from USGS (1980)

Figure 1. Geologic map of the study area, indicating the extent of karst where the Boone Formation (light grey color) occurs at land surface. BNR is Buffalo National River; BC is Big Creek and LFBC is Left Fork of Big Creek. The CAFO is shown by the red square, and the spreading fields for waste mostly lie between 7 & 6 on the west side of Big Creek. The study area is outlined by the black rectangle. Numbers 6 & 7 are referenced to Table 2. Numbers 5 & 30 are the furthest extent of groundwater tracing in the study area from dye input at 36, which has an altitude greater than any of the dye-receiving sites. Color legend for the map is in Figure 2.

included as temporary holding facilities for urine, feces, and wash water from the operation. In addition, about 243 hectares of pasture land for waste were also approved on land underlain by the Boone Formation, or in the valleys with thin alluvial deposits directly overlying the Boone (Braden and Ausbrooks 2003). The waste generated from this CAFO is equivalent to the waste generated by a city of 17,000 people (Tietz, 2006).

In addition to the lack of characterization of 1) karst, 2) basic hydrogeology, and 3) a baseline assessment of water quality (Brahana and Hollyday 1988, Edmunds and Shand 2008), the risk of similar environmental and water-quality problems occurring on the Buffalo had been well-documented elsewhere (Quinlan 1989, Quinlan et al. 1991, Funkhouser et al. 1999, Varnell and Brahana 2003, Palmer 2007, Gurian-Sherman 2008, Brahana et al. 2014, Kocic et al. 2015). The waste generated from 6,503 hogs of this size exceeds more than 7.5 million liters per year, and it must be periodically removed to avoid overfilling the waste lagoons (Pesta 2012). Insofar as the swimmers, fishermen, and canoeists cannot escape primary contact with water in the Buffalo National River, which has been classified as an ERW, this research was undertaken as part of a sequence of karst hydrogeologic studies to fill in the missing scientific gaps that were not addressed in the original permitting and approval process.

Water samples from wells, springs, and streams in the study area were collected during the summer and fall of 2013 prior to waste spreading from the CAFO. Sampling was conducted in the field by teams of volunteers using approved U.S. Geological Survey methods (Wilde 2006). Prior to collecting each water sample, field parameters of temperature, specific conductance, and pH were measured and reported. Site location was determined using a Garmin Colorado global positioning system, with latitude and longitude recorded in degrees and decimal minutes, to four significant figures of decimal minutes.

Sampling and Sample Preservation

Grab samples were obtained at each of approximately 40 sites and shipped to the Ouachita Baptist University Water Lab. Samples were taken to accurately represent water-quality at the time of collection. Each sample was divided into 5 fractions, and appropriate preservation initiated for each subsample as indicated below.

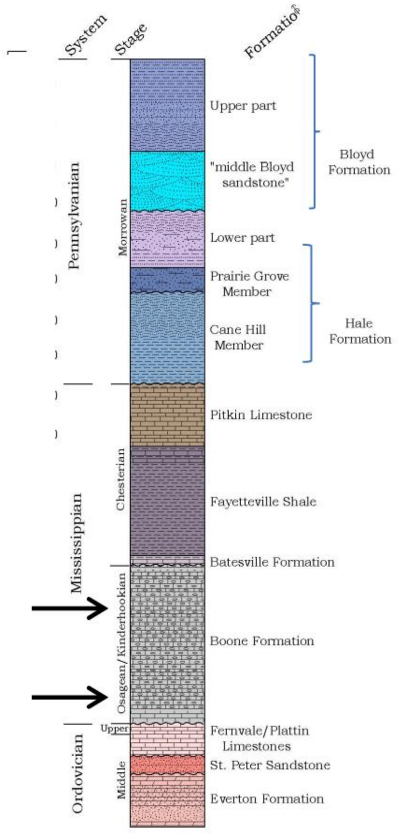


Figure 2. Stratigraphic column of the study area, showing the extent of karst where the Boone Formation (light grey color) occurs at land surface. Arrows identify the chert-rich interval of the formation. Total thickness of the Boone is about 110 m. Figure modified from Braden and Ausbrooks (2003).

Methods

Raw Unacidified {R_u] Sample: An untreated aliquot was placed in a 500 mL plastic bottle and placed on ice. This subsample was used for the lab determination of alkalinity, turbidity, and specific conductance.

Raw Acidified (sulfuric acid) [R_a] Sample: a sub-sample was placed in a 250 mL plastic bottle then acidified with sulfuric acid to pH 2 then placed on ice. This subsample was used for the determination of total phosphorus, total Kjeldahl nitrogen, and ammonia nitrogen.

Filtered Acidified [F_a] Sample: A 25- mL subsample was filtered through a 0.45 micron filter using a syringe and a plastic Swinex filter holder. The sub-sample was then acidified to pH 2 with nitric acid then placed on ice. This subsample was used for the determination of sodium, potassium, calcium, magnesium, iron, manganese, copper, and zinc.

Filtered Unacidified [F_u] Sample: A 25-mL subsample was filtered through a 0.45 micron filter then placed in a 25-mL plastic bottle then placed on ice. This fraction was used for the determination of nitrate nitrogen, chloride, and sulfate.

Microbial Sample: Microbial samples were collected in 125 mL sterile cups, with no filtration and no acidification ($_{\text{raw}}$). The sample was placed on ice, and transported to the analyzing laboratory (University of Arkansas Water Lab) within 8 hours from sampling.

Laboratory and Field Analyses

Major constituents and nutrients were analyzed by the Ouachita Baptist University Water Lab in Arkadelphia, Arkansas. Cations were analyzed with an inductively coupled plasma optical emission chromate-graphy (ICP-OEC), and anions were analyzed by high performance liquid chromatography (HPLQ). Pathogens were analyzed by the Arkansas Water Quality Lab (AWQL) on the campus of the University of Arkansas. This lab accommodated the short holding-time requirements. *E. coli* data reported in this paper were taken from the BCRET (2015) report, with analyses provided by AWQL using Idexx Quanti-tray equipment following Standard Methods in Water and Wastewater Analysis, method 89223-B. Stable isotopes of deuterium and oxygen-18 and dissolved selected trace constituents were analyzed by the University of Arkansas Stable Isotope Lab (UASIL) using Thermo Scientific iCAP Q inductively-coupled plasma mass spectrometer. Dissolved oxygen data were collected by the USGS using a dissolved oxygen logger that sampled every 15 minutes. The logger was deployed in Big Creek, and calibrated biweekly, following the procedure of Green and Usrey (2014).

Quality Assurance

Quality assurance, holding times, and sampling procedures employed in this study followed U.S. Geological Survey protocols (Wilde 2006). The Ouachita Baptist University Water Laboratory maintains an internal and an external quality assurance program, which includes periodic blind audits, checks for both precision and accuracy, and field blanks. The laboratory is certified by the ADEQ for each of the parameters reported. The minimum detection limits (MDL) for each parameter are given in Table 1.

Table 1. Chemical parameters analyzed by the Ouachita Baptist University Lab, and their minimum detection limits (MDL).

Parameter	MDL (in mg/L)
Major Anions	
Chloride	0.11
Sulfate	0.12
Alkalinity	1.08
Major Cations	
Sodium	0.06
Potassium	0.002
Calcium	0.079
Magnesium	0.006
Nutrients	
Ammonia Nitrogen	0.006
Nitrate Nitrogen	0.006
TKN	0.027
Total Phosphorus (low range)	0.008

Results and Discussion

Major Constituents

Water-quality data and synthesis from the major constituents indicate that the dominant processes controlling dissolved species in the water are dissolution, which is to be expected from precipitation recharging shallow aquifers, especially in karst regions. Mixing is also a predominant process, owing to the close interaction of surface and groundwater in karst settings, wherein recharge from surface precipitation events dilutes dissolved species in the groundwater. Background concentrations of dissolved chloride in groundwater were less than 5 mg/L, and concentrations of dissolved nitrate typically in the range of 1 mg/L or greater (Figure 3). Surface water samples typically had concentrations less than the mean for chloride, caused by dilution from upstream sources; nitrate experienced similar dilution, with reported concentrations not uncommonly between 0.1 to 0.5 mg/L (Figure 3).

Groundwater from the Boone Formation wells, springs, and surface water from Big Creek all are calcium- bicarbonate type (Figure 4). Deep wells beneath the cover of terrigenous sediments show the effect of less mixing, being more mineralized but still dominantly a calcium bicarbonate waters (Figure 4). Shallow wells and springs in the upper, overlying younger sediments (Figure 2) are indicative of less dissolution (Figure 3), with greater components of chloride and sulfate, typical of shales. Insofar as these are natural inorganic chemical solutes derived from dissolution and modified by mixing, and within EPA guidelines, none are considered to be hazardous to the overall health of water quality in Big Creek valley.

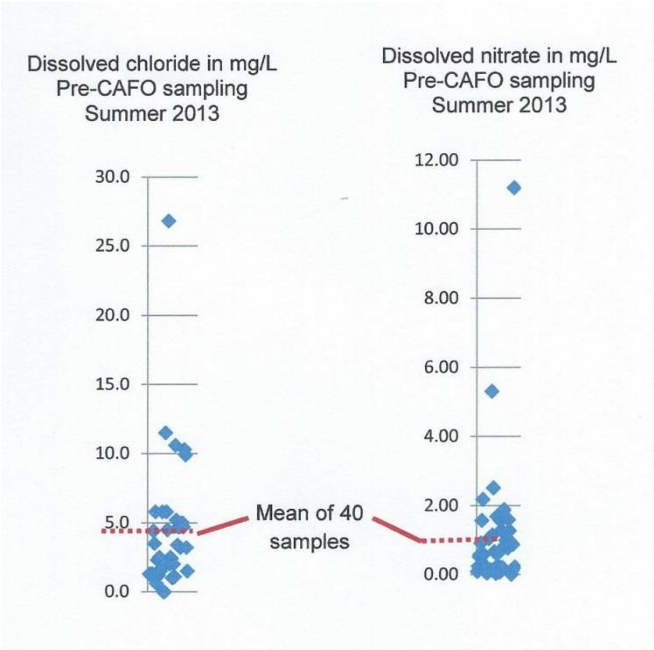


Figure 3. Concentration of dissolved chloride and nitrate sampled during the summer of 2013, prior to spreading of hog feces and urine on the spreading fields. The mean chloride concentration of 40 samples, which included groundwater from wells and springs and surface water from streams in the study area, was 4.5 mg/L. The mean nitrate concentration of 40 samples in the study area was 1.15 mg/L. Mean concentrations are shown by the dotted line. All units of concentration are mg/L

Microbes

Microbes are microscopic organisms that live in the guts of warm-blooded animals; they move into the environment upon defecation by the host, and they have the potential to be pathogenic to animals and humans when entrained in water and ingested. *E. coli* are an indicator organism of bacterial microbes. They are sampled to assess risk from primary contact with natural waters (Usrey 2013). In Big Creek, *E. coli* were sampled by the Big Creek Research and Extension Team (BCRET), as well as, the Karst Hydrogeology of the Buffalo National River (KHBNR) team. The Arkansas Pollution Control and Ecology Commission [APCEC] established criteria (APCEC 2015) for *E. coli* limits for impairment of surface waters in the state, and for those having a drainage basin greater than 26.24 kilometers^2 (10 miles^2) it was 410 colonies per 100 milliliters (col/100 mL). This limit for *E. coli* requires “no exceedance of more than 25% of samples from no less than eight samples taken during the primary contact season or during the secondary contact season” (ADPCE 2015).

E. coli concentrations of single grab samples greater than 410 col/100 mL are not uncommon in streams, wells, and springs in the Big Creek drainage basin. For example, sites sampled during the summer of 2016 [6/14/2016 through 8/08/2016] (Figure 5) by KHBNR reflect extreme fluctuations that are attributed to multiple factors. These concentrations varied from less than 10 to 6,200 col/100 mL. Other examples included 6/24/14 *E.coli* concentrations in Big Creek which were 28,150 col/100 mL at site 6 , and 24,950 col/100 mL at site 7 (BCRET 2014).

Rapid changes in concentrations of microbes are a common expectation and have been observed in the Boone aquifer elsewhere (Marshall et al. 1999, Ting 2005), caused by mobilization of *E. coli* by resuspension in rapidly flowing surface and groundwater. Microbes have mass, and are deposited on the base of the flow systems when velocities slow during flow recession. Turbulence from rapid recharge from storms resuspends the *E. coli* from the floor of the flow system, accounting for orders of magnitude increases. A key consideration here is that many of the *E.coli* persist in groundwater for periods of many months because of the lack of exposure of groundwater to ultraviolet rays, as well as to cooler groundwater temperatures. Although some die off of *E. coli* occurs in the subsurface, most organisms are entrained alive in the bottom sediment and have been shown to be viable for months (Whitsett 2001, Hamilton 2002). The dynamic nature and flow-path heterogeneity of karst flow ensures that each flow reach has a continuous and viable supply of these bacteria to share with downgradient receiving streams.

The similarity in timeframe and exceedingly high conecntrations of *E. coli* at KHBNR sites is consistent with the connectivity of surface and groundwater in this watershed. Connectivity has been shown to directly impact the quality of downstream water in numerous other karst settings and locations (Winter et al. 1999; Palmer 2007).

Nutrients

Nutrients are compounds that are essential for plant and animal nutrition, and for this study the focus was primarily on nitrate. Animal feces are rich in nutrients, and too great an agricultural application rate can produce water-quality problems in receiving streams and groundwaters (Peterson et al. 2002, Sauer et al. 2008, Jarvie et al. 2014). Figure 7 shows a plot of nitrate concentrations versus time for two BCRET sites (BCRET 2016), 6 (upstream CAFO) and 7 (downstream CAFO) [Figure 1]. The dissolved nitrate concentrations from site 7 are greater than site 6 for the period of record, explained in part by the inflow of groundwater to Big Creek from springs which occur in the bed of the stream upgradient from site 7. Also notable are objectionable algal densities downgradient from these substream springs (Figure 8). Larger springs have been dye-traced from dye-injection well, site 36 (Figure 1) surrounded on 3 sides by spreading fields, and site 39 (Figure 1) across a county road and 200 m from the CAFO.

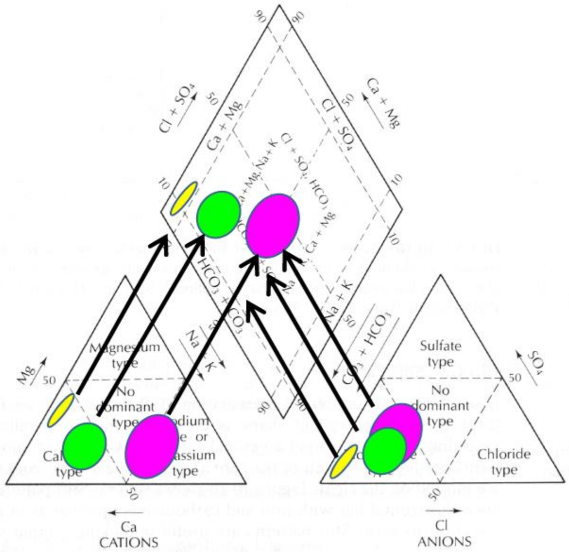


Figure 4. Piper diagram [modified from Hem (1993)] showing the general water-quality types in the exposed area of the Boone Formation (green), area of deeply buried Boone Formation with slow-flow karst attributes (yellow), and area of exposed, overlying, nonkarstified sandstone and shale aquifers (pink). These indicate that dissolution is the dominant geochemical process, coupled with mixing. This plot is based on pre-CAFO (2013) water samples. Figure 6 shows a cross-sectional view that identifies the general location of where these water types typically are found.

Summer 2013 analyses of nitrate in water in Big Creek valley (Figure 3) indicate that in some areas of the valley, the natural system had received more nutrients than could be adequately assimilated by crops, with dissolved concentrations of NO_3 as great as 11.3 mg/L analyzed from springs. Maximum EPA limits for nitrate are 10 mg/L, and although these elevated concentrations were present before the CAFO started, the groundwater system was obviously stressed during this time. In other locations in the valley where adequate dilution occurs, concentrations of dissolved nitrate typically are less than 1.0 mg/L.

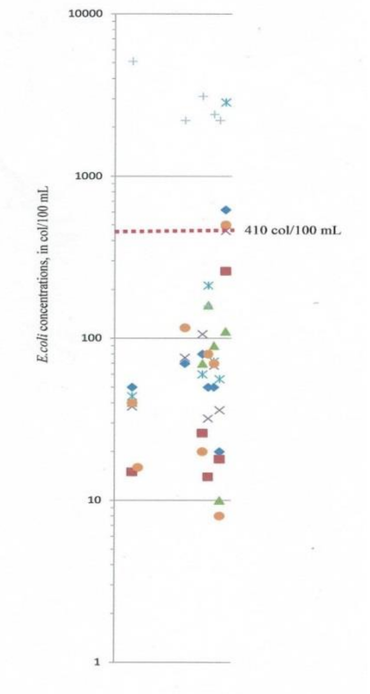


Figure 5. Semi-logarithmic plot of *E. coli* concentrations (in colonies/100 mL) for eight sampling intervals between 6/14/16 and 8/8/16. Samples were collected by the KHBNR team. Different patterns on the graph show different sampling periods. The red dashed line at 410 col/100 mL represents the *E. coli* concentration limit for Big Creek (non-extraordinary waters) the primary period. To be classed as impaired, a stream must be above this limit for five successive samples made during a 30-day period.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations in Big Creek were sampled by the U.S. Geological Survey at station 07055814 Big Creek at Carver. Automated probes sampled at 15-minute intervals, and were calibrated on a biweekly basis. Results from 2014 show a diurnal pattern of high concentrations during daylight hours, and low concentrations during the nighttime, which is typical. During daylight, algae in the creek generates oxygen, which is added to the water as it absorbs sunlight (due to photosynthesis). At night, oxygen is removed from the water, thus depleting DO from streams and rivers as part of a natural cycle. However, if measurements show the DO

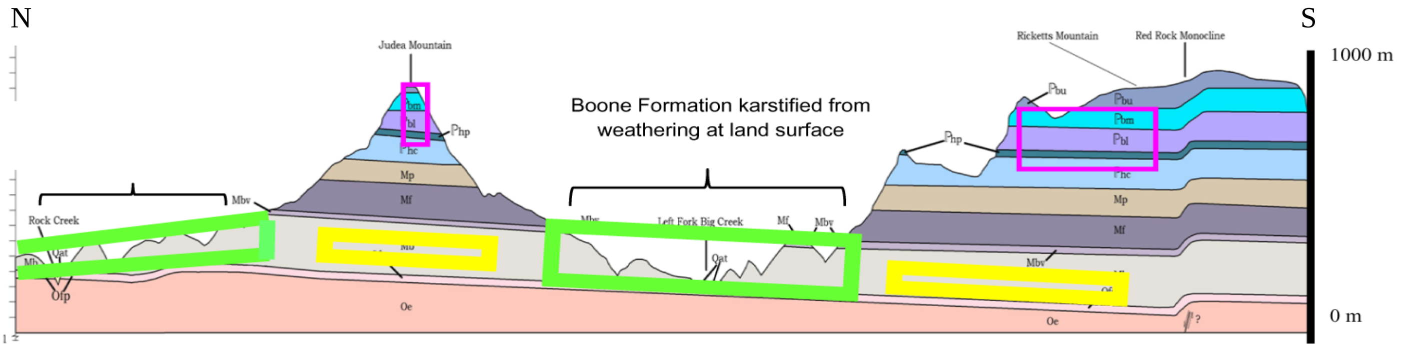


Figure 6. Generalized cross section showing typical water-quality types in the exposed area of the Boone Formation (green rectangles), area of deeply buried Boone Formation with slow-flow karst attributes (yellow rectangles), and area of exposed, overlying, nonkarstified sandstone and shale aquifers (pink rectangles). The line of section is along west edge of study area. Figure modified from Braden and Ausbrooks (2003).

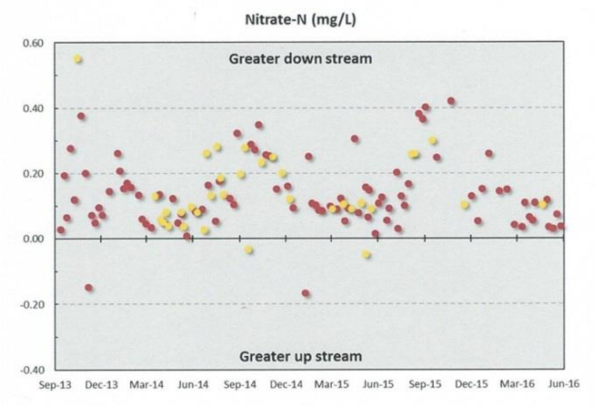


Figure 7. Plot of nitrate in mg/L verses sampling date showing the relation between upstream (Site 6-Figure 1) versus downstream BCRET sites (Site 7-Figure 1). Source of data and graph is BCRET (2016). Negative values for upstream site are necessary to plot the two stations together. Actual concentrations are positive.

Table 2. Periods of DO exceedence of Regulation 2 standards (APCEC 2015) during selected 8+ hour intervals in the summers of 2014 and 2015. Data are from U.S. Geological Survey (2016), site 07055814 Big Creek at Carver downstream from the study area.

Date	Start Time	Stop Time	Minimum Measured DO	Minimum DO Allowed
			(mg/L)	(mg/L)
8/24/2014	2:45	11:00	4.4	5.0
8/25/2014	2:45	11:30	4.4	5.0
8/30/2014	3:15	12:00	4.5	5.0
9/1/2014	4:15	12:45	4.2	5.0
10/8/2014	5:45	15:15	5.8	6.0
8/10/2015	3:15	12:45	4.5	5.0

Figure 8. Objectionable algal densities on Left Fork of Big Creek downstream from an anomalously large spring (Brahana, 1997) at site 30 (Figure 1). Under high flow conditions, groundwater and dye were traced to site 30 beneath the topographic divide that separates Big Creek from Left Fork Big Creek.

concentration in the stream has dropped below the critical level, the stream is classified as impaired.

Minimum concentration of DO in this part of the Ozarks during the critical period is 5 mg/L for times when the water temperature is greater than 22^{o} C. Big Creek fell below 5.0 mg/L on multiple occasions during the summers of 2014 and 2015 (Table 2). Recently reported results from the National Park System conducting ongoing 15-minute DO monitoring of Big Creek during the summer of 2016 showed ongoing continuation of depressed DO.

As a comparison of DO on Big Creek to a nearby stream, DO concentration in the Little Buffalo River, slightly more than 10 km upstream from the confluence of Big Creek and the Buffalo River, was below 6 mg/L only 1 time for less than 3 hours total for

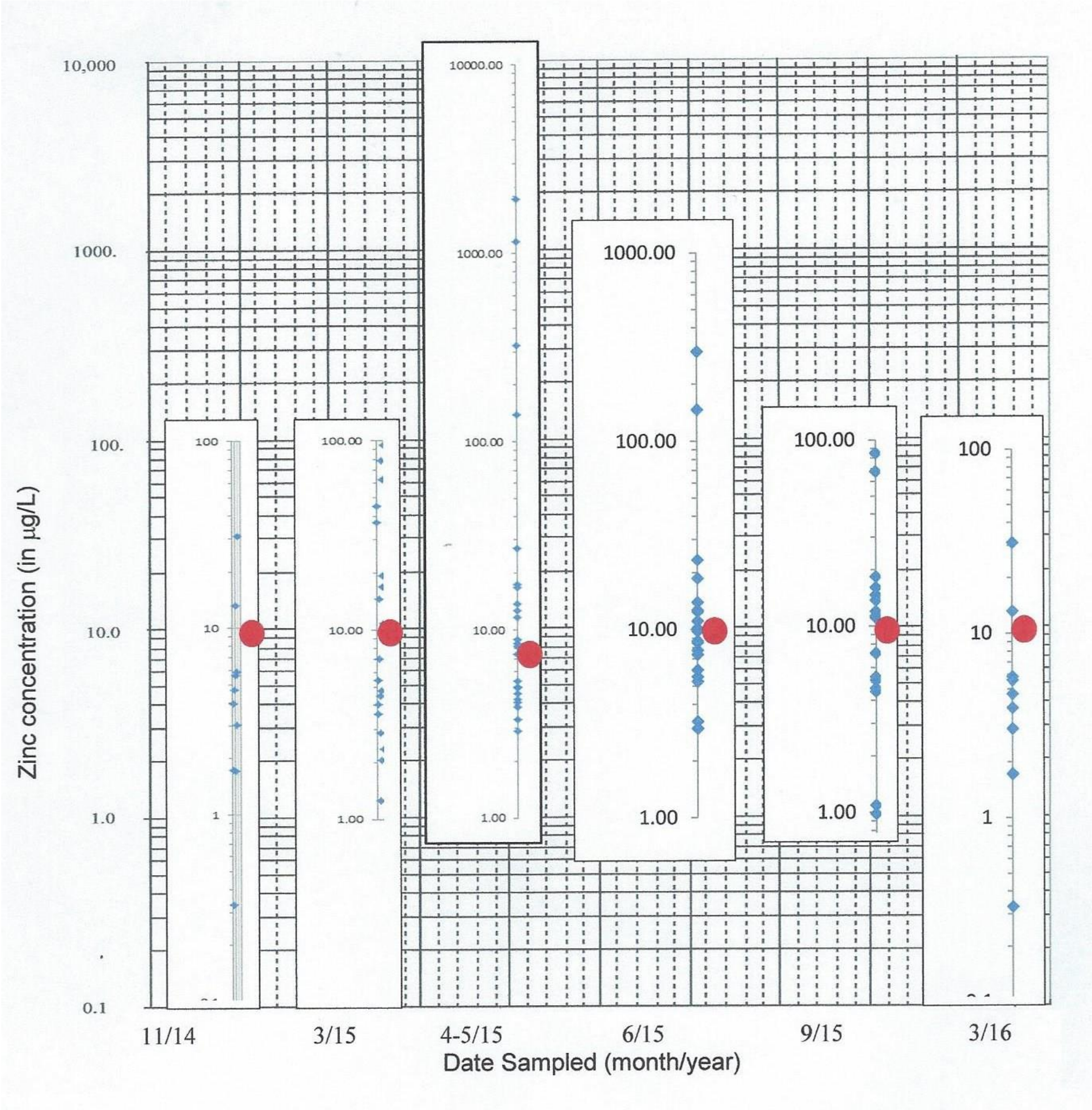


Figure 9. Dissolved zinc concentrations in groundwater and surface water in µg/L (ppb) plotted by date sampled, plotted on semi-logarithmic paper in blue diamonds. QA/QC values are shown by the red circles, and reflect the iCAP MS value for 10 µg/L standard for each suite of analysis by date. Precise sampling dates and hydrogeologic conditions during sampling are November 15, 2014 (low flow); March 17-18, 2015 (intermediate flow); April 13-May 11, 2015 (high flow); June 3-4, 2015 (high flow); September 8,2015 (intermediate flow); and March 7, 2016 (low flow).

the period measured during the sampling interval of summer 2013. The drainage basin of the Little Buffalo River has a similar distribution of land use and population as Big Creek, but it does not contain any CAFOs.

Trace Metals

Trace metals are dissolved cationic constituents that typically occur in water in very small concentrations (parts per billion or µg/L). Trace metals serve as effective tools for hydrogeologists to determine if groundwater contamination is occurring.

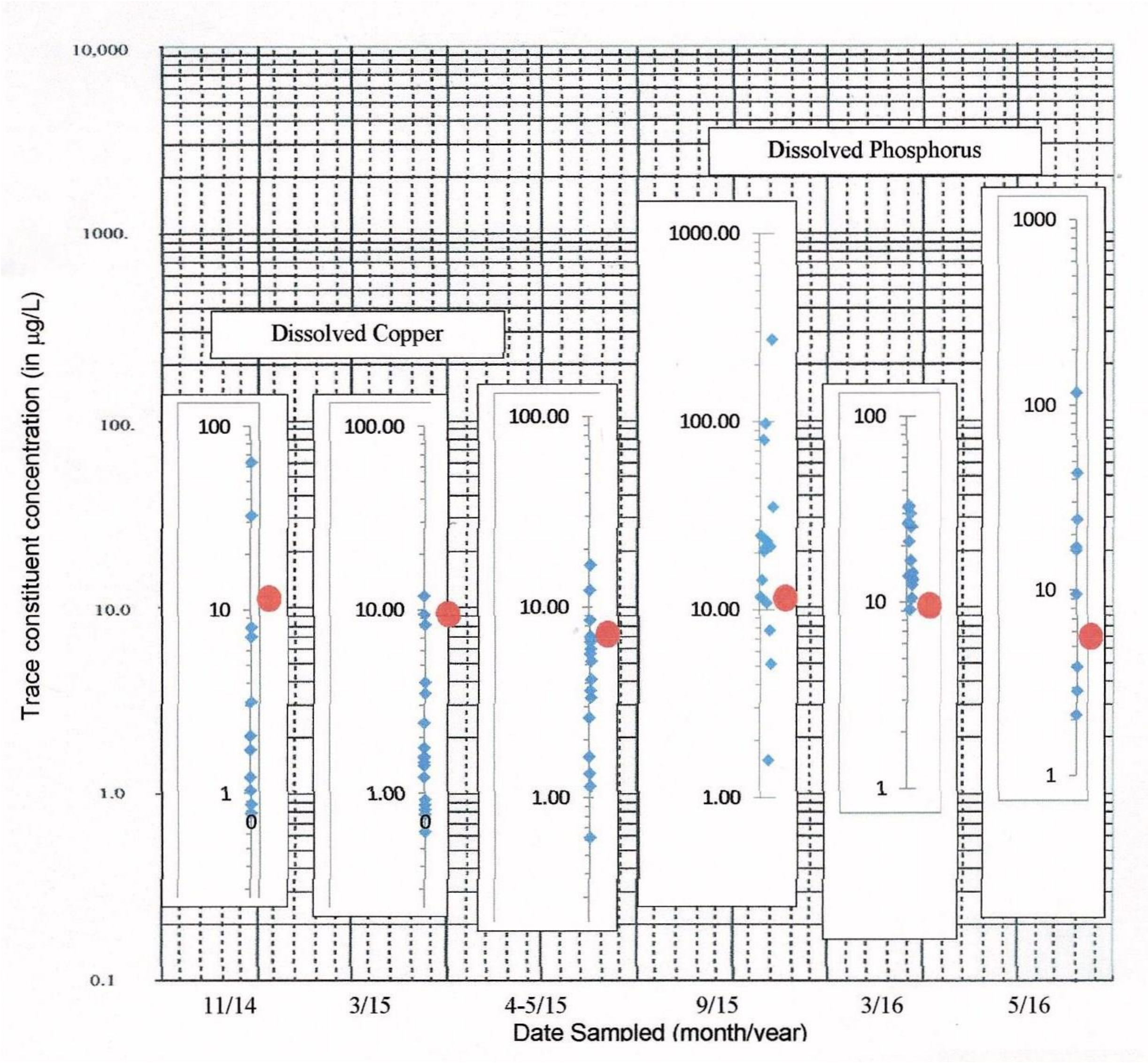


Figure 10. Dissolved copper and phosphorus concentrations in groundwater and surface water in µg/L (ppb) plotted by date sampled, plotted on semi-logarithmic paper in blue diamonds. QA/QC values are shown by the red dots, and reflect the iCAP MS value for 10 µg/L standard for each suite of analysis by date. Precise sampling dates and hydrogeologic conditions during sampling are November 15, 2014 (low flow); March 17-18, 2015 (intermediate flow); April 13-May 11, 2015 (high flow); September 8,2015 (intermediate flow); March 7, 2016 (low flow); and May 10, 2016 (intermediate flow).

If the trace metals can be connected with a specific land use, they may also serve as valuable indicators to suggest the potential contamination source. Relevant to this study, two of these trace metals are reported to be additives to pig feed (Jacela et al. 2010), including zinc (Zn), and copper (Cu). Phosphorus (P), a non-metal was also included in this study because its isotope ^{31}P is an indicator constituent of animal feces. Selected Zn analyses are shown in Figure 9, and Cu and P are shown in Figure 10. Seven trace-constituent sampling campaigns were undertaken between November 15, 2014, and May 10, 2016.

Preliminary results of this part of the sampling program revealed that two specific regions of the study area had anomalously high concentrations of Zn, Cu, and P. These locations included sites 13, 15, and 36 (Figure 1), which are surrounded by spreading fields that lie immediately upgradient from these springs and well, and sites 39 and 40 (Figure 1), wells that are down-gradient and within 200 m of the CAFO infrastructure and its ponds. Concentrations of trace constituents in these two general areas typically varied from one to two orders of magnitude greater than samples from surface water.

Stable Isotopes

The stable isotope ratios, deuterium/protium ($^2H/^1H$) and oxygen -18/oxygen-16 ($^{18}O/^{16}O$) were analyzed for each of ten water samples collected during a single sampling interval on March 7, 2016. The results are shown in Figure 11, and may be synthesized as lying on the global meteoric water line. The $\delta\ ^{18}O$ values in units of per mil ($^{o/oo}$; parts per thousand against standard mean ocean water) have been plotted against the $\delta\ ^2H$ values for each of the samples, and are shown superimposed on the global meteoric water line (Craig 1961, White 1988). This close relation of the data to the meteoric water line gives us confidence that the interpretation that the source of the water comes wholly from precipitation, and that no geochemical processes (evaporation, addition of deep thermal water) are acting on the water to shift the data above or below the line. The global meteoric water line can be defined by an equation:

$$\delta\ ^2H = 8.0 \times \delta\ ^{18}O + 10\ ^{o/oo}$$

(Craig 1961) that relates the average relationship between H and O isotope ratios in natural terrestrial waters, expressed as a worldwide average (Standard Mean Ocean Water).

Ancillary Observation

Field observations of streams, springs and wells in Big Creek basin provide a good general overview of the general health of the integrated natural water system. During late-summer low-flow conditions when evapotranspiration is at its greatest, many of the tributaries and even the main stem of Big Creek cease to flow on land surface, a common occurrence on karst lands elsewhere. Water that has been trapped and pooled on the surface is evaporated, and commonly leaves a crust on the dry streambed (Figure 12). These reaches in the study area in the summer of 2013 smelled like a poultry CAFO, and the fields upgradient that supplied recharge to the creeks were reported (not verified) to have received poultry litter. The presence of the evaporative crust does establish the fact that solutes are present in the stream water.

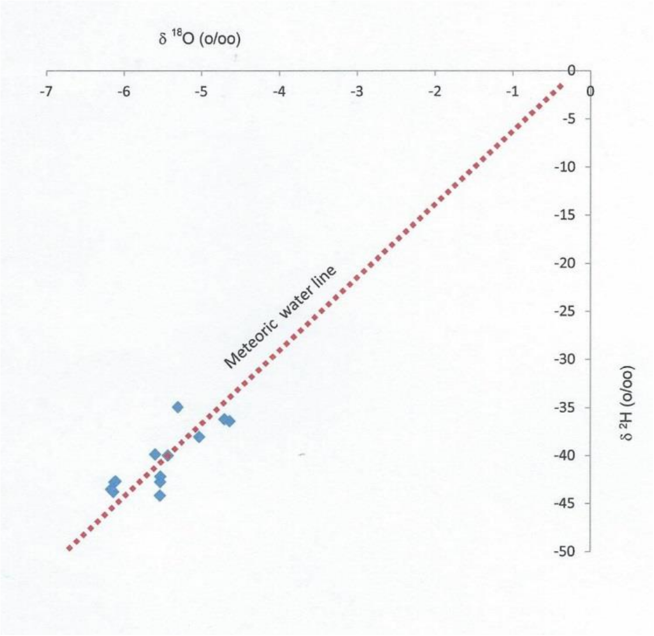


Figure 11. The stable isotopes of hydrogen and oxygen have been plotted for samples collected on March 7, 2016, and they lie on the meteoric water line. Data are shown as blue diamonds, and the meteoric water line is dashed, in red. Units of measurement are per mil (o/oo).

Summary

Data from major constituents indicate that the dominant geochemical processes controlling water quality in Big Creek basin are dissolution and mixing with meteoric water, which is to be expected in a region underlain by karst. Groundwater in the Boone Formation from wells and springs, and surface water from Big Creek and its tributaries are a calcium-bicarbonate type, with various contributions from animal husbandry and other land-use activities on the land surface. Deep wells beneath the cover of terrigenous sediments show the effect of less mixing and dilution, being more mineralized but still dominantly calcium bicarbonate type (Figure 4). Shallow wells and springs in the overlying younger sediments are indicative of less mineralization, with greater concentrations of chloride and sulfate, typical of shales with interbedded sandstones.

Observations of objectionable algal densities and nuisance water-plant growth are indicative of excessive nutrients that have been added to the water from activities on the land surface. At this time, Big Creek basin does not typically experience water quality that exceeds acceptable EPA limits. However, numerous observations indicate that Big Creek basin has greater nitrate concentrations at its downstream sample site 7

(BCRET 2016). U.S. Geological Survey DO and BCRET and KHBNR *E. coli* data also document that Big Creek does qualify as an impaired stream during some summertime periods. Because Big Creek drains the fifth largest subbasin to the Buffalo, and animal husbandry is the dominant land use, we need to carefully manage the feces and urine we allow to leak into its flow paths.

All data suggest that it is important to incorporate karst and hydrogeology into our permitting process for CAFOs on soluble rock if we intend to preserve these environments and their contained water resources (Kosič et al. 2015). Groundwater is hidden from view, but it plays a dominant role in the hydrologic budget of karst. Considering the fact that the Buffalo National River is the main drain for all waters flowing from Big Creek, the many users of the river deserve a scientifically accurate assessment of the risks of primary contact with water for any number of intended uses. It is our opinion that water-quality in Big Creek valley is being degraded, and ongoing monitoring of both surface and groundwater is essential.

Figure 12. During the summer of 2013, when precipitation declined and evapotranspiration increased, surface streams Big Creek and Left Fork of Big Creek displayed sections downstream from animal production fields that pooled, evaporated, and left a crust of dissolved minerals on the streambed. This evaporative crust was thicker, more odoriferous (strong poultry litter-like smell), and far more extensive than any personal observations of the coauthors had experienced during their careers in this region. It is shown here as white covering of the streambed.

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From:	Jessie Green
To:	Water Draft Permit Comment; McWilliams, Katherine; Osborne, Caleb; Solaimanian, Jamal
Subject:	[BULK] 5264-W Comments
Date:	Thursday, April 06, 2017 4:22:51 PM
Attachments:	1992 CAFO Moratorium.pdf BCRET_01-2017.xlsx UofA and ADEQ_BCRET MOA.pdf TNC DRASTIK.pdf Murdoch et al 2016.pdf Brahana et al 2016_geochemical processes big creek.pdf Sharpley et al 2003.pdf 5264-W Comments_JJG.docx

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Attached are the comments and referenced attachments. Please accepts all as part of my formal comments.

Thank you for this opportunity.

Jessie J. Green
White River Waterkeeper

From: Jessie Green
To: Water Draft Permit Comment; McWilliams, Katherine; Osborne, Caleb; Solaimanian, Jamal
Subject: [BULK] Re: 5264-W Comments
Date: Thursday, April 06, 2017 4:31:52 PM

Also, don't hesitate to let me know if you have any further question regarding my comments. I will be forwarding comments along to the BBRAC group probably sometime next week when I get a chance to write them a more detailed explanation of how I think these comments can be used to help inform any subcommittees or working groups that may be necessary for better understanding of managing resources on karst terrain in sensitive watersheds such as the Buffalo River. In addition, more details will also be provided of the fun things I have been up to since taking off my ADEQ Office of Water Senior Ecologist hat and how I can assist the BBRAC group in my new role as White River Waterkeeper!

Take care!

Jessie

On Thu, Apr 6, 2017 at 4:19 PM, Jessie Green <jessie@whiteriverwaterkeeper.org> wrote:

> Attached are the comments and referenced attachments. Please accepts all as part of my formal comments.
>
> Thank you for this opportunity.
>
> Jessie J. Green
> White River Waterkeeper