“Protecting the public health and natural resources of the White River watershed through advocacy, education, and research”

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10 September 2018

Ms. Sarah Clem
Planning Branch Manager, Office of Water Quality
Arkansas Department of Environmental Quality
5301 Northshore Drive
North Little Rock, AR 72118
Sent via email to clem@adeq.state.ar.us, WaterbodyComments@adeq.state.ar.us

Re: 2018 Draft 303(d) Public Comments

Dear Ms. Clem,

Thank you for the opportunity to comment on Arkansas's 2018 draft list of impaired waterbodies (hereinafter, the list).[1] Accompanying EPA's delegated authority to the state is "the primary responsibility and right to prevent, reduce and eliminate pollution rests with the State, provided that the State's program for these purposes shall also promote and fulfill federal objectives and requirements."[2] Carrying out sections 303(d) and 305(b) of the Clean Water Act are integral to the permitting framework[3] and Arkansas's delegated authority to administer the NPDES program. Among many requirements, is that which ensures permits can be terminated or modified for "change in any condition that requires either a temporary or permanent reduction or elimination of the permitted discharge."[4, 5] The due-diligence to properly carry out each component of the CWA's framework is necessary "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[6]

[1] Prepared pursuant to CWA Section 303(d); 40 CFR 130.7
[2] See p. 7, MOA between EPA and AR, https://www.epa.gov/sites/production/files/2013-08/documents/ar-moa-npdes.pdf
[3] https://www.epa.gov/tmdl/program-overview-impaired-waters-and-tmdls
[4] CWA § 402(b)(1), emphasis on 402(b)(1)(C)(iii),
[5] AR Code 8-4-208(a) - Arkansas Department of Environment Quality is vested with the authority and power to meet the requirements of § 402(b) of the CWA. This includes the ability to provide a weight-of-evidence and best professional judgement approach when making attainment decisions not encompassed in the Assessment Methodology (AM).
[6] CWA § 101(a)

In addition to informing proper discharge controls, the list identifies where funding and control measures are needed to address nonpoint source pollution.[7, 8] The list accounting for 35% of variable funding through Section 106 grants, for which funding for pollution control programs is contingent on the state's ability to properly monitor, compile, and analyze data for determining the quality of waters throughout the state (including classification according to eutrophic condition).[9]

The responsibility placed on ADEQ's Water Quality Planning Branch is undoubtedly tremendous. However, as impaired waterbodies factor significantly into federal funding provided to the states to carry out water pollution control programs, perhaps ADEQ will take the opportunity to be more inclusive when reporting waterbodies not attaining water quality standards. Aside from the funding aspect, it's impossible to formulate an effective plan to address pollution concerns without first identifying and understanding problems. Thank you for the efforts on behalf of the Planning Branch to carry out such an immense and significant undertaking for the state.

White River Waterkeeper (WRW) reserves the right to rely on all public comments submitted and requests written response to all comments.

SPECIFIC COMMENTS

I. ADEQ has failed to provide adequate justification for placing impaired waters in Category 4b.

Category 5 refers identifies and sets priority-ranking of water quality-limited segments still requiring a TMDL, essentially making up "the list."[10] 40 C.F.R. § 130.7(b)(1) requires state to identify those water quality-limited segments still requiring TMDLs within its boundaries for which:

> technology-based effluent limitations required by sections 301(b), 306, 307, or other sections of the Act; more stringent effluent limitations (including prohibitions) required by either State or local authority preserved by section 510 of the Act, or Federal authority (law, regulation, or treaty); and other pollution control requirements (e.g., best management practices) required by local, State, or Federal authority are not stringent enough to implement any water quality standards (WQS) applicable to such waters.[11]

Category 4b is reserved for situations where controls are already in place that are demonstrably sufficient to achieve water quality standards. It requires that the alternative

[7] CWA § 319

[8] The Integrated 303(d) and 305(b) Report serves as the nonpoint source assessment report. See p. II-17, Assessment, Arkansas 2016 Integrated Water Quality Monitoring Assessment Report, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/final-2016-305b-report.pdf

[9] CWA § 106(e)(1)

[10] 40 C.F.R. § 130.7(b)

[11] 40 C.F.R. § 130.7(b)(1)(i)-(iii)

control measures be "expected to result in attainment of designated uses." EPA guidance provides further clarification: "EPA would like to reiterate that States have the opportunity to assign impaired waters to Category 4b where controls sufficient to achieve water quality standards in a reasonable period of time are already in place."[12] EPA requires states to demonstrate how the alternative pollution controls will achieve the water quality standards, that the controls are actual requirements, estimate the time it will take for the controls to achieve the water quality standard, and provide a schedule for implementing the controls. But a "goal" is not a "schedule."

Additionally, states are expected to provide EPA with a "linkage analysis (i.e., cause-and-effect relationship between a water quality target and sources)" evaluating **point** and nonpoint source loadings that when implemented will achieve water quality standards.[13]

a. ADEQ has failed to demonstrate that TMDL alternatives are stringent enough to implement water quality standards.[14]

Furthermore, "The Section 303(d) listing requirement applies to waters impaired by point and/or nonpoint sources, pursuant to EPA's long-standing interpretation of Section 303(d)."[15] Information provided on ADEQ's website regarding Category 4b Determinations are limited to alternative [voluntary] management plans for non-attainment decisions for assessment units in the Illinois River, Buffalo River, and Beaver Lake watersheds.[16, 17, 18, 19] [Emphasis added].

i. Technology-based effluent limitations (TBELs) required by the CWA are <u>NOT</u> stringent enough to implement applicable standards in the Buffalo River watershed.[20]

Regarding Confined Animal Feeding Operations (CAFOs), point sources,[21] TBELs refer to "best practicable control technology currently available as defined

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[12] October 12, 2006, EPA, Information Concerning 2008 Clean Water Act Sections 303(d), 305(b), and 314 Integrated Reporting and Listing Decisions (hereinafter "2006 IRG") at 5-6.
[13] See p. 8, *Id*.
[14] *Id*.
[15] 19 July 2017, EPA Action on Arkansas's 2010, 2012, 2014, and 2016 § 303(d) Lists, Enclosure 2, p. 2. https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/epa-decision-2017.pdf
[16] ADEQ Category 4b Determinations, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/category-4b-determinations.pdf
[17] Beaver Lake Watershed Protection Strategy http://www.beaverwatershedalliance.org/pdf/Beaver-Lake-Watershed-Protection-Strategy.pdf
[18] Buffalo River Watershed Management Plan https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/2018-05-22-final-buffalo-river-wmp.pdf
[19] Watershed-Based Management Plan for the Upper Illinois River Watershed https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/uirw-watershed-based-plan-2012-11-30-final.pdf
[20] 40 C.F.R. § 130.7(b)(1)(i) and (ii)
[21] CWA § 502(14)

by the Administrator pursuant to section 304(b)."[22, 23] CAFO TBELs focus on adequate lagoon design and adequate land application to avoid "discharge of process wastewater pollutants into U.S. waters."[24] Many of the following arguments apply to other watersheds, including the Illinois River, especially those within karst landscapes. These considerations should be given to all watersheds where CAFOs generate and land apply waste. Site-specific examples provided below with focus solely on the Buffalo River watershed.

ADEQ identified four waterbody/pollutant pairs in the Buffalo River watershed as not attaining water quality standards (**Table 1**).

Within the Big Creek watershed, the only facilities with water related permits are CAFOs. This includes C&H Hog Farm, the only large swine CAFO in the Buffalo River watershed. The public comment record related to the draft permit decision for 5264-W[25] includes an extensive review of TBELs insufficient to support water quality standards. WRW's comments highlighted data collected by Big Creek Research and Extension Team providing further evidence that current TBELs are not enough, as data indicate significantly higher nitrate and total nitrogen concentrations in Big Creek attributed to C&H Hog Farms.[26]

Despite violations of C&H's holding pond pointed out through a slurry of public comments,[27] ADEQ has maintained that no violations have been found.[28] Therefore, one must infer the construction, design, and integrity of the holding ponds are in accordance with TBELs required by the CWA. Considering anecdotal evidence that waste from cattle, poultry, or humans does not compare to the amount of waste generated and spread in the watershed than that by C&H, it is apparent that C&H is a major pollution source.[29] Therefore, special consideration should be given to this factor, regarding Category 4b or Category 5 placements, when determining if all requirements have been met to demonstrate TBELs **are**

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[22] CWA 301(b)(1)(A)
[23] 40 C.F.R. § 412.31
[24] Noting exception of overflow attributed to 10-year, 24-hour rainfall runoff events; 40 C.F.R. 412.
[25] Public comments received on Permit No. 5264-W, https://www.adeq.state.ar.us/home/pdssql/p_permits_online_npdes_additonal.aspx?PmtNbr=5264-W&Category=PermitInformation&Title=Permit%20Information; emphasis given to comments submitted by Buffalo River Watershed Alliance, https://www.adeq.state.ar.us/downloads/WebDatabases/PermitsOnline/NPDES/PermitInformation/5264-W_G%20Watkins%20BRWA%20Public%20Comments_20170405.pdf
[26] See p. 3-6, 6 April 2017, WRW Comments Re: Permit 5264-W; AFIN 51-00164; C&H Hog Farms, Inc., https://www.adeq.state.ar.us/downloads/WebDatabases/PermitsOnline/NPDES/PermitInformation/5264-W_J%20Green%20Public%20Comments_20170406.pdf
[27] See also, *Id.* Table 1.
[28] See Response to Comment No. 329, p. 290, Response to Comments Final Permitting Decision Permit No: 5264-W, https://www.adeq.state.ar.us/water/bbri/c-and-h/pdfs/5264-w-response-to-comments-final-20180110.pdf
[29] See p. 3-6, 6 April 2017, WRW Comments Re: Permit 5264-W

stringent enough. In the case of Big Creek and the Buffalo River, this demonstration has not been met.[30]

1. **The current Arkansas Phosphorous Index (API) is not sufficient for use on karst terrain.**

   Nutrient Management Plans (NMP) required by animal waste discharge permits must develop a method that considers potential P loss from agricultural fields and that P applications are based on soil-test P levels (agronomic soil-test interpretation), soil-test P threshold (environmental interpretation of soil-test P), or a P index (site-specific assessment of potential P delivery).[31] Arkansas makes use of the API in NMPs required by animal waste discharge permits. [32]

   As stated in University of Arkansas Division of Agriculture publications, consideration of karst topography in development of NMPs in Northern Arkansas is a major concern.[33] Moreover, studies in locations comparable to the Big Creek and Buffalo River watersheds[34] have noted the significant concern of Phosphorous (P) retention and remobilization within the karst, causing a lag-time. This not only makes cause-effect studies difficult, but also provides for legacy P concerns.[35]

   All P application rates approved in C&H's NMP are above agronomic rates, as is the intent and design of phosphorus indices. As such, excess phosphorous either runs off horizontally to surface water, leaches vertically to groundwater and karst conduits, or accumulates in soil. The long-term accumulation of P in soil, however, can be released slowly to soil water.[36, 37]

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[30] See Response to Comment No. 273, p. 290, Response to Comments Final Permitting Decision Permit No: 5264-W. ADEQ has continuously refused to consider site specific considerations when permitting and requiring various P management options.
[31] Nutrient Management (590) standard
[32] See Section 1.5.1.2, ARG590000
https://www.adeq.state.ar.us/downloads/WebDatabases/PermitsOnline/NPDES/Permits/ARG590000.pdf
[33] Nutrients and Water Quality Concerns, Publication 9517-PD-9-05N, U of A, Division of Agriculture, https://www.uaex.edu/publications/PDF/FSA-9517.pdf
[34] Cite bcret publications comparing Illinois river and buffalo river, savoy farm or whaterver
[35] Jarvie, Helen P., et al. "Phosphorus retention and remobilization along hydrological pathways in karst terrain." Environmental science & technology 48.9 (2014): 4860-4868, (**Attachment 1**); noting "the potential for contaminant retention in the subsurface karst drainage system, where contaminant storage and gradual rerelease may occur over time scales of at least a decade."
[36] Jarvie et al.
[37] Sharpley, Andrew N., et al. "Evaluating the success of phosphorus management from field to watershed." Journal of Environmental Quality 38.5 (2009): 1981-1988, https://pubag.nal.usda.gov/pubag/downloadPDF.xhtml?id=43156&content=PDF

A considerable failing of the API in karst is the disregard for leaching and vertical movement of P to the subsurface.[38] In a recent deposition, the author of the API was recently asked and answered the following regarding the API in karst:[39]

> **Q.** Can infiltration be the dominant pathway of nutrient losses in karst areas that have soils with high infiltration rates?
> **A**. Probably.

In the interim of Arkansas adapting the API to accommodate for karst and subsurface loss of P,[40] **ADEQ must provide a rationale justifying why subsurface leaching is not a concern in Arkansas**, and specifically the Buffalo River watershed. The API is handicapped to predicting edge-of-field P loads; however, Alabama, Florida, Kentucky, North Carolina,[41] South Carolina, and Pennsylvania,[42] factor subsurface leaching into their P index equations.[43] [44]

As recommended by the author of the API, "Ideally for water quality protection, the interpretation of different levels of risk would not be uniform across all watersheds. Rather, the risk categories and the limits should be assigned based on water quality targets and the assimilative capacity of the receiving water body."[45] Arkansas may consider a P application rate in karst incorporating a changepoint in soil test phosphorus and dissolved P.[46]

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[38] Osmond, D. L., et al. "Comparing ratings of the southern phosphorus indices." Journal of Soil and Water Conservation 61.6 (2006): 325-337; http://srwqis.tamu.edu/media/11740/pindexpub.pdf
[39] 25 May 2018, Oral Deposition of Andrew Sharpley, Before the APC&EC in the Matter of C&H Hog Farms, Inc., Docket No. 18-001-P, p. 89-90. (Record retained on file, not attached due to ongoing appeal. Not currently publicly available.)
[40] Sharpley et al., 2010, Arkansas Phosphorus Index, FSA9531, https://www.uaex.edu/publications/PDF/FSA-9531.pdf
[41] The N.C. PLAT Committee. 2005. North Carolina Phosphorus Loss Assessment: I. Model Description and II. Scientific Basis and Supporting Literature, North Carolina Agricultural Research Service Technical Bulletin 323, North Carolina State University, Raleigh, N.C., http://nutrients.soil.ncsu.edu/software/ncanat/plat/PLAT_Science_behind_the_tool.pdf
[42] Weld, Jennifer L., et al. "Evaluation of phosphorus-based nutrient management strategies in Pennsylvania." Journal of Soil and Water Conservation 57.6 (2002): 448-454. https://pubag.nal.usda.gov/pubag/downloadPDF.xhtml?id=23632&content=PDF
[43] Osmond, D. L., et al. "Comparing ratings of the southern phosphorus indices." Journal of Soil and Water Conservation 61.6 (2006): 325-337. http://srwqis.tamu.edu/media/11740/pindexpub.pdf
[44] Bolster, C. H. (2011). A critical evaluation of the Kentucky phosphorus index. Journal of the Kentucky Academy of Science, 72(1), 46-58. https://naldc.nal.usda.gov/download/55055/PDF
[45] Sharpley, A. N., et al. "Revision of the 590 nutrient management standard: SERA-17 recommendations." Southern Cooperative Series Bulletin 412 (2011). https://sera17dotorg.files.wordpress.com/2015/02/590-sera-17-recommendations.pdf (**Attachment 2**)
[46] McDowell, R. W., and A. N. Sharpley. "Approximating phosphorus release from soils to surface runoff and subsurface drainage." Journal of environmental quality 30.2 (2001): 508-520. https://pubag.nal.usda.gov/pubag/downloadPDF.xhtml?id=14882&content=PDF

ii. Implementation of voluntary Watershed Management Plans (WMP) are not pollution control *requirements*.[47]

In the case of Big Creek and the Buffalo River impairment decisions, the Beautiful Buffalo River Action Committee (BBRAC), with a non-regulatory driven mission, is proposed as sufficient 4b demonstrations for their commitment to carry out the Buffalo WMP, a non-regulatory, voluntary document.[48, 49] **ADEQ must demonstrate how pollution control *requirements* already in place will achieve attainment of water quality standards.**

b. The BBRAC has not demonstrated how water quality standards will be achieved through the Buffalo River WMP.

Public notice documents providing rationale for Category 4b Determinations states, "The Buffalo River WMP outlines voluntary measures to reduce nonpoint source runoff as well as makes recommendations for water quality monitoring and studies within the watershed. ADEQ believes stakeholders and BBRAC partners are necessary for successful strategy and milestone development. ADEQ and BBRAC are committed to revising the strategy as necessary to achieve ultimate attainment of water-quality standards in the Buffalo River."[50]

i. The BBRAC does not foster relevant and necessary stakeholder involvement needed to implement pollution controls that would achieve water quality standards in Big Creek and the Buffalo River.

The BBRAC Charter states it provides support for coordinating the actions of Arkansas state agencies **and interested partners**. Nothing could be further from reality. The BBRAC is comprised of Arkansas Department of Environmental Quality, Arkansas Natural Resource Commission, Arkansas Game and Fish Commission, Arkansas Geographic Information Systems, Arkansas Department of Health, and Arkansas Department of Parks and Tourism. However, Arkansas state agencies are insignificant land holders in the Buffalo River watershed (**Table 2**). Regardless of the National Park Service being significant stakeholders and land managers, Buffalo National River staff have yet to be invited to participate as a member of the BBRAC.

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[47] 40 C.F.R. § 130.7(b)(1)(iii)
[48] Arkansas's 2018 List of Impaired Waterbodies, Executive Summary, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/executive-summary.pdf
[49] Category 4b Determinations, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/category-4b-determinations.pdf
[50] https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/category-4b-determinations.pdf

Table 2. Public lands in the Buffalo River watershed.

Land Holder	% of Watershed Held
National Park Service	11%
National Forest Service	26%
Arkansas Game and Fish Commission	3%

In addition, the public is barred from participating in BBRAC meetings. Public engagement during the development of the Buffalo River WMP was deemed a sufficient means of involving the public. The last meeting of the WMP was held 12 October 2017. Although Director Keogh (ADEQ), BBRAC co-chair, decided the public's ability to attempt to talk to directors and staff informally before or after meetings is sufficient[51] – in no way does it suffice. The BBRAC has maintained that submission of comments to the BBRAC members, agency directors, is an adequate means of fulfilling their commitment to public involvement. However, WRW has not had success engaging BBRAC members to discuss harmful algal bloom (HAB) related illnesses, algae monitoring, confirmation of *Microsciera wollei* in the Buffalo River, and cyanotoxin testing.[52] Despite significant public interest and health related concerns surrounding these topics, the BBRAC meeting held one month after receipt of this letter failed to address any of the concerns detailed in WRW's 20 July 2018 letter. In fact, besides vague mention to toxin levels and HABs across the nation, there was no mention of HABs at all, and certainly not in relation to the Buffalo River.

Due to the lack of opportunity for public participation, and lack of meaningful information or actions coming out of the BBRAC meetings, public attendance is negligible, at best.[53] Coupled with the added hinderance of quarterly BBRAC meetings held three hours from the Buffalo River watershed, it is not surprising that the public has lost interest. Since the formation of BBRAC in September 2016, at least a dozen interested stakeholders (e.g., watershed organizations, land owners) have expressed interest in actively participating with BBRAC members to develop and carry out actionable items. At least so far as WRW, Buffalo River Watershed Alliance, Ozark River Stewards, Ozark Society, and Friends of the

[51] See Public Engagement, p. 5-6, 17 January 2017, Beautiful Buffalo River Action Committee minutes, https://bbrac.arkansas.gov/pdfs/20170117-bbrac-minutes.pdf

[52] 20 July 2018, WRW Letter to BNR, ADEQ, ADH Re: Harmful Algae in the Buffalo National River, (**Attachment 3**); As of 10 September 2018, the only response received to this letter was from Nathaniel Smith, Director, ADH (23 July 2018) with a phone number to the communicable disease nurse and mention that ADH has "collected specimens for clinical testing but are still working with the CDC and other partners to determine the best strategy for testing."

[53] Less than six members of the general public in attendance of the 21 August 2018 BBRAC quarterly meeting, North Little Rock, AR. *Personal observation.*

North Fork and White Rivers – none have been invited to participate in active discussions related to water quality concerns and means of resolving them. This is noteworthy, as our organizations are actively involved in the watershed, conduct water quality monitoring, organize citizen science volunteers, have large memberships with vested interests in the Buffalo River, and have continuously expressed interest in working with state (and federal) agencies to address water quality problems.

ii. At present, the Buffalo River WMP does not address targets, schedules for compliance, monitoring plans, or pollution controls to achieve water quality standards in water quality limited segments in the Buffalo River watershed.

Pollution reduction targets identified in the Buffalo WMP[54] are limited to priority watersheds, which do not overlap with impaired stream segments identified by ADEQ (**Figure 1**). Regardless of limited faith in BBRAC's ability to carry out the suggestions of the Buffalo River WMP, the WMP does not address subwatersheds for segments ADEQ is proposing to place in Category 4b.

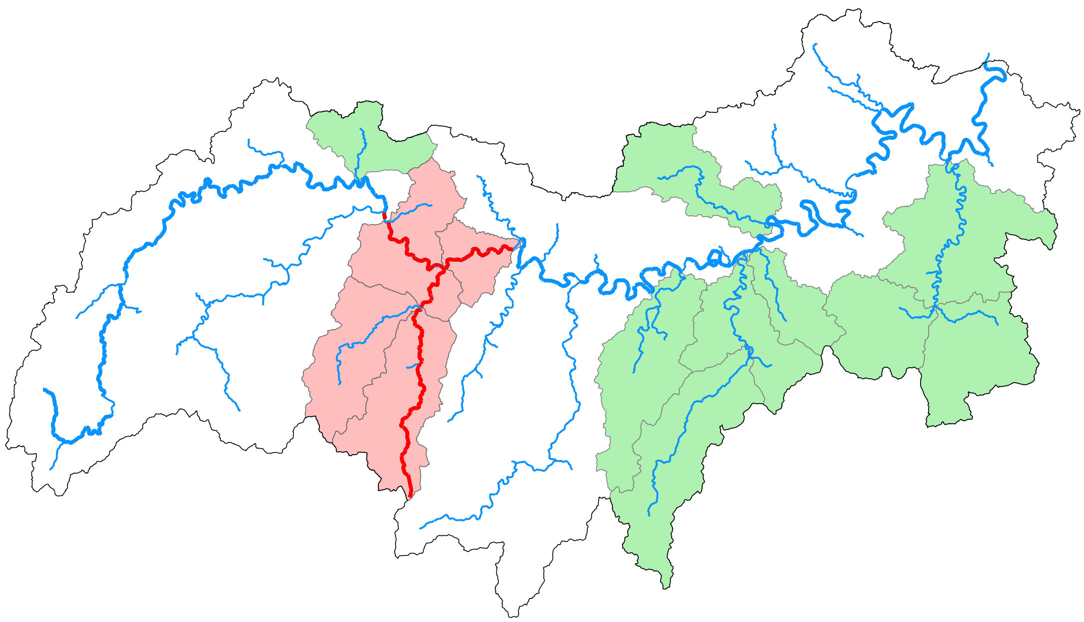

Figure 1. Buffalo River Watershed with priority subwatersheds identified by the Buffalo River WMP (green). Impaired stream segments on Big Creek and Buffalo River (red), and corresponding subwatersheds (pink), do not overlap with WMP targets (priority subwatersheds) identified for initial management practices and activities.

[54] 22 May 2018, Buffalo River Watershed-based Management Plan, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/2018-05-22-final-buffalo-river-wmp.pdf

II. ADEQ Fails to Account for all Water Quality Standards (i.e., numeric criteria, narrative criteria, waterbody uses, and antidegradation requirements) when Developing the 303(d) List.[55]

a. ADEQ's tiered AM for listing waterbodies as impaired for nutrients[56] is not adequate for determining attainment of the narrative nutrient criteria.

i. At the very least, ADEQ should adopt a 25% screening threshold for the first tier of nutrient attainment decisions.

Please address the comments posed by JoAnne Burkholder during the 2016 303(d) cycle for why ADEQ deems it is appropriate to "sets thresholds for excess TN and TP at a much higher, much less protective level than would be set from use of U.S. EPA's recommended protocols,"[57] with a clear explanation related to scientific justification of how ADEQ's methodology assures attainment of Arkansas's narrative nutrient criteria.

ii. ADEQ does not collect, or assess, sufficient data to determine whether most waterbodies are attaining the narrative nutrient criteria.

In addition to the many failings of Arkansas's nutrient AM, is the glaring problem that the three-tiered attainment decision approach was designed as an obstacle for making **any** non-attainment decisions for nutrients. In 2018,[58] 2016,[59] and 2014,[60] there were no waterbody/pollutant pairs listed for failure to meet Arkansas's nutrient criteria.[61] There are two listings on the 2018 draft for nitrates (NO_3; Elcc Tributary – 8040201-606, Sager Creek – 11110103-932), both carried over from 2008. No Cat. 5 listing decisions for any form of phosphorus have been proposed by ADEQ in the last ten years. This is not a true reflection of water quality-limited segments, those failing to meet applicable water quality standards (i.e., narrative nutrient criteria, as defined by Reg. 2.509) across the state of Arkansas.

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55 40 C.F.R. § 130.7(b)(3)

56 Figure 3, p. 67, 25 July 2018, 2018 AM, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/final-2018-assessment-methodology.pdf

57 See p. 11-12, Comments on the Draft: Assessment Methodology for the Preparation of The 2014 Integrated Water Quality Monitoring and Assessment Report, and The 2016 Water Quality Monitoring and Assessment Report, authored by the Arkansas Department of Environmental Quality (ADEQ) JoAnn M. Burkholder, Ph.D., 15 March 2016, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/comments/anna-weeks.pdf

58 Draft 2018 New Listings, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/2018-draft-list-public-notice-new-listings.pdf

59 Draft 2016 New Listings, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/new-listings-county.pdf

60 New Listings for 2014, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2014/new-listings.pdf

61 There are no New Listing documents on ADEQ's website for 2012, 2010, or 2008. https://www.adeq.state.ar.us/water/planning/integrated/303d/list.aspx

The lack of numeric nutrient criteria is not an excuse for failing to assess attainment of the narrative nutrient criteria in Reg. 2.509(a):

> Material stimulating algal growth shall not be present in concentrations sufficient to cause objectionable algal densities or other nuisance aquatic vegetation or otherwise impair any designated us of the waterbody.

The AM for nutrients, in theory, is designed *only* to assess impairments to the aquatic life designated use.[62] And while ADEQ's AM doesn't even adequately determine if aquatic life designated uses are impaired, it completely ignores impairment of other, more sensitive designated uses (i.e., Extraordinary Resource Waters) for which scenic beauty, aesthetics, and recreation potential are major attributes.[63] ADEQ's notation in Table 4 of the AM designated uses and regulations used for assessment, in relation to Tier III waters and Reg 2.509, is inaccurate and should be revised. There is no scientifically viable explanation as to how this could be the case when the screening threshold is based on the 75th ecoregion percentile.

iii. ADEQ should take a more literal, and direct, approach to determine water-quality limited segments that fail to meet Arkansas's narrative nutrient criteria.

ADEQ has the discretion, and obligation, to consider all existing and readily available data. Failings of ADEQ's AM to provide methodologies for determining attainment of **all** water quality standards is not an excuse to ignore considerations of other types of data and information missing from the AM.

1. ADEQ should consider feedback from the general public and waterbody users about the condition of the waterbody such as photographs or testimonials of abundant algal mats that impede recreation or create unsightly aesthetics in the waterbody.[64]

The 2014 IRG details other states utilizing such data and information to identify nutrient-related impaired waters for the 303(d) list based on narrative nutrient water quality criteria and/or direct evidence of failure to support designated uses, include, but are not limited to:

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[62] See Section 6.9, 2018 AM

[63] Reg. 2.302(a) defines the Extraordinary Resource Water designate use as "a combination of the chemical, physical, and biological characteristics of a waterbody and its watershed which is characterized by **scenic beauty**, **aesthetics**, scientific values, broad scope **recreation potential** and intangible social values."

[64] As recommended in the 2014 IRG, see p. 8., https://www.epa.gov/sites/production/files/2015-10/documents/final_2014_memo_document.pdf

- **Vermont –** waters are considered impaired if an ongoing record of public complaint concerning the algal conditions in the water has been established.[65]
- **Montana –** photo documentation is adequate to make an impairment determination for aquatic life use.[66]

iv. ADEQ must provide a scientifically defensible rationale supporting the sensitivity of biological community indices in relation to nutrient enrichment.

Biological endpoints must be sensitive to pollutants (i.e., nitrogen, phosphorus) of concern. In addition to lacking documentation to support ADEQ's macroinvertebrate community analysis and fish community structure index, ADEQ has provided no information as to how "reference" is determined.

> Metric values from each study site are compared to metric values from a reference site for five of the seven metrics to calculate a Percent Comparison to Reference value.[67]

Please provide responses to questions and concerns related to 5.0 Biological Integrity and 6.9 Nutrients that were submitted to ADEQ by WRW in response to the public comments solicited on the revised 2018 AM. [68]

v. ADEQ currently has sufficient data to support segments of the Buffalo National River are not meeting the state's narrative nutrient criteria and should therefore include on the 2018 303(d) List.

Despite ADEQ developing nuisance and harmful algae bloom complaint forms, these submissions are not uploaded to ADEQ's online complaint database.[69] However, ADEQ has a compilation of these data and information readily available, as Planning Branch staff have presented a summary of complaints received in the Buffalo River

[65] See Assessment Use Support Determinations for Swimming/Contact Recreation Use (p. 23), Secondary Contact/Non-Contact Recreation Use (p. 25), and Aesthetics Use (p. 26). Vermont Surface Water Assessment and Listing Methodology (2016), http://dec.vermont.gov/sites/dec/files/wsm/mapp/docs/WSMD_assessmethod_2016.pdf

[66] See Section 3.2.5 (p. 3-11), Assessment Methodology for Determining Wadeable Stream Impairment Due to Excess Nitrogen and Phosphorus, Montana Department of Environmental Quality, 2016, http://deq.mt.gov/Portals/112/Water/WQPB/QAProgram/Documents/PDF/SOPs/NtrntAssessMethod_May2016_FINAL.pdf

[67] See Section 5.0, p.28, 2018 AM

[68] 13 November 2017, 2018 Assessment Methodology, (**Attachment 4**)

[69] Accessed 9 September 2018, https://www.adeq.state.ar.us/complaints/searches/

watershed in 2016, 2017, and 2018.[70, 71, 72] WRW has compiled an online story map for ease of reference for ADEQ, although ADEQ likely has many complaint submissions not reflected in this map. Visit: www.whiteriverwaterkeeper.org/algaemap.

ADEQ failed to provide a rationale for public review and comment addressing their decision not to use submissions through the algae complaint forms to list waters not meeting the state's narrative nutrient criteria.[73] As such, ADEQ blatantly ignored their obligation to "assemble and evaluate all existing and readily available water quality-related data **and information**". At minimum, this includes "waters for which water quality problems have been reported by local, state, or federal agencies; members of the public; or academic institutions."[74]

1. **ADEQ should work with local citizen monitoring groups to determine meaningful and discrete ways in which they can assist with algae efforts.**

   WRW is still awaiting a reply to our 20 July 2018 letter re: Harmful Algae in the Buffalo National River.[75]

vi. To date, ADEQ has continued to ignore their obligation to assess and list waters based on attainment of antidegradation requirements.

40 C.F.R. 130.7(b)(3) - For the purposes of listing waters under § 130.7(b), the term "water quality standard applicable to such waters" and "applicable water quality standards" refer to those water quality standards established under section 303 of the Act, including numeric criteria, narrative criteria, waterbody uses, and **antidegradation requirements**.

Besides specific criteria for bacteria related to Tier III waters, ADEQ does not evaluate whether waterbodies are *maintaining* the level of water quality for which their designation was granted. This is a serious problem and concern across the entire state. Trend data, information from responsible agencies (i.e., USFWS regarding threatened and endangered species; Arkansas Natural Heritage Commission regarding status of endemic aquatic and semi-aquatic species), and academic literature should not only be utilized in attainment decisions, but should be actively solicited by ADEQ.

[70] 18 October 2017, ADEQ Memo Re: 2017 Buffalo River Nuisance Algae Report, (**Attachment 5**).
[71] History of Filamentous Algae in the Buffalo River, Nathan Wentz, Arkansas Department of Environmental Quality, Arkansas Water Resource Conference, Fayetteville, AR, 24 July 2018.
[72] History of Filamentous Algae in the Buffalo River, Nathan Wentz, Arkansas Department of Environmental Quality, Beautiful Buffalo River Action Committee, North Little Rock, AR, 21 August 2018.
[73] Information specifically required, pursuant to 40 CFR 130.7(b)(6)(iii).
[74] 40 CFR 130.7(b)(5)
[75] Attachment 3

1. **ADEQ should list the Eleven Point River for failure to attain Ecologically Sensitive Waterbody (ESW) designated use, and failure to attain antidegradation requirements.**

   40 C.F.R. 131.12(a)(3) states, "Where high quality waters constitute an outstanding National resource, such as waters of National and State parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be **maintained and protected**."

   In 2016, USFWS provided comments supporting the need for listing the Eleven Point River (11010011-001) as impaired, due to significant habitat and population declines of the Ozark Hellbender.[76] Wheeler et al. (2003) noted a 77% population decline during the last two decades.[77] Reasons for population declines are further supported in Solis et al (2007).[78] The ESW designated use "identifies segments know to provide habitat within the existing range of threatened, endangered or endemic species of aquatic or semi-aquatic life forms."[79] Arkansas WQS specifically notes the Eleven Point River's ESW designation is specifically given due to the "location of the Ozark Hellbender."[80]

   ADEQ failed to add this impairment listing on the basis turbidity criteria attainment.[81] However, the supporting information provided by USFWS clearly indicates that the ESW designated use is **not** attained. Please update the 2018 303(d) list to reflect this revision **or** provide a comprehensive response as to how these data and information provided by USFWS are lacking to support a non-attainment decision of the ESW designated use. Does ADEQ choose to ignore WQS that are not addressed in their most current AM when making decisions?

2. **Failure to list water quality limited segments identified in the Buffalo River watershed for failure to meet antidegradation requirements, is not only against federal requirements, but also jeopardizes the first national river.**

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[76] 7 March 2016, USFW 2016 303(d) public comments, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/comments/us-fws.pdf

[77] Wheeler, Benjamin A., et al. "Population declines of a long-lived salamander: a 20+-year study of hellbenders, Cryptobranchus alleganiensis." Biological Conservation 109.1 (2003): 151-156, https://ag.purdue.edu/fnr/discover/HerpetologyLab/Documents/Wheeler_PopulationDeclines.pdf

[78] Solis, Mauricio E., et al. "Occurrence of organic chemicals in two rivers inhabited by Ozark hellbenders (Cryptobranchus alleganiensis bishopi)." Archives of environmental contamination and toxicology 53.3 (2007): 426-434,.https://www.researchgate.net/profile/Dev_Niyogi/publication/6111457_Occurrence_of_Organic_Chemicals_in_Two_Rivers_Inhabited_by_Ozark_Hellbenders_Cryptobranchus_alleganiensis_bishopi/links/0f31752fbb30de3f07000000/Occurrence-of-Organic-Chemicals-in-Two-Rivers-Inhabited-by-Ozark-Hellbenders-Cryptobranchus-alleganiensis-bishopi.pdf

[79] Reg. 2.302(b)

[80] Arkansas Regulation No. 2, Appendix A, Designated Uses: Ozark Highland Ecoregion.

[81] ADEQ 2016 303(d) Response to Comments, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/response-to-comments-summary.pdf

Models generated by the preparers of the Buffalo River WMP were "used to accomplish the main objective of this study, which is the prioritization of HUC12 sub-watersheds, so that investment strategies can be developed that will have the greatest impact on water quality objectives."[82] Not only are proper attainment decisions integral in the ability to pursue limited funding opportunities to implement pollution controls, but also for the achievement of antidegradation requirements.
The Buffalo River is designated as an Extraordinary Resource Water in Reg. 2, the definition of which clearly extends to the watershed of the Buffalo River.[83] **Table 1** denotes additional Category 5 determinations that should be added to the 2018 303(d) list. Waterbody-pollutant pairs were identified from the Buffalo River WMP, accepted by EPA, and commissioned by ADEQ and ANRC. Proposed segments for addition are based on trends of statistically significant water quality declines (i.e., where water quality has not been ***maintained***).[84] The fact that ADEQ has not developed numeric **criteria** for total nitrogen, inorganic nitrogen, total phosphorus, or sediment does not negate ADEQ's responsibility to properly assess applicable **designated uses** and **antidegradation requirements**.

Furthermore, if a TMDL is warranted for impaired segments on the mainstem of the Buffalo River, and over half the work has already been compiled and analyzed through an EPA funded and accepted WMP, then it would be preposterous not to develop a TMDL for the entire Buffalo River watershed. If ADEQ is able to provide adequate supporting documentation to fulfill 4b justifications, and shift pollutant pairs to the 4b designation, appropriate non-attainment determinations are still needed. As reminded above, it's vital to consider attainment of **all** WQS to properly plan and to open the door to limited, available funding to implement pollution controls.

[82] Buffalo WMP, Appendix E, Buffalo River SWAT Model Report, p. 5-1
[83] Reg. 2.302(a) – "This beneficial use is a combination of the chemical, physical and biological characteristics of a waterbody **and its watershed** which is characterized by scenic beauty, aesthetics, scientific values, broad scope recreation potential and intangible social values."
[84] See specifically Section 6.2 (p. 6-5) and Table 3.7 (p. 3-35), Buffalo River WMP

Table 1. Proposed Category 5, 303(d), additions within the Buffalo River watershed. Segments in **bold** are currently proposed for placement under Category 4b. Segments denoted in *italics* are priority watersheds identified by the Buffalo River WMP. Reference reaches underlined below refer to the HUC 12 code, where ADEQ designated reaches could not be found.

Waterbody Name	HUC	RR	WQParameter	Current Listing	Proposed Listing
Big Creek	**11010005**	**020**	Dissolved Oxygen	4b	Cat. 5 - High
Big Creek	**11010005**	**022**	Pathogens	4b	Cat. 5 - High
Buffalo River	**11010005**	**011**	Pathogens	4b	Cat. 5 - High
Buffalo River	**11010005**	**010**	Pathogens	4b	Cat. 5 - High
Mill Creek	*11010005*	*913*	Pathogens, Inorganic N	3?	Cat. 5 - High
Calf Creek	*11010005*	*025*	TN, TP, Sediment*	3?	Cat. 5 - High
Bear Creek	*11010005*	*026*	Inorganic N*	3?	Cat. 5 - High
Brush Creek	*11010005*	*405*	Inorganic N	3?	Cat. 5 - High
Tomahawk Creek	*11010005*	*904*	Inorganic N	3?	Cat. 5 - High
Big Creek	*11010005*	*505*	Pathogens, Inorganic N, Turbidity*	3?	Cat. 5 - High
Big Creek	*11010005*	*029*	Pathogens, Inorganic N, Turbidity*	3?	Cat. 5 - High
Big Creek	*11010005*	*028*	Pathogens, Inorganic N, Turbidity*	3?	Cat. 5 - High
Buffalo @ Wilderness Area	11010005	014	Inorganic N	3?	Cat. 5 - High
Buffalo at Ponca	11010005	012	Inorganic N	3?	Cat. 5 - High
Buffalo River at Pruitt	11010005	012	Pathogens	3?	Cat. 5 - High
Buffalo River at Woolum	11010005	007	Inorganic N	3?	Cat. 5 - High
Buffalo River at Hwy. 65	11010005	004	Inorganic N	3?	Cat. 5 - High
Buffalo at Mouth	11010005	001	Pathogens	3?	Cat. 5 - High
Ponca Creek	11010005	205	Inorganic N	3?	Cat. 5 - High
Cecil Creek	11010005	204	Pathogens	3?	Cat. 5 - High
Mill Creek (upper)	11010005	912	Pathogens, Inorganic N	3?	Cat. 5 - High
Little Buffalo River	11010005	015	Pathogens	3?	Cat. 5 - High
Davis Creek	11010005	009	Inorganic N	3?	Cat. 5 - High
Cave Creek	11010005	023	Pathogens	3?	Cat. 5 - High
Bear Creek at mouth	11010005	026	Inorganic N	3?	Cat. 5 - High
Water Creek	11010005	408	Pathogens, Inorganic N	3?	Cat. 5 - High
Rush Creek	11010005	501	Inorganic N	3?	Cat. 5 - High

III. ADEQ Fails to Follow Appropriate Federal Regulations and EPA Guidance.

The 2018 Assessment Methodology states "ADEQ follows the specific requirements of 40 C.F.R. § 130.7-130.8 and EPA's most current 305(b) reporting and 303(d) listing requirements and guidance when developing this assessment methodology."[85] Furthermore, it is stated that the 2018 report "is prepared using the Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b), and 314 of the Clean Water Act (EPA 2005) which is supplemented by memoranda regarding development of the 2008, 2010, 2012, 2014, and 2016 305(b) Reports (EPA 2006, 2009, 2011, 2013, and 2015 respectively). Arkansas's waters are evaluated in terms of whether their assigned water quality standards and designated uses, as delineated in the Arkansas Pollution Control and Ecology Commission's (APC&EC) Regulation No. 2 Water Quality Standards for Surface Waters of the State of Arkansas (Reg. 2) (APC&EC 2017), are being attained."[86]

a. ADEQ should explain why it chose procedures for preparing the Integrated Report that differed from the procedures outlined in the guidance and how the procedures they developed are appropriate for safeguarding the quality of the waters in Arkansas.

The procedures ADEQ uses often do not follow that guidance. Moreover, ADEQ's variations from EPA's guidance consistently lessens protection for water quality and the environment.

b. ADEQ has arbitrarily removed five pollutant pairs from the 303(d) list without providing this information for public participation.

40 C.F.R. § 130.7(b)(6) requires that "[e]ach State shall provide documentation to the Regional Administrator to support the State's determination to list or not to list its waters as required by §§ 130.7(b)(1) and 130.7(b)(2). This documentation shall be submitted to the Regional Administrator together with the list required by §§ 130.7(b)(1) and 130.7(b)(2) and shall include…a description of the methodology used to develop the list and a description of the data and information used to identify the waters."[87] Additionally, where EPA requests it, states must "demonstrate good cause for not including a water or waters on the list."[88]

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[85] Section 1.0., p. 6, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/final-2018-assessment-methodology.pdf
[86] *Id.*
[87] 40 C.F.R. §130.7(b)(6)(i) and (ii)
[88] *Id.* at 40 C.F.R. §130.7(b)(6)(iv)

EPA guidance on good cause states:

> Good cause includes, but is not limited to, more recent and accurate data, more sophisticated water quality modeling, flaws in the original analysis that led to the waterbody being listed, or changes in conditions, e.g. new control equipment, or elimination of discharges. Where a waterbody was previously listed based on certain data or information, and the state or territory removes the waterbody without developing or obtaining any new information, EPA will carefully evaluate the state's or territory's re-evaluation of the available information, and will not approve such removals unless the state's or territory's submission describes why it is appropriate under the current regulations to remove each affected waterbody. EPA has the authority to disapprove the list if EPA identifies existing and readily available information, available at the time the state or territory submitted the list, that shows a waterbody does not attain water quality standards.[89]

The Record of Decision (ROD) for EPA Action on Arkansas' 2008 303(d) List added the following waterbodies for total phosphorous:[90, 91]

- Muddy Fork (11110103-027)
- Osage Creek (11110103-030, 11110103-930)
- Spring Creek (11110103-931)
- Town Branch (11110103-901)

Although ADEQ left these off all subsequent 303(d) lists, EPA recommended Category 4b designations for these pollutant pairs on the 2018 list.[92] However, these pollutant pairs are not included on the 2018 draft 303(d) list,[93] formally delisted,[94] or included in Category 4b determinations.[95] ADEQ cannot choose to delist waters simply on a whim. WRW has requested any supporting information to justify these delistings from ADEQ

[89] November 19, 2001, EPA, 2002 Integrated Water Quality Monitoring and Assessment Report Guidance at Introduction.
[90] 18 June 2008, EPA 2008 303(d) ROD, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2008/epa-rod.pdf
[91] Arkansas Final Impaired Waterbodies List 2008, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2008/303d-list.pdf
[92] 19 July 2017 Letter from William Honker Re: EPA Action on Arkansas's 2010, 2012, 2014, and 2016 § 303(d) Lists, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2017/epa-decision-7192017.pdf
[93] Draft 2018 Category 5, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/2018-draft-list-public-notice.pdf
[94] Draft 2018 Waters Delisted from Final Category 5 2016 303(d) List, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/2018-draft-list-public-notice-delistings-listings.pdf
[95] ADEQ Category 4b Determinations, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/category-4b-determinations.pdf

and has yet to receive a reply.[96] As such, the public has not been provided an opportunity for meaningful comment and review.

c. ADEQ should add whole sediment toxicity tests and data interpretation of results consistent with EPA IRG to its monitoring program.

IRG states that contaminated sediments may be directly toxic to aquatic life or can be a source of bioaccumulation and that protecting sediment quality is an important part of restoring and maintaining the biological integrity of water bodies. The ADEQ sampling program, includes no sediment sampling for making use attainability determinations.

d. ADEQ has failed to develop the 303(d) list pursuant to applicable water quality standards.

States are required to identify "those waters within its boundaries" where controls "are not stringent enough to implement *any water quality standard applicable to such waters.*"[97] EPA IRG specifically addresses whether Category 5 decisions should include impaired waters for which WQS are being revised to be less stringent. The answer, of course, is yes.[98] The fact that ADEQ is working to revise minerals standards, to justify the change from 10% to 25% exceedance rate for site specific criteria as "part of a negotiated solution with the regulated community"[99] is in no way conceivably allowable under the CWA.[100]

Additionally, while ADEQ states that the minerals revision will allow for tiered aquatic life designated use "to specifically protect Outstanding Resource Waters (ORW) to limited use waterbodies,"[101] alternately, they could continue doing this now, rather than then years from now. This can easily be accomplished by following the CWA, and utilizing applicable WQS to base attainment decisions on a 10% exceedance threshold.

ADEQ's failure to provide the public with specific segments exceeding site specific minerals criteria (at 10% exceedance rate), that fall below ADEQ's arbitrary 25% rate developed to placate the regulated community, is an egregious act to misinform the

[96] 5 September 2018, Re: 2018 Draft 303(d) Supplemental Materials - FOIA Request and Clarifications, (**Attachment 6**).
[97] Section 3039d)(1)(A) of the CWA.
[98] 2004 IRG, https://www.epa.gov/sites/production/files/2015-10/documents/2003_07_23_tmdl_tmdl0103_2004rpt_guidance.pdf
[99] See p. 7, Responsiveness Summary to Comments Concerning Arkansas's Draft 2016 303(d) List, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/response-to-comments-summary.pdf
[100] ADEQ must continue to base attainment decisions on 10% exceedance threshold, see p. 10, 24 January 2008 Record of Decision for Reg. 2, https://www.adeq.state.ar.us/water/planning/reg2/pdfs/record-of-decision/2007-epa-action-ltr-rod-ar-tr-phase-2.pdf
[101] See p. 3, Arkansas 2018 Draft 303(d) List Executive Summary, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/executive-summary.pdf

public. These data and information should be provided to the public for full review and comment.

WRW specifically requests ADEQ to:

i. Provide the public with detailed information related to site specific minerals criteria assessments, and include, at minimum: stream name, HUC, reach, criteria, number of exceedances, number of samples assessed within period of record, and percent exceedance for all AUs under Reg. 2.511;

ii. Add all AUs designated as an ORW (Extraordinary Resource Waters, Ecologically Sensitive Waterbodies, and Natural and Scenic Waterways)[102] to the 2018 303(d) list based on a 10% exceedance threshold. This includes, but is not limited to all segments identified in Table 2 of EPA's comments of the draft 2016 303(d) list.[103]

e. ADEQ has failed to provide appropriate justification for adoption of less stringent methodologies for assessing bacteria.

The 2018 303(d) Executive Summary states, "The scope for evaluating E. coli data was expanded to allow multiple years of data within the period of record"[104] Multiple years of data were always *allowed.* The revised AM now states that if assessment of non-support is based on only one season of data, the AU will be placed in Category 3. Now, at least two seasons of data are required to place AUs in Category 5.[105] ADEQ made the decision to adopt a less stringent interpretation of the methodology during the 2016 listing cycle to avoid listing Big Creek (11010005-022) on the 303(d) list. This segment is still impaired due to exceedance of the *E. coli* criteria. All ADEQ accomplished was kicking the can down the road two years, and now we are two years behind in being able to adequately address the problem.

As was pointed out during the public comment opportunity regarding revisions to the AM, ADEQ does not have a robust enough bacteria monitoring program to justify this change.[106] This is an attempt to limit the number of waterbodies for which assessment determinations can be made. Furthermore, this is not in line with any listing

[102] Reg. 2.302(a)-(c)
[103] 10 March 2016, EPA letter Re: Draft 2016 Impaired Waterbodies List, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/comments/epa-stacey-dwyer.pdf
[104] See p. 3, Arkansas 2018 Draft 303(d) List Executive Summary, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/executive-summary.pdf
[105] See p. 56 of 2018 Assessment Methodology, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/final-2018-assessment-methodology.pdf
[106] See Section 6.6 Bacteria, p. 8-9, WRW comments re: 2018 Assessment Methodology, (**Attachment 4**)

determinations previous to 2016, as is supported by numerous bacteria TMDLs developed based on one season of data.[107, 108, 109]

Historically all other attainment decisions have been allowable based on one season of data. ADEQ must provide a scientifically defensible rationale as to why this change was made in 2016. Evidence must support how the current listing methodology is equally as protective of designated uses, especially primary contact and extraordinary resource waters.

Please provide a detailed review of potential listing discrepancies between ADEQ's traditional means of assessing bacteria attainment (i.e., one contact season allowable) compared to ADEQ's newly concocted method (i.e., two contact seasons required).

IV. Limited Public Comment Documents Provide Insufficient Information for Informed Public Comment.

ADEQ should provide tables detailing designated use attainment, source, cause, and status for all monitored and evaluated segments, as well as those unevaluated.[110] During the AM stakeholder process, multiple requests were made for ADEQ to provide the public the 305(b) report in its entirety for public review and comment alongside the 303(d) list. At the very least, ADEQ could provide information supplied traditionally in Appendix A with public comment documents available for review of the 303(d) list. These data and information are important for facilitating meaningful comments from the public.

With limited information provided, it is difficult to determine what changes have been made between this and last list. Public comment documents do not provide specific explanations for changes made. The public needs detailed information to determine what factors were used to remove waters.

Thank you for the opportunity to comment and thoroughness in your anticipated response,

Jessie J. Green
Executive Director & Waterkeeper

[107] Pathogen TMDLS for Selected Reaches in Planning Segment 1C https://www.adeq.state.ar.us/downloads/WebDatabases/Water/TMDL/pdfs/Mine_Creek_2008_01_07.pdf

[108] Pathogen TMDLS for Selected Reaches in Planning Segment 2B https://www.adeq.state.ar.us/downloads/WebDatabases/Water/TMDL/pdfs/pathogen_2b_2007_06_01.pdf

[109] Pathogen TMDLs for Planning Segments 4D Reaches https://www.adeq.state.ar.us/downloads/WebDatabases/Water/TMDL/pdfs/Seg%204D%20Pathogens.pdf

[110] See information provided in Appendix A of the 2016 Integrated Report. https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/integrated-report.pdf

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Phosphorus Retention and Remobilization along Hydrological Pathways in Karst Terrain

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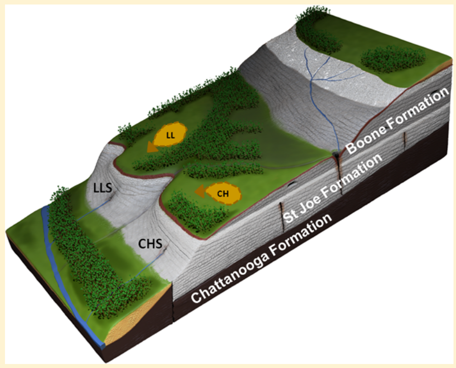
S *Supporting Information*

ABSTRACT: Karst landscapes are often perceived as highly vulnerable to agricultural phosphorus (P) loss, via solution-enlarged conduits that bypass P retention processes. Although attenuation of P concentrations has been widely reported within karst drainage, the extent to which this results from hydrological dilution, rather than P retention, is poorly understood. This is of strategic importance for understanding the resilience of karst landscapes to P inputs, given increasing pressures for intensified agricultural production. Here hydrochemical tracers were used to account for dilution of P, and to quantify net P retention, along transport pathways between agricultural fields and emergent springs, for the karst of the Ozark Plateau, midcontinent USA. Up to ~70% of the annual total P flux and ~90% of the annual soluble reactive P flux was retained, with preferential retention of the most bioavailable (soluble reactive) P fractions. Our results suggest that, in some cases, karst drainage may provide a greater P sink than previously considered. However, the subsequent remobilization and release of the retained P may become a long-term source of slowly released "legacy" P to surface waters.



■ INTRODUCTION

More than 25% of the world's population either lives on or obtains its drinking water from karst aquifers. Karst underlies 30% of the land area of China, 30% of Europe, and 20% of the United States.[1,2] Karst aquifers exert an important control on the quality and ecology of surface waters in these areas.[3] The complexity of subsurface drainage[4,5] and the difficulties in deconvoluting flow pathways and groundwater contributing areas[6] have been a significant barrier to detailed studies of nutrient transport and fate in karst systems.[7,8] Nevertheless, it is widely assumed that karst drainage systems (formed by dissolution of carbonate rocks, mainly limestone) are highly vulnerable to phosphorus (P) impairment from agricultural sources.

This vulnerability is assumed to arise from the low nutrient buffering capacity of the thin cherty soils which overlie karst and the rapid transmission of surface runoff through conduits enlarged by dissolution,[9,10] which is thought to bypass the zones where key processes of P retention occur.[11−13] Nonetheless, highly intensive monitoring of Irish karst springs, in areas of livestock, demonstrated major P attenuation (reduction in P concentrations) relative to agricultural runoff,[14,15] with low P concentrations in spring discharge, even during storm events when agricultural P losses are expected to be highest. This attenuation was attributed to a combination of both hydrological dilution and P retention during infiltration and transmission of runoff along groundwater conduit pathways.

Crucially, we lack information on the extent to which P attenuation is controlled by P retention processes during transit along karst flow paths,[14] or by hydrological dilution of agricultural runoff by cleaner groundwater sources.[16] This is of strategic importance for understanding the P buffering capacity and wider resilience of karst landscapes to nutrient inputs.[10,17,18] Many karst lands have traditionally been used for low-intensity livestock farming, owing to poor soils and their unsuitability for arable production.[9] However, there is increasing pressure for intensive livestock production, as global demands for greater efficiency in food production intensify.[19,20] Given the move toward more intensive livestock production systems, which accumulate P,[21,22] and the perceived vulnerability of karst drainage systems to P loss, there is now a pressing and strategic

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Table 1. Summary of Concentrations of Soluble Reactive Phosphorus (SRP), Total Phosphorus (TP), Potassium (K), Rubidium (Rb), and Calcium (Ca) in Field Runoff and Spring-Water Samples

		field runoff (m^3 ha^{-1}) spring flow (L s^{-1})	SRP (mg L^{-1})	TP (mg L^{-1})	Rb (μg L^{-1})	K (mg L^{-1})	Ca (mg L^{-1})
Langle Field (LL)	mean	38.0	2.21	2.57	6.97	10.4	5.12
	median	35.5	1.87	2.12	5.96	10.2	4.94
	range	3.4−91.5	0.59−5.02	0.8−5.53	0.93−20.6	2.04−26.3	2.11−9.87
Copperhead Field (CH)	mean	23.1	0.68	1.09	2.94	6.11	3.45
	median	14.6	0.57	1.03	2.52	5.11	3.43
	range	1.8−79.9	0.47−1.22	0.63−1.91	0.58−8.76	1.4−14.7	1.95−7.34
Langle Spring (LLS)	mean	13.1	0.029	0.057	1.06	1.54	37.5
	median	9.38	0.012	0.034	0.878	1.14	36.7
	range	1.24−59	0−0.403	0.002−0.608	0.195−3.57	0.534−4.92	12.2−65.9
Copperhead Spring (CHS)	mean	22.5	0.019	0.041	1.08	1.37	40.5
	median	2.62	0.017	0.032	1.1	1.4	42.9
	range	0.19−253	0.001−0.12	0−0.58	0.328−1.9	0.84−2.17	14.5−61.5

need for better understanding of the fate and transport of P in karst landscapes. Here this shortfall is addressed for karst terrain in south-central USA. Hydrochemical tracers and endmember mixing analysis[23−26] were used to assess the vulnerability to P loss, by accounting for the hydrological dilution of agricultural runoff and directly quantifying net P retention, during infiltration through the soil, and along karst transport pathways, through to the emergent springs.

EXPERIMENTAL METHODS

Study Area. The study was undertaken at the University of Arkansas long-term Savoy Experimental Watershed (SEW), NW Arkansas, USA.[27] The SEW is located in the Illinois River Watershed, a mixed land-use watershed (~4330 km^2), which spans the states of Arkansas and Oklahoma.[28,29] The SEW covers 1250 ha and is typical of the karst terrain of the Ozark Plateau of midcontinental USA (Figure SI-1a, Supporting Information). The soils of the SEW are predominantly silt loams (see Supporting Information). Around 70% of the land is native forest, with the remaining 30% rolling pasture grazed by beef cattle (~2 cows ha^{-1}). The SEW also supports poultry production, with the resulting poultry litter used to fertilize pastures. There are no septic tanks or settlements in the SEW, and agricultural runoff from pastures grazed by cattle provides the overwhelmingly dominant P source in the watershed.[30]

The stratigraphy of the SEW[30−32] (see Figure SI-1c, Supporting Information) includes (a) the limestone aquifer of the St. Joe Formation, (b) the Boone Formation, an impure limestone which mantles the St. Joe Formation and forms "epikarst", and (c) a layer of regolith (vadose zone) which overlies the Boone Formation. Karst drainage has a major control on water quality in the Illinois River;[29,33] 67% of annual river flow comes from karst springs, rising to 80% of flow in the summer and fall.[34]

Sample Collection and Analysis. Surface runoff and spring-water chemistry and flow monitoring (Figure SI-1a and c, Supporting Information) were undertaken at the following: (1) two adjacent karst springs (Langle Spring, LLS, and Copperhead Spring, CHS), which flow continually from the St. Joe Formation (focused conduit flow) springs; (2) two surface runoff field plots (Langle, LL, 1.07 ha, and Copperhead, CH, 1.05 ha), which are located above and within the watershed (recharge zone) of the LLS and CHS springs. These runoff plots are located on Razort silt loams which make up most of the grazed pastures of the SEW. All pastures are treated similarly in terms of grazing intensity and maintenance fertilizer applications (30 kg P ha^{-1} every two years as either poultry litter or diammonium phosphate).

Flows at the karst springs (LLS and CHS) were monitored on 15-min intervals (see Supporting Information). Karst spring water was sampled weekly, with stage-triggered, subdaily automated sampling using an ISCO sampler during storm events. Figure SI-2 (Supporting Information) shows the distribution of samples collected on the rising and falling stage of the storm hydrographs. The volume of surface runoff from both fields was automatically measured, and samples were collected on a flow-weighted basis by an ISCO autosampler. All water samples were filtered within 24 h of the water being sampled and were analyzed following EPA standard protocols, as described below (and in the Supporting Information). Filtered (<0.45 μm) samples were analyzed for soluble reactive phosphorus (SRP), by colorimetric analysis,[35] and for a full suite of major cations (including potassium, K, and calcium, Ca) and trace elements (including lanthanum, La, and rubidium, Rb) (see Supporting Information). Unfiltered samples were analyzed for total phosphorus (TP), after acid-persulfate digestion, by colorimetric analysis.[35,36] These measurements are consistent with standard protocols for TP and SRP analysis.[37]

Use of Conservative Tracers and Endmember Mixing Analysis. Conservative chemical tracers and endmember mixing models were used to apportion water sources, and to differentiate the effects of hydrological dilution from the biogeochemical processes, which retain and cycle P during transit through the karst drainage system. Chemical tracers have been widely used in watershed hydrology for tracing water sources and flow pathways,[38] owing to their conservative behavior (chemical inertness). Here we made use of chemical tracers already in the watershed to apportion water sources. Using the hydrochemical monitoring data, tracers were chosen which had elevated concentrations in either base flow groundwater or in agricultural runoff. First, two-component endmember mixing models[23,39] were used to link the spring-water chemistry to sources within the watershed, by (a) quantifying the relative proportions of surface runoff and groundwater and (b) estimating the contribution of surface runoff from the agricultural grazed land. Second, comparing the mixing patterns of P in spring water with a conservative tracer of agricultural runoff allowed us to directly evaluate whether P was behaving nonconservatively (i.e., being taken up or released) along the hydrological pathways in the karst drainage system.

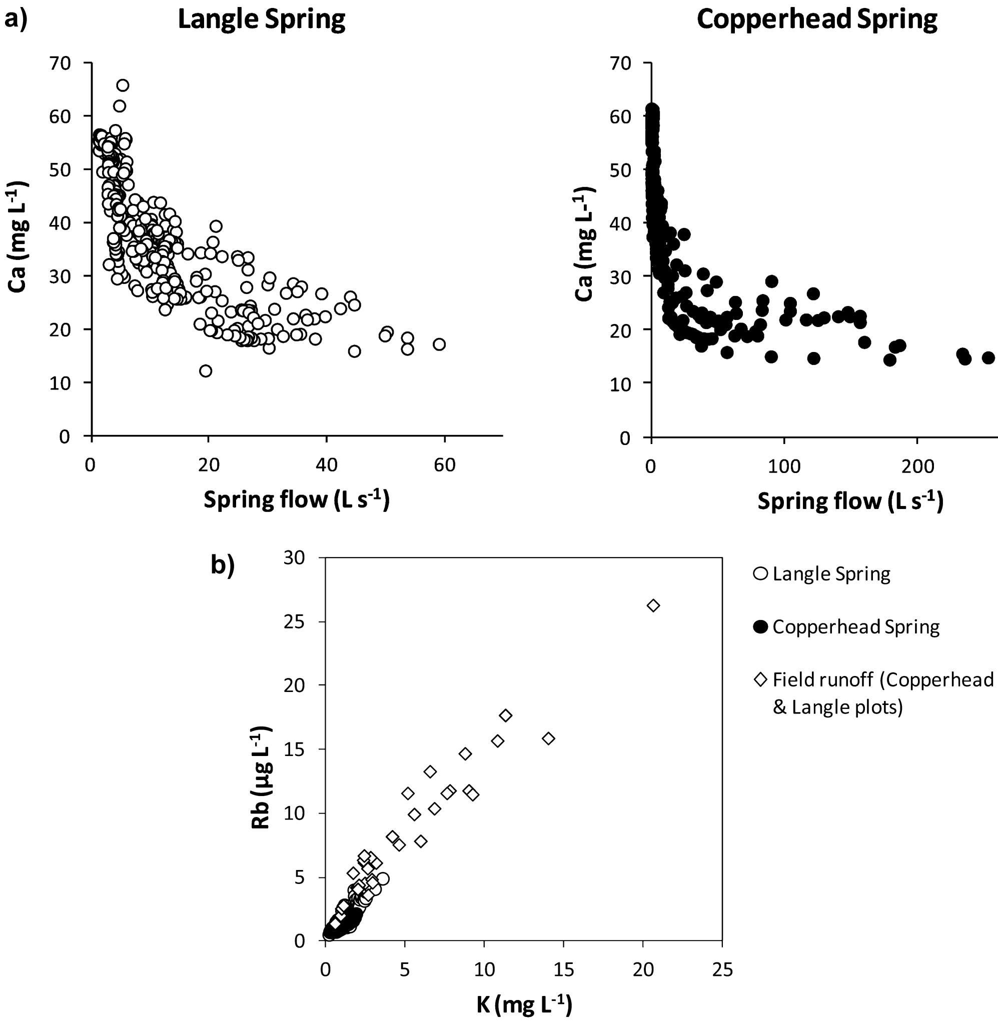

Figure 1. (a) Relationships between calcium (Ca) concentrations and flow at Langle and Copperhead springs. (b) Relationship between rubidium (Rb) and potassium (K) concentrations in field runoff and spring-water samples.

RESULTS AND DISCUSSION

Comparison of Agricultural Runoff and Spring-Water Chemistry. Concentrations of TP, SRP, K, and Rb were consistently highest in field runoff, relative to the springs (Table 1), and runoff from the grazed fields provides the greatest concentrations of P, K, and Rb within the SEW. In contrast, Ca concentrations were consistently highest in the springs, compared with runoff. This indicates a dominant base flow groundwater source of Ca, from dissolution of limestone, which is diluted by surface runoff (Figure 1a).

Concentrations of SRP, TP, K, and Rb were all higher in field runoff at LL compared with CH. This likely reflects higher cattle grazing density at LL (2.5 cows ha^{-1}) than at CH (1.0 cows ha^{-1}), as well as higher runoff per unit area that likely led to greater solute and particulate entrainment and transport capacity compared with CH. This may also reflect a larger hydrologically active area contributing runoff at LL, linked to greater soil compaction from more intensive cattle grazing.

For the springs, there was a greater variability in SRP, TP, K, and Rb concentrations at LLS than at CHS, despite a much lower variability in spring flow at LLS (Table 1). However, concentrations of TP, SRP, K, and Rb did not correlate with flow at either of the springs. For most storm events at LLS, concentrations of TP, SRP, K, and Rb increased dramatically above base flow concentrations, especially on the rising stage of the storm hydrograph (Figure SI-2, Supporting Information). These high concentrations on the rising stage are likely due to upstream point recharge of surface runoff from pasture land into the underlying St. Joe aquifer in locations where the confining chert layer is breached. At CHS, the response of TP, SRP, K, and Rb to storm events was more mixed. Small initial increases in concentration occurred with the onset of higher flows, followed by marked reductions in concentration, reflecting substantial dilution by a water source with relatively low SRP, TP, K, and Rb concentrations, most likely from the nonagricultural (ungrazed and forested) parts of the watershed. Indeed, karst inventories have verified that this part of the flow regime reflects runoff from areas which are not grazed by livestock.[30,31]

To evaluate the attenuation (i.e., the reductions in concentrations) of TP, SRP, K, and Rb during transit through the karst, the median concentrations in agricultural runoff were compared with the corresponding median concentrations in CHS and LLS springs (Table 1). The average attenuation of TP and SRP concentrations ranged from 96% to 99%. In contrast, the average attenuation of K and Rb concentrations was lower, at 56% to 89%. Correspondingly, under storm flow conditions, comparisons of average field runoff concentrations and the 90th percentile concentrations in spring water (which typically correspond with the rising stage of the storm hydrographs of

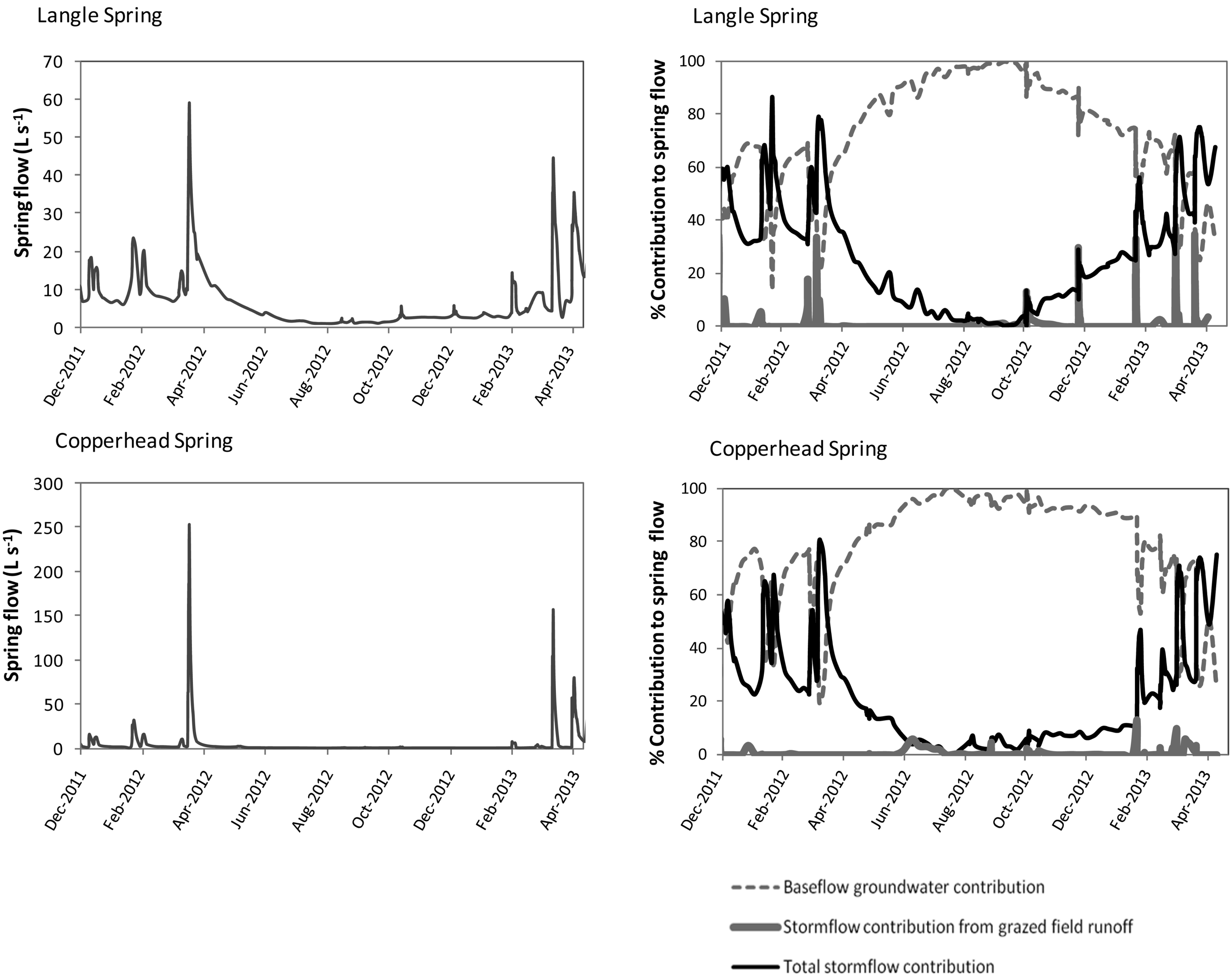

Figure 2. Hydrographs and water source apportionment for Langle and Copperhead springs.

the springs) revealed that storm flow attenuation of TP and SRP ranged from 93% to 96%, compared with 46% to 74% for K and Rb. Across all flow conditions, the higher rates of attenuation of P concentrations, relative to K and Rb, reflect the nonconservative behavior of P during transit through the karst.

K and Rb show high correlation (Figure 1b) due to their similar hydrogeochemistry (group 1a monovalent base cations of relatively small hydration size). Figure 1b shows a dominant two-component mixing series between a high concentration "endmember" (i.e., surface runoff from fertilizer and grazed pastures in runoff) and a low concentration spring-water "endmember" (i.e., runoff from nonagricultural and forested areas, which have no grazing or fertilizer inputs). Both K and Rb are highly soluble monovalent ions, and once transmitted into the karst drainage system, chemical interactions will be relatively small. Therefore, the attenuation of K and Rb during transport through the karst will be largely controlled by hydrological dilution, without retention mechanisms (with only possibly a small attenuation or release within the epikarst where there is a high proportion of clays[31,40]). In contrast, P behaves nonconservatively, reflected by the higher rates of attenuation of P relative to K and Rb.

Spring Hydrology and Water-Source Apportionment. Comparing the hydrology of the two springs (Figure 2), base flows at CHS were consistently lower than at LLS; the median flow at CHS was 2.62 L s^{-1}, compared with 13.1 L s^{-1} at LLS (Table 1). Further, CHS exhibited a more flashy flow regime than LLS, and storm flows were dramatically higher at CHS. For instance, the average of the highest 10% of flows was 139 L s^{-1} at CHS, compared with 40 L s^{-1} at LLS. This discrepancy reflects the following: (i) LLS being the "underflow" spring (3 cm lower than CHS), with a much larger groundwater drainage area under low-flow conditions than CHS, which accounts for the higher base flows at LLS; (ii) water capture (spring "piracy") by CHS during storm events, which has been shown to result in a dramatic expansion in the watershed drainage area for CHS relative to LLS.[32,33]

Contributions to spring water at LLS and CHS were apportioned by two-component endmember mixing analysis.[23,41] Here Ca was used as a tracer of groundwater and K as a tracer of agricultural runoff, based on the observed dominant groundwater source of Ca and the dominant agricultural runoff source of K. For the mixing model, endmembers were defined as the following:

(i) A base flow groundwater endmember with elevated Ca, and a storm flow endmember with low Ca concentrations.
(ii) Runoff endmember from agricultural land with high K concentration, and a spring base flow low K endmember.

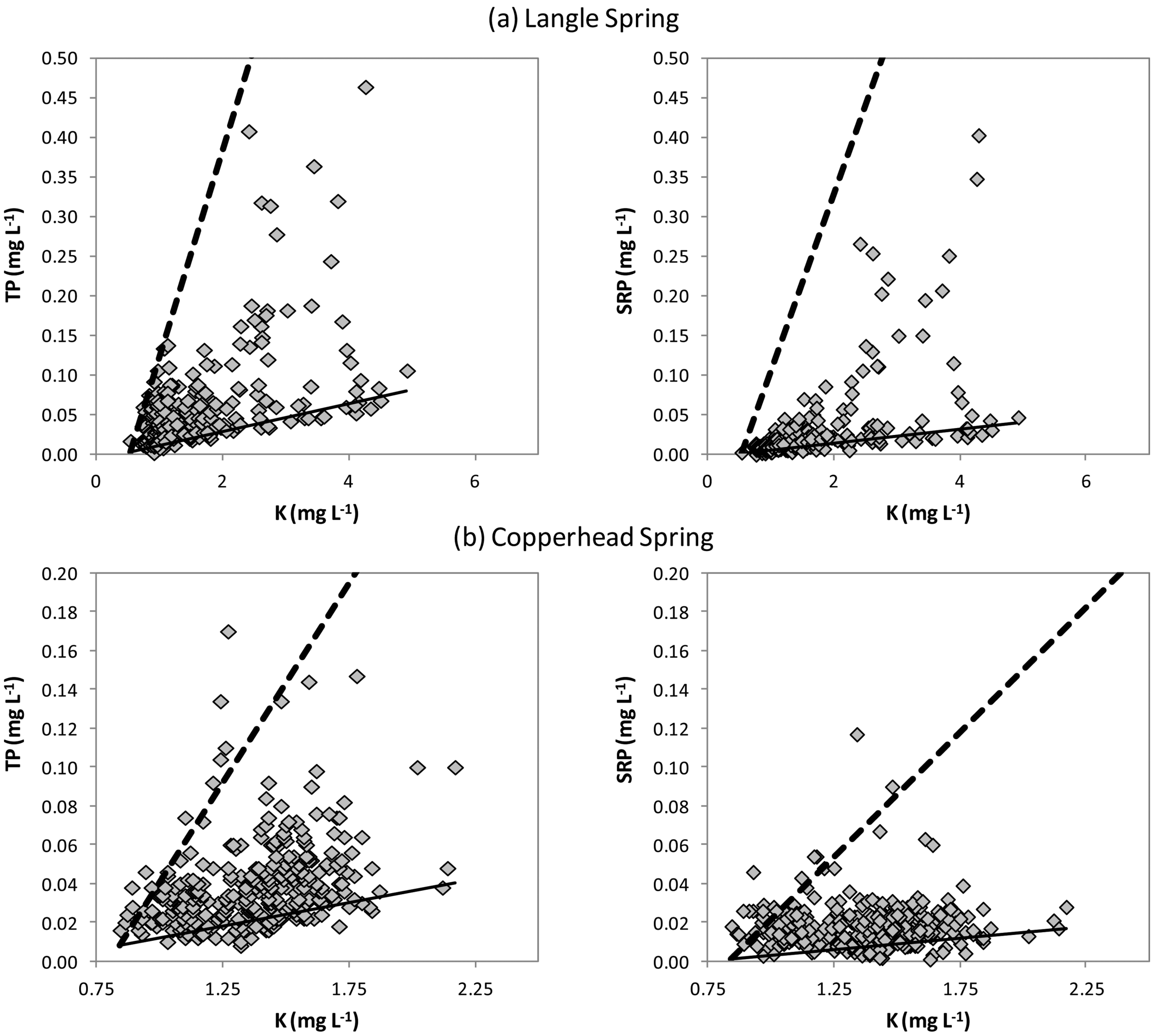

Figure 3. Relationships between total phosphorus (TP), soluble reactive phosphorus (SRP), and potassium (K) for (a) Langle Spring and (b) Copperhead Spring. The dashed line denotes the conservative mixing line, and the solid line denotes a line of maximum P retention (see text for explanation).

Applying a simple two-component mixing model[23,41] (eq 1) and the endmembers identified above, Ca concentrations were used to partition the contributions to spring flow at LLS and CHS from base flow groundwater (the high concentration endmember) and from stormwater runoff (the low concentration endmember). Then a second two-component mixing model was used for K, to quantify the contributions from grazed pasture runoff (eq 2).

$$\% \text{ total storm runoff} = 100 \times (Ca_{gw} - Ca_{m})/(Ca_{gw} - Ca_{ro}) \quad (1)$$

$$\% \text{ agricultural runoff} = 100 \times (K_{bf} - K_{m})/(K_{bf} - K_{ag}) \quad (2)$$

where Ca_{gw} was the groundwater Ca concentration (high concentration base flow endmember), defined here as the average Ca concentration for the lowest 10% of flows sampled, Ca_m was the measured spring-water Ca concentration, Ca_{ro} was the stormwater (agricultural runoff) endmember, defined here as the average field runoff Ca concentration, K_{bf} was the base flow endmember (average K concentration for the lowest 10% of spring flows sampled), K_m was the measured spring-water K concentration, and K_{ag} was the agricultural runoff endmember, defined here as the average field runoff K concentration. The values used to define the endmember concentrations at LLS and CHS are shown in Table SI-1, Supporting Information.

The water source apportionment for LLS and CHS (Figure 2) showed similar percentage contributions from base flow groundwater and total storm flow at LLS and CHS for most of the year and particularly during storm events. During winter and spring storm events, a much greater proportion of flow at LLS was derived from agricultural (grazed field) runoff (up to approximately a third of flow). This greater contribution of water from pastures than from nonagricultural land at LLS accounted for the higher storm-event concentrations of K and Rb at LLS. Agricultural runoff contributed a much lower proportion of winter and spring storm event flow at CHS (typically less than 10%). These results and the much higher storm flow discharges at CHS suggest that the water "piracy" at CHS, during storm events, captured water sources, which had a lower K and Rb concentration, from the nonagricultural (ungrazed and forested) areas.

Table 2. Measured and "Conservative" Annual Loads, and Mean Daily Base Flow and Storm Flow Loads, of Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP) in Langle and Copperhead Springs, with Net and Percentage TP and SRP Retention

		measured P load (kg y^{-1} or g d^{-1})	"conservative" P load (kg y^{-1} or g d^{-1})	net P retention (kg y^{-1} or g d^{-1})	% net P retention
Langle Spring (LLS)	annual TP load (kg y^{-1})	7.01	22.3	15.3	69
	annual SRP load (kg y^{-1})	1.85	19.0	17.2	90
Copperhead Spring (CHS)	annual TP load (kg y^{-1})	2.65	5.7	3.1	54
	annual SRP load (kg y^{-1})	0.98	3.3	2.3	70
Langle Spring (LLS)	avg base flow TP load (g d^{-1})	10.3	23.3	13.0	56
	avg base flow SRP load (g d^{-1})	2.21	19.8	17.6	89
Copperhead Spring (CHS)	avg base flow TP load (g d^{-1})	1.27	3.55	2.28	64
	avg base flow SRP load (g d^{-1})	0.45	2.14	1.69	79
Langle Spring (LLS)	avg storm flow TP load (g d^{-1})	112	1448	1336	92
	avg storm flow SRP load (g d^{-1})	51.4	1240	1189	96
Copperhead Spring (CHS)	avg storm flow TP load (g d^{-1})	445	971	527	54
	avg storm flow SRP load (g d^{-1})	175	567	392	69

Quantifying Net P Retention in Karst Drainage. Endmember mixing analysis[23−26] was applied using the "conservative" tracer, K, to explore the net P retention and release along karst hydrological pathways from infiltration through the soil, to spring discharge. First, concentrations of TP and SRP were plotted against K as the "conservative" tracer (Figure 3). Two dominant and distinct sources of spring water (both with different TP, SRP, and K concentrations) are hypothesized (Table SI-1, Supporting Information): (i) a high concentration agricultural endmember source (K_{ag}, TP_{ag}, SRP_{ag}), defined here as the average concentrations (of K, TP, and SRP) in agricultural field runoff at the LL and CH field plots, and (ii) a low concentration (nonagricultural) endmember (K_{na}, TP_{na}, SRP_{na}). As the source of this low concentration runoff could come from a wide range of nonagricultural sources (ungrazed and forest land) across the watershed, the most reliable means of capturing the integrated low-concentration endmember signal was to use the minimum measured spring-water K, TP, and SRP concentrations at LLS and CHS.

A theoretical linear two-component mixing series, i.e, a "conservative mixing line" between the high concentration and low concentration endmembers (Figure 3), would be observed if P behaved conservatively during mixing of the two endmember water sources during transport through the karst. In contrast, the observed relationships between TP and K, and SRP and K, in spring water were highly scattered at LLS and CHS (Figure 3). Most of the samples plot well below the conservative mixing line, showing predominantly net retention of TP and SRP relative to K. A few isolated samples plotted above the conservative mixing line, which are indicative of some sporadic net P release relative to the K tracer. The mixing patterns between TP, SRP, and K concentrations in Figure 3 had a well-defined lower boundary of samples with the lowest P concentrations relative to K (shown in Figure 3 as a "line of maximum P retention"). This line of maximum P retention probably represents a secondary endmember mixing line, between the same low concentration nonagricultural runoff endmember and a secondary agricultural field runoff endmember, with high K but lower P concentrations as a result of P retention processes filtering out P. We posit that the majority of this P was "filtered" out during diffuse recharge of water as through the soil and the epikarst, into the karst aquifer. The spring-water samples which lie between the line of maximum retention and the conservative mixing series therefore likely reflect the *net* effects of P retention and remobilization processes for runoff water entering the karst drainage system via a mixture of diffuse and point recharge.

By comparing the observed spring-water TP and SRP versus K relationships with the theoretical linear conservative mixing series, the *net* effects of P retention and release can be directly quantified (Figure 3). By applying the theoretical conservative mixing series (TP versus K and SRP versus K) to the measured spring-water K concentrations at LLS and CHS, "conservative" TP and SRP concentration time series were derived (Figure SI-3a,b, Supporting Information) and converted to loads, using the corresponding spring flow data. By taking the difference between measured and "conservative" TP and SRP loads, we calculated net TP and net SRP retention on an annual basis, as well as for base flows (lowest 10% of flows) and storm flows (highest 10% of flows) (Table 2).

Annual net TP retention ranged from 69% at LLS to 54% at CHS. Net percentage P retention was consistently higher for SRP compared with TP, not only on an annual basis but also under storm and base flow conditions. This indicated preferential retention of more labile SRP fractions by sorption/uptake and greater mobility of TP organic and particulate P fractions. Similar patterns of soluble and particulate P retention have also been observed in other karst soils and drainage systems.[7,11,13] Highest percentage net P retention occurred during storm events at LLS (92% TP retention and 96% SRP retention). However, the two springs showed very different patterns in P retention under storm and base flow conditions. At LLS, net P retention was greatest during storm flows than under base flow conditions, reflecting a high efficiency of P retention from agricultural runoff at LLS. In contrast, at CHS, a greater percentage of the P load was retained

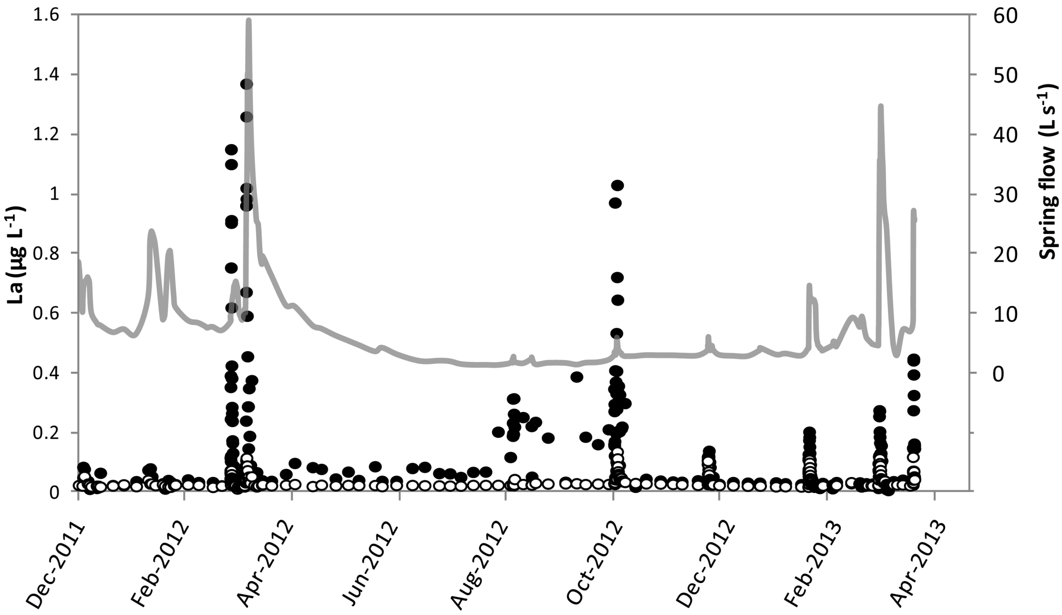

Figure 4. Time series of measured and "conservative" lanthanum (La) concentrations and flow at Langle spring. Measured La concentrations are denoted by solid circles; "conservative" La concentrations are denoted by open circles. See text for explanation of how "conservative" La concentrations were calculated.

under base flow than during storm flow. This reflects much lower base flows at CHS, which increase water residence time and promote particulate sedimentation and P retention, and higher storm flows linked to stream piracy, which provide greater flushing from nonagricultural areas, where flows have a low P concentration.

Contaminant Residence Times in Karst Drainage. While monitoring P relative to a conservative tracer provides us with valuable information on rates of annual and storm flow/base flow net retention, it provides no information about the residence times of P within the karst, or the time scales over which retention and remobilization may occur. This is of strategic concern in relation to the "legacy" of P within watersheds,[42,43] whereby time-lags in release of retained P may mask the effects of conservation measures on receiving water quality. By measuring a full suite of trace elements using ICP-MS, a "serendipitous" observation was made, which may help provide clues about the wider contaminant residence times within the karst drainage. Concentrations of "dissolved" (<0.45 μm) lanthanum (La) in storm flow spring discharge at LLS were more than an order of magnitude higher than could be accounted for by the runoff sources measured within the SEW. Figure 4 shows the concentrations of La in the spring discharge at LLS and a "conservative" (maximum) concentration from runoff, which accounts for the dilution of agricultural runoff during transit through the karst drainage, using K as a tracer. The high storm flow La concentrations observed at LLS are likely a "legacy" signal from a past tracer experiment. In 2001, lanthanum-labeled montmorillonite clays were injected into a losing stream at SEW as part of a study to examine clay and bacterial transport.[44]

While the La tracer was detected at LLS around 16 h after it was injected,[44] our monitoring suggests the La tracer was also retained within the karst drainage system and continues to be remobilized and released during storm events more than 10 years later. Unfortunately, it is impossible to perform a mass balance to quantify how much of the La applied in the tracer study remains within the karst drainage system and how long a La "legacy" might persist, as no La measurements were made in the intervening 10 years between the tracer injection in 2001 and our monitoring which started in November 2011. Within the scope of this study, it was also not possible to determine whether the La concentrations measured were truly dissolved or a <0.45 μm colloidal/clay fraction or whether La geochemistry is sufficiently similar to be used as an indicator of P transport. However, these results indicate that La, a tracer expected to be flushed rapidly through the karst, was retained and continues to be remobilized and released during storm events, more than 10 years later. This indicates the potential for contaminant retention in the subsurface karst drainage system, where contaminant storage and gradual rerelease may occur over time scales of at least a decade.

Wider Implications. Hydrochemical tracers of agricultural runoff allowed us to directly evaluate the nonconservative behavior of P, within karst drainage, and quantify net P retention. Our results challenge the widely held assumption that karst landscapes are always highly vulnerable to P loss and suggest that, in some cases, karst drainage may provide a greater sink for P than previously considered. P from agricultural runoff was attenuated by hydrological dilution from cleaner (nonagricultural) sources during transport through karst drainage. However, there was also a high capacity for net P retention, especially for Langle Spring, which was subject to the highest agricultural P loadings. Here ~70% of the annual TP flux and ~90% of the annual SRP flux was retained. Moreover, the buffering within the soils and karst drainage not only retained a high proportion of incoming fluxes of P from agricultural runoff but preferentially retained the most bioavailable P fractions. For instance, much research has documented the capacity of soil to retain applied P in various inorganic (Al, Fe, Ca complexes) and organic forms of varying stability.[45,46] The long-term accumulation of P in soil, however, can be released slowly to soil water.[28,47]

The mechanisms of P retention were not investigated here but likely include varying combinations of processes including adsorption onto clays, coprecipitation of P with $CaCO_3$, and binding with particulate humic substances[11−13] in the soil, in epikarst, and within the fractures and conduits. These adsorption products and precipitates will be physically retained as the water velocity slows and will be deposited as sediment along the base of the conduit flow paths. With the recurrence of high flow, these sediments are resuspended by turbulent flow and moved along the flow path, until redeposited, or eventually resurged at the base-level spring. Given the potential importance of $CaCO_3$–P coprecipitation for P retention in karst terrain, and the possibility of reductions in the efficiency of this coprecipitation mechanism under higher P and dissolved organic carbon (DOC) concentrations,[12,48,49] further work is needed to examine any unforeseen impacts of increasing agricultural intensification on this "self-cleansing" P retention mechanism. However, in this study, the site with the higher livestock intensity and with higher manure-enriched runoff actually demonstrated greater efficiency of P retention. This may indicate that critical P and DOC thresholds for inhibition of $CaCO_3$ precipitation were not reached or that other P retention process mechanisms were occurring.

The patterns in spring-water La concentrations suggest continued released of La from springs more than 10 years after a tracer injection and indicate the potential for long-term contaminant retention, storage, and subsequent release. Indeed, the complex nature of karst hydrological pathways can result in large distributions in water and contaminant residence times, and lag times for discharge to surface waters may be much longer than expected.[50−52] Our findings indicate that retention of P within karst drainage may reduce the risk of acute episodic storm-driven losses of agricultural P. However, the potential buffering of P in the epikarst, and within the fracture and conduit drainage system, can provide a slow, but long-term, source of P released via springs to surface waters. Further work is needed to determine the ecological impacts of such patterns of P release to receiving streams and the ability of those streams to assimilate those inputs, compared with higher pulse inputs during storm flows.

■ ASSOCIATED CONTENT

Supporting Information

Map of the SEW and the karst water flow system; time series of spring-water TP, SRP, K, and Rb concentrations; table of Ca, TP, and SRP endmember concentrations; soils and geology of the Savoy Experimental Watershed; experimental methods. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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REVISION OF THE 590 NUTRIENT MANAGEMENT STANDARD: SERA-17 RECOMMENDATIONS

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Minimizing Agricultural Phosphorus Losses
for Protection of the Water Resource

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Organization to Minimize
Phosphorus Loss from Agriculture

SERA-17

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ABSTRACT

In late 2009, NRCS requested a Working Group within SERA-17 be established to review and revise the 590 Nutrient Management Conservation Standard. This was in response to growing concern in certain areas of the U.S., that current risk assessment tools were not bringing about as great a change in phosphorus (P) management or P load reductions from agricultural lands as deemed accepted by some action agencies and NGOs. The SERA-17 Working Group were given five charges by NRCS, related to P loss risk assessment as part of the 590 that were to define: (1) criteria establishing the range of soil test P (STP) values where a P Index risk assessment is needed; (2) upper P Index threshold that limits P application; (3) minimum requirements of P Indices; (4) a process to evaluate P Indices; and (5) long-term goals for development of the next generation P Indices. This report documents the findings and recommendations of the SERA-17 Working Group. This document was reviewed by SERA-17 members, NRCS, EPA, and NGOs, and represents to the best degree possible, a consensus statement of P loss risk assessment for agricultural sites.

FORWARD

Since its introduction in the early 1990's, the P Index has morphed from an educational to an implementation, targeting, manure scheduling tool, and in some cases, a regulatory tool. A great deal of research has been conducted across the U.S. to derive, validate, and support components of the P Indexing concept, particularly those related to source factors. The general P Indexing concept has been modified state by state to consider their particular soil, land management, physiographic, and hydrologic controls influencing the potential for P loss. As a result, there are many variations in Indices now in use as part of the NRCS 590 Nutrient Management Conservation Standard. This variation is both a strength and weakness of the Indexing concept. Variability demonstrates the robustness of the approach but has led to differences in P management recommendations under relatively similar site conditions.

The inconsistency among Phosphorus (P) Indices in terms of level of detail and scientific underpinnings among states, as well as in recommendations and interpretations based on site risk, prompted this review of the P-Indexing approach as it is used in nutrient management planning. The need for revision has been heightened by a slower than expected decrease in P-related water quality impairment and, in some cases, an increase in soil P to levels several fold greater than agronomic optimum due to continued application of P with approval of the P Index.

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REVISION OF THE 590 NUTRIENT MANAGEMENT STANDARD: SERA-17 RECOMMENDATIONS

BACKGROUND

In certain areas of the U.S., there is growing concern that phosphorus (P) based nutrient management was not bringing about as great a reduction in elevated soil P levels and P loss from agricultural lands as expected or desired. While a portion of the lack of response may reflect legacy effects of past management and a slow system response to change, there was indeed a need to address the approaches to determine and guide P-based nutrient management. As a result, NRCS undertook a revision of the 590 Nutrient Management Conservation Standard in mid 2009. A major component of this was to review and revise as necessary, the site risk assessment tool - P Index, used 590 nutrient management planning. In an effort to develop and science-based consensus on the nature of this revision and national standard for a P risk assessment tool, NRCS requested SERA-17 lead this task. In November, 2009, a SERA-17 Working Group was formed under guidance from NRCS and the SERA-17 Executive Committee.

NRCS's goals for a revised Phosphorus Index (P Index) or Phosphorus Risk Assessment Tool (PRAT) were to:

1. Prevent the gradual loading of phosphorus (P) to high water quality risk levels.
2. Assist producers in mitigating existing high water quality risk situations to lower sustainable P levels.
3. Determine and implement a "cutoff" to identify those conditions where no additional P shall be applied.
4. In order to accomplish the above goals, the P Index should include the following:
   a. A tool built on a national platform with scientific underpinnings.
   b. A tool to assess the potential for edge-of-field P runoff and leaching.
   c. A tool based on the best available science that can be refined / improved as better technology or science becomes available.
   d. A tool that can utilize local soil, hydrology, and climate data (these data already reside in wind and water erosion prediction tools used in NRCS field offices) that can track erosion and sediment transport to concentrated flow, to a point of deposition, or edge of field.
   e. A tool that can address, where needed, irrigation-induced erosion, runoff, and leaching.
   f. A tool that can assess risk from manure and/or P fertilizer.
   g. Although the proposed P Index would be quantitative, it is not necessary that the results be delivered numerically. A narrative or category rating (Very Low, Low, Medium, High, Very High, etc.) would be satisfactory.
   h. The minimum criteria for edge-of-field P runoff should be that nutrient concentrations in runoff reaching a stream or water body will not cause water quality impairment (algae,

aquatic habitat, etc.). The tool will also need to identify those fields/situations where even with the best conservation, no additional P should be applied.

THE CHARGE TO SERA-17

Based on the above requirements the SERA-17 subgroup had the following charges (Figure 1):

1. Define criteria establishing the range of soil test P (STP) values where a P Index risk assessment is needed.
2. Define the upper P Index threshold that limits P application.
3. Define the minimum requirements of P Indices.
4. Define a process to evaluate P Indices.
5. Define long-term goals for development of the next generation P Indices.

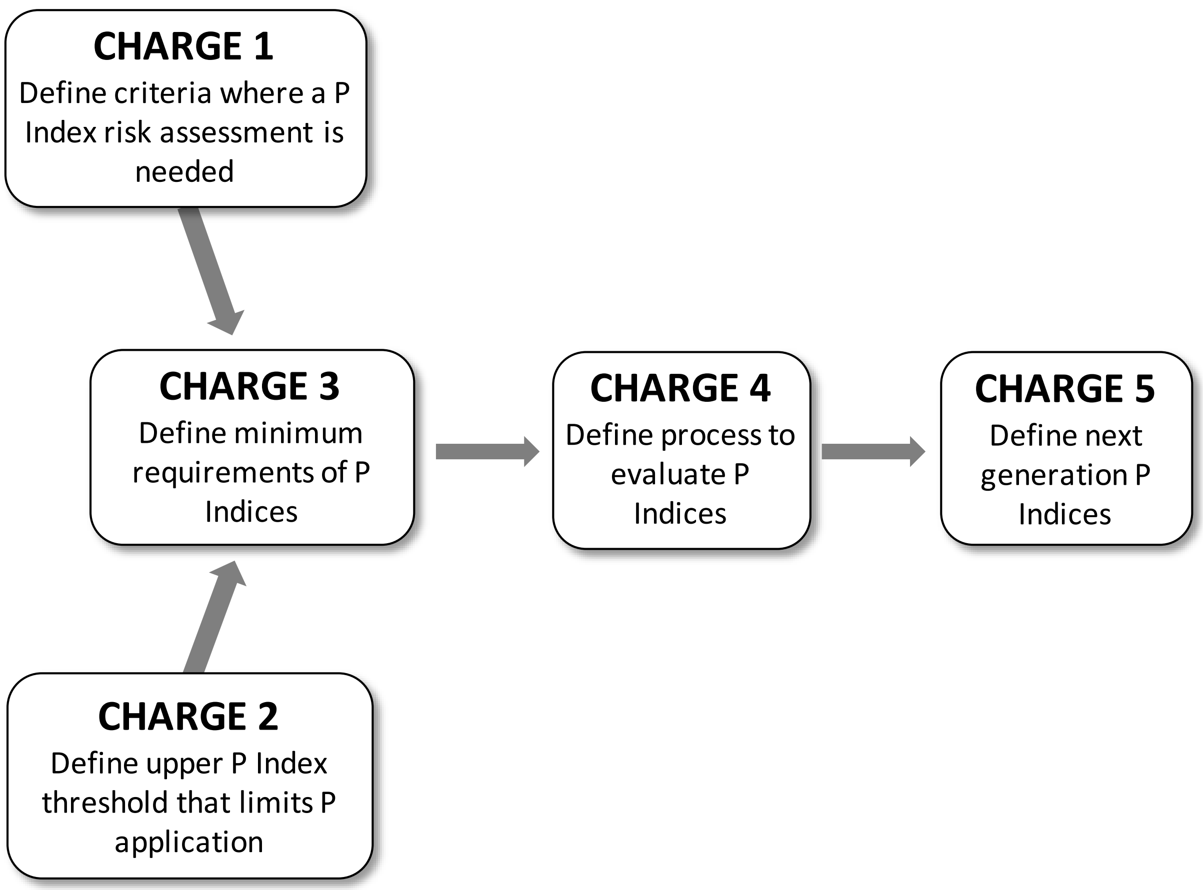

Figure 1. Organization scheme of the 590 revision charges.

EXECUTIVE SUMMARY

- The goal of a P Index is to estimate the potential for P loss from any agricultural field. Phosphorus Indices were not designed to address or solve the broader issue of regional P surpluses. Many P Indices force a P balance approach on individual fields at some point; however, this point varies greatly and P Index cutoff values (the P Index value where no additional P is recommended) are not tied directly to water quality. A separate effort to address P balance (i.e., inputs equal to or less than outputs) at a watershed scale is needed. A P-balance approach will involve alternative technologies for manure utilization and export of manure from many farms in some watersheds.
- Many states have developed adequate tools to estimate the potential for P loss by describing the main factors and conditions controlling P loss in their state. However, there is substantial variation among P Indices in their structure, algorithms, and cutoff values used to delineate very low, low, medium, high, and very high risk of P loss. More importantly, there is a great deal of inconsistency in results and interpretation regardless of the details of the tool used.
- States may find it appropriate to eliminate the requirement of a P Index assessment when P applications are based on land-grant university nutrient recommendations and appropriate Best Management Practices (BMPs) for land application of P sources as defined by NRCS Conservation Practice Standards. For P application in excess of recommended rates, a P Index assessment will need to be conducted.
- All P Indices should "zero out" at some point. That is, there is a point above which the risk of P loss from a field is too great to warrant the application of P in any form. Each state should demonstrate that its P Index meets this criterion. We provide several approaches to determine this point, and where field-based research has been conducted to develop upper limits, state specific information should take precedence.
- There are too many legitimate differences in soils, climate, cropping systems, water body sensitivities, etc., and insufficient progress in modeling of all processes to support development and use of a single National P Index that addresses all of these differences, especially if a National Index must be user-friendly and require minimal input data and training for end-users at this time. Development of a National P Index will require a long-term commitment of time and resources similar to that required for the development of the USLE. Development of a P loss assessment tool that addresses the P loss issues specific to a physiographic region is desirable and should be a long-term goal of SERA-17 and NRCS collaboration.
- Although there is no scientific evidence to support the use of STP or P saturation alone to determine the risk of P loss; because P is a finite resource, states should consider establishing an upper limit of STP above which manure cannot be applied, regardless of P Index assessment.
- There needs to be a concerted training effort on how to use P Indices in the context of nutrient management planning and how to address any concerns identified by the P Index used during the planning/implementation process.

CHARGE 1

CRITERIA ESTABLISHING THE RANGE OF SOIL TEST PHOSPHORUS VALUES WHERE A PHOSPHORUS INDEX RISK ASSESSMENT IS NEEDED

Recommendation

The lower limit of the range of STP values where a P Index risk assessment is needed can be based on land-grant university P application recommendations. States may find it appropriate to eliminate the requirement of a P Index assessment when P applications are based on land-grant university nutrient recommendations and appropriate Best Management Practices (BMPs) for land application of P sources (NRCS Conservation Practice Standards). For P application in excess of recommended rates, a P Index assessment will need to be conducted. States could develop a screening tool or other resources to identify high risk areas where a P Index assessment should be conducted even if STP results in a P application recommendation.

Because P is a finite resource, states should establish an upper limit of STP above which manure cannot be applied, regardless of P Index assessment. However there is no scientifically defensible way to set a uniform national upper STP bound based solely on water quality goals.

Considerations

Setting the lower STP limit when no P Index assessment is required

- The P Index (or pre-screening tool) should only be optional for fields with an agronomic need for P, based on STP and land-grant university nutrient recommendations.
- Producers are required to meet all other field-specific NRCS conservation objectives and standards, including erosion control, manure application setbacks, proper timing of manure application, and annual N limits for the crop. These conservation requirements apply to all nutrient applications independent of source according to the NRCS National Nutrient Management Standard.
- A low STP level does not mean there is no risk for P loss from manure or fertilizer application. For instance, the application of P to critical risk areas, such as fields adjacent to a stream with a high transport risk should be avoided. States that do not require the use of the P Index when an agronomic P need exists, could develop and use a screening tool to identify any local high risk situations (e.g., 303(d) listed waters for P or other state designated P-related impairment, erosion greater than T, high runoff potential, and within 30 m of flowing water) where the P Index should be used even when P applications are recommended.
- In some states, the P Index may allow repeated N-based applications, which can lead to a buildup of STP in excess of soil test P-driven nutrient recommendations. Because the recommended approach of Charge 1 never allows P applications to exceed crop rotation requirements, it is more restrictive than repeated N-based application rates.
- This approach promotes use of manure as a nutrient resource and ensures that farmers who manage manure P in this way can avoid conducting a P Index assessment when developing a

nutrient management plan or adjusting a manure application rate based on new information, such as information from regular and ongoing soil or manure test results. This allows limited planning resources to be targeted to higher priority areas.

- Manure P can be applied at a rate to meet the recommendation for multiple crop years (length to be determined by each state) without the need to do a P Index assessment. For example, with a three-year limit, a farmer could apply manure (based on the total P concentration of manure) in one year to meet three years of crop P need, as long as crop N requirements are not exceeded. No additional P is applied in the current and two additional years. However, given the short-term over application of P, states may want to provide additional guidance requiring agronomic practices that have been shown to minimize P runoff (e.g., subsurface placement, injection).
- It is theoretically possible that this approach would allow a manure or fertilizer application when the P Index recommends no application of manure. Reviewing current P loss assessment strategies from 21 states, shows that the P Indices in six of these states may indeed prevent manure application to fields when STP values are below the agronomic threshold (Table 1). In most cases, this would occur under specific and limited conditions (e.g., organic soils, high transport potential, proximity to a stream, specialty crops) for manure application and/or when manure application rate was high. Soil test P values at which no additional P is recommended are summarized in Table 2 for 24 states.
- Given the urgent need for improvements in P recommendations for environmental risk assessment purposes, continued efforts to use accurate data are essential. Private soil testing laboratories should be encouraged, if they are not already doing so, to participate in a laboratory certification program to verify that analytical procedures are performed correctly. T hey should also be encouraged to work with land-grant universities to ensure testing methods are consistent with extraction protocols established by the land-grant university in the state where the soil sample was taken. In addition, NRCS 590 standards should require soil test laboratories be certified and use land-grant university nutrient recommendations for both N and P. For states that do not have this requirement in their NRCS 590 standard, soil testing analysis and recommendations can vary significantly. See Appendix A for more information.

Setting the upper STP limit when no more P should be applied because of limited P resources

- There is no scientific evidence to support the use of STP or P saturation alone to determine the potential for P loss from a field. A wealth of scientific evidence is available documenting that agronomic STP or soil P saturation is only one of several factors influencing the risk of P loss from a field. Use of agronomic STP or P saturation alone will not capture a site's risk for P loss (see Appendix B for more information). Any effort to set regional or national limits based solely on STP or P saturation will encounter the following challenges:

1. Inability to define cutoff values based on water quality criteria because of the lack of a correlation between STP or P saturation and edge-of-field runoff water quality.
2. Because several different STP methods and depths of soil sampling are used across the U.S., equivalent values for each method would have to be determined.

- There are legitimate reasons to set an upper STP boundary not directly associated with current P loss potential of a field:
  1. Phosphorus is a finite natural resource that needs to be conserved. Thus, we support achieving on-farm and regional P balance with the long-term goal of meeting agronomic requirements. The unlimited over-application of P to soils is not a sustainable use of this finite resource. Limited buildup of STP above agronomic thresholds (Table 2) can achieve both agronomic and economic goals by maintaining agronomic P levels through a rotation or as a hedge against volatile fertilizer prices. At some point, continued buildup of STP has no possible agronomic value and can only be classified as a waste disposal P application.
  2. There is no guarantee that conditions currently limiting P transport on low P index fields will be maintained in perpetuity.
- The P index in many (if not all) states allows build up of STP above agronomic need on most fields. States should consider defining where STP buildup transitions above "insurance" applications. Such a boundary may be considered as a limit to P application to meet resource conservation goals or as an educational tool so farmers understand there is little or no expectation of utilization for applied P to fields with STP above that limit.

The following are possible approaches states may use if they choose to set an upper STP threshold above which no manure application is allowed:

1. **Select a multiple of agronomic STP optimum**. The resulting limit could be interpreted correctly independent of the extraction procedure. States using a specific extraction procedure could later translate the guidance into specific extract concentrations.
2. **Select a draw down STP level** that would require no more than a set number of years to be drawn down to optimum under normal cropping conditions.

Table 1. Conditions under which P Indices could limit P applications on a field with an agronomic need for P in selected states.

State	Can state P Index restrict P applications on soils with an agronomic need for P?	Basis of Determination	Reference
AK	Yes	Can limit agronomic applications where site, transport, methods of application and timing factors are all at very high or worst-case scenario levels.	NRCS Alaska PI Index. May 2002.
AR	No	Restrictions most likely to occur on soils with high rates of P application coupled with high transport potential.	Moore, P.A., Jr., A. Sharpley, W. Delp, B. Haggard, T. Daniel, K. VanDevender, A. Baber, and M. Daniel. 2010. The Revised Arkansas Phosphorus Index. Arkansas Natural Resources Commission Title 20. http://www.anrc.arkansas.gov/Title%2020%2012-10-09.pdf .
CO	No	P index does not need to be run if STP is less than 10 mg kg^{-1} AB-DTPA, 30 mg kg^{-1} Bray-I P, 40 mg kg^{-1} Mehlich-3 P or 20 mg kg^{-1}Olsen P. This will result in no restriction on agronomic P applications except for potatoes.	USDA-NRCS State of Colorado. Agronomy Technical Note No. 95 (revised). Colorado Phosphorus Index Risk Assessment (Version 4). October 1, 2008.
CT	No	State has no P-Index, but P applications are not restricted if soil test recommends P applications.	http://efotg.sc.egov.usda.gov/references/public/CT/CT_590_2010_F.pdf
DE	No	The State of Delaware's Nutrient Management Commission has established a Mehlich 3 P threshold of 150 mg kg^{-1} (3 times the University of Delaware M3 P critical value of 50 mg kg^{-1}) as the basic definition of a "high P" soil. By state law (Delaware Nutrient Management Act of 1999), soils that are "high" in P can continue to receive manure or fertilizer P in any given year at the rate that will	Sims, J. T. and Leytem, A. B. 2002. The Phosphorus Site Index: A phosphorus management strategy for Delaware's agricultural soils. Nutrient Management Fact Sheet No. 5. University of Delaware College of Agriculture and Natural Resources, Newark, DE 19717-2303.

		be removed by crop harvest in the next 3 years, but no additional P can then be applied for 3 years (i.e., P is applied once at a "3-year crop P removal" rate, then again 3 years later). However, farmers are given the option to use a P Site Index for soils with M3-P > 150 mg kg^{-1} and to apply manure and fertilizer P in accordance with the recommendations of the P Site Index. The University of Delaware recommends that no manure or fertilizer P be applied if a field has a "Very High" P Index rating. For soils with a "High" P Index value, the recommendation is that "…fertilizer P, other than a small amount used in starter fertilizers, will not be needed. Manure may be in excess on the farm and should only be applied to fields with a lower P Site Index value." It is possible, but highly unlikely, that soil erosion or artificial drainage could result in a Very High P Index value and restrict manure applications to a soil with an agronomic need for P.	
GA	Yes	P Index could restrict agronomic applications in soils with high transport potential.	Cabrera, M.L., D.H. Franklin, G.H. Harris, V.H. Jones, H.A. Kuykendall, D.E. Radcliffe, L.M. Rise, and C.C. Truman. 2002. The Georgia Phosphorus Index. Cooperative Extension Service, Publications Distribution Center, University of Georgia, Athens, Georgia, 4pp.
IN	No	Application rate bases for nutrient applications are determined by STP according to Chart B if the Indiana off-site risk pre-screening tool value is <6. If the Indiana off-site risk pre-screening tool is >6, the Indiana Off-Site Risk Index (ORI) must be completed and all risk components identified must be addressed. After all risk components identified by the ORI have been addressed nutrient applications are determined by STP according to Chart B.	Indiana Nutrient Management Standard. July 2001.
KS	No	There is no restriction in P application when STP less than 50 mg kg^{-1} Mehlich 3 P regardless of the P index rating.	Kansas Nutrient Management Standard, November 2009. http://efotg.sc.egov.usda.gov/references/public/KS/590st.pdf

KY	No	P Index is not required until Mehlich-3 STP values exceed 200 mg kg^{-1} which is ~ 7 times greater than the agronomic recommendation for most crops.	Kentucky Nutrient Management Standard, May 2001.
MD	Yes	P Index may restrict agronomic applications for sites with very high off-site transport potential (e.g. high erosion potential) and close proximity to surface water and/or surface application of manure.	Coale, F.J. 2005. The Maryland Phosphorus Site Index Technical Users Guide. Soil Fertility Management Series, SFM-7. Maryland Cooperative Extension. http://www.anmp.umd.edu/files/SFM-7.pdf.
ME	No	Restrictions affect soils with soil test P greater than 20 mg kg^{-1} where no P application is recommended.	
MO	No	P Index is designed to insure rating of no higher than "medium" on fields with agronomic need and soil loss less than 2T. Therefore, the P index should never limit agronomic applications on fields where erosion limits of the 590 standard are being met.	Lory, J.A., R. Miller, G. Davis, D. Steen and B. Li. 2007. The Missouri Phosphorus Index. MU Extension Pub. G9184.
NC	Yes	P Index almost always restricts agronomic applications on organic soils at the agronomic cutoff for P. Most manure, however, is not applied to organic soils.	Johnson, A.M., D.L. Osmond, and S.H. Hodges. 2005. Predicted impacts of North Carolina's Phosphorus Loss Assessment Tool. *J. Environ. Qual*. 34:1801-1810.
NY	No	Restrictions most likely to occur on soils with high rates of P application coupled with high transport potential.	Czymmek, K.J. Q. M. Ketterings, L. D. Geohring, G. L. Albrecht. 2003. The New York Phosphorus Runoff Index. User's Manual and Documentation. CSS Extension Publication E03-13. 64 pages.
OK	No	Nutrient Management Standard states that no manure application only on fields with Mehlich3-P >150 mg kg^{-1} (STP Index >300).	Oklahoma Nutrient Management Standard. March 2007.
PA	Yes	Using all the worst-case scenarios leads to no application if the P application rate from all sources exceeds 100 lbs $acre^{-1}$. Result only applicable in special protection watersheds and applications within 150 feet of receiving water.	2007. The Pennsylvania Phosphorus Index, Version 2.

SC	No	P Index cannot be used to limit or deny applications of P when it is recommended for crop growth through soil test results	The Phosphorus Index: South Carolina. 210-AWMFH, SC Supplement, July 2004.
TN	No	The P Index assessment is required for P applications where no further P additions are agronomically needed as defined by Mehlich-1 soil test P.	Tennessee Phosphorus Index: A Planning Tool to Assess & Manage P Movement. 2001.
TX	No	When the Mehlich-3 soil test P reaches 200 mg kg^{-1} in East Texas (counties with greater than 25 inches of precipitation) or 350 mg kg^{-1} (counties with less than 25 inches of precipitation and named streams greater than 1 mile away), the maximum application would be 1.0X P annual crop removal rate, not to exceed the annual N rate of application for PI ratings of Very Low, Low, Medium, or High and for Very High it is 0.5X the annual P crop removal rate.	Texas Nutrient Management Practice Standard. July, 2007.
UT	No	Nutrient management guidance states that Olsen-P of 50 mg kg^{-1} manure can be applied according to the agronomic N need. Between 50 and 100 mg kg^{-1}, manure should be applied according to the agronomic P need. Above 100 mg kg^{-1} Olsen P, manure should only be applied at 50% of agronomic P need.	Utah 590 Standard: http://extension.usu.edu/files/publications/publication/AG_Soils_2008-01pr.pdf
VA	No	P Index does not come into effect until Mehlich 1 P above agronomic optimum	http://p-index.agecon.vt.edu/
WI	Yes	It is possible to have particulate P loss that exceeds the WI target P Index value with STP in the optimum range for high P demand crops (e.g., potato) even when erosion is below T; these crops rarely receive manure.	2010. The Wisconsin Phosphorus Index, http://wpindex.soils.wisc.edu/

Table 2. Soil test P at which land-grant universities recommend no additional P be applied.

State	Method	Soil sampling depth	Soil test P where no additional P recommended	References
		inches	mg kg^{-1}	
AK	Mehlich-3	Plow depth to a maximum of 6 inches	15-66 Starter P typically recommended	USDA NRCS Alaska Technical Note 16 - Making fertilizer recommendations from soil test reports-October 2008.
AR	Mehlich-3	4 (pastures) or 6 (row crops)	36-50	Espinosa, L., N. Slaton, and M. Mozaffari. 2006. The soil test report. University of Arkansas Division of Agriculture, Cooperative Extension Service Fact Sheet FSA2153. http://www.uark.edu/depts/soiltest/NewSoilTest/pdf_files/FSA-2153.pdf
CO	AB-DPTA Olsen	Plow depth or 4 inches	8-11 15-22 P always recommended for potatoes	Davis, J.G. and D.G. Westfall, Fertilizing corn. CSU Ext. Pub. No. 0.538. Oct.. 2009. Davis, J.G. and D.G. Westfall, Fertilizing sugar beets. CSU Ext. Pub. No. 0.542. Apr. 2009. Davis, J.G., R.D. Davidson and S.Y.C. Essah. Fertilizing potatoes. CSU Ext. Pub. No. 0.541. May 2009.
CT	Modified Morgan	6-8	10	University of Connecticut Soil Nutrient Analysis Laboratory Recommendations for Agronomic Growers
DE	Mehlich-3	4 pastures 8 row crops	100 †	Sims, J. T. A. B. Leytem, and K. L. Gartley. 2002. Interpreting soil phosphorus tests. Nutrient Management Fact Sheet No. 4. University of Delaware College of Agriculture and Natural Resources, Newark, DE 19717-2303. Sims, J. T., and K. L Gartley. 1996. Nutrient management handbook for Delaware. Coop. Bull. 59. Univ. Delaware, Newark, DE.
GA	Mehlich-1	4 (pastures) 6 (row crops vegetables)	14-70	Kissel, D.E. and L.S. Sonon. 2008. Soil test handbook for Georgia. http://aesl.ces.uga.edu/publications/soil/STHandbook.pdf

IN	Bray 1	8	40-50	Vitosh, M.L., J.W. Johnson, and D.B. Mengel. 1996. Tri-state fertilizer recommendations for corn, soybeans, wheat and alfalfa. Ohio State Univ. Bulletin E-2567
KS	Bray 1	6	20-30	Leikam, D.F., R.E. Lamond, and D.B. Mengel. 2003. Soil test interpretations and fertilizer recommendations. Kansas State Univ. Agricultural Experiment Station and Cooperative Extension Service Pub. MF-2586. Manhattan, KS.
KY	Mehlich 3	3-4 (consv till) 6-7 (conv till)	30-40	Murdock, L. and G. Schwab. 2010. Lime and fertilizer recommendations. University of Kentucky Extension Publication AGR-1
MI	Bray 1	8	40-50	Vitosh, M.L., J.W. Johnson, and D.B. Mengel. 1996. Tri-state fertilizer recommendations for corn, soybeans, wheat and alfalfa. Ohio State Univ. Bulletin E-2567
MD	Mehlich-3	8	50	McGrath, J. 2010. Agronomic crop nutrient recommendations based on soil tests and yield goals. Soil Fertility Management Series, SFM-1. Maryland Cooperative Extension. http://www.anmp.umd.edu/files/SFM-1.pdf.
ME	Morgan	6	20	Hoskins, B.R. 1997. Soil Testing Handbook. Revised 2001. Available at http://anlab.umesci.maine.edu/soillab_files/faq/handbook.pdf.
MO	Bray 1	6	35	Soil Test and Interpretations Handbook. Revised 5/2004. Available at http://aes.missouri.edu/pfcs/soiltest.pdf
MS	Lancaster	4–6 pastures, 6 crops	36	Oldham, J.L., and K.K. Crouse. Soil test-based inorganic fertilizer nutrient recommendations for Mississippi agronomic crops. MSU Extension Service Soil Testing Laboratory.
NC	Mehlich 3	4 (consv till) or 8 (conv till)	60	Hardy, D.H., M.R. Tucker, C.E. Stokes. 2009. Crop fertilization based on soil test report. http://www.ncagr.gov/agronomi/pdffiles/obook.pdf. NCDA&CS, Raleigh, NC
NY	Morgan	6-8	20	Ketterings, Q.M., K.J. Czymmek and S.D. Klausner. 2003. Phosphorus guidelines for field Crops in New York. Second Release. Department of Crop and Soil Sciences Extension Series E03-15. Cornell Univ., Ithaca NY. 35 pp.

OH	Bray 1	8	40-50	Vitosh, M.L., J.W. Johnson, and D.B. Mengel. 1996. Tri-state fertilizer recommendations for corn, soybeans, wheat and alfalfa. Ohio State Univ. Bulletin E-2567
OK	Mehlich 3	6	41 ¶	Zhang, H. and B. Raun. 2006. Oklahoma Soil Fertility Handbook. 6th Edition. OSU Extension Publication.
PA	Mehlich 3	8	50	AASL.psu.edu Penn State Soil Fertility Handbook
SC	Mehlich 1	6 (crops) 3 (pasture)	27.5 - 40	
TN	Mehlich 1	6	>15	http://soilplantandpest.utk.edu/pdffiles/soiltestandfertrecom/chap2-agronomic_mar2009.pdf
TX	Mehlich 3	6	50	Provin, Tony. 2010. Soil, water and forage testing laboratory methods and recommendations. http://soiltesting.tamu.edu .
UT	Olsen P	12 ‡	15	Cardon, G.E., J. Kotuby-Amacher, P, Hole, R. Koenig. 2008. Understanding your soil test report. Utah State Cooperative Extension Service AG/Soils/2008-01pr. http://extension.usu.edu/files/publications/publication/AG_Soils_2008-01pr.pdf
VA	Mehlich 1	4 no-till, 6-8 conventional till	55	Maguire, R.O., and S.E. Heckendorn. 2009. Soil test recommendations for Virginia (Update of 1994 version). Virginia Cooperative Extension.
WI	Bray 1	6-8	17-80§ P always recommended for potatoes	Laboski, C.A., J.B. Peters, L.G. Bundy. 2006. Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin. UW-Extension A2809.

† Optimum range for M3-P in Delaware is 50-100 mg kg^{-1} by Mehlich 3 P. In almost all cases, only starter P is recommended when M3-P values are > 50 mg kg^{-1}.
‡ Value is 32.5 mg kg^{-1} if P is measured colorimetrically.
¶ Recommendation is that the sample be confined to the upper foot. Most will focus on extracting from 6 to 10 inches deep.
§ Value within range depends on crop and soil type.

CHARGE 2

DEFINING AN UPPER PHOPSHORUS INDEX THRESHOLD THAT LIMITS PHOSPHORUS APPLICATION

Recommendation

All P Indices should "zero out", which means they must identify a critical risk of P loss from a field beyond which no P in any form should be applied. Each state must demonstrate that its P Index meets this criterion for combinations of parameters that influence P loss potential. The upper criteria or threshold should be determined based on local water quality criteria where available, or on a basic set of conditions that in combination lead to an unacceptable risk of P loss. The upper threshold should be used to establish the minimum standard for restricting P applications on a field and should not be used to justify raising limits on P applications in states with more restrictive P Indices.

Considerations

Possible methods for establishing an upper P Index threshold are detailed below and outlined in Table 3.

1. Define P loss limits for a field based on quantitative water quality criteria for the target water body.
    - This approach is similar to that for establishing TMDLs, and provides a quantitative measure justified directly by water quality standards for a specific region. Essentially, the following are estimated: (a) how much total P a specific water body can assimilate without adverse water quality impacts; (b) how much of that total acceptable P load can come from agriculture in the watershed; and (c) an allowable field scale P loss based on the total allowable agricultural P load to the water body.
    - Unfortunately, there are significant technical challenges to setting field-level P limits based on numeric water quality criteria. Currently, numeric criteria for P water quality standards only exist for a limited number of water bodies; and methods to establish field-specific limits on P loss based on numeric water quality limits are not well developed.
    - This approach requires use of a P Index that estimates field scale P loss in lb/ac so P Index results can be directly related to water quality estimates.
2. Run a range of scenarios and estimate P loss for each of them using an appropriate model. Use professional judgment to set runoff P limits that clearly limit risky management and/or prevent levels of P loss likely to degrade water quality.
    - This approach integrates professional judgment and local management into the establishment of P limits. However, subjective criteria are used to connect P loss limits with water quality criteria.

3. Run a comprehensive set of representative P runoff scenarios for a state or region using an appropriate model and set P limits to eliminate application on a specified upper percentile of the scenarios (e.g., top 20%).
   - This approach provides a limit based on local scenarios that will reliably establish and identify the worst situations. However, there is no connection between the limit and any water quality criteria. The limit could be either more restrictive or more liberal than needed.
   - To be successful, this approach requires knowing and running the full range of real field scenarios, from the lowest to the highest P loss rating.

Table 3. Potential strategies to identify field P loss limits in runoff where a P risk assessment strategy should zero out P applications.

Approach Description	Strengths	Weaknesses
Set field runoff P limits based on water quality criteria of the target watershed.	• Quantitative measure justified directly by water quality standards for a specific region. • Preferred approach in TMDL watersheds and when other water quality criteria are available.	• Requires quantitative water quality criteria to be in place and a mechanism to convert to field –level P loss limits. There is insufficient information in place to calculate such limits in many locations.
Run a range of scenarios and estimate P loss for each of them using an appropriate model. Use professional judgment to set runoff P limits that clearly limits risky management and/or prevents levels of P loss likely to degrade water quality.	• Integrates professional judgment and local management into the establishment of P limits.	• Subjective criteria used to connect P loss limit with water quality criteria.
Run a comprehensive set of representative P runoff scenarios for a state or region using an appropriate model and set P limits to eliminate application on a specified upper percentile of the scenarios (e.g., top 20%).	• Provides a limit based on local scenarios that will reliably establish and identify the worst situations.	• No connection between the limit and any water quality criteria. Limit could be either more restrictive or more liberal than needed. • Requires that the full range of real field scenarios be known and run, from the lowest to the highest loss rating, to be successful.

CHARGE 3

DEFINING THE MINIMUM REQUIREMENTS OF PHOSPHORUS INDICES

Recommendations

1. Soil test P, P additions, runoff, and erosion should be continuous variables in all P Indices.
2. The risk assigned by all Indices must increase with increasing STP, P additions, runoff, erosion, and leaching where applicable.
3. Management interpretations of P Indices should provide clear direction, and have at a minimum P-based and no P application categories. Narrative statements of management recommendations (e.g., "conservation measures should be considered to decrease the risk of P loss") have limited specificity in terms of nutrient management and implementation and, therefore, have no place in P Index interpretations.

Considerations

Differences in category boundaries and how those categories affect management are separate issues from differences in calculation. Even using similar calculation methods, there are a wide range of management interpretations for a given risk. Having different categories for management response to the same risk interpretation does not necessarily mean that one P Index is less protective of local water quality than another. Ideally for water quality protection, the interpretation of different levels of risk would not be uniform across all watersheds. Rather, the risk categories and the limits should be assigned based on water quality targets and the assimilative capacity of the receiving water body. However, some P Indices never reach a risk level assessment that restricts manure application to a field (Osmond et al., 2006), and this situation must be addressed.

Clearly, the fact that there is not a framework for establishing risk categories based on water quality is problematic. Without such a framework, the determination of "how much is too much" is generally a value judgment. At present, few states have established numeric P water quality standards. Even with numeric standards in place, it is difficult to make the connection between a field-based risk assessment and P concentrations or loads in receiving waters. We recommend that where water quality criteria are available, such as in TMDL areas, the process used in evaluating P Indices in Charge 4, also be used for setting management interpretation categories. Requirements related to each interpretation category should be clear and descriptive. As stated under Charge 2, all indices should have a no P application interpretation category.

CHARGE 4
DEFINING A PROCESS TO EVALUATE PHOSPHORUS INDICES

Recommendations

1. Ideally, local water quality data should be used to evaluate P Indices and to establish thresholds based on local water quality criteria.
2. Given that there are limited edge-of-field water quality data available, an alternative approach is to use a nonpoint source model to estimate P loss from a range of conditions consistent with P Index assessment for each state.
3. Where states have already used and validated a regionally appropriate model, that model should be used. Examples of default models are provided below.
4. Reference to any specific model to evaluate P Indices does not imply a recommendation that the model be used as an alternative risk assessment tool to the P Indexing approach.

Recommended Approach to Evaluate P Indices: Using Data and Models

Local water quality standards should be used to evaluate the P Index and to establish P application rate thresholds based directly on these water quality criteria. Unfortunately, these data are limited or unavailable in many states, particularly at scales required to validate the P Index. However, where measured data do exist (e.g., local research sites, National Resource Inventory [NRI] sites) they should be used to validate P indices; and SERA-17 should be encouraged to maintain a database of benchmark fields where water quality data are available for P Index validation (e.g., Harmel et al., 2008). As an alternative to direct evaluation with measured data, appropriate models could be used to provide information for evaluating P Indices, as long as the model selected has been validated to reliably predict field-scale P loss (e.g., Veith et al., 2005). This could also be used as the basis for justifying and documenting if P Index risk assessment does in fact limit P application at a certain specific pre-approved set of threshold conditions (see Charge 2 earlier).

We envision that in a state, or better yet a physiographic region, a model that has been evaluated for local conditions could be used to run simulations on a broad range of scenarios that would cover the expected conditions and management in that region. The P Index would then be run on the same scenarios using the same inputs that were used in the model and that apply to that particular Index. The results of model simulations and P Index evaluations would then be compared. At the present time, a nationally applicable model does not exist to use as the standard against which to compare all P Index assessments. Until a consensus driven alternative is selected, the following models are suggested as an interim option;

- Spreadsheet P runoff model of Vadas et al. (2005 and 2009) to estimate P loss in surface runoff from a range of source conditions consistent with P Index assessment for each state. This spreadsheet operates on an annual time step and is appropriate to evaluate the source components of a P Index for a user-defined set of runoff and erosion conditions. The spreadsheet does not itself predict runoff or erosion.

- Agricultural Policy Environmental eXtender (APEX; Gassman et al., 2009), which is a daily time step model that predicts runoff, erosion, and P loss for a user-defined set of field, management, and weather scenarios. APEX has been run as part of the Conservation Effects Assessment Project (CEAP). More than 22,000 sites across the nation have been modeled. The NRI sites could serve as evaluation points for the model, and where appropriate, can be used as actual data points for evaluating a P Index.
- Where locally calibrated / validated models are available, such as the quantitative P loss assessment tool for agricultural fields developed by White et al. (2010), their use would be appropriate.

This approach should be used to evaluate P Indices across the country to determine the directional and proportional integrity of P Indices with increasingly “risky” management scenarios. The model used must appropriately simulate the P loss processes under evaluation. For example, a model without a well-developed manure application or P leaching routine may not be appropriate for assessing the risk of P loss from surface applied manures or artificially drained soils, respectively. Regardless of the model used, conditions must still be defined that result in both unacceptable P loss within the model and high or very high P Index ratings that limit or preclude P applications run under the same set of conditions. Comparisons could be based on P loss estimates from the model but would not depend on any particular quantitative result for the P Index being evaluated as many P Indices are qualitative tools.

The primary criteria for comparison would be that the model and the P Index agree directionally and proportionally for an appropriate range of management, runoff, and erosion conditions. For use in regulatory programs, it is likely that more rigorous statistical criteria will need to be developed for this comparison. This evaluation approach would allow the use of existing P Indices as long as they meet the evaluation criteria. This approach can also be used to identify and support changes to existing P Indices to improve the assessment and could help in designing a new P Index. It is important to note however, that use of any model to evaluate a P Index does not imply use of the model as an alternative to existing P risk assessment tools / P Indices.

Because of the innate variability of natural systems, methods should be developed to estimate the uncertainty in predictions by P-indices and models. An example of a tool that could be used for this is @RISK commercial software which is a plug-in for Excel spreadsheets (http://www.palisade.com/decisiontools_suite/). Uncertainty in predictions should be considered when using models to test P Indices.

CHARGE 5

LONG-TERM GOALS FOR DEVELOPMENT OF NEXT GENERATION PHOSPHORUS INDICES

Recommendations

1. Development of a National P Risk Assessment Tool should be considered. Information needed to represent all situations, soils, management, physiographic settings, etc., must be compiled. This will require a major investment of resources and infrastructure, particularity for a reliable representation of landscape hydrology, surface runoff and leaching generation, and flow pathways.
2. NRCS should use a P loss assessment approach based on physiographic regions or NRCS Major Land Resource Areas (MLRAs) rather than national or state boundaries.
3. Next generation Indices should be constructed on a GIS platform to facilitate integration of current and future information databases.
4. There needs to be a concerted training effort on how to use P Indices in the context of nutrient management planning and how to address any concerns identified by the P Index used during the plan development/implementation process.

Considerations

The initial P Index ranked transport and source factors and added them together (Lemunyon and Gilbert, 1993). Because individual states were allowed to write their own NRCS 590 standard and modify the original P Index to address local priorities and conditions, there are large structural variations in P Indices. In addition, each state's P Index was developed for a slightly different purpose, and thus variations between them are apparent. Most states have made one or more of the following changes to the original design and formula proposed by Lemunyon and Gilbert (1993): 1) source and transport factors are multiplied rather than added; 2) distance from water resources is considered; and 3) some factors, such as soil loss, STP and P application rate, are quantified continuous inputs (Sharpley et al., 2003).

Developing a National P Index

We currently do not have the science, technologies, hydrological models, political will, resources, or infrastructure to implement a single approach to P loss risk assessment that covers all situations, soils, management, and physiographic settings. It would take an effort similar to that invested in USLE to develop and implement a national P risk assessment tool. There are several important factors influencing categorization and interpretation of P Index risk assessment, which vary greatly among states. This variation influences the outcomes and management recommendations as a result of an Index assessment and many are independent of the functionality of Indices in general. These factors include the spatial and temporal resolution and representation of Indices, multiplicative versus additive approaches, and state fertilizer recommendations. While some of this variability can be addressed during the Index revision process, external factors will have to be evaluated separately.

Spatial Representation

Most P Indices are state specific. This is primarily due to the requirements of state regulations and state 590 standards. Predominant mechanisms of P loss vary widely depending on soil and climate conditions, which are certainly not uniform across the country and rarely follow state boundaries. Consequently physiographic regions would be the more logical basis for regionalization of P Indices than state boundaries.

In the Chesapeake Bay watershed for example, which only represents a small area of the country, there are five main distinctly different physiographic regions; Coastal Plain, Piedmont, Great Valley, Appalachian Mountains, and Appalachian Plateau (Figure 2). Most of the states in this watershed contain three or more of these physiographic regions. It is very difficult to develop a practical P loss assessment tool that will work equally well for all these physiographic regions. Consequently, compromises are often necessary which are usually less than ideal in any of these regions.

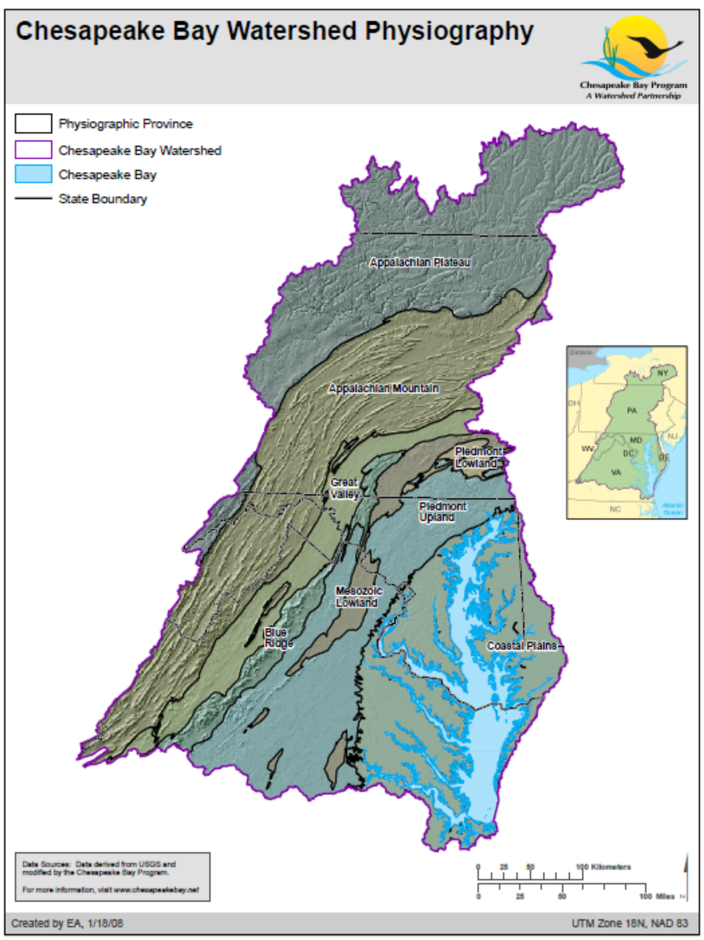

Figure 2. Physiographic regions of the Chesapeake Bay Watershed (courtesy of the Chesapeake Bay Program Resource Library - http://www.chesapeakebay.net/maps.aspx?menuitem=16825).

For example, how do you develop a P risk assessment tool that adequately addresses the predominantly leaching-driven losses of P in the Coastal Plain, where erosion is only a minor mechanism and the predominantly erosion- and runoff-driven losses in the Appalachian Mountains where leaching is much less of a factor? Indices in Maryland and Virginia attempt to do this. Because of these widely varying conditions and different relative areas of these physiographic regions in these two states, the approach to compromise varies enough that there are often significant differences in the P loss risk assessments from these states even on the same field.

Thus, in the Chesapeake Bay Watershed for example, a better approach would be to have an Index for each of the physiographic regions rather than one for each state (i.e., Delaware, Maryland, New York, Pennsylvania, and Virginia). These would be specifically tailored to the soils, climate, and management systems in these regions and be used within each physiographic region across all of the states. The challenge is to get acceptance within government programs of P Indices that cross state lines. States are generally reluctant to base regulations on something that they do not completely control.

GIS and Database Interfacing

The NRCS and EPA require the use of the Revised Universal Soil Loss Equation, Version 2 (RUSLE2) to determine soil erosion when developing nutrient management plans (NMPs). The standard approach to estimating a crop field's soil loss with RUSLE2 involves selecting a single soil type in the field. If the field has more than one soil type, the field's "dominant critical area" is supposed to be used as a “surrogate” to determine soil loss for the entire field in the conservation plan. However, the dominant critical area soil may not be the predominant soil in the field and it may not be the soil that should be used in making nutrient recommendations or in assessing the risk of nutrient and sediment loss from the field. A "spatial" approach to estimating soil loss for a field with RUSLE2 involves estimating soil loss for all digitized soil survey polygons whose boundaries overlap with the field's boundary. This would eliminate the need to select a single soil for a field to run RUSLE2, while allowing traditional conservation planning to be done on the basis of a single soil. Similarly, the P Index could be also calculated for each soil polygon in the field, using each polygon's underlying soil properties as inputs to the P Index.

Training and Support

Next generation P Index development plans need to include funding and resources to ensure effective implementation and long term support for the tool that is developed. Resource requirements for implementation are likely to be greater than those for initial development. An on-going training effort for NRCS staff, technical service providers and farmers on the use of the P Index in nutrient management planning will be needed. Planners and farmers need to understand the P Index as an indicator of P loss risk to find appropriate solutions to high P loss areas during the planning process and to be able to make appropriate adjustments when needed as the plan is implemented.

To be effective, any P loss assessment tool must be completely integrated with the nutrient management planning process. Nutrient management takes place in an agricultural landscape that is constantly changing, and ongoing funding for updates will be needed to maintain this integration. This will be especially true of assessment tools using computer software.

APPENDIX A

CURRENT STATE OF LAND-GRANT UNIVERSITY NUTRIENT RECOMMENDATIONS

Agronomic soil testing for P has been conducted for many years. These tests were initially developed to identify soils where plant-available P is insufficient to support maximum crop growth and where further addition of fertilizer was not needed. In many situations, P may not be recommended where the relative yield is >95% of the maximum yield or the likelihood of crop response to applied P is less than 5%. Soil test P where no additional P is recommended will vary with soil properties, crop type, and yield goal. Also, many states include a crop removal recommendation for STP just above this crop response critical level, as most farmers only test their soils periodically (every 2 to 5 years). This is to ensure that STP levels will not drop below the crop response critical level between soil tests. Soils are typically categorized (i.e., Very Low P, Low P, or below optimum P; Sufficient, Moderate P, or optimum P; High P, Very High P or above optimum P) based on the probability of crop response to additional P.

Soil testing to assess the potential environmental impact of P is a relatively recent development. Agronomic soil P tests were developed to assess the potential for crop response to applied P. The crop response categories / agronomic interpretations should not be equated to environmental risk interpretations. A number of tests and relationships of these P tests with runoff P have been developed for this purpose. However, there are too many other variables independent of soil P, such as P application, runoff and erosion potential, and distance to a stream or concentrated flow channel, for agronomic STP to be used as the sole indicator of the risk for P loss from a field.

Most P fertilizer recommendations for crops were established by scientists associated primarily with land-grant universities. Much of this work was done when commercial fertilizers first became widely available beginning in the 1950's. In the recent past, much less emphasis has been given to this type of research by public institutions and once-common publicly funded soil testing laboratories are now rare. This can be problematic when government programs refer to university recommendations for a standard but the land-grant university can no longer support soil test calibration research and updates. Thus, updating nutrient recommendations should be supported as new crop varieties and yield response data become available.

APPENDIX B

RELATING PHOPSHORUS LOSS IN RUNOFF TO SOIL TEST PHOPSHORUS, SOIL PHOPSHORUS SATURATION AND PHOPSHORUS INDEX RISK

There is no scientific evidence to support the use of STP or soil P saturation alone to determine the amount of P loss from a field. A wealth of scientific evidence is available documenting that STP and/or soil P saturation are one of several factors influencing the risk of P loss from a field. Use of STP or soil P saturation alone will not capture a site's risk for P loss and may be less restrictive than a well designed P Index, thereby increasing the potential for P runoff and leaching (Figure 3). The data in Figure 3 is from the FD-36 watershed on south-central Pennsylvania and is adapted from that presented in Sharpley et al. (2001). Runoff was collected from 2-m^2 plots subject to 70 mm hr^{-1} rainfall (to create 30 minutes of runoff) across the watershed and related to plot Mehlich-3 STP and soil P saturation of 0 to 5 cm samples collected after rainfall, as well as P Index ratings determined by the Pennsylvania P Index (Sharpley et al., 2001). Of the three methods, the P Index rating best represented the loss of P in runoff over the various soil, management, hydrology, and topographic conditions across the watershed (Figure 3).

More importantly, there were sites with "low" STP and soil P saturation, which had high losses of P due to a combination of factors that include high runoff volumes and / or application of fertilizer or manure. It should be noted that these "low" P sites are above the agronomic response range (i.e., >50 mg P kg^{-1} as Mehlich-3 soil P). On the other hand, there were sites with low P loss but had high STP or soil P saturation values (Figure 3). A similar lack of a strong relationship between STP and runoff P loss was demonstrated by Butler et al. (2010) for runoff from several fields in Georgia, which had received varying amounts and forms of P (Figure 4).

In summary, we recognize that the relationship between STP or P saturation and runoff dissolved P concentration is well established (e.g., Vadas et al., 2005). However, this relationship can vary as a function of soil type and land cover, and P loss is influenced by many site factors such as applied P (type, rate, method, and timing) runoff, erosion, landscape position, etc. Further, use of soil P saturation in place of STP is only suitable for noncalcareous soils where Fe and Al dominate soil P reactions. In light of these factors, it is inappropriate to use STP or soil P saturation alone to estimate P loss in runoff from a given site.

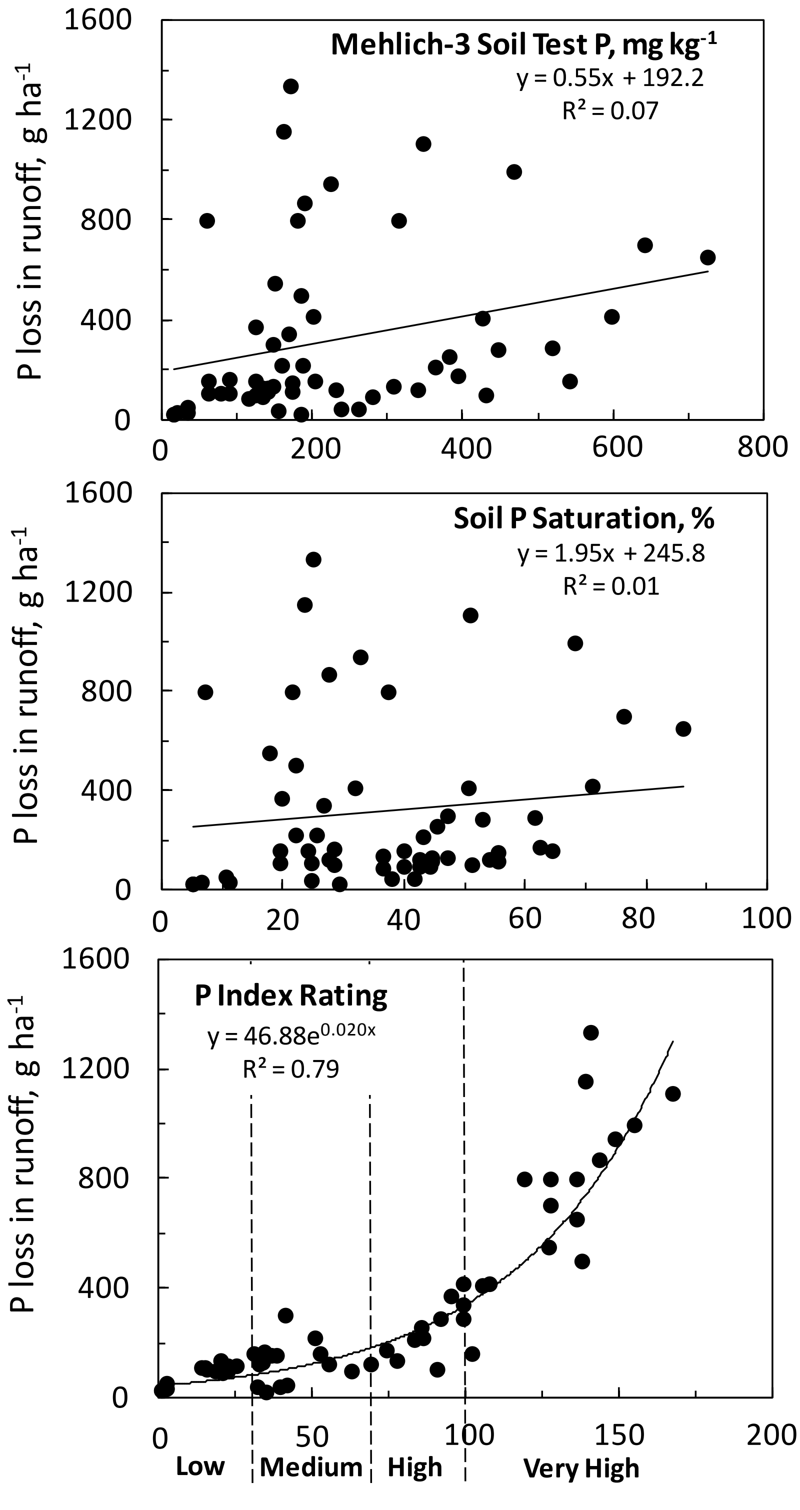

Figure 3. Relationship between the loss of total P in runoff and Mehlich-3 soil test P, soil P saturation, and the Pennsylvania P Index ratings for the plots in the FD-36 watershed, PA (adapted from Sharpley et al., 2001).

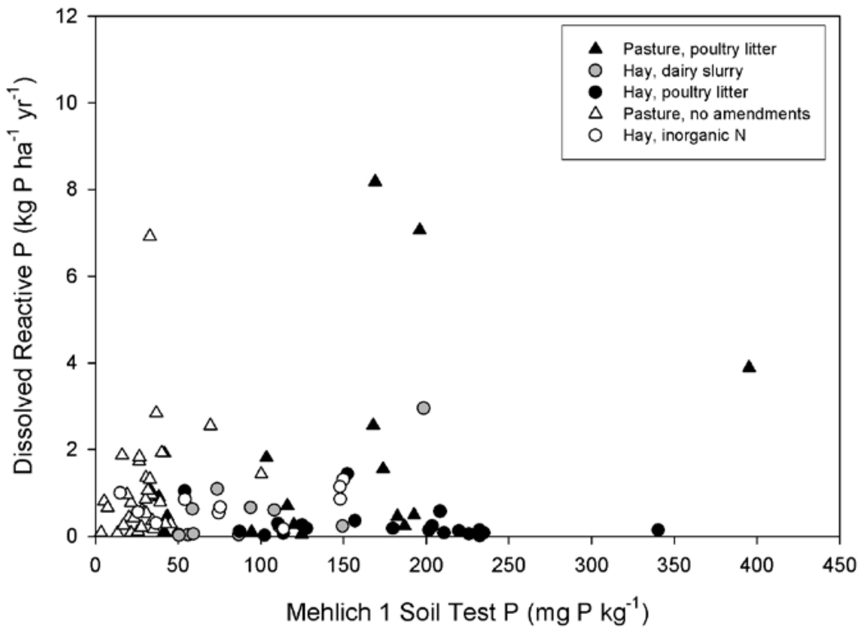

Figure 4. Relationship between Mehlich-1 soil test P and the loss of total P in runoff for several fields in Georgia (adapted from Butler et al., 2010).

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Re: Harmful Algae in the Buffalo National River

Directors and Superintendent,

Thank you for your agencies' efforts to protect public health and the natural resources of the Buffalo National River (BNR). As the crown jewel of Arkansas, with a thriving toursit economy, and dozens of communities throughout the watershed, protecting our first national river and those that visit, requires a collaborative approach. Although partnerships and collaborative projects are often more difficult to execute and coordinate, White River Waterkeeper commends the effort to pool resources and expertise to best address water quality and human health concerns in the BNR. Continued partnerships, and inclusion of diverse stakeholders, will ensure everything that can be done, is being done.

Following continued reports of nuisance algae on the Buffalo River, and confirmed presence of harmful algae (cyanobacteria), *Microseira wollei*, from locations between Spring Creek and Dillard's Ferry, and information that a joint project between Arkansas Department of Environmental Quality (ADEQ), Arkansas Department of Health (ADH), and Buffalo National River (BNR) is underway, I submit the following joint letter to your agencies and other relevant officials.

Toxins of Concern

White River Waterkeeper is aware of ongoing efforts to monitor the presence and concentrations of two common cyanotoxins, microcystin and cylindrospermopsin. Recent studies have cited cylindrospermopsin as a known toxin produced by *M. wollei*[1][2], and numerous others have noted the production of saxitoxins - potent, acutely lethal neurotoxins[3][4][5][6][7].

Human Health Threat

While there is still much the scientific community does not know when it comes to harmful algal blooms (HABs), a considerable amount of research and readily available literature provide insight into the public health threats associated with cyanotoxins. Although your agency and personnel are likely well informed about HABs and the threats posed to human health from exposure to cyanotoxins, it is worthwhile to note a few key facts regarding saxitoxins:

> "*The oral LD50 for humans is 5.7 µg/kg, therefore approximately 0.5 mg of saxitoxin is lethal if ingested and the lethal dose by injection is about ten times lower. The human inhalation toxicity of aerosolized saxitoxin is estimated to be 5 mg/min/m3. Saxitoxin can enter the body via open wounds and a lethal dose of 0.05 mg/person by this route has been suggested. Saxitoxin is 1,000 times more toxic than the potent nerve gas sarin.*"[8]

Saxitoxins can also be accumulated in freshwater fish.[9] No antidote exists for saxitoxin toxicity, making supportive care the only available means of treatment.

Algae and Cyanotoxin Monitoring

At present, it is acknowledged that recent monitoring efforts by ADEQ, ADH, and BNR have been conducted to evaluate the presence and concentrations of microcystin and

---

[1] Seifert, M., McGregor, G., Eaglesham, G., Wickramasinghe, W., & Shaw, G. (2007). First evidence for the production of cylindrospermopsin and deoxy-cylindrospermopsin by the freshwater benthic cyanobacterium, Lyngbya wollei (Farlow ex Gomont) Speziale and Dyck. *Harmful Algae*, 6(1), 73-80.

[2] McGregor, G. B., & Sendall, B. C. (2015). Phylogeny and toxicology of *Lyngbya wollei* (Cyanobacteria, Oscillatoriales) from north-eastern Australia, with a description of *Microseira* gen. nov. *Journal of Phycology*, 51(1), 109-119.

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[8] Patockaa, J., & Stredab, L. (2002). Brief review of natural nonprotein neurotoxins. ASA Newsletter, 89, 16-24.

[9] Galvao, J. A., Oetterer, M., do Carmo Bittencourt-Oliveira, M., Gouvêa-Barros, S., Hiller, S., Erler, K., ... & Kujbida, P. (2009). Saxitoxins accumulation by freshwater tilapia (*Oreochromis niloticus*) for human consumption. *Toxicon*, 54(6), 891-894.

cylindrospermopsin, confined mostly (noting sampling location downstream of Spring Creek) to public access locations on the mid to lower Buffalo. However, from my own visual observations and monitoring, I have concerns that the locations and analytes are not as robust as they should be.

Despite the need to quantify saxitoxin concentrations, my personal observations and monitoring efforts indicate that *M. wollei* are presently localized considerable distances from public access points along the river. With many people confined to floating lower sections of river this time of year, the chance of encountering these algae and their associated toxins are high for many people. My own observations noted presence of *M. wollei* confined to the margins along shallow banks near gravel bars, mixed with mats of green algae.

While it may seem reasonable to inform the public that contact with algae are avoidable, it also must be acknowledged that it's nearly impossible to get out of one's canoe or kayak without wading through algae if one desires to get out of their boat to swim, or even just take a break on a gravel bar along the river. However, as mentioned above, direct contact with water is not the only mode of assimilating these toxins, a fact that the public needs to be aware of.

Advisories

In the interim of finalizing a comprehensive response plan, given the serious threat these blooms could pose to public health, it is prudent that the public is made aware of the potential health effects and how best to safeguard themselves. It is also necessary that this is done in a timely fashion. Being open and transparent with the public should be considered the **bare minimum** action that should be taken. Despite knowing how best to proceed at present, **it must be acknowledged that a significant threat exists**.

If thresholds for advisories and river closures are still being discussed, that does not negate the agency's responsibility to provide the public with useful and comprehensive educational information in the interim. However, since draft response plans and current analytical sampling omits monitoring and actions to be taken with regard to presence and concentration of saxitoxins, there should be concerns about whether or not the action plan is comprehensive enough to address known, and suspected, concerns in the Buffalo National River.

Future Steps

As BNR, ADH, and ADEQ move forward with developing monitoring and response plans, White River Waterkeeper would like to be advised of and involved in the process. While I understand that staff resources can be limiting, and I applaud the effort to further investigate HABs on the Buffalo River; however, I also believe more should ***and can*** be done.

Being a Waterkeeper means being the eyes, ears, and voice of the waterbodies for which we speak. This includes monitoring and patrolling of our watersheds. As BNR's press release last Friday stated *"concerned citizens, communities, and agencies are working together to better understand the sources of the problems, determine the potential risks, and evaluate the best practices for eliminating or managing the threats,"* White River Waterkeeper would like to, once again, request to be included in this multifaceted partnership as plans and developments move forward. This should be an easy step, as I have personally partnered with many of your field staff and personnel on projects over the past ten years.

Now is the time for pooling resources to adequately protect the public's health.

Illness Reporting

Having had personal conversations with individuals reporting symptoms commonly associated with exposure to cyanotoxins after visiting the Buffalo River, I am aware that ADH and the National Park Service (NPS) are engaged in documenting and facilitating examinations and diagnostic testing. However, if a reporting system has been made available to the public, it is not readily apparent to most.

To better document illness reports and identify commonalities in symptoms and exposure events, White River Waterkeeper has developed a Recreational Water Quality Illness Survey[10]. These results will be summarized and shared with your agencies, omitting any personal or identifying information of participants. However, **we respectfully request an immediate response regarding contact information to disseminate to participants, so they can report to you directly as well.**

Diagnostic Testing

To date, there is probable cause to attribute multiple illness reports to exposure to cyanotoxins on the Buffalo River. However, personal communications with those reporting illnesses have not indicated that specific diagnostic testing has been conducted at the behest of ADH or NPS to confirm the presence of cyanotoxins in patients.

Although I am aware this is a field of evolving technology, there are studies reporting convincing evidence for successfully isolating and quantifying cyanotoxins, particularly saxitoxin, from human blood and urine samples[11][12]. If ADH and NPS are not already moving forward with requesting such tests, please respond as to what the current limitations and hesitations are.

I look forward to individual responses from your agencies, as all are playing separate and integral roles.

Respectfully,

Jessie J. Green

Jessie J. Green
Executive Director & Waterkeeper

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[10] https://www.whiteriverwaterkeeper.org/survey

[11] Wharton, R. E., Feyereisen, M. C., Gonzalez, A. L., Abbott, N. L., Hamelin, E. I., & Johnson, R. C. (2017). Quantification of saxitoxin in human blood by ELISA. *Toxicon*, 133, 110-115.

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13 November 2017

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RE: 2018 Assessment Methodology

Ms. Barnett,

Thank you for the opportunity to comment on the Draft 2018 Assessment Methodology. This voluntary exercise provides the public with more ways to contribute meaningful suggestions and input to better protect our state's waters. Responding to comments, questions, and concerns will offer insight into ADEQ's approach and will help better inform outside sources of how they can further contribute to the important tasks carried out by the Planning Branch. Taking the time to provide transparency in this process is viewed in high regard. The efforts of the Planning staff on this matter are greatly appreciated. I hope you will view the length and scope of my comments as an expression of the value I hold for this chance to provide input on this integral document.

Comments below are broken out by section and referenced to specific language where applicable.

3.4 Tiered Approach to Qualifying Data –

- *Data received by ADEQ may be used in assessments and for attainment decisions, may be used for screening purposes only, or may not be used at all depending on the level of data quality.*

  Questions and Comments
  - Please describe "screening purposes" and how ADEQ utilizes that data and information. This may help inform outside sources of whether it is worthwhile to submit data to ADEQ that do not meet considerations outlined in the Assessment Methodology.
  - Does ADEQ maintain a Record of Decision for outside datasets that do not meet data quality considerations? If not, this would be valuable information to the public and would provide detailed, meaningful feedback to the entities interested in having their data utilized by ADEQ.
  - A review of ADEQ's 2016 303(d) and 305(b) Integrated Report does not provide any information from datasets utilized for screening purposes. If not incorporated in the 305(b) report, then how does ADEQ make use of these data?

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3.7 Statistical Confidence –

- *Table 3: Maximum number of sample exceedances allowed in order to assess as attaining (de-list) water quality standards, using binomial distribution, with 90% confidence that the true exceedance percentage in the waterbody is greater than or equal to 10%, 20%, 2%.*

  Questions and Comments
    - Small typo. Revise 2% to 25%.

3.8 Internal Data Assessment Method –

- WQAR automatically calculates attainment of each standard using station data pulled directly from ADEQs internal Laboratory Information Management System (LIMS).

  Questions and Comments
    - Does WQAR automatically omit duplicate or data that has been flagged by the lab for QA/QC purposes?

3.11 Final Attainment Decision Process

- *Final attainment decisions that differ from initial attainment decisions reached using WQAR (for internal data) or Excel (or similar software for external data, biological data, WET data, etc.) will be justified within the 305(b) report as well as submitted with the 303(d) list for public notice and any supporting documentation will be provided.*

  Questions and Comments
    - What is the methodology for assessing WET data for 303(d)/305(b) determinations?
    - EPA regulations require "reports from dilution calculations and predictive modeling" be included in the data and information that a state considers in its assessment process for section 303(d) listing (Category 5) purposes (40 CFR 130.7(b)(5)(ii))[1]. It is not clear how ADEQ utilizes these data, as it is not addressed in the Assessment Methodology. Please provide further detail on how ADEQ adheres to this requirement.

4.1 Antidegradation –

  Questions and Comments
    - As noted in Section 4.2, the primary purpose of the 303(d) list of impaired waterbodies is to identify those waters that are not currently meeting water quality standards. Water quality standards include an antidegradation component to *maintain* high quality and outstanding resource waters. Besides specific criteria for bacteria related to Tier III waters, it is not clear how ADEQ evaluates whether waterbodies are *maintaining* the level of water quality for which their designation was granted. The Assessment Methodology outlines a methodology for protecting

[1] 2006 Integrated Reporting Guidance, p. 38. https://www.epa.gov/sites/production/files/2015-10/documents/2006irg-report.pdf

and evaluating Tier I waters. If ADEQ is upholding their Antidegradation Policy when assessing waters for the 303(d) list, it is unclear how ADEQ makes those determinations. Please elaborate and provide information on this process. If ADEQ is using alternative methods for assessing Tier II and Tier III waters, it will benefit the public to have a better understanding of this so outside sources of data can better contribute to ADEQ's assessment process.

4.2 Designated Uses –

- *The support/non-support status of designated uses is most often determined utilizing water quality criteria or other water quality indicators.*

  Questions and Comments

  - If 304(a) recommended criteria were demonstrated to be more protective of designated uses, would ADEQ utilize those over criteria adopted into Regulation No. 2? If the purpose is to assess designated use support, why would ADEQ *not* utilize 304(a) criteria supported by ample documentation?

5.0 Biological Integrity –

Questions and Comments

- This section detailed how biological data would be used to evaluate the biological integrity criteria, and therefore inform the aquatic life designated use assessments. However, no mention is given to how the biological integrity criteria will be used to evaluate extraordinary research waters (ERW) and ecologically sensitive waterbodies (ESW) designated uses. Please provide an explanation for how ADEQ assesses aquatic life designated uses on a tiered approach, especially for ERWs and ESWs, that were designated at least in part, or entirely, for the present aquatic biota.
- Since the only biological data utilized in assessing biological integrity are fish and macroinvertebrate data, how does this protect waters that were designated for the suitable habitat of other species, such as mussels and Ozark hellbenders?
- How are habitat data incorporated into this assessment?

Assessment Methodology for Biological Integrity

- *"Biological data must have been collected over two seasons."*

  Questions and Comments

  - Please define "two seasons" in this context.
  - The purpose of utilizing biological data is to get a more accurate representation of water quality impacts. Discreet monthly water quality samples do not provide a comprehensive picture of overall water quality conditions.
  - Monitoring higher trophic levels (i.e., fish communities) integrates changes happening at lower trophic levels (e.g., primary producers and macroinvertebrates), and can represent stream conditions over long temporal

and spatial scales due to longer life spans, ontological shifts, and increased mobility[2][3]. Biological communities can be affected by a combination of chemical and physical parameters. Relying on the non-attainment of a specific chemical or physical criterion in association with biological data negates the purpose of utilizing biological data.

- Water quality data is not a surrogate for comprehensive biotic assessments and ignores changes in watershed hydrology, habitat modifications, and alteration of energy sources[4]. Paired water quality data is not necessary to validate the accuracy of a scientifically defensible biological monitoring assessment.

Macroinvertebrate Assemblage Analysis

- *Modified metrics set forth in Rapid Bioassessment Protocols for Use in Stream and Rivers (Plafkin et al. 1989) are used in analysis of macroinvertebrate community samples.*

  Questions and Comments
  - Why is Plafkin et al. 1989 utilized instead of Shackleford 1988[5], that was developed specifically for use in Arkansas?
- *See Arkansas's Water Quality and Compliance Monitoring Quality Assurance Project Plan (ADEQ 2016) at the ADEQ website: http://adeq.state.ar.us for more information.*

  Questions and Comments
  - Please update the assessment methodology with the specific web address to this document: https://www.adeq.state.ar.us/water/planning/surface/pdfs/2016-qapp.pdf. The QAPP doesn't actually provide "more information," however.
- *Macroinvertebrate community analysis is as follows. Using raw data, calculate all seven Metric Values for each study site and reference site.*

  Questions and Comments
  - Since the majority of ADEQ's studies are not associated with upstream/downstream sampling designs, what does ADEQ use as a reference site[6]?

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[2] Karr, J. R. 1981. Assessment of Biotic Integrity Using Fish Communities. Fisheries 6:21-27.
[3] Smith, M.P., Schiff, R., Olivero, A. and MacBroom, J.G., 2008. THE ACTIVE RIVER AREA: A Conservation Framework for Protecting Rivers and Streams. The Nature Conservancy, Boston, MA. https://www.floods.org/PDF/ASFPM_TNC_Active_River_%20Area.pdf
[4] Karr, J. R. 1981. Assessment of Biotic Integrity Using Fish Communities. Fisheries 6:21-27.
[5] https://www.adeq.state.ar.us/water/planning/pdfs/publications/WQ88-00-0.pdf
[6] A recent FOIA request dated 22 October 2017 included a request for data and information regarding how ADEQ defines "reference" condition. Response materials did not address this topic. This suggests that ADEQ does not have a predefined method for determining reference condition.

- How does ADEQ determine reference condition and how are outside data evaluated to determine whether chosen reference sites meet ADEQ's definition of "reference"?
- "A biological condition score is calculated for each sample and sample site" – This does not address how multiple samples are utilized for a single AU. In the past, ADEQ has collected two macroinvertebrate samples, per site, for two seasons. How are those data utilized? ADEQ is now collecting three discrete macro samples per site, once per year. How are those data going to be used for assessment purposes?
- If ADEQ is utilizing "reference" values for each metric based on the 1987 Ecoregion Reference study[7], please provide the reference scores for each metric.

Other Macroinvertebrate Community Analysis Questions and Comments

- The 1989 Rapid bioassessment protocols for use in streams and rivers is a difficult publication to find online. Could ADEQ please make a copy of this publication available on its website and link the web address in the full citation? Or, even better, also include the actual formulas used to calculate each metric.
- *Hilsenhoff Biotic Index* – What tolerance values does ADEQ apply to their macroinvertebrates? Are there any families of macroinvertebrates that were not assigned tolerance values by Plafkin or Hilsenhoff? Has there been any testing of the appropriateness of these tolerance values in Arkansas? Please make these data and information available.
- *Ratio of EPT to Chironomid Abundances* – What is the advantage of using this metric over the Indicator Assemblage Index, that was referenced by Plafkin[8], and developed by Bruce Shackleford for use in Arkansas?
- *% Contribution of Dominant Taxa* – How are dominant taxa defined? By Order, Family, or Genus? What number of dominant taxa are included in this calculation? The recommended metric for biocriteria in Arkansas compares dominants in common[9].
- *EPT Index* – As Plafkin explains, "headwater streams which are naturally unproductive may experience an increase in taxa (including EPT taxa) in response to organic enrichment. In this situation, a "missing genera" approach may be more valuable." Again, Shackleford (1988) is cited. Are there instances, especially when evaluating attainment of nutrients, when ADEQ utilizes the "missing genera" metric instead?
- *Community Loss Index* – What is the formula for this index?

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[7] Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions, Volume 1: Data Compilation. ADEQ Water Division, 1987. https://www.adeq.state.ar.us/water/planning/pdfs/publications/WQ87-06-1.pdf

[8] See description of Ratio of EPT and Chironomidae Abundance on p. 6-24 of Plafkin 1989.

[9] See Biometric (1) on page 17 of https://www.adeq.state.ar.us/water/planning/pdfs/publications/WQ88-00-0.pdf

- Please provide a comprehensive list of aquatic macroinvertebrates with a table indicating tolerance values that will be assigned for calculating HBI scores.

Fish Assemblage Analysis

Questions and Comments

- Please update the assessment methodology with the specific web address to this document: https://www.adeq.state.ar.us/water/planning/surface/pdfs/2016-qapp.pdf.
- Please incorporate a comprehensive list of fish taxa found in Arkansas and denote which species will be included in the "Sensitive Species" metric[10]. The Fish Community Structure Index[11] denotes criteria that apply to streams and rivers >10 mi^2. It is likely these metrics, and expected values are not applicable in non-wadeable streams. Many species considered more tolerant in smaller streams can be denoted as "sensitive species" in large rivers[12]. Examples include: *Campostoma pullum, Luxilus chrysocephalus, Notropis maculatus, Minytrema melanops, Moxostoma poecilurum, Noturus phaeus, Esox niger, Etheostoma histrio, Percina maculata.*

Fish Assemblage Analysis

- *The fisheries designated use may be assessed as support, despite an initial evaluation of non-support, if it is demonstrated that the non-support assessment is due to unrepresentative biological community data and not an environmental factor (low dissolved oxygen, low pH, toxicity); based on acceptable variances in ecoregion community structures. Under certain conditions, biological community data can be skewed due to an unrepresentative sample, which includes but is not limited to: Collection of irruptive species (e.g., large percentage of young-of-year in an isolated area that is not representative of the entire reach), which could trigger an inaccurate 'non-support' determination.*

  Questions and Comments

  - ADEQ does not have an assessment methodology to evaluate physical habitat or hydrological alteration. Assuming biological data are erroneous based on the limited scope of water quality parameters assessed ignores the purpose of biological data being superior to assessments based solely on measured concentrations of specific chemical and physical parameters.
  - Young-of-year (YOY) should be denoted separately when enumerating fishes. YOY should not be included in *any* of the metric evaluations besides calculating species richness. This should not be an issue.

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[10] The "FISHLIST.xls" document that was received from ADEQ in response to 22 October 2017 FOIA request for information on species considered "sensitive" was not a comprehensive list of species found in Arkansas.

[11] See Appendix 4: Fish Community Biocriteria in the 2016 QAPP https://www.adeq.state.ar.us/water/planning/surface/pdfs/2016-qapp.pdf

[12] Shields, F.D., S.S. Knight, and C.M. Cooper. 1995. Use of the Index of Biotic Integrity to Assess Physical Habitat Degradation in Warmwater Streams. Hydrobiologia 312:191-208.

6.1 Temperature –

- *Trout waters will be assessed using discrete data only.*
  Questions and Comments
  - Please explain this rationale.
- *Short-term data sets, such as 72-96 hour diel studies will be used for screening purposes only.*
  Questions and Comments
  - Please explain this rationale.
  - Temperature standards were developed from short-term continuous data monitors[13][14]. This should provide substantial reason to list waters as impaired based on short-term data sets. A limited number of deployments should not warrant a determination that waters are attaining temperature standards, however.
- *Meter must be deployed and taking readings for no less than two-thirds of the critical season at no less than hourly readings.*
  Questions and Comments
  - Since critical season is defined by temperature, then how is this possible to determine whether two-thirds of the critical season was captured?
  - A more appropriate requirement may be to require long-term continuous data to be collected for X number of days within the summer months.

6.2 Turbidity –

- *Stream, river, reservoir, and lake AUs will be assessed as non-support when, using the twenty-five percent exceedance rate within Table 2, greater than or equal to the minimum number of samples for the entire qualifying data set (sample set not to be fewer than 24 data points) exceed the applicable storm flows values listed in APC&EC Reg. 2.503.*
  Questions and Comments
  - A 20% exceedance rate is in effect for storm water values. EPA has not approved the change to 25%[15].
- *Base flows season is defined, in Reg. 2, as June to October.*
  Questions and Comments
  - Please specify what date range will be entered into WQAR. 1 June to 30 September?

6.3 pH –

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[13] Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions, Volume 1: Data Compilation. ADEQ Water Division, 1987. https://www.adeq.state.ar.us/water/planning/pdfs/publications/WQ87-06-1.pdf

[14] Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions, Volume 2: Data Analysis. ADEQ Water Division, 1987 https://www.adeq.state.ar.us/water/planning/pdfs/publications/WQ87-06-2.pdf

[15] See pages 21-22 of 31 October 2016 letter from EPA including Technical Support Document for EPA Region 6 Review of Regulation No. 2. https://www.adeq.state.ar.us/water/planning/reg2/pdfs/record-of-decision/20161028-final-ar-tsd.pdf

- *AUs will not be listed as "non-attain" if the non-attainment decision is a result of data representing natural conditions (i.e., anthropogenic activities cannot be identified by ADEQ as the source).*

  Questions and Comments
  - Since ADEQ does not collect flow data and does not monitor precipitation, please provide a rationale for how ADEQ can rule out low pH due to acid rain.
  - How will ADEQ make determinations that exceedances are due to "natural causes" and not legacy land use effects?

6.4 Dissolved Oxygen –

- *Critical season: Water temperatures exceed 22 degrees Celsius.*

  Questions and Comments
  - Based on 1987 Ecoregion Reference studies, the basis for the ecoregion-specific temperature and dissolved oxygen criteria, it may not be appropriate to consider the critical season definition based literally on temperature being above 22°C for *all* of the Critical Season DO assessments. Temperatures from Ozark Highland reference streams were far lower than other ecoregions and did not exceed 22°C for a considerable portion of the summer-time studies[16]. Development of critical season DO criteria were not contingent on temperatures absolutely being above 22°C.
- *Continuous data must cover consecutive months for at least two-thirds of critical season with at least hourly readings.*

  Questions and Comments
  - It would be more appropriate to re-word this to state "Continuous data must cover consecutive months for at least two-thirds of the period between mid-May to mid-September with at least hourly readings.

6.6 Bacteria –

- *If the assessment of non-support is based on only one (1) season of data (eight (8) discrete samples within one primary contact season, or within one secondary contact season), the AU will be placed in Category 4b and more data will be collected for re-assessment in a future assessment cycle.*

  Questions and Comments
  - Alternative pollution control requirements must be identified to list a waterbody in Category 4b.
  - Listing in Category 4b requires states to provide a rationale that includes a *description of, and schedule for, monitoring milestones for tracking and reporting progress to EPA on the implementation of the pollution controls and a commitment to revise the implementation strategy and pollution controls if*

[16] Figure T-3, p. 66, Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions, Volume 2: Data Analysis. ADEQ Water Division, 1987 https://www.adeq.state.ar.us/water/planning/pdfs/publications/WQ87-06-2.pdf

progress towards meeting water quality standards is not being shown[17]. Will this information be made available in the draft 303(d) list that goes out for public comment?
  - ADEQ does **not** have a robust bacteria monitoring program (Table 1). There are very few waterbodies that will ever meet the requirements to determine if a TMDL is necessary.
  - Only 11 sites sampled by ADEQ between 2012-2017 have two seasons of bacteria data within a period of record[18]. Ten of those sites are part of a two-year bacteria monitoring study of the Mill Creek watershed, a tributary to the Buffalo National River. ADEQ does not routinely collect two seasons of bacteria data.
  - Pollution control *requirements* must be identified when placing a waterbody in 4b; therefore, ADEQ will have to adequately identify the likely sources of contamination. Most sources listed in past 303(d) lists are denoted as "unknown." This does not foster confidence in ADEQ's ability to implement additional requirements to the appropriate source.
  - What pollution control requirements will be implemented if point source dischargers are the expected source?
  - What *requirements* will be implemented to address nonpoint sources?

- Table 1. ADEQ water quality monitoring data were assessed to determine the number of monitoring stations with sufficient data to assess *E. coli* data by contact season[19]. Data from the 2017 primary contact season is outside the period of record for the 2018 303(d) list. The 2017-2018 secondary contact season is not over.

	Number of sites meeting data quality requirements for assessment of:	
Year	Primary Contact Season[20]	Secondary Contact Season[21]
2012	0	0
2013	0	0
2014	0	0
2015	0	0
2016	48for th	0
2017	18	n/a

6.9 Nutrients –

- Reg. 2.509 states "*Because nutrient water column concentrations do not always correlate directly with stream impairments, impairments will be assessed by a combination of factors such as water clarity, periphyton or phytoplankton production, dissolved oxygen*

[17] 2006 Integrated Reporting Guidance pp. 54-56. https://www.epa.gov/sites/production/files/2015-10/documents/2006irg-report.pdf
[18] Note: Data are from 2016 and 2017 primary contact seasons. The 2017 primary contact season will not be assessed for the 2018 303(d) list. Period of record from 1 April 2012 through 31 March 2017.
[19] Water Quality Monitoring Data Access database was downloaded 5 November 2017 from https://www.adeq.state.ar.us/techsvs/env_multi_lab/water_quality_station.aspx.
[20] May 1 to September 30, Reg. 2.507
[21] October 1 to April 30, Reg. 2.507

values, dissolved oxygen saturation, diurnal dissolved oxygen fluctuations, pH values, aquatic-life community structure and possibly others."

- *The mean total phosphorus or total nitrogen concentration of the monitoring segment is greater than the 75th percentile of the total phosphorus or total nitrogen data from wadeable stream and river AUs within an ecoregion.*

  Questions and Comments
  - Reg. 2.509 acknowledges that "nutrient water column concentrations do not always correlate with stream impairment." Requiring an arbitrary screening value of requiring nutrient water column concentrations must exceed the 75th percentile to be assessed for non-attainment of designated uses ignores that nutrients are often bound and transported in sediments which are deposited on bottom substrates. Including this screening criteria seems to target point sources and ignores nonpoint source runoff. It would be more protective, and therefore more appropriate, to disregard this screening limit when assessing the effects of nutrient enrichment.
  - Will the 75th percentile be calculated from the average concentrations of each site for the period of record?
- *Critical season is defined, in Reg. 2, as that time of year when water temperatures naturally exceed 22 degrees Celsius for the given AU.*

  Questions and Comments
  - Further define how critical season is determined. If the water temperature exceeds 22°C during any portion of the day, would all samples for that day be considered as collected during the critical season?
  - Dissolved oxygen is expected to be lowest during early morning hours before sunrise (before photosynthesis resumes). Therefore, streams would likely gradually be cooling throughout this period of sun cessation. Extreme daytime temperatures would likely exacerbate the stress caused to aquatic life by evening oxygen depletion.
- *Do both of the two 72-hour data sets, or the long-term continuous data set, have and 1 of the 2 water quality translators exceeded?*

  Questions and Comments
  - Why were the three dissolved oxygen translators previously used[22] replaced with "Dissolved oxygen exceeds water quality standard greater than 10% of time". A waterbody now has to be impaired for DO to be impaired for nutrients? Why not add that to the list and determine exceedance at 2 of 5 listed? Please explain how the revised methodology is more protective of designated uses and why the current methodology is more appropriate.

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[22] See Table XIV. Nutrient Assessment Flowchart for Wadeable Streams and Rivers in 2016 Assessment Methodology https://www.adeq.state.ar.us/water/planning/integrated/assessment/pdfs/2016-assessment-methodology-draft-04apr16-305b.pdf

- *Macroinvertebrate communities must be collected during the same year as fish collections, during either fall or spring base flow conditions. Fall macroinvertebrate collections are preferred.*

  Questions and Comments

  - According to ADEQ's publication on Biocriteria Development[23], Plafkin et al. 1987 is cited as justification for the statement that in Arkansas, "optimum sampling periods that correspond to stable flows are generally from July through September in the summer and from February through March in the late summer." What is the basis for ADEQ limiting data from summer collections? Please explain why Fall collections are preferred.

6.10 Site Specific Mineral Quality –

- *Stream, river, reservoir, and lake AUs with site specific mineral criteria will be assessed as non-support when, using the twenty-five percent exceedance rate within Table 2, greater than or equal to the minimum number of samples for the entire qualifying data set exceed the applicable site specific mineral criteria listed in APC&EC Reg. 2.511(A).*

  Questions and Comments

  - Previous water quality standards (WQS) set the allowable exceedance limits of these criteria at 10%[24]. ADEQ removed the 10% exceedance language from the current version of Arkansas WQS. EPA disapproved this. Therefore 10% remains in effect for Clean Water Act purposes, such as developing the 303(d) list[25]. Please revise frequency component of the methodology or explain why ADEQ is choosing to ignore EPA's disapproval.

6.11 Non-Site Specific Mineral Quality; and Domestic, Agricultural, and Industrial Water Supply Uses –

- *This section establishes the protocol for determining attainment of non-site specific mineral quality criteria and domestic water supply designated uses within Arkansas's surface waters, per APC&EC Reg. 2.511(C)*

  Questions and Comments

  - This does not address non-site specific mineral quality at all for purposes of determining aquatic life designated uses. This only addresses the assessment of domestic, agricultural, and industrial water supply uses.
  - For all other waters without site-specific standards, there is no attempt to protect aquatic life designated uses. How does this stand up to Arkansas's antidegradation policy? How is this protective of Ecologically Sensitive Waterbody designated

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[23] See Seasonality p. 5-6 of Rapid Bioassessments of Lotic Macroinvertebrate Communities: Biocriteria Development (Shackleford 1988). https://www.adeq.state.ar.us/water/planning/pdfs/publications/WQ88-00-0.pdf

[24] See Arkansas Pollution Control and Ecology Commission Regulation 2.511 in the 2004 version of Reg. 2. https://www.adeq.state.ar.us/downloads/regs/oldregs/reg02_final_040517.pdf

[25] See pp. 10-11 of 2007 EPA Record of Decision Arkansas Triennial ("Phase II") Revisions to Regulation No. 2 https://www.adeq.state.ar.us/water/planning/reg2/pdfs/record-of-decision/2007-epa-action-ltr-rod-ar-tr-phase-2.pdf

uses, as well as other Tier III designated uses? How is this protective of Tier II waters?
- ADEQ tried to add language to the WQS stating Reg. 2.511 (B) Ecoregion Reference values would not be used in developing the 303(d) list. EPA did not approve; therefore, where site-specific standards do not apply, aquatic life designated uses should be assessed based on these values[26].
- While it is acknowledged that ADEQ is working with EPA to develop a strategy for minerals, please provide an explanation of why it would not be more protective and appropriate to utilize 2.511 (B) criteria and if a non-attainment decision is derived from these, then to place in Category 5 with a Low priority listing.

6.12 Ammonia –

- *Assessments can be made with discrete samples collected when early life stage fishes are present. The actual months will vary for specific waterbodies.*

  <u>Questions and Comments</u>
  - The 2016 Assessment Methodology stated, "The Chronic Criterion for fish early life stages present apply during the critical season (April 1 thru October 31)." Removing the date range that will be applied as a default will require ADEQ to provide additional information in the 305(b) Report detailing the specific date range that was used for every waterbody. If a default date range is utilized in WQAR, please provide that information.
  - What will be the critical season utilized for trout waters?
  - Are there any date ranges that vary for other waters? Please provide this information so that comments on the 2018 303(d) list can be composed of meaningful data and information if other sources indicate more appropriate dates should be applied.
  - What will be ADEQ's approach for determining the appropriate critical season on a waterbody specific basis?
  - What early life stages will be protected when assessing lakes and reservoirs? What date range will be used?

Best regards,

Jessie J. Green

Jessie J. Green
Executive Director & Waterkeeper

[26] See pp. 18-20 of EPA Record of Decision for Arkansas 2013 Triennial Revisions to Regulation No. 2 https://www.adeq.state.ar.us/water/planning/reg2/pdfs/record-of-decision/20161028-final-ar-tsd.pdf

ADEQ
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Memorandum

TO: **Caleb J. Osborne, Associate Director, OWQ**

THROUGH: **Sarah Clem, Branch Manager, OWQ**

FROM: **Nathan Wentz, Ecologist Coordinator, OWQ**

DATE: **October 18, 2017**

SUBJECT: **2017 Buffalo River Nuisance Algae Report**

2017 Buffalo River Nuisance Algae Report

Notification of Bloom

The ADEQ Nuisance Algae Complaint tool received two notifications of nuisance algae blooms on the Buffalo River near Sand Hole which were observed on August 4, 2017 (Figure 1). Complaints were received by Ms. Jessie Green and Mrs. Carol Bitting on August 6, 2017 and August 7, 2017, respectively. ADEQ Office of Water Quality Planning Branch investigated the reported occurrence of the lower event approximately 1 mile below Tomahawk Creek confluence. Planning Branch representatives were Mandy Bates and Tate Wentz. National Park Service staff Shawn Hodges and Ashley Rodman assisted Planning in accessing and measuring extent of the events. Three separate locations were reported to ADEQ (Figure 1) and spanned approximately 4.5 miles, starting downstream of the confluence of Brush Creek and terminating 1 mile downstream of Tomahawk Creek confluence. Further discussion with complainants indicated that the lower event near Rocky Hollow was significantly larger than the other two.

Investigation

Investigation began approximately 2.5 miles downstream of the beginning of the lowest reported location near the Tomahawk Creek confluence. The river was accessed via Sanders Field Road at a large pool with minimal visible flow. One of three potential algal taxa (herein referred to as taxon A) appeared to be dominant in this pool, and total algal coverage was estimated to be >50% of the bottom substrate. Increasing areal coverage and density of taxa B and C were observed as the team progressed upstream to the coordinates provided by one of the complainants. However, habitats seemingly suitable for colonization were observed with no or minimal algal coverage.

Because of sporadic occurrence and coverage, it was determined in field that an individual bloom event would be based upon distance from upstream or downstream events/blooms and areal coverage. For the purpose of this investigation, an individual bloom would be considered distinct from others when a minimum of 100 linear meters separated a previous location and covered greater than 50% of wetted channel. *In-situ* dissolved oxygen, dissolved oxygen saturation, temperature, specific conductance, and pH were collected at the upper, middle, and lower portions of each bloom event. Parameters were collected from a YSI ProDSS Multi-Parameter handheld meter. Visual estimates of substrate type, depth, and measured wetted width were also recorded.

Bloom 1 began approximately 1 mile downstream of Tomahawk Creek confluence and extended unabated through a pool-glide complex for 555 meters. Average pool depth was 1.5 meters. Average in-situ parameters for bloom 1 were 9.16 mg/L dissolved oxygen, 114.3 % saturation, 230.5 µS/cm, 27.1ºC, and 7.67 pH. Algae observed in the pool were loose, unattached, and gelatinous forms ranging in color from dark to neon green (Figure 2). Algae present in shallow, higher velocity habitat were more filamentous, developed long strands, and were attached to the substrate (Figures 3-4).

Bloom 2 length was the shortest measured at 380 meters. It began approximately 380 meters downstream of Bloom 1 terminus. Average in-situ readings were 10.25 mg/L dissolved oxygen, 130.3 % saturation, 226.8 µS/cm, 27.5 ºC, and 8.03 pH.

Bloom 3 was the most extensive in terms of coverage, density, and habitats. Bloom length was approximately 930 meters and began almost 1 kilometer downstream from bloom 2. Average in-situ readings were 10.3 mg/L dissolved oxygen, 130.5 % saturation, 228 µS/cm, 27.5 ºC, and 7.76 pH.

For all blooms, preferred substrate appeared to be small diameter gravel and was less dense in areas with bedrock, boulder, and cobble substrate. The team observed that greater current velocity appeared to reduce algal density; however, long filamentous strands were present amidst higher velocity riffles. Other variables are likely influencing algae presence in pools. Between blooms 2 and 3, multiple habitat types were observed to be free from any form of algae.

Following investigation of blooms between Tomahawk Creek confluence and Sanders Field, the team evaluated two downstream access points, North Maumee and Highway 14 (Dillard's Ferry). At both sites, visually estimated coverage of filamentous and loosely attached algae was ≥75% of channel width. Communication with a National Park Service Ranger indicated that algae was extensive from Spring Creek to Dillard's Ferry on August 10, 2017. He was unaware of any indication of algal presence downstream to Rush.

Flow conditions were evaluated from the USGS 07056000 Buffalo River gage near St. Joe. On the day of the investigation, gage height (feet) was 3.6 ft (Figure 5).

Updates*:*

August 14, 2017

National Park Service staff indicated little to no change in bloom conditions near Sand Hole. This bloom was first observed on August 4, 2017, first reported on August 7, 2017 and evaluated by NPS staff on August 9, 2017. NPS staff also evaluated the river below Bear Creek and Brush Creek and observed some dislodged algae floating in the current, but minimal coverage.

August 17, 2017

Heavy rains fell for several day throughout the watershed. The Buffalo River near St. Joe rose approximately 2.5’ (Figure 5).

August 25,2017

Algae reported in isloated pools of Brush Creek by NPS staff (Figure 6). The river crested, but visability is poor to evaluate whether a scour occurred.

August 31,2017

NPS staff reported to ADEQ that no major algae coverage was observed at Highway 14 (Dillard’s Ferry) as of August 29, 2017. Algal blooms were observed on August 28, 2017 within the Lower Wildneress Area and on August 30, 2017 above Highway 65 near Mt. Hersey (Figure 7-8). Bloom coverage was not included with the NPS observation.

September 20, 2017

Ms. Carol Bitting submitted a complaint and photos from the 11.5 mile portion of the Buffalo River from Gilbert to North Maumee and “algae was continuous through the trip” (Figure 9). Correspondence with NPS staff observed less algal coverage in the area of Sand Hole, which was a previously submitted bloom on August 14, 2017. Verbal correspondence with NPS and USGS staff did indicate increased coverage in pools above Highway 65 in the vicinity of Mt. Hersey.

ADEQ staff will continue to converse with the NPS on locations and size of blooms during the 2017 growing season.

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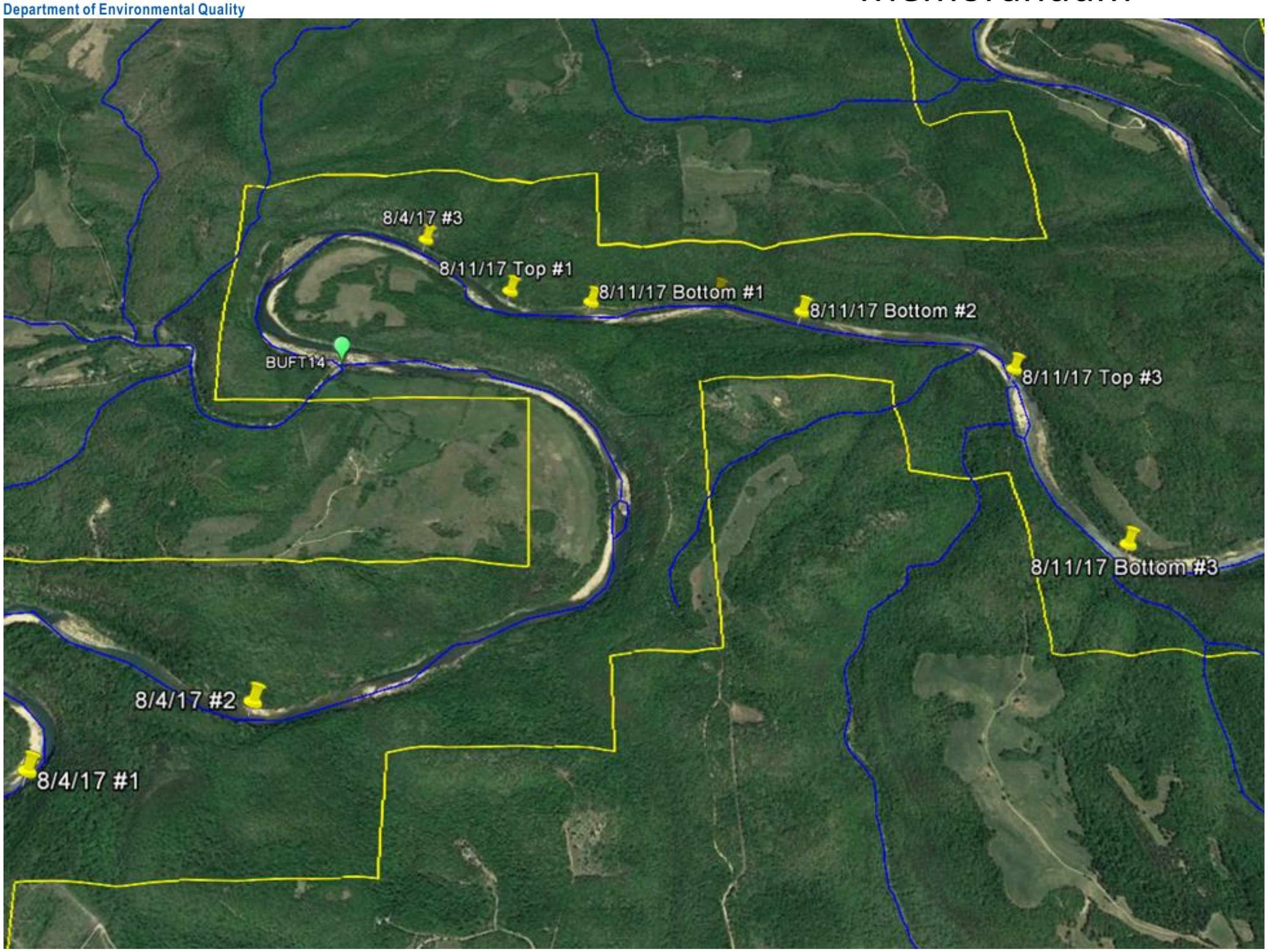

Figure 1. Locations of complaintant observed events (August 4, 2017) and those observed by ADEQ and NPS on 11August2017.

Figure 2. Presence of gelatinous algae within pool margins.

Figure 3. Long filamentous algae present at bloom 3.

Figure 4. Long filamentous algae across wetted width at bloom 3.

Table 1. Average i*n-situ* water quality.

	Water Quality Parameters				
	[DO]		Temperature	Specific Conductance	pH
Bloom 1	9.16 mg/L	114.3%	27.1°C	230.5 µS/cm	7.67
Bloom 2	10.25 mg/L	130.3%	27.5°C	226.8 µS/cm	8.03
Bloom 3	10.3 mg/L	130.5%	27.5°C	228 µS/cm	7.76

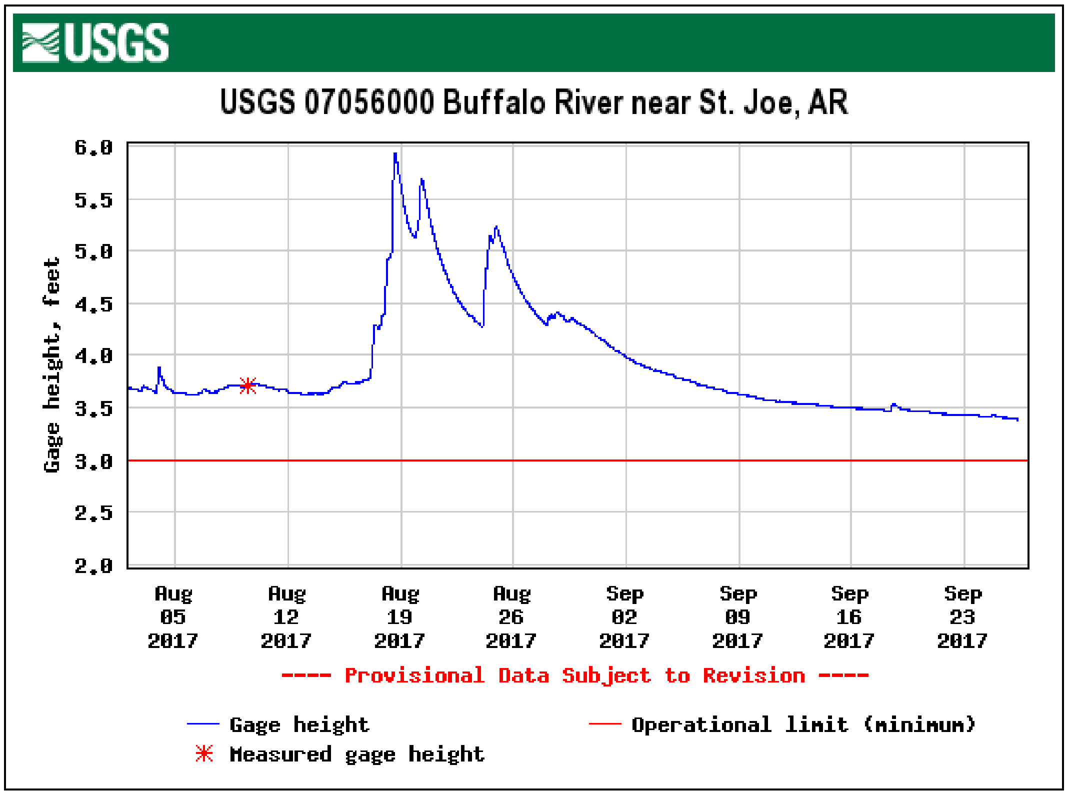

Figure 5. Measured gage height for the Buffalo River near St. Joe, Arkansas.

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Figure 6. Brush Creek on August 24, 2017 upstream of Searcy County Road 416.

Figure 7. Long filamentous algae coverage observed in the Lower Wilderness Area by NPS staff on August 29, 2017.

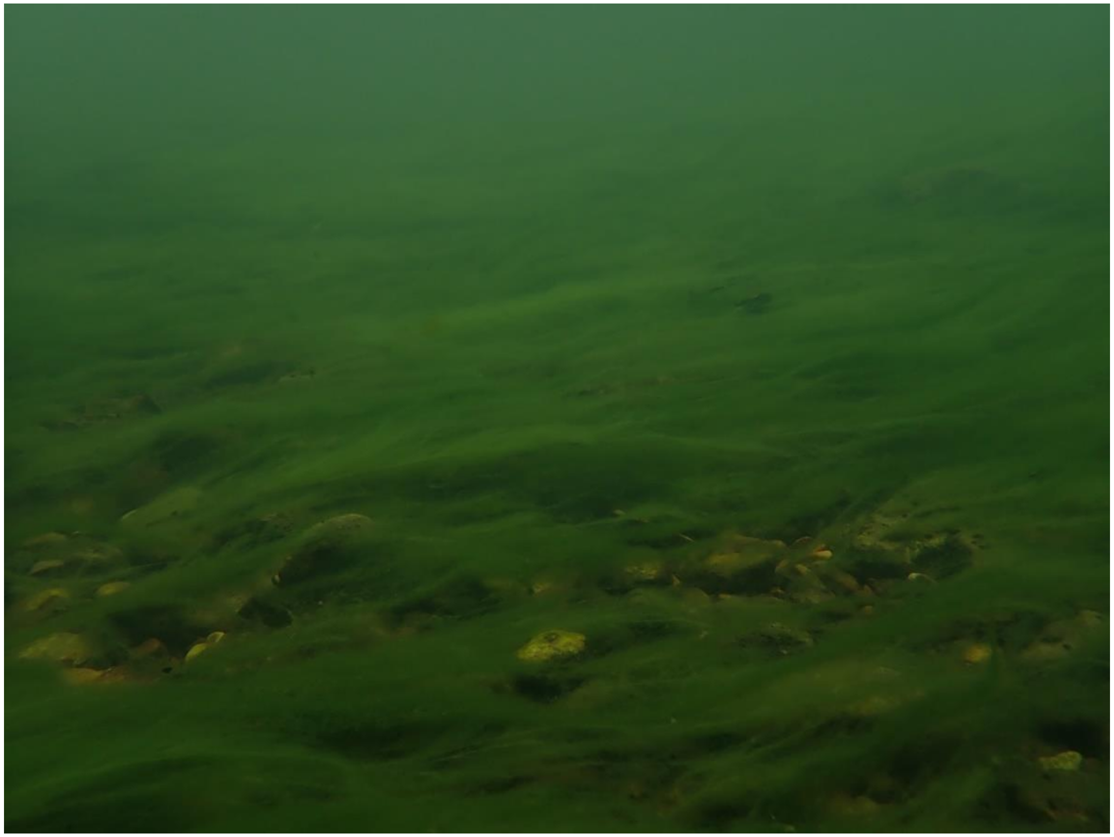

Figure 8. Underwater photo of attached algae at NPS reported bloom at Mt. Hersey on August 30, 2017.

Figure 9. Photo taken on September 19, 2017 just downstream of the Gilbert access and submitted by complainant on September 20, 2017.

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5 September 2018

Ms. Sarah Clem
Planning Branch Manager, Office of Water Quality
Arkansas Department of Environmental Quality
5301 Northshore Drive
North Little Rock, AR 72118
Sent via email to clem@adeq.state.ar.us, FOIA@adeq.state.ar.us

Re: 2018 Draft 303(d) Supplemental Materials - FOIA Request and Clarifications

Dear Ms. Clem,

I would like to start by saying I commend ADEQ's efforts in compiling an extensive amount of information and supplemental materials to support Arkansas's Integrated Report. However, I have not been able to track down a few specifics that should currently be out for public review and comment regarding the 2018 draft 303(d) list. Information was also not included in response to my 28 June 2018 FOIA request, specifically regarding "correspondence between ADEQ and EPA regarding the 2018 draft 303(d) list of impaired waterbodies from (22 October 2017 – present)."[1]

Category 4b Determinations vs. Demonstrations

Background

Information provided on ADEQ's website regarding Category 4b Determinations are limited to alternative management plans for non-attainment decisions for assessment units in the Illinois River, Buffalo River, and Beaver Lake watersheds.[2, 3, 4, 5]

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[1] 28June2018 Letter from WRW to ADEQ Re: Assessment Methodology and 3039d) List FOIA Request

[2] ADEQ Category 4b Determinations, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/category-4b-determinations.pdf

[3] Beaver Lake Watershed Protection Strategy http://www.beaverwatershedalliance.org/pdf/Beaver-Lake-Watershed-Protection-Strategy.pdf

[4] Buffalo River Watershed Management Plan https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/2018-05-22-final-buffalo-river-wmp.pdf

[5] Watershed-Based Management Plan for the Upper Illinois River Watershed https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/uirw-watershed-based-plan-2012-11-30-final.pdf

EPA recommends states should submit Category 4b ***demonstrations*** with Integrated Report submissions that address the following six elements:[6]

1. Identification of segment and statement of problem causing the impairment;
2. **Description of pollution controls and how they will achieve water quality standards**;
3. **An estimate or projection of the time when WQS will be met**;
4. **Schedule for implementing pollution controls**;
5. **Monitoring plan to track effectiveness of pollution controls**; and
6. Commitment to revise pollution controls, as necessary.

Information is lacking to sufficiently to address elements in **bold**. While voluntary watershed management plans address nonpoint source controls that can help achieve water quality standards (although, targets outlined in the Buffalo River Watershed Management Plan do not correspond to impaired AUs), this falls short of EPA recommendations. Regarding *Element #2*, states are expected to provide EPA with a "linkage analysis (i.e., cause-and-effect relationship between a water quality target and sources)" evaluating **point** and nonpoint source loadings that when implemented will achieve water quality standards.[7]

Request

Although the supplemental materials provided on ADEQ's website document the rationale for Category 4b **determinations**, information seems to be lacking adequate details ***demonstrating*** how implementation strategies of controls already in place are sufficient to achieve water quality standards in a reasonable period of time.

If additional materials addressing elements #2, 3, 4, and 5 (**bold**), outside of those provided on ADEQ's website, currently exist, I would like to request them formally. If materials addressing these elements do not exist, please confirm such.

Removal of Total Phosphorous Pollutant Pairs

Background

The Record of Decision (ROD) for EPA Action on Arkansas' 2008 303(d) List proposed the following additions for total phosphorous:[8, 9]

- Muddy Fork (11110103-027)
- Osage Creek (11110103-030, 11110103-930)

[6] See p. 7, 12 October 2006 Memo, Diane Regas, EPA, Re: Information Concerning 2008 Clean Water Act Sections 303(d), 305(b), and 314 Integrated Reporting and Listing Decisions, https://www.epa.gov/sites/production/files/2015-10/documents/2006_10_27_tmdl_2008_ir_memorandum.pdf

[7] See p. 8, *Id.*

[8] 18 June 2008, EPA 2008 303(d) ROD, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2008/epa-rod.pdf

[9] Arkansas Final Impaired Waterbodies List 2008, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2008/303d-list.pdf

- Spring Creek (11110103-931)
- Town Branch (11110103-901)

Although ADEQ left these off all subsequent 303(d) lists, EPA recommended Category 4b designations for these pollutant pairs.[10] However, these pollutant pairs are not included on the 2018 draft 303(d) list,[11] formally delisted,[12] or included in Category 4b determinations.[13]

Request
If additional delisting or otherwise related materials currently exist, outside of those provided on ADEQ's website, I would like to request them formally. If materials addressing the apparent delisting do not exist, please confirm such.

<u>303(d) Public Participation</u>

In the event of proposed changes or additional information provided in response to the above concerns, will ADEQ submit these for public comment and review, and subsequently extend the comment period?

Thank you for your timeliness in this response.

Jessie J. Green

Jessie J. Green
Executive Director & Waterkeeper

[10] 19 July 2017 Letter from William Honker Re: EPA Action on Arkansas's 2010, 2012, 2014, and 2016 § 303(d) Lists, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2017/epa-decision-7192017.pdf
[11] Draft 2018 Category 5, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/2018-draft-list-public-notice.pdf
[12] Draft 2018 Waters Delisted from Final Category 5 2016 303(d) List, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/2018-draft-list-public-notice-delistings-listings.pdf
[13] ADEQ Category 4b Determinations, https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2018/category-4b-determinations.pdf

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